SECTION 6. ESTABLISHING THE ALLOCATIONS FOR THE BASIN-JURISDICTIONS

The process that informed EPA's decisions establishing the Chesapeake Bay TMDL involved many stakeholders, most notably, the Bay jurisdiction partners. A four-step process was used for the development of the TMDL. Those steps were

1. EPA defined 19 major river basin and jurisdictional loading allocations—July 1, 2010, for nitrogen and phosphorus; August 13, 2010, for sediment. The methodology that EPA used in defining those allocations is described in detail in this section.
2. Each jurisdiction developed a Phase I Watershed Implementation Plan (WIP) that described how it would achieve the target allocations for nitrogen, phosphorus, and sediment assigned to the jurisdictions and basins in step 1.
3. EPA evaluated the jurisdictions' suballocations and final Phase I WIPs to determine whether they met the jurisdiction-wide and major river basin allocations, included adequate detail to ensure that NPDES permits are consistent with the assumptions and requirements of the WLAs, and provided sufficient reasonable assurance that nonpoint source reductions could be achieved and maintained through credible and enforceable or otherwise binding strategies in jurisdictions that are signatories to the Chesapeake Bay Agreement, and similarly effective strategies in non-signatory jurisdictions. That evaluation and its results are described in detail in Section 8.

On the basis of the results of its evaluation, EPA established an allocation scenario for the final Chesapeake Bay TMDL, including allocations for each of the 92 Bay segments, using suballocations provided in the final Phase I WIPs, alternative EPA backstop allocations, or a combination of the two. Tables showing the 92 Bay segment-specific and sector-specific allocations of the Chesapeake Bay TMDL are in Section 9.

This section describes the method used to derive the basin-jurisdiction allocations described in Step 1 above. The following subsections discuss the specific approaches adopted to address specific technical aspects of the Chesapeake Bay TMDL:

- 6.1-Establishing the overall model parameters
- 6.2-Establishing the nitrogen and phosphorus model parameters
- 6.3-Methodology for establishing the basin-jurisdiction allocations for nitrogen and phosphorus
- 6.4-Establishing the Basin-jurisdiction allocations for nitrogen and phosphorus
- 6.5-Establishing the sediment model parameters
- 6.6-Establishing the basin-jurisdiction allocations for sediment
- 6.7-Basin-jurisdiction allocations to achieve the Bay WQS
- 6.8-Attainment of the District of Columbia pH WQS

The Chesapeake Bay Program partners initiated discussions related to the technical aspects of the Chesapeake Bay TMDL starting at the September 2005 Reevaluation Workshop sponsored by what would become the partnership's Water Quality Steering Committee (Chesapeake Bay Reevaluation Steering Committee 2005). Over the next 5 years, EPA and its partners, in particular members of the Water Quality Steering Committee (2005–2008) and then the Water Quality Goal Implementation Team (WQGIT) (2009–present) systematically evaluated and agreed on approaches to address multiple technical aspects related to developing the Bay TMDL.

EPA, together with its seven watershed jurisdictional partners, developed and applied approaches and methodologies to address a number of factors in developing the Bay TMDL. A multitude of policy, programmatic, and technical issues were addressed through this collaborative process.

6.1 Establishing the Overall Model Parameters

The first step in the process was to establish the key parameters for the models used in developing the TMDL. The model parameters discussed below are those that are common to developing TMDLs that ensure attainment for all three water quality criteria: DO, chlorophyll *a* and submerged aquatic vegetation (SAV)/water clarity. Those key parameters are: (1) the hydrologic period, or the period that is representative of typical conditions for the waterbody; (2) the seasonal variation in water quality conditions and the factors (e.g., temperature, precipitation and wind) that directly affect those conditions; and (3) the development of daily loads for the TMDL.

6.1.1 Hydrologic Period

The hydrologic period for modeling purposes is the period that represents the long-term hydrologic conditions for the waterbody. This is important so that the Bay models can simulate local long-term conditions for each area of the Bay watershed and the Bay's tidal waters so that no one area is modeled with a particularly high or low loading, an unrepresentative mix of point and nonpoint sources or extremely high or low river flow. The selection of a representative hydrologic averaging period ensures that the balance between high and low river flows and the resultant point and nonpoint source loadings across the Bay watershed and Bay tidal waters are appropriate. The hydrologic period also provides the temporal boundaries on the model scenario runs from which the critical period is determined (see Section 6.2.1).

To identify the appropriate hydrologic period, EPA analyzed decades of historical stream flow data. It is important when determining representative hydrology to be able to compare various management scenarios through the suite of Bay models. In the course of evaluating options for the TMDL, EPA and its jurisdictional partners ran numerous modeling scenarios through the Bay Watershed and the Bay Water Quality Sediment Transport models with varying levels of management actions (e.g., land use, BMPs, wastewater treatment technologies) held constant against an actual record of rainfall and meteorology to examine how those management actions perform over a realistic distribution of simulated meteorological conditions.

Because of the long history of monitoring throughout the Chesapeake Bay watershed, the CBP partners were in the position of selecting a period for model application representative of typical hydrologic conditions of the 21 contiguous model simulation years—1985 to 2005. Two extreme conditions occurred during the 21-year model simulation period for the Chesapeake Bay models: Tropical Storm Juan in November 1985, and the Susquehanna *Big Melt* of January 1996. In the

Chesapeake Bay region, Tropical Storm Juan was a 100-year storm primarily affecting the Potomac and James River basins. No significant effect on SAV or DO conditions was reported in the aftermath of Tropical Storm Juan. In the case of the Susquehanna Big Melt in January 1996, a warm front brought rain to the winter snow pack in the Susquehanna River basin and caused an ice dam to form in the lower reaches of the river. No significant effects on SAV or DO were reported from that 1996 extreme event, likely because of the time of year when it occurred (late winter).

From the 21-year period, EPA selected a contiguous 10-year hydrologic period because a 10-year period provides enough contrast in different hydrologic regimes to better examine and understand water quality response to management actions over a wide range of wet and dry years. Further, a 10-year period is long enough to be representative of the long-term flow (Appendix F). Finally, a 10-year period is within today's capability of computational resources, particularly for the Chesapeake Bay Water Quality Sediment Transport Model (Bay Water Quality Model), which required high levels of parallel processing for each management scenario. The annualized Bay TMDL allocations are expressed as an average annual load over the 10-year hydrologic period.

EPA then determined which 10-year period to use by examining the statistics of long-term flow relative to each 10-year period at nine USGS gauging stations measuring the discharge of the major rivers flowing to the Bay (Appendix F). All the contiguous 10-year hydrologic periods from 1985 to 2005 appeared to be suitable because quantifiable assessments showed that all the contiguous 10-year periods had relatively similar distributions of river flow.

EPA selected the 10-year hydrologic assessment period from 1991 to 2000 from the 21-year flow record for the following reasons:

- It is one of the 10-year periods that is closest to an integrated metric of long-term flow.
- Each basin has statistics for this period that were particularly representative of the long-term flow.
- It overlaps several years with the previous 2003 tributary strategy allocation assessment period (1985–1994), which facilitated comparisons between the two assessments.
- It incorporates more recent years than the previous 2003 tributary strategy allocation assessment period (1985–1994).
- It overlaps with the Bay Water Quality Transport Model calibration period (1993–2000), which is important for the accuracy of the model predictions.
- It encompasses the 3-year critical period (1993–1995) for the Chesapeake Bay TMDL as explained in Section 6.2.1 below.

More detailed documentation on the determination of the hydrologic period is provided in Appendix F.

6.1.2 Seasonal Variation

A TMDL analysis must consider the seasonal variations within the watershed (CWA 303(d)(1)(C); 40 CFR 130.7). The Chesapeake Bay TMDL inherently considers all seasons through the use of a continuous 10-year simulation period that captures seasonal precipitation on a year-to-year basis throughout the entire watershed. Furthermore, the critical periods selected for this TMDL, being a minimum of 3 consecutive years provide further assurance that the seasonality of the Bay loading and other dynamics are properly addressed in this TMDL. In this way, the TMDL simulations ensure attainment of WQS during all seasons.

Seasonal Variation in the Jurisdictions' Bay Water Quality Standards

In the case of the Chesapeake Bay TMDL, the Chesapeake Bay WQS adopted by the four tidal Bay jurisdictions are biologically based and designed to be protective of Chesapeake living resources, including full consideration of their unique seasonal-based conditions (see Section 3) (USEPA 2003a, 2003c). To assess the degree of WQS achievement using the Bay Water Quality Model, an overlay of the time and space dimensions are simulated to develop an assessment that is protective of living resources with consideration of all critical periods within the applicable seasonal period (USEPA 2007a).

The same approach of considering the time and space of the critical conditions is applied in the assessment of the WQS achievement with observed monitoring data. Ultimately, the time and space of water quality exceedances are assessed against a reference curve derived from healthy living resource communities to determine the degree of WQS achievement (USEPA 2007a).

Model Simulation Supporting Seasonal Variation

The suite of Chesapeake Bay Program models being used to establish the Chesapeake Bay TMDL—Bay Airshed, Bay Watershed, Bay Water Quality, Bay Sediment Transport, Bay filter feeders—all simulate the 10-year period and account for all storm events, high flows/low flows, and resultant nitrogen, phosphorus, and sediment loads across all four seasons. The full suite of Chesapeake Bay models operate on at least an hourly time-step and often at finer time-steps for the Bay Airshed Model and the Bay Water Quality Model (see Sections 5.4 and 5.9, respectively). Therefore, through proper operation of the suite of Bay models, the Chesapeake Bay TMDL considers all seasons and within season variations through the use of a continuous 10-year simulation period (see Section 6.1.1).

Seasonal Variations Known and Addressed through Annual Loads

A key aspect of Chesapeake Bay nitrogen and phosphorus dynamics is that annual loads are the most important determinant of Chesapeake Bay water quality response (USEPA 2004c). Chesapeake Bay physical and biological processes can be viewed as integrating variations in nitrogen, phosphorus, and sediment loads over time. The integration of nitrogen, phosphorus, and sediment loads over time allows for an analysis of loads in the Chesapeake Bay that is minimally influenced by short-term temporal fluctuations. Bay water quality responds to overall loads on a seasonal to annual scale, while showing little response to daily or monthly variations within an annual load.

Numerous Chesapeake Bay studies show that annually based wastewater treatment of nitrogen and phosphorus reductions are sufficient to protect Chesapeake Bay water quality (Linker 2003, 2005). The seasonal aspects of the jurisdictions' Chesapeake Bay WQS are due to the presence and special seasonal needs of the living resources being protected (e.g., spawning), but annual nitrogen, phosphorus, and sediment load reductions are most important to achieve and maintain the seasonal water quality criteria, some of which protect multiple season designated uses—open-water, shallow-water bay grass, and migratory spawning and nursery (USEPA 2003a, 2003d).

6.1.3 Daily Loads

Consistent with the D.C. Circuit Court of Appeals decision in *Friends of the Earth, Inc. v. EPA*, in addition to the annual loading expressions of the pollutants in this TMDL, EPA is also expressing its Chesapeake Bay TMDL in terms of daily time increments (446 F.3d 140 [D.C. Cir. 2006]). Specifically, the Chesapeake Bay TMDL has developed a maximum daily load based on annual and seasonal loads for nitrogen, phosphorus, and sediment for each of the 92 Chesapeake Bay segments. EPA also recognizes that it may be appropriate and necessary to identify non-daily allocations in TMDL development despite the need to also identify daily loads. In an effort to fully understand the physical and chemical dynamics of a waterbody, TMDLs can be developed using methodologies that result in the development of pollutant allocations expressed in monthly, seasonal, or annual periods consistent with the applicable WQS. TMDLs can be developed applying accepted and reasonable methodologies to calculate the most appropriate averaging period for allocations on the basis of factors such as available data, watershed and waterbody characteristics, pollutant loading considerations, applicable WQS, and the TMDL development methodology. Consistent with that policy, the Chesapeake Bay TMDL was developed and is expressed in annual loads. In addition, EPA calculated daily loads to reflect a statistical expression of an annually-based maximum daily load and a seasonally-based maximum daily load. Appendix R of this TMDL includes detailed nitrogen, phosphorus, and sediment annually based maximum daily allocations to achieve applicable WQS. The spreadsheet lists total nitrogen, phosphorus, and sediment loads as delivered to the Chesapeake Bay's tidal waters. Daily load allocations are shown for each of the 92 segments and by sources for WLAs including agriculture (CAFOs), stormwater (MS4s), wastewater (CSO) and wastewater (significant and nonsignificant by NPDES permit); and for LAs including agriculture, forest, nontidal atmospheric deposition, onsite treatment systems, and urban sources.

Approach for Expressing the Maximum Daily Loads

The methodology applied to calculate the expression of the maximum daily loads and associated wasteload and load allocations in the Chesapeake Bay TMDL is consistent with the approach contained in EPA's published guidance, *Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA, et al., No. 05-5015, (April 25, 2006) and Implications for NPDES Permits*, dated November 15, 2006 (USEPA 2006). Additionally, the analytical approach selected in the Bay TMDL is similar to the wide range of technically sound approaches and the guiding principles and assumption described in the technical document *Options for the Expression of Daily Loads in TMDLs* (USEPA 2007c).

Computing the Daily Maximum Loads and the Seasonal Daily Maximum Loads

Annually based maximum daily loads are derived for each of the 92 tidal segments and for each of the three pollutants—nitrogen, phosphorus, and sediment—as a direct product of the Chesapeake Bay TMDL and associated modeling. That modeling output serves as the starting point for the annually-based maximum daily load expression and the seasonally-based maximum daily load expression. Those daily maximum loads are a function of the 10-year continuous simulation produced by the paired Bay Watershed-Bay Water Quality models. The modeling approach allows for the daily maximum load expression to be taken directly from the output of the TMDL itself, assuring a degree of consistency between the daily maximum load calculation and the annual loads necessary to meet applicable WQS included in the final TMDL. That is, the methodology uses the annual allocations derived through the modeling/TMDL analysis, and converts those annual loads to daily maximum loadings.

Both the Chesapeake Bay TMDL annually-based maximum daily load and seasonally based maximum daily load represents the 95th percentile of the distribution to protect against the presence of anomalous outliers. That expression implies a 5 percent probability that an annually-based daily or seasonal-based daily maximum load will exceed the specified value under the TMDL condition. However, during such unlikely events, compliance with the annual loading will assure that applicable WQS will be achieved.

On the basis of probability analysis, a loading that will be achieved 100 percent of the time cannot be calculated. So some percentage probability of attainment must be chosen that is less than 100 percent but high enough that there is comfort that the loading will be achieved. A 95 percent probability is often determined by EPA to be appropriate in environmental matters (like WQS and NPDES permitting) and has also been chosen in this application. The EPA guidance mentioned above provides for much discretion in selecting the percent probability to use in the daily calculation. Because the calculation is for a daily maximum value, it is EPA's professional opinion that, with regard to the Chesapeake Bay TMDL, a 95 percent probability is most appropriate. The steps employed to compute the annually or seasonally based maximum daily load for each segment were as follows:

1. Calculate the annual average loading for each of the 92 Bay segments; that would be the annual loading under the TMDL/allocation condition. Annual allocations are in Section 9 and Appendix Q.
2. Calculate the 95th percentile of the daily loads delivered to each of the 92 Bay segments (using the same loading condition as step 1).
3. Calculate the Annual/Daily Maximum ratio (ADM) for each of the 92 Bay segments by dividing the annual average load by the 95th percentile calculated in Step 2.
4. Calculate a Baywide ADM by computing a load-weighted average of all 92 Bay segments ADM ratios. Table 6-1 provides the annual Baywide ADM.
5. Divide all the annual TMDLs, WLAs, and LAs in each of the 92 Bay segments in the TMDL by the Baywide ADM. Those are the calculated annual-based daily maximum loads found in Appendix R.
6. Using the approach described in steps 1–5 above, calculate a Baywide ADM for each season for each of the 92 Bay segments. Table 6-1 provides the Seasonal Baywide ADM.
7. Divide all the annual TMDLs in each of the 92 tidal segments in the TMDL by Seasonal ADM to calculate the seasonally-based maximum daily load.

Table 6-1. ADM for calculating daily maximum loads

	Winter	Spring	Summer	Fall	All year
Total Nitrogen	123.7	80.9	337.1	210.9	123.6
Total Phosphorus	95.8	60.1	260.7	141.2	98.2
Total Suspended Solids	96.5	58.0	384.7	158.1	100.3

It should be noted that a statistical expression of a daily load is just that, an expression of the probability that a specific maximum daily load will occur in a given segment for a specific pollutant. The magnitude of the TMDL allocations was established to assure the attainment of all applicable WQS in each of the 92 tidal Bay segments. EPA has provided annually based maximum daily load expressions in Appendix R. Seasonally based maximum daily loads can be calculated by dividing the annual allocations by the seasonal ADMs in Table 6-1. That seasonal expression reflects a temporally variable target because the various pollutant sources (point and nonpoint) vary significantly by month and by season. The annually based daily maximum loads represent the infrequent, maximum inputs into the Chesapeake Bay. The annually based maximum daily load and the seasonally based maximum daily load provide a range of conditions that are acceptable on a daily basis and that will meet overall TMDL allocations and the applicable WQS.

The Expression of Daily Loads and NPDES Permits

NPDES permit regulations require that effluent limits in permits be expressed as monthly average and either weekly average or daily maximum, unless impracticable. As reflected in EPA's March 3, 2004 Memorandum *Annual Permit Limits for Nitrogen and Phosphorus for Permits Designed to Protect Chesapeake Bay and its tidal tributaries from excess nitrogen and phosphorus loadings under the National Pollutant Discharge Elimination System* and EPA's December 29, 2004 letters to each Chesapeake Bay watershed jurisdiction, which enclosed the *NPDES Permitting Approach for the Discharges of Nitrogen and Phosphorus in the Chesapeake Bay Watershed* it is EPA's best professional judgment that, when developing NPDES permit limits consistent with this TMDL, jurisdictions should consider expressing permit effluent limits for nitrogen and phosphorus as annual loads, instead of expressing the limits as monthly, weekly, or daily limits (USEPA 2004c, 2004d). After consideration of complex modeling of the effect of nitrogen and phosphorus loading to the Bay from individual point source discharges, EPA concluded that the Chesapeake Bay and its tidal tributaries in effect integrate variable point source monthly loads over time, so that as long as a particular annual total load of nitrogen and phosphorus is met, constant or variable intra-annual load variation from individual point sources has no effect on water quality of the main Bay. EPA recommends that because of the characteristics of nitrogen and phosphorus loading and its effect on the water quality of the Bay, the derivation of appropriate daily, weekly, or monthly permit limits is impracticable, and the permit limits expressed in annual loads is appropriate. To protect local water quality, or for other appropriate reasons, the NPDES permitting authority may also express the effluent limits in monthly or daily terms.

6.2 Establishing the Nitrogen and Phosphorus Related Model Parameters

6.2.1 Critical Conditions

TMDLs are required to identify the loadings necessary to achieve applicable WQS. The allowable loading is often dependent on key environmental factors, most notably wind, rainfall, streamflow, temperature, and sunlight. Because those environmental factors can be highly variable, EPA regulations require that in establishing the TMDL, the critical conditions (mostly environmental conditions as listed above) be identified and employed as the design conditions of the TMDL [40 CFR 130.7(c)(1)].

When TMDLs are developed using supporting watershed models, such as the Chesapeake Bay TMDL, selecting a critical period for model simulation is essential for capturing important ranges of loading/waterbody conditions and providing the necessary information for calculating appropriate TMDL allocations that will meet applicable WQS. Because the WQS applicable to this TMDL are assessed over 3-year periods, the critical period is defined as the 3-year period within the previously selected 1991–2000 hydrologic period (see Section 6.1.1) that meets the above description (USEPA 2003a). Critical conditions for sediment and SAV are discussed in Section 6.5.1 below.

Critical Conditions for DO

In the Chesapeake Bay, EPA has found that as flow and nitrogen and phosphorus loads increase, DO and water clarity levels decrease (Officer 1984). Therefore, EPA bases the critical period for evaluation of the DO and water clarity WQS on identifying high-flow periods. Those periods were identified using statistical analysis of flow data as described below and in detail in Appendix G.

For the Bay TMDL, EPA conducted an extensive analysis of streamflow of the major tributaries of the Chesapeake Bay as the primary parameter representing critical conditions. In that analysis, it was observed that high streamflow most strongly correlated with the worst DO conditions in the Bay. That is logical because most of the nitrogen and phosphorus loading contributing to low DO in the Bay comes from nonpoint sources, whose source loads are driven by rainfall and correlate well to rainfall and higher streamflows. Additionally, higher freshwater flows generally increase water column stratification, preventing the low-DO bottom waters from being reaerated.

Because future rainfall conditions cannot be predicted, EPA analyzed rainfall from past decades to derive a critical rainfall/streamflow condition that would be used to develop the allowable loadings in the TMDL. The initial analysis concluded that the years 1996–1998 represented the highest streamflow period for the Chesapeake Bay drainage during the 1991–2000 hydrology period. However, it was later discovered that this 3-year period represented an extreme high-flow condition that was inappropriate for the development of the TMDL—the high-flow period would generally occur once every 20 years (Appendix G). After further analysis, EPA selected the second highest flow period of 1993–1995 as the critical period. The 1993–1995 critical period experienced streamflows that historically occurred about once every 10 years, which is much more typical of the return frequency for hydrological conditions employed in developing TMDLs (Appendix G). Thus, while the modeling for the Bay TMDL consists of the entire hydrologic period of 1991–2000, EPA used the water quality conditions during the 1993–1995 critical period to determine attainment with the Bay jurisdictions' DO WQS.

Critical Conditions for Chlorophyll *a*

Algae, measured as chlorophyll *a*, responds to a multitude of different environmental factors, parameters, and conditions including the following:

- Nitrogen and phosphorus loads
- Water column temperature
- pH conditions
- Local nitrogen and phosphorus conditions (e.g., fluxes of nitrogen and phosphorus from the bottom sediment)
- River flow influences on dilution of existing algae populations
- River flow, bathymetry, and other factors influencing residence time
- Local weather conditions (e.g., wind, percentage of sunlight)
- Other conditions and parameters not well understood within the current state of the science

Some of those same factors influence DO conditions, while others are unique to algae. As documented in Appendix G, using the same methodology as was used to determine the DO critical period for the entire Chesapeake Bay, EPA conducted a flow analysis to support the selection of a critical period for the tidal James River, which has numeric chlorophyll *a* criteria. EPA based that analysis on the correlation between flow and violations of the numeric chlorophyll *a* water quality criteria. The analysis showed no strong correlation between streamflow and chlorophyll *a* conditions (Appendix G). As a result, EPA assessed numeric chlorophyll *a* attainment using all eight of the 3-year criteria assessment periods (e.g., 1991–1993, 1992–1994) that occur within the hydrologic period of 1991–2000.

6.2.2 Assessment Procedures for DO and Chlorophyll a Standards

The Bay Water Quality Model is used to predict water quality conditions for the various loading scenarios explored. It is necessary to compare these model results with the applicable WQS to determine compliance with the standards. This section describes the process by which model results are compared to WQS to determine attainment.

In general, to determine management scenarios that achieved WQS, EPA ran model scenarios representing different nitrogen, phosphorus, and sediment loading conditions using the Bay Watershed Model. EPA then used the resultant model simulated nitrogen, phosphorus, and sediment loadings as input into the Bay Water Quality Model to evaluate the response of critical water quality parameters: specifically DO, SAV, water clarity, and chlorophyll *a*.

To determine whether the different loading scenarios met the Bay DO and chlorophyll *a* WQS, EPA compared the Bay Water Quality Model's simulated tidal water quality response for each variable to the corresponding observed monitoring values collected during the same 1991-2000 hydrological period. In other words, the Bay Water Quality Model was used primarily to estimate the *change* in water quality that would result from various loading scenarios. The model-simulated change in water quality is then applied to the actual observed calibration monitoring data. In its simplest terms, the following steps were taken to apply the modeling results to predict Bay DO and chlorophyll *a* WQS attainment:

1. Using the 1991 to 2000 hydrologic period, calibrate the Bay Water Quality Model to Bay water quality monitoring data.
2. Run a model simulation for a given loading scenario (usually a management scenario resulting in lower loads relative to the calibration scenario) through the Phase 5.3 Chesapeake Bay Watershed Model (Bay Watershed Model) and Bay Water Quality Model.
3. Determine the model simulated change in water quality from the calibration scenario to the given loading scenario.
4. Apply the change in water quality as predicted by the Bay Water Quality Model to the actual historical water quality monitoring data used for calibration and evaluate attainment on the basis of that scenario-modified data set.
5. If WQS are met, use the allocations for the TMDL. If WQS are not met, reduce and readjust loads to meet WQS.

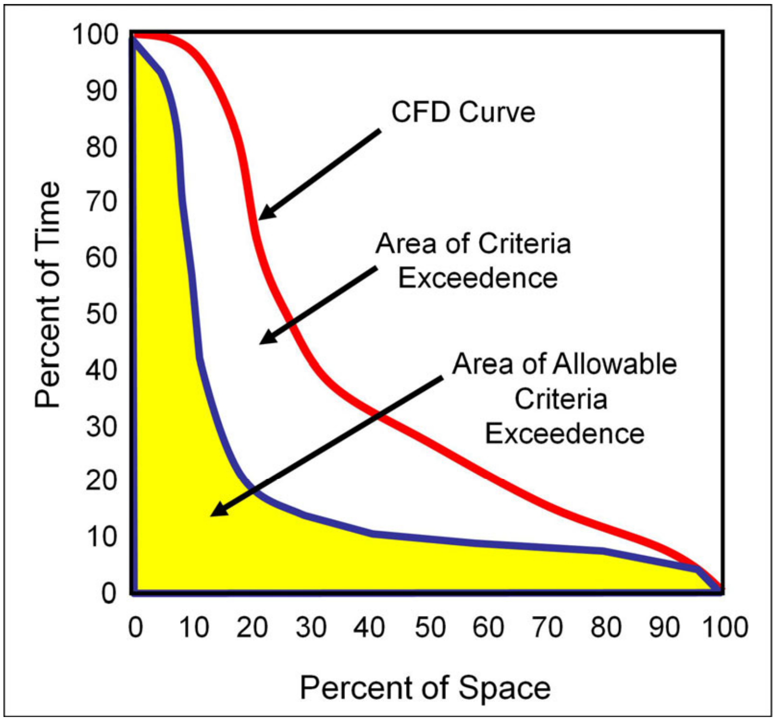
For a full discussion of the procedure, see Appendix H and the original report titled *A Comparison of Chesapeake Bay Estuary Model Calibration With 1985–1994 Observed Data and Method of Application to Water Quality Criteria* (Linker et al. 2002).

6.2.3 Addressing Reduced Sensitivity to Load Reductions at Low Nonattainment Percentages

Mathematical models, including the models used in the Chesapeake Bay TMDL, are not perfect representations of the real world. For that reason, it is important to use professional judgment in the interpretation of those model results. One example of that is, for some segments, the Bay Water Quality Model showed persistent nonattainment at consistently low levels even after the loadings were lowered. After careful analysis, EPA concluded that the low (1 percent) modeled nonattainment levels were more an artifact of the modeling and assessment process, than a representation of actual nonattainment. For that reason, EPA concluded that modeled nonattainment of 1 percent or less was, in fact, attainment with the applicable WQS. The subsection below describes the analysis that EPA conducted to arrive at this conclusion.

The Chesapeake Bay water quality criteria that the jurisdictions adopted into their respective WQS regulations provide for allowable exceedances of each set of DO, water clarity, SAV, and chlorophyll *a* criteria defined through application of a biological or default reference curve (USEPA 2003a). Figure 6-1 depicts that concept in yellow as allowable exceedance of the criterion concentration.

To compare model results with the WQS, EPA analyzes the Bay Water Quality Model results for each scenario and for each modeled segment to determine the percent of time and space that the modeled waster quality results exceed the allowable concentration. For any modeled result where the exceedance in space and time (shown in Figure 6-1 as the area below the red line) exceeds the allowable exceedance (shown in Figure 6-1 as the area below the blue line that is shaded yellow), that segment is considered in nonattainment. The amount of nonattainment is shown in the figure as the area in white between the red line and the blue line and is displayed in model results as percent of nonattainment for that segment. The amount of nonattainment is reported to the whole number percent.



Source: USEPA 2003a

Figure 6-1. Graphic comparison of allowable exceedance compared to actual exceedance.

Dissolved Oxygen

Figure 6-2 displays Bay Water Quality Model results showing percent nonattainment of the 30-day mean open-water DO criterion for various basinwide loading levels of the Maryland portion of the lower central Chesapeake Bay segment CB5MH_MD.

As can be seen in Figure 6-2, there is a notable improvement in the percent nonattainment as the loads are reduced until approximately 1 percent nonattainment. At a loading level of 191 million pounds per year TN, the 1 percent nonattainment is persistent through consecutive reductions in loading levels and remains consistent until a loading level of 170 million pounds per year TN is reached. While this is one of the more extreme examples of persistent levels of 1 percent nonattainment, this general observation of persistent nonattainment at 1 percent is fairly common to the Bay Water Quality Model DO results (Appendix I).

Clear evidence of small, yet persistent percentage of model projected DO WQS nonattainment over a wide range of reduced nitrogen and phosphorus loads across a wide range of segments and designated uses, all of which are responding to nitrogen and phosphorus load reductions, is documented in Appendix I. Because of those widespread observations, supported by independent validation, and for purposes of developing the Chesapeake Bay TMDL, EPA determined that nonattainment percentages projected by the Bay Water Quality Model rounded to 1 percent would be considered in attainment for a segment's designated use. For a more detailed discussion, see Appendix I.

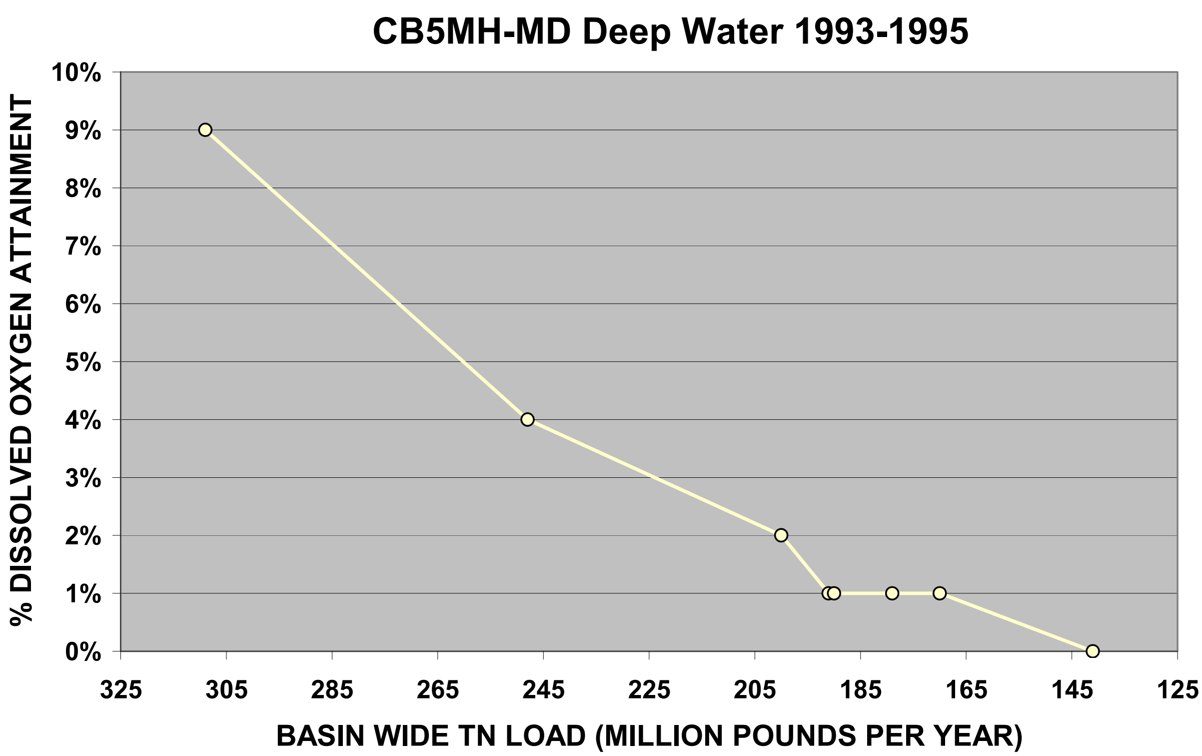


Figure 6-2. Example of DO criteria nonattainment results from a wide range of nitrogen and phosphorus load reduction model scenarios.

Chlorophyll *a*

In the case of assessment of the numeric chlorophyll *a* WQS in the tidal James River in Virginia, there was limited evidence of a reduced sensitivity when approaching the criteria values as compared with the suite of DO WQS as described above for across multiple designated uses and segments. However, as illustrated in Figure 6-3, there is a clear pattern of diminishing response to lowered loadings of nitrogen and phosphorus as the graph approaches 1 percent nonattainment. On the basis of that analysis, combined with the pattern that was even more pronounced with DO, it is EPA's professional judgment that modeled levels of 1 percent nonattainment of the numeric chlorophyll *a* WQS is considered in attainment. In developing the James River Basin allocations under the Bay TMDL, the vast majority of the spring and summer season 3-year periods came into full attainment at the established nitrogen and phosphorus allocations of 23.5 million pounds of nitrogen per year and 2.35 million pounds of phosphorus per year (Appendix O). EPA considered 1 percent nonattainment of the applicable segment and season-specific chlorophyll *a* criteria in attainment for only a limited number of segment/season/3-year period combinations given the evidence, though limited, of reduced sensitivity when approaching full attainment of the criteria values (Appendix I).

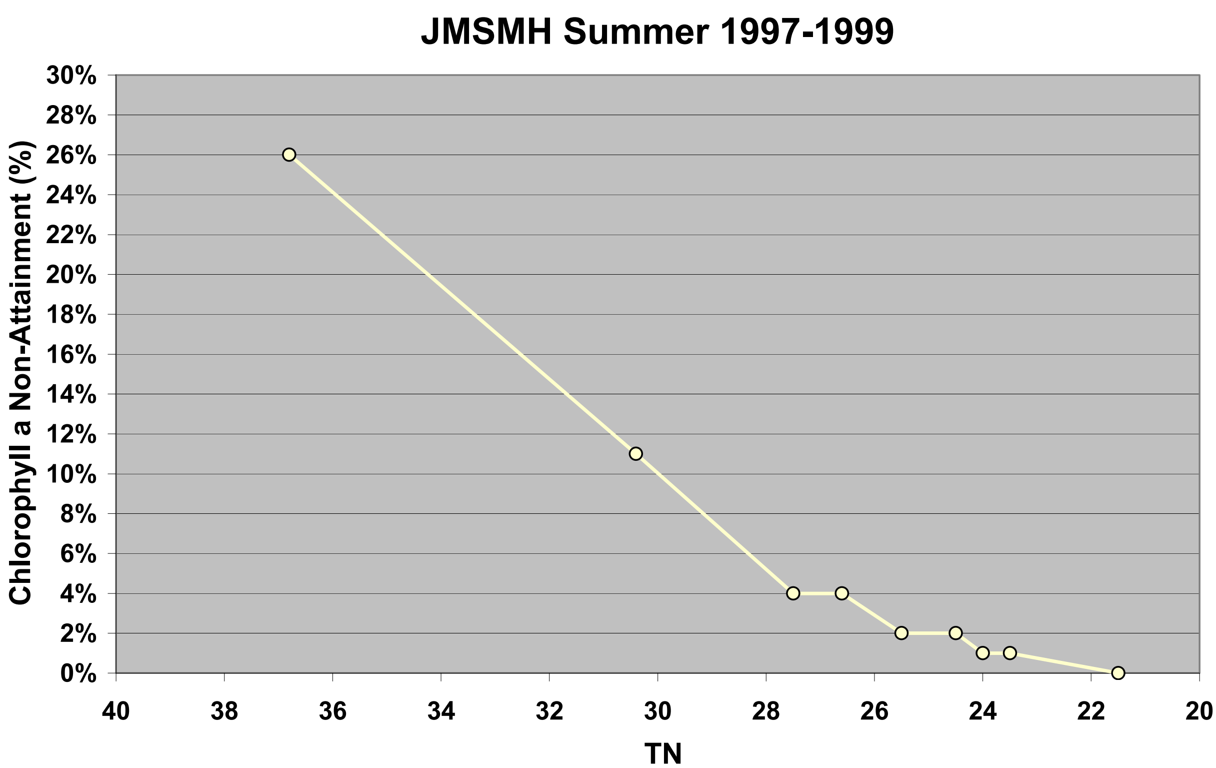


Figure 6-3. Example of a James River segment's spring chlorophyll *a* WQS nonattainment results from a wide range of TN loading Chesapeake Bay Water Quality Model scenarios.

6.2.4 Margin of Safety

Under EPA's regulations, a TMDL is mathematically expressed as

$$\text{TMDL} = \sum WLA + \sum LA + MOS$$

where

- TMDL is the total maximum daily load for the water segment
- WLA is the wasteload allocation, or the load allocated to point sources
- LA is the load allocation, or the load allocated to nonpoint sources
- MOS is the margin of safety to account for any uncertainties in the supporting data and the model

The margin of safety (MOS) is the portion of the TMDL equation that accounts for any lack of knowledge concerning the relationship between LAs and WLAs and water quality [CWA 303(d)(1)(c) and 40 CFR 130.7(c)(1)]. For example, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from various sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural waterbodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection. On the basis of EPA guidance, the MOS can be achieved through two approaches (USEPA 1999): (1) implicitly incorporate the MOS by using conservative model assumptions to develop allocations; or (2) explicitly specify a portion of the

TMDL as the MOS and use the remainder for allocations. Table 6-2 describes different approaches that can be taken under the explicit and implicit MOS options.

Table 6-2. Different approaches available under the explicit and implicit MOS types

Type of MOS	Available approaches
Explicit	• Set numeric targets at more conservative levels than analytical results indicate. • Add a safety factor to pollutant loading estimates. • Do not allocate a portion of available loading capacity; reserve for MOS.
Implicit	• Use conservative assumptions in derivation of numeric targets. • Use conservative assumptions when developing numeric model applications. • Use conservative assumptions when analyzing prospective feasibility of practices and restoration activities.

Source: USEPA 1999

Implicit Margin of Safety for Nitrogen and Phosphorus

The Chesapeake Bay TMDL analysis is built on a foundation of more than two decades of modeling and assessment in the Chesapeake Bay and decades of Bay tidal waters and watershed monitoring data. The Bay Airshed, Watershed, and Water Quality models are state-of-the-science models, with several key models in their fourth or fifth generation of management applications since the early and mid-1980s. The use of those sophisticated models to develop the Bay TMDL, combined with application of specific conservative assumptions, significantly increases EPA’s confidence that the model’s predictions of standards attainment are correct and, thereby, supports the use of an implicit MOS for the Chesapeake TMDL.

The Chesapeake Bay TMDL for nitrogen and phosphorus applies an implicit MOS in derivation of the DO and chlorophyll *a*-based nitrogen and phosphorus allocations through the use of numerous conservative assumptions in the modeling framework. The principal set of conservative assumptions used in the determining the actual allocations is as follows.

The basinwide allowable nitrogen and phosphorus loads were determined on the basis of achieving a select set of deep-water and deep-channel DO standards in the mainstem Bay and adjoining embayments—upper (CB3), middle (CB4MH) and lower (CB5MH) central Chesapeake Bay, and lower Potomac River (POTMH_MD). The Bay TMDL calls for nitrogen load reductions upwards of 50 million pounds greater than that necessary to achieve the applicable DO WQS in those four Bay segments compared with many of the remaining 88 Bay segments.

The open-water and deep-water standards adopted by the jurisdictions have DO WQS that apply to a 30-day mean and an instantaneous maximum. The open-water standards also have a 7-day mean and the deep water use has a 1-day mean. Last, the deep channel use has only a deep-channel instantaneous minimum. The Bay TMDL assessed attainment of each of those standards. But, as described in Appendix D and summarized in Section 3.3.3, the 30-day mean was clearly the most restrictive of the standards for the open-water and deep-water use classifications. For that reason, the allocations were based on 30-day mean for open-water and deep-water and instantaneous standards for deep channel. Because the allocations to achieve those standards are significantly more restrictive than the allocations needed to achieve the other DO standards for the Bay segments, there is an implicit MOS in achieving many of the Bay DO standards.

The DO standards apply year-round. Yet, at the allocated loadings, for the non-summer months of the year, the standards will be readily achieved. Further, as described above, most of the Bay and tributary tidal waters will readily achieve the applicable WQS at the allocated loads because of the conservative assumption described above. So from an aggregate viewpoint, the expected water quality at the allocated loads will readily attain the applicable WQS most of the time and will marginally attain the applicable WQS only about once in 10 years, and only for a small fraction of the summer months, and only for a very small portion of the volume of the Bay and tidal tributary waters.

An assumption of the model is the concentration of nitrogen, phosphorus, and sediment from the ocean waters entering the Bay. This is called a boundary condition. With improvement in pollutant controls, it is expected that the coastal ocean concentration of the pollutants will go down. EPA has conservatively estimated this reduction in coastal ocean water pollutant levels but only for reductions in atmospheric deposition (see Appendix L). EPA has not adjusted this boundary condition for expected land-based reductions. Such significant reductions can be expected from Long Island Sound, Delaware River, and other mid-Atlantic estuaries that all contribute nitrogen and phosphorus loads to Chesapeake Bay via the ocean boundary. Thus the boundary condition in the model for the concentration and, therefore the loading, of nitrogen, phosphorus, and sediment is higher than the concentration likely to exist with the application of coastal, land-based controls.

In addition to the above, the extensive development and refinement of the Bay models provides for excellent confidence in the modeling accuracy and conversely speaks to the need for a minimal (implicit) MOS. The following are some, but not all, of the model attributes that are in Section 5 that demonstrate the robust science behind the modeling network in support of the bay TMDL:

- The models are based on decades of data (1985–2005) used to develop, calibrate, and validate the models.
- A substantial increase in the number of stations was used to calibrate the watershed model to available data.
- The models are in some cases in their fifth generation of refinement, because of extensive input from baywide and national experts in the field.
- The modeling grid for both the Bay Watershed and Bay Water Quality and Sediment Transport models has been refined up to ten times the previous number of modeling segments.

The individual reasons cited above may not be sufficient to singly merit the conclusion that an implicit MOS is appropriate for the nitrogen and phosphorus allocations, but together those reasons provide ample support, in EPA's professional judgment, that an implicit MOS is adequate.

6.3 Methodology for Establishing the Basin-Jurisdiction Allocations for Nitrogen and Phosphorus

An early step in the process of developing the Bay TMDL, especially for nitrogen and phosphorus, is to determine the allowable loading from jurisdictions and major basins draining to the Bay. As a result, an equitable approach must be employed to apportion the allowable loading among the jurisdictions. This subsection describes the process EPA ultimately selected for this Bay TMDL.

Nitrogen and phosphorus from sources further upstream within the Chesapeake Bay watershed affect the condition of local receiving waters and affect tidal water quality conditions far downstream, hundreds of miles away in some cases. For example, the middle part of the mainstem Chesapeake Bay is affected by nitrogen and phosphorus from all parts of the Bay watershed. A key objective of the nitrogen and phosphorus allocation methodology was to find a process, based on an equitable distribution of loads for which the basinwide load for nitrogen and phosphorus could be distributed among the basin-jurisdictions. This section describes the specific processes involved in allocating the nitrogen and phosphorus loads necessary to meet the jurisdictions' Chesapeake Bay DO and chlorophyll *a* WQS. While many alternative processes were explored (Appendix K), only the process determined to be appropriate by EPA and agreed upon by five of the seven Bay watershed jurisdictional partners are described here.

Principles and Guidelines

The nitrogen and phosphorus basin-jurisdiction allocation methodology was developed to be consistent with the following guidelines adopted by the partnership:

- The allocated loads should protect the living resources of the Bay and its tidal tributaries and result in all segments of the Bay mainstem, tidal tributaries, and embayments meeting WQS for DO, chlorophyll *a*, and water clarity.
- Major river basins that contribute the most to the Bay water quality problems must do the most to resolve those problems (on a pound-per-pound basis).
- All tracked and reported reductions in nitrogen and phosphorus loads are credited toward achieving final assigned loads.

A number of critical concepts are important in understanding the major river basin by jurisdiction nitrogen and phosphorus allocation methodology. They include the following:

- Accounting for the geographic and source loading influence of individual major river basins on tidal water quality termed relative effectiveness
- Determining the controllable load
- Relating controllable load with relative effectiveness to determine the allocations of the basinwide loads to the basin-jurisdictions

The following subsections further describe the above concepts and how they directly affect the Chesapeake Bay TMDL.

6.3.1 Accounting for Relative Effectiveness of the Major River Basins on Tidal Water Quality

Relative effectiveness accounts for the role of geography on nitrogen and phosphorus load changes and, in turn, Bay water quality. Because of various factors such as in-stream transport and nitrogen and phosphorus cycling in the watershed, a given management measure on water quality in the Bay, varies depending on the location of its implementation within the watershed (USEPA 2003b). For example, the same control applied in Williamsport, Pennsylvania, will have less of an effect on Bay DO than one applied in Baltimore, Maryland.

A relative effectiveness assessment evaluates the effects of both estuarine transport (location of discharge/runoff loading to the Bay) and riverine transport (location of the discharge/runoff loading in the watershed). EPA determined the relative effectiveness of each contributing river basin in the overall Bay watershed on DO in several mainstem Bay segments and the lower Potomac River by using the Bay Water Quality Model to run a series of isolation runs and using the Bay Watershed Model to estimate attenuation of load through the watershed.

From the relative estuarine effectiveness analysis, several things are apparent. Northern, major river basins have a greater relative influence than southern major river basins on the central Bay and the lower Potomac River DO levels because of the general circulation patterns of the Chesapeake Bay (up the Eastern Shore, down the Western Shore). Nitrogen and phosphorus from the most southern river basins of the James and York rivers have relatively less influence on mainstem Bay water quality because of their proximity to the mouth of the Bay. Because these southern river basins are on the western shore, the counterclockwise circulation of the lower Bay also tends to transport nitrogen and phosphorus loads from those larger southern river basins out of the Bay mouth. That same counterclockwise circulation tends to sweep loads from the lower Eastern Shore northward.

River basins whose loads discharge directly to the mainstem Bay, like the Susquehanna, tend to have more effect on the mainstem Bay segments than basins with long riverine estuaries (e.g., the Patuxent, Potomac, and Rappahannock rivers). The long riverine estuaries, with longer water residence times, allow nitrogen and phosphorus attenuation (burial and denitrification) before the waters reaching the mainstem Chesapeake Bay. The size of a river basin is uncorrelated to its relative influence, although larger river basins, with larger loads, have a greater absolute effect. The upper tier of relative effect on the three mainstem segments includes the largest river basin (Susquehanna) and the smallest (Eastern Shore Virginia). Their high degree of impact is because they both discharge directly into the Bay, without intervening river estuaries to attenuate loads, and they are both up-current relative to the general Bay circulation pattern.

The estuarine effectiveness is estimated by running a series of Bay Water Quality Model scenarios holding one major river basin at E3 loads and all other major river basins at calibration levels. After considering several metrics to assess the DO benefit from progressive reductions in nitrogen and phosphorus loadings, EPA chose a 25th percentile. The advantage of this metric was that it was based on DO values at the more critical lower end of the range (25th percentile) yet, unlike a percent nonattainment metric, it could also be used for segments that were in attainment under some loading scenarios. For each scenario, the increase in the 25th percentile DO concentration during the summer criteria assessment period in the critical segments CB3MH, CB4MH, and CB5MH for deep-channel and CB3MH, CB4MH, CB5MH, and POTMH for deep-water was recorded. The 25th percentile was selected as the appropriate metric as indicative of a change in low DO. The riverine effectiveness is calculated as the fraction of load produced in the watershed that is delivered to the estuary. It is estimated as an output of the watershed model. For more details on this method, see Appendix K.

Absolute estuarine effectiveness accounts for the role of both total loads and geography on pollutant load changes to the Bay. The absolute estuarine effectiveness of a contributing river basin, measured separately both above and below the fall line, is the change in 25th percentile DO concentration that results from a single basin changing from calibration conditions to E3. For example, if the 25th percentile DO in the deep water of the lower Potomac River segment POTMH moves from 5 to 5.3 mg/L from a change in loads from calibration to E3 in the Potomac above fall line basin, the absolute estuarine effectiveness is 0.3 mg/L. Comparing the absolute estuarine effectiveness among basins helps to identify which major river basins have the greatest effect on WQS.

Relative estuarine effectiveness is defined as absolute estuarine effectiveness divided by the total load reduction, delivered to tidal waters, necessary to gain that water quality response. For example, if the load reduction in the Potomac above fall line basin was 30 million pounds of pollutant to get a 0.3 mg/L change in DO concentration, the relative estuarine effectiveness is 0.01 mg/L per million pounds. The higher the relative estuarine effectiveness, the less reduction required to achieve the change in status. The relative estuarine effectiveness calculation is an attempt to isolate the effect of geography by normalizing the load on a per-pound basis. Comparing the relative estuarine effectiveness among the major river basins shows the resulting gain in attainment from performing equal pound reductions among the major river basins.

Riverine attenuation also has an effect on overall effectiveness. Loads are naturally attenuated or reduced as they travel through long free-flowing river systems, making edge-of-stream loads in headwater regions less effective on a pound-for-pound basis than edge-of-stream loads that take place nearer tidal waters in the same river basin. The watershed model calculates delivery factors as the fraction of edge-of-stream loads that are delivered to tidal waters. The units of riverine attenuation are delivered pound per edge-of-stream pound.

Multiplying the estuarine relative effectiveness (measured as DO increase per delivered pound reduction) by the riverine delivery factor (measured as delivered pound per edge-of-stream pound) gives the overall relative effectiveness in DO concentration increase per edge-of-stream pound. The relative estuarine effectiveness is the same for nitrogen or phosphorus, while the riverine delivery is different, so the overall relative effectiveness is calculated separately for nitrogen and phosphorus. Table 6-3 gives the overall relative effectiveness for nitrogen and phosphorus for the watershed jurisdictions by major river basin for above and below the fall line.

The relative effectiveness numbers are separate for WWTPs and all other sources. The distinction is made because of the following:

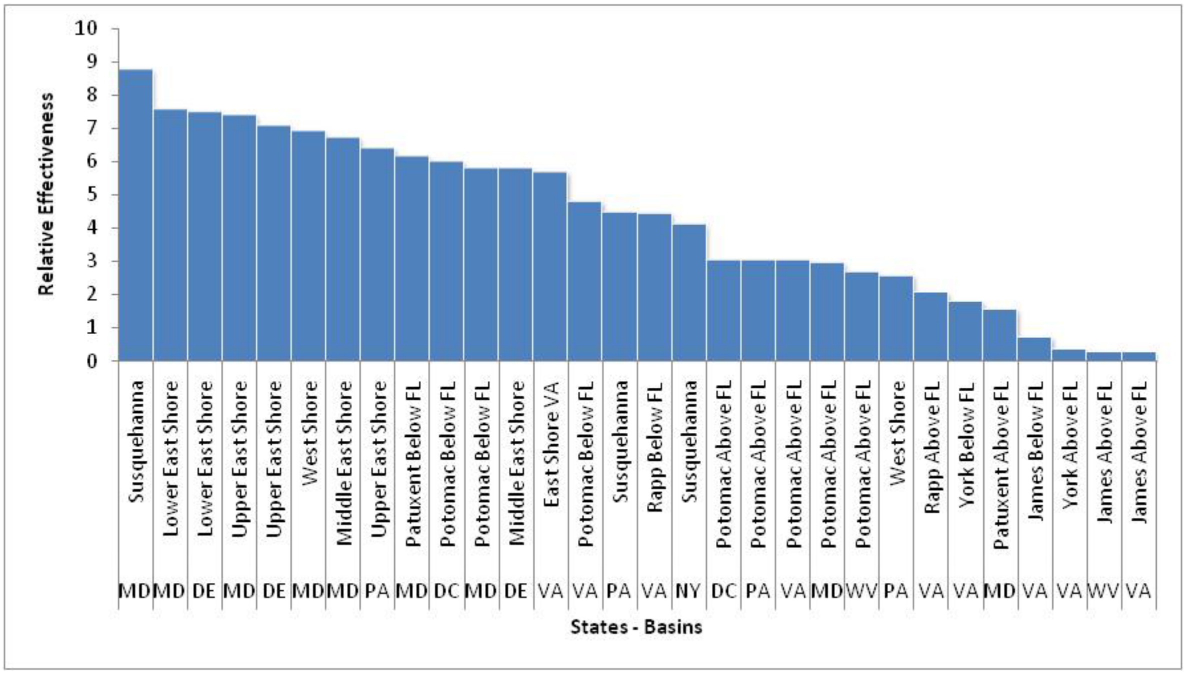
1. There is a wide disparity in the percent loading from WWTPs when comparing one basin to another.
2. On the basis of information in Appendix K, it is EPA’s professional judgment that WWTPs can achieve a much higher percent of controllable load than that for other sources.

The difference in relative effectiveness is because of the geographic location of the sources. For example, in the Maryland western shore basin, the majority of the wastewater treatment load is discharged directly to tidal waters, whereas a significant fraction of all other sources are upstream, including areas that are above reservoirs with very low delivery factors.

Table 6-3. Relative effectiveness (measured as DO concentration per edge-of-stream pound reduced) for nitrogen and phosphorus for watershed jurisdictions by major river basin and above and below the fall line

Jurisdiction	Basin	WWTP nitrogen	All other nitrogen	WWTP phosphorus	All other phosphorus
District of Columbia	Potomac above Fall Line	6.09	6.09	3.08	3.08
District of Columbia	Potomac below Fall Line	6.17	5.15	6.17	5.62
Delaware	Lower East Shore	7.93	7.30	7.97	7.46
Delaware	Middle East Shore	4.13	4.74	5.51	5.83
Delaware	Upper East Shore	6.75	6.75	7.10	7.10
Maryland	Lower East Shore	7.88	7.37	7.89	7.55
Maryland	Middle East Shore	6.91	6.49	6.92	6.71
Maryland	Patuxent above Fall Line	1.89	1.25	1.66	1.58
Maryland	Patuxent below Fall Line	6.38	6.20	6.38	6.10
Maryland	Potomac above Fall Line	3.32	3.25	2.99	2.99
Maryland	Potomac below Fall Line	6.17	4.86	6.12	5.75
Maryland	Susquehanna	9.39	8.68	9.11	8.77
Maryland	Upper East Shore	7.49	7.27	7.49	7.40
Maryland	West Shore	7.83	4.98	7.68	6.13
New York	Susquehanna	5.60	4.58	4.25	4.11
Pennsylvania	Potomac above Fall Line	2.10	1.98	3.08	3.08
Pennsylvania	Susquehanna	6.99	6.44	4.38	4.58
Pennsylvania	Upper East Shore	5.50	5.95	6.12	6.47
Pennsylvania	West Shore	2.23	2.23	2.61	2.61
Virginia	East Shore VA	5.72	5.72	5.72	5.72
Virginia	James above Fall Line	0.23	0.25	0.33	0.31
Virginia	James below Fall Line	0.79	0.61	0.79	0.70
Virginia	Potomac above Fall Line	1.45	1.97	3.08	3.08
Virginia	Potomac below Fall Line	5.54	3.54	5.49	4.62
Virginia	Rappahannock above Fall Line	1.05	0.83	2.10	2.10
Virginia	Rappahannock below Fall Line	4.48	4.41	4.48	4.47
Virginia	York above Fall Line	0.37	0.31	0.43	0.40
Virginia	York below Fall Line	1.85	1.77	1.85	1.82
West Virginia	James above Fall Line	0.06	0.06	0.34	0.34
West Virginia	Potomac above Fall Line	1.34	1.72	2.12	2.89

Figure 6-4 illustrates the relative effectiveness scores for nitrogen of the major river basins provided in Table 6-3 in descending order.



Source: Table 6-3

Figure 6-4. Relative effectiveness for nitrogen for the watershed jurisdictions and major rivers basins, above and below the fall line, in descending order.

Figure 6-5 and Figure 6-6 provide additional graphical illustration of the relative effectiveness concept for all the basins in the watershed related to nitrogen and phosphorus loading, respectively. The figures illustrate that, on a per-pound basis, a large disparity exists among basin loads on the effect of DO concentrations in the Bay. Generally, the northern and eastern river basins have a greater effect on water quality than do other basins.

6.3.2 Determining Controllable Load

Modeling in support of developing the Chesapeake Bay TMDL employs two theoretical scenarios that help to illustrate the load reductions in the context of a controllable load.

The No Action scenario is indicative of a theoretical worst case loading situation in which no controls exist to mitigate nitrogen, phosphorus, and sediment loads from any sources. It is specifically designed to support equity among basin-jurisdiction allocations in that the levels of all control technologies, BMPs, and program implementation are completely removed.

The E3 scenario—everything by everyone everywhere—represents a best-case possible situation, where a certain set of possible BMPs and available control technologies are applied to land, given the human and animal populations, and wastewater treatment facilities are represented at highest technologically achievable levels of treatment regardless of costs. Again, it considers equity among the allocations in that the levels of control technologies, BMPs, and program implementation are the same across the entire watershed.

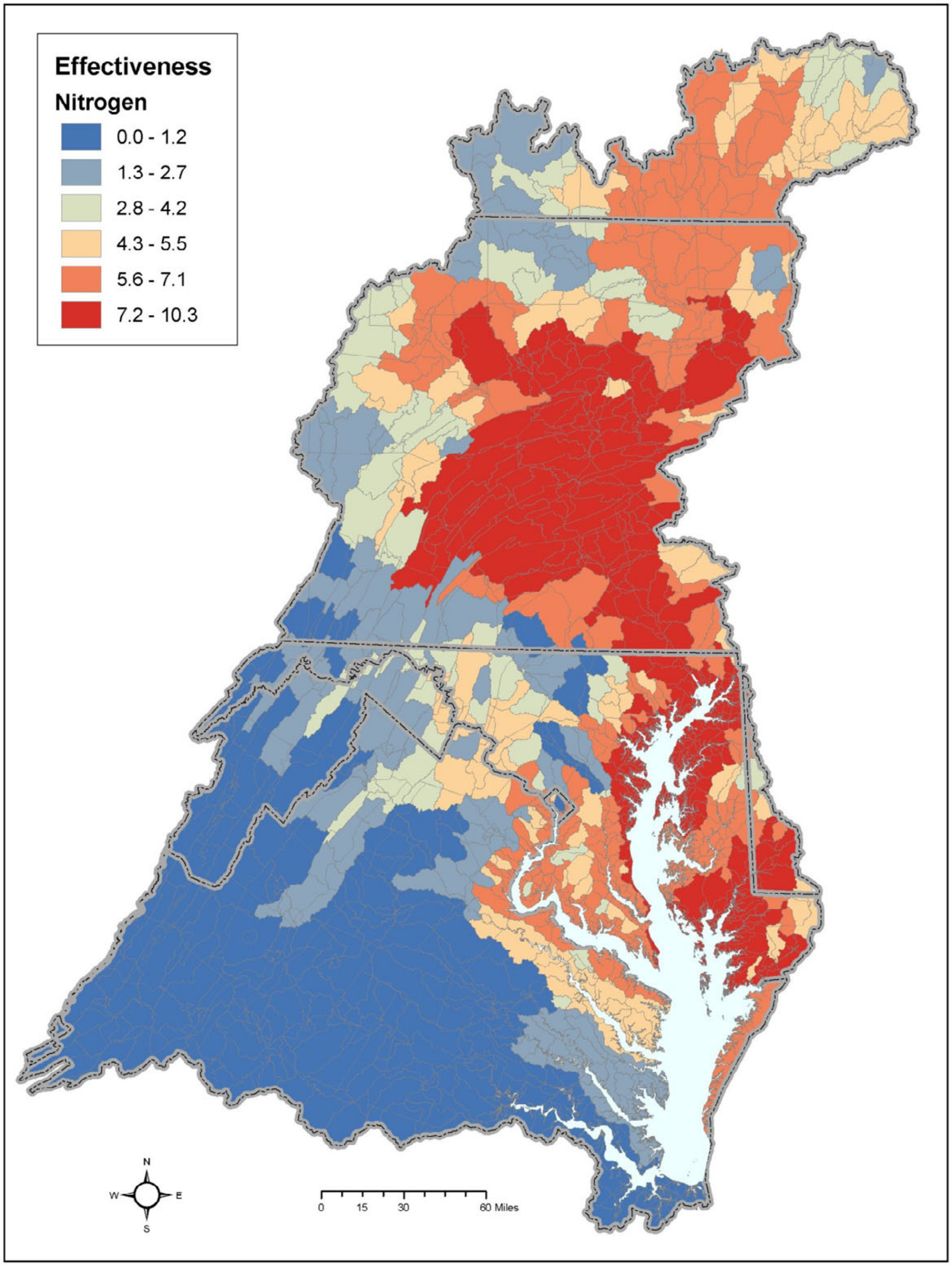


Figure 6-5. Relative effectiveness illustrated geographically by subbasins across the Chesapeake Bay watershed for nitrogen.

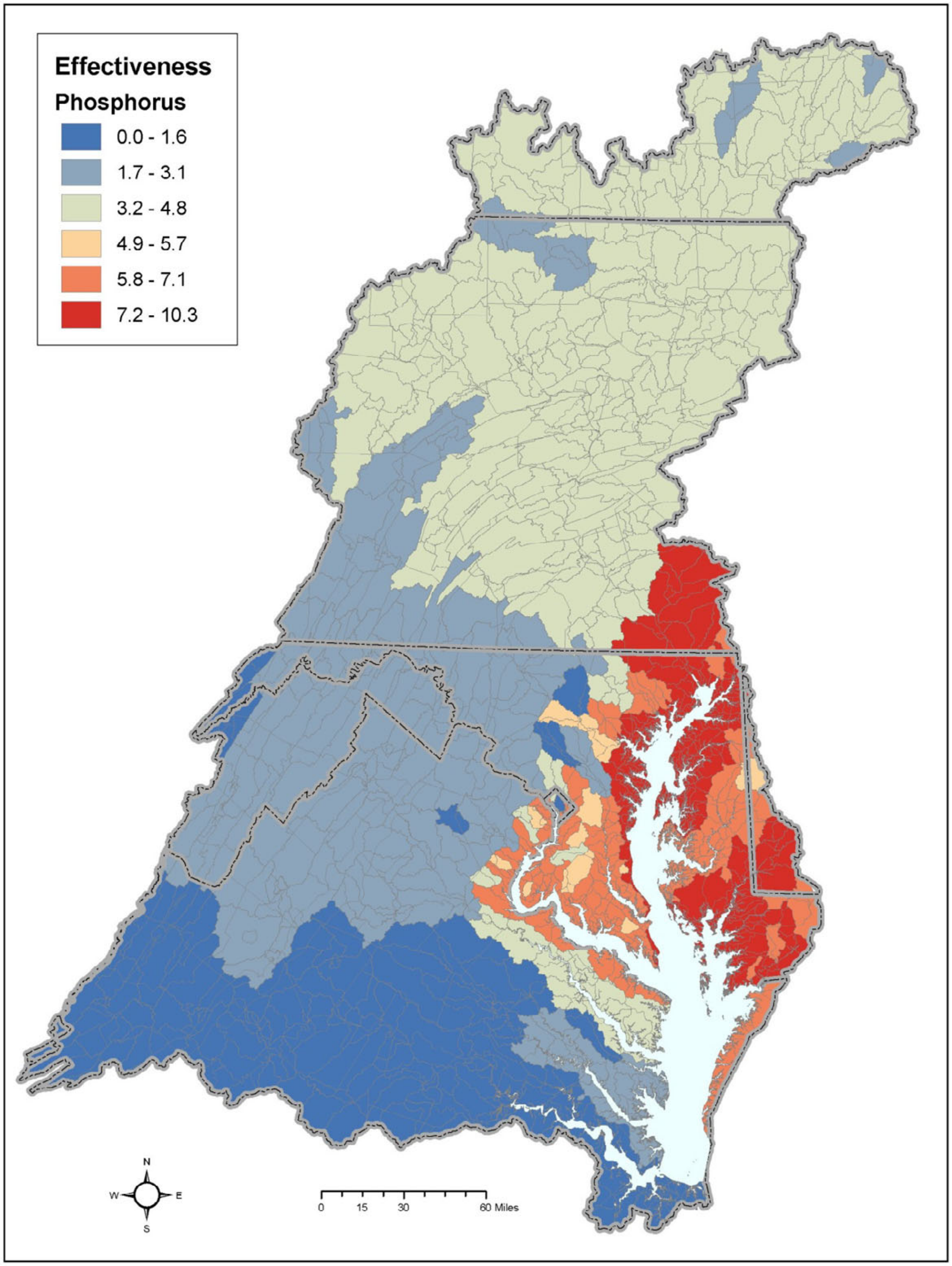


Figure 6-6. Relative effectiveness for illustrated geographically by subbasins across the Chesapeake Bay watershed for phosphorus.

The gap between the No Action scenario and the E3 scenario represents the maximum theoretical controllable load reduction that is achievable by fully implementing the control technologies included in E3 scenario. Those and other key reference scenarios are defined and documented in detail in Appendix J.

Each scenario can be run with any given year's land-use representation. The year 2010 was selected as the base year because it represents conditions at the time the Bay TMDL is developed. Thus, the 2010 No Action scenario represents loads resulting from the mix of land uses and point sources present in 2010 with no effective controls on loading, while the 2010 E3 scenario represents the highest technically feasible treatment that could be applied to the mix of all land use-based sources and permitted point sources in 2010 (Table 6-4).

Basinwide, anthropogenic, controllable loads are determined by subtracting the basinwide E3 load from the basinwide No Action load. Calculated *percentage of E3* is used as a comparative tool for assessing the relative level of effort between various loading reduction scenarios.

Table 6-4. Pollutant sources as defined for the No Action and E3 model scenarios

Model source	Scenario	
	No Action	**E3 = Everyone Everything Everywhere**
Land uses	No BMPs applied to the land	All possible BMPs applied to land given current human and animal population and land use
Wastewater Dischargers	Significant municipal WWTPs Flow = design flows TN = 18 mg/L TP = 3 mg/L BOD = 30 mg/L DO = 4.5 mg/L TSS = 15 mg/L	Significant municipal WWTPs Flow = design flows TN = 3 mg/L TP = 0.1 mg/L BOD = 3 mg/L DO = 6 mg/L TSS = 5 mg/L
	Non-significant municipal WWTPs Flow = existing flows TN = 18 mg/L TP = 3 mg/L BOD = 30 mg/L DO = 4.5 mg/L TSS = 15 mg/L	Non-significant municipal WWTPs Flow = existing flows TN = 8 mg/L TP = 2 mg TP/l BOD = 5 mg/L DO = 5 mg/L TSS = 8 mg/L
CSOs	Flow = 2003 base condition flow TN = 2003 load estimate TP = 2003 load estimate BOD = 2003 load estimate DO = 2003 load estimate TSS = 2003 load estimate	Full storage and treatment of CSOs
Atmospheric deposition	1985 Air Scenario	2030 Air Scenario, max reductions

Source: Appendix J
Note: BOD = biological oxygen demand; DO = dissolved oxygen; TN = total nitrogen; TP = total phosphorus; TSS = total suspended solids

6.3.3 Relating Relative Impact to Needed Controls (Allocations)

To apply the allocation methodology, loads from each major river basin were divided into two categories—wastewater and all other sources (Figure 6-7). The rationale for such separate accounting is the higher likelihood of achieving greater load reductions for the wastewater sector than for other source sectors (Appendix K). In addition there was a wide disparity between basin and jurisdictions on the fraction of the load coming from the wastewater sector as opposed to other sectors. Therefore, that disparity is addressed by separate accounting for the wastewater sector from the other sectors in the allocation methodology. Wastewater loads included all major and minor municipal, industrial and CSO discharges. Then lines were drawn for each of the two source categories such that the addition of the two lines would equal the basinwide nitrogen and phosphorus loading targets for nitrogen and phosphorus.

Using the general methodology described above, the CBP partners considered many different combinations of wastewater and other sources controls and slopes of the lines on the allocation graph (Appendix K). After discussing the options at length, the following graph specifications were generally accepted by the partners and determined to be appropriate by EPA.

The wastewater line was set first and would be a hockey stick shape with load reductions increasing with relative effectiveness until a maximum percent controllable load was reached.

For nitrogen

- The maximum percent controllable load was 90 percent, corresponding to an effluent concentration of 4.5 mg/L.
- The minimum percent controllable load was 67 percent, corresponding to an effluent concentration of 8 mg/L.

For phosphorus

- The maximum percent controllable load was 96 percent, corresponding to an effluent concentration of 0.22 mg/L.
- The minimum percent controllable load was 85 percent, corresponding to an effluent concentration of 0.54 mg/L.

For both the nitrogen and phosphorus wastewater lines

- Any relative effectiveness that was at least half of the maximum relative effectiveness value was given maximum percent controllable.
- The minimum controllable load value was assigned to a relative effectiveness of zero, and all values of relative effectiveness between zero and half of the maximum value were assigned interpolated percentages (Figure 6-7).

The other sources line was set at a level that was necessary to achieve the basinwide load needed for achieving the DO standards in the middle mainstem Bay and lower tidal Potomac River segments. That line was set at a slope such that there was a 20 percent overall difference from highest controllable load to lowest, ranging from 56 percent of controllable loads for basins with low relative effectiveness to 76 percent of controllable loads for basins with high relative effectiveness for nitrogen (Figure 6-7). The slope was chosen as the most supported by the jurisdiction partners after exploring many options. The slope provides a balance of enough relief of controls for the less effectiveness basins yet still requires significant controls for all basins.

For each category—wastewater and all other sources—loads are aggregated by major basin and reductions are assigned according to the process detailed above. The graph in Figure 6-7 illustrates the methodology for the total nitrogen target load of 190 million lbs per year.

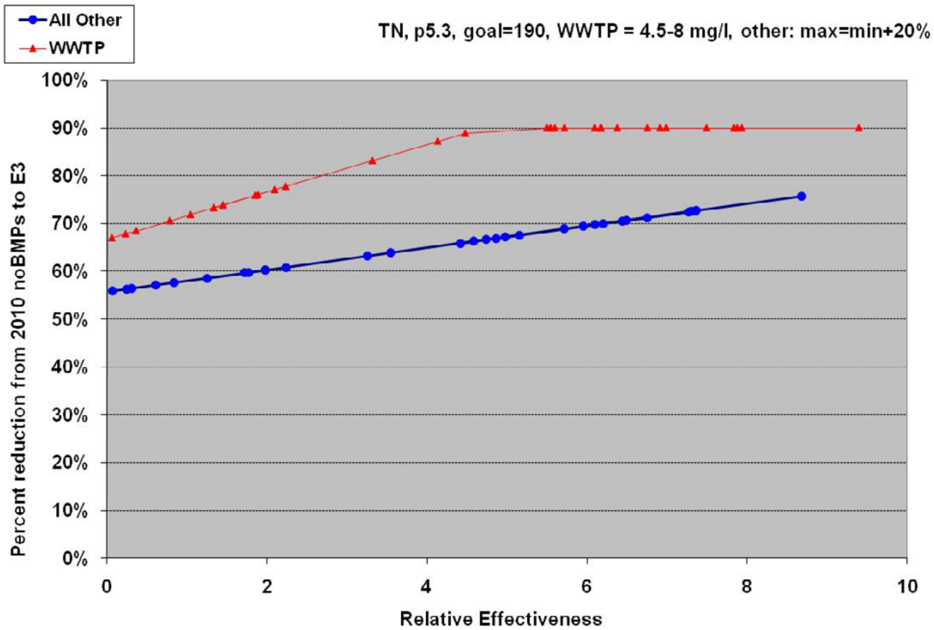


Figure 6-7. Allocation methodology example showing the *hockey stick* and straight line reductions approaches, respectively, to wastewater (red line) and all other sources (blue line) for nitrogen.

6.4 Establishing the Basin-Jurisdiction Allocations for Nitrogen and Phosphorus

This subsection describes the application of all the processes described earlier in this section. EPA identified the nitrogen and phosphorus allocations to the basin-jurisdictions in a letter on July 1, 2010, from the EPA Region 3 Administrator to the seven watershed jurisdictions (USEPA 2010f). The allocations to the seven watershed jurisdictions were derived to achieve Chesapeake Bay WQS recently adopted by the four Bay jurisdictions.

The Bay jurisdictions' WQS are described in Section 3.3. The allocations in the letter cited above are the allocations on which the jurisdictions based their draft and final Phase I WIPs. The full process for establishing the nitrogen and phosphorus basin-jurisdiction allocations is described below:

- Established the atmospheric deposition allocations on the basis of addressing the requirements of the CAA to meet existing national air quality standards out through 2020.
- Set the basinwide nitrogen and phosphorus loads on the basis of attaining the applicable DO criteria in those Bay segments (middle Chesapeake Bay mainstem and the lower tidal Potomac River) and designated uses (deep-water and deep-channel) whose water quality

conditions are influenced by major river basins and jurisdictions throughout the Bay watershed.

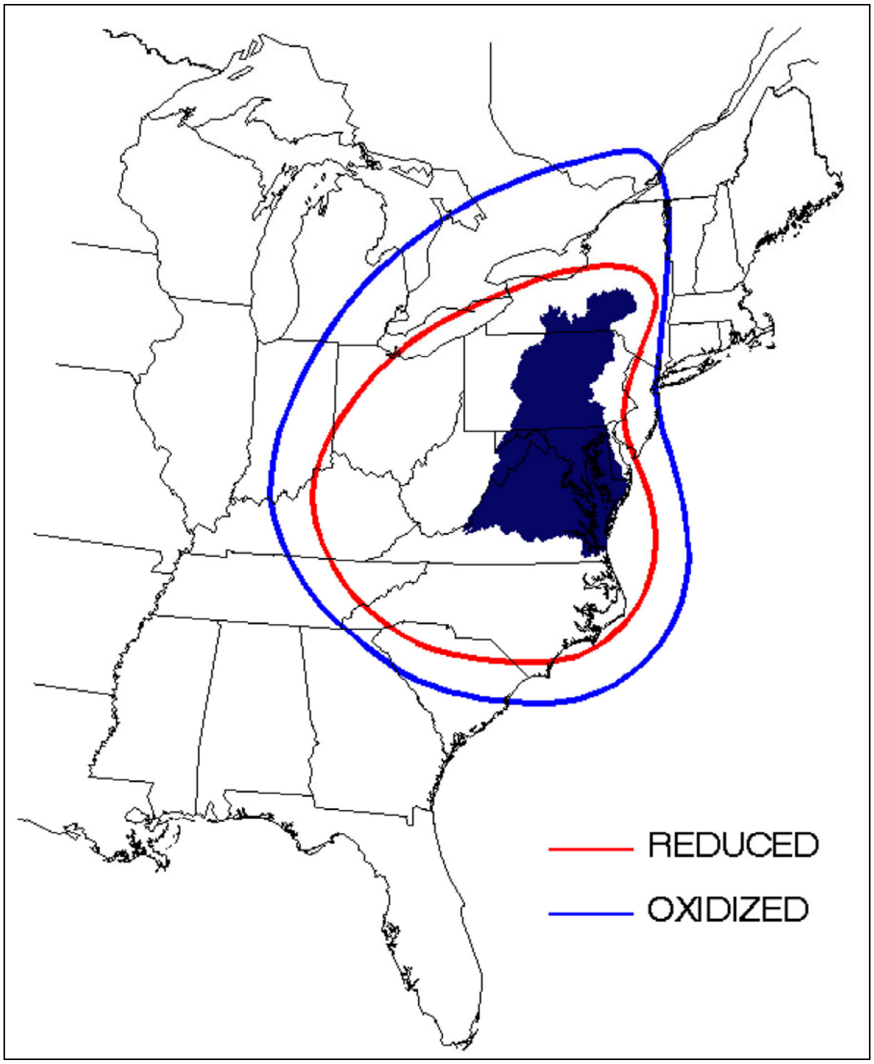
- Distributed the basinwide nitrogen and phosphorus loads by major river basin and jurisdiction following the methodology developed by the partnership (see Section 6.2).
- Made certain discretionary adjustments to the allocations to New York and West Virginia.
- Allowed for individual jurisdictions to exchange nitrogen and phosphorus loads within and between their major river basins using specific exchange ratios, as long as the exchanges still resulted in attainment of all WQS.
- Identified those individual Bay segments still not attaining their applicable DO/chlorophyll *a* WQS at the allocated basinwide nitrogen and phosphorus loads and addressed the remaining nonattainment segments.
- Derived the final basin-jurisdiction nitrogen and phosphorus allocations to achieve the applicable WQS for DO and chlorophyll *a* in all 92 Bay segments.

Individual jurisdictions further suballocated their major river basin-jurisdiction allocated loads within their Phase I WIPs down to their respective Bay segment watersheds in their jurisdiction. After in-depth review of the final Phase I WIPs and the public comments, EPA made final determinations on the allocations as described in Section 8.

6.4.1 Setting the Atmospheric Nitrogen Deposition Allocation

Atmospheric deposition of nitrogen is the major source of nitrogen to the Chesapeake Bay watershed, greater than the other sources of fertilizer, manures, or point sources. For that reason, it is necessary to allocate an allowable loading of nitrogen from air deposition in the Chesapeake Bay TMDL. The nitrogen loadings come from many jurisdictions outside the Chesapeake Bay watershed. Figure 6-8 shows the approximate delineation of the Bay airshed. Seventy-five percent of the nitrogen air deposition loads to the Chesapeake watershed originate from sources within the Bay airshed, with twenty-five percent originating from sources beyond the airshed, and in the largest sense, the source of atmospheric loads to the Chesapeake Bay watershed are global. That is reflected in the Bay Airshed Model, which has a domain of all North America (with boundary conditions to quantify global nitrogen sources). About 50 percent of the oxidized nitrogen (NOx) atmospheric deposition loads to the Chesapeake watershed and tidal Bay come from the seven Bay watershed jurisdictions. For more detailed discussion, see Appendix L.

By including air deposition in the Bay TMDLs LAs, the Bay TMDL accounts for the emission reductions that will be achieved by seven watershed jurisdictions and other states in the larger Bay airshed. If air deposition and expected reductions in nitrogen loading to the Bay were not included in the LAs, other sources would have to reduce nitrogen discharges/runoff even further to meet the nitrogen loading cap. Because CAA regulations and programs will achieve significant decreases in air deposition of nitrogen by 2020, EPA believes the TMDL inclusion of air allocations (and reductions) is based on both the best available information with a strong reasonable assurance that those reductions will occur. The TMDL developed for the Chesapeake Bay will reflect the expected decreases in nitrogen deposition and the 2-year federal milestones will track the progress of CAA regulations and programs.



Source: Dr. Robin Dennis, USEPA/ORD/NERL/AMAD/AEIB

Figure 6-8. Principal areas of nitrogen oxide (blue line) and ammonia (red line) emissions that contribute to nitrogen deposition to the Chesapeake Bay and its watershed (dark blue fill).

In determining the allowable loading from air deposition, EPA separated the nitrogen atmospheric deposition into two discreet parcels: (1) atmospheric deposition occurring on the land and nontidal waters in the Bay watershed, which is subsequently transported to the Bay; and (2) atmospheric deposition occurring directly onto the Bay tidal surface waters.

The deposition on the land becomes part of the allocated load to the jurisdictions because the atmospheric nitrogen deposited on the land becomes mixed with the nitrogen loadings from the land-based sources and, therefore, becomes indistinguishable from land-based sources. Furthermore, once the nitrogen is deposited on the land, it would be managed and controlled along with other sources of nitrogen that are present on that parcel of land. In contrast, the atmospheric nitrogen deposited directly to tidal surface waters is a direct loading with no land-based management controls and, therefore, needs to be linked directly back to the air sources and air emission controls. For more detailed discussion, see Appendix L.

EPA included an explicit basinwide nitrogen atmospheric deposition allocation in the Bay TMDL and determined it to be 15.7 million pounds per year of nitrogen atmospheric deposition loads direct to Chesapeake Bay tidal tributary and embayment waters (Appendix L) (see Section 9.1). Activities associated with implementation of CAA regulations by EPA and the jurisdictions through 2020 will ensure achievement of that allocation and are already accounted for within the jurisdictions' major river basin nitrogen allocations. Any additional nitrogen reductions realized through more stringent air pollution controls at the jurisdictional level, beyond minimum federal requirements to meet air quality standards, may be credited to the individual jurisdictions through future revisions to the jurisdictions' WIPs, 2-year milestones, and the Chesapeake Bay TMDL tracking and accounting framework (Appendix L).

In determining the amount of air controls to be used as a basis for the Bay TMDL air allocation, EPA relied on current laws and regulations under the CAA. Those requirements, together with national air modeling analysis, provided the resulting allocated air load from direct deposition to the tidal surface waters of the Bay and its tidal tributaries (Appendix L).

The air allocation scenario represents emission reductions from regulations implemented through the CAA authority to meet National Ambient Air Quality Standards for criteria pollutants in 2020. The air allocation scenario includes the following:

- The Clean Air Interstate Rule (CAIR) with second phase and the Clean Air Mercury Rule (CAMR)
- The Regional Haze Rule and guidelines for Best Available Retrofit Technology (BART)
- The On-Road Light Duty Tier 2 Rule
- The Clean Heavy Duty Truck and Bus Rule
- The Clean Air Non-Road Diesel Tier 4 Rule
- The Locomotive and Marine Diesel Rule
- The Non-road Large and Small Spark-Ignition Engines Programs
- The Hospital/Medical Waste Incinerator Regulations

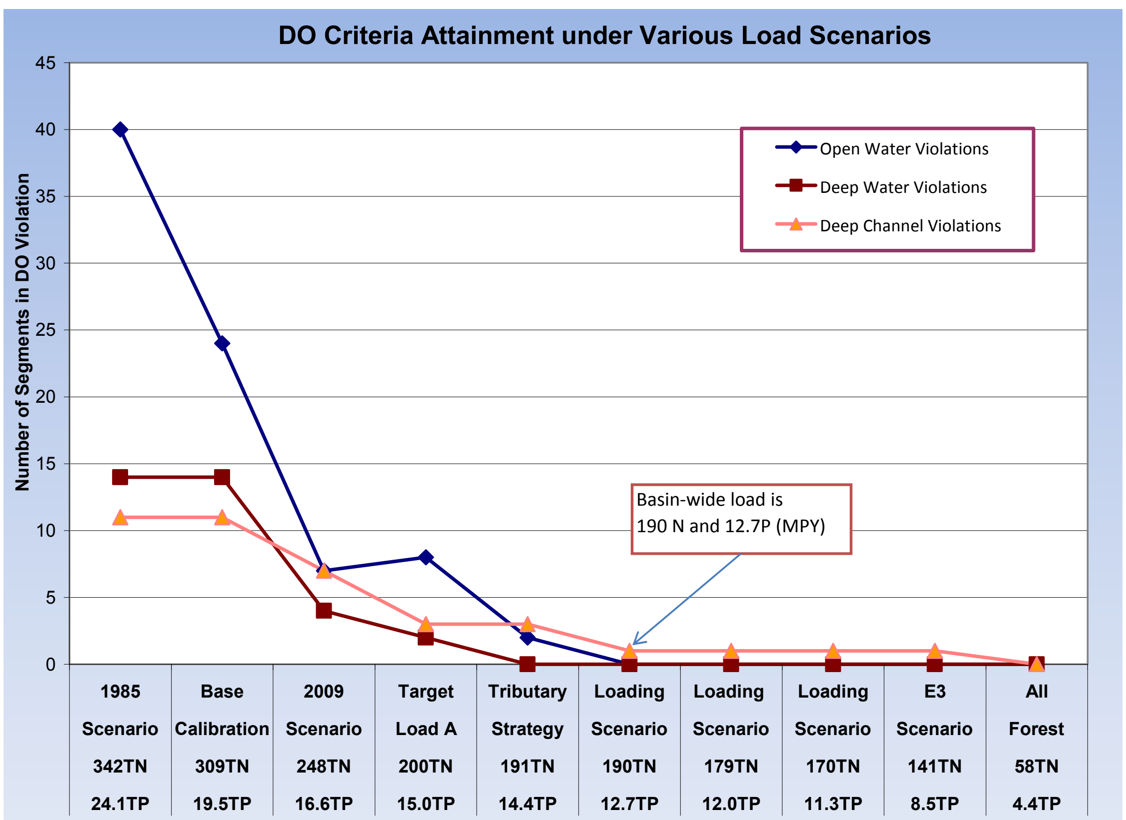
The controls described above were modeled using the Community Multiscale Air Quality (CMAQ) national model, which enabled quantification of deposition direct to the Chesapeake Bay tidal waters to be determined. Information on the CMAQ modeling analysis is at http://www.epa.gov/cair/technical.html. That approach is the basis for the previously mentioned 15.7 million pounds per year as the allocation in the Bay TMDL for air deposition directly to the tidal waters. Appendix L provides a more detailed description of the process for establishing the atmospheric deposition allocations for nitrogen.

6.4.2 Determining the Basinwide Nitrogen and Phosphorus Target Load Based on Dissolved Oxygen

With the air allocated loads being set at 15.7 million pounds per year, the next step in the process was to determine the basinwide nitrogen and phosphorus loadings that would cause the mainstem Bay and major tidal river segments—all influenced by nitrogen and phosphorus loads from multiple jurisdictions—to achieve all the applicable DO WQS. Numerical chlorophyll *a* WQS were not used for this basinwide loading determination because they apply to only the tidal James River and the District of Columbia's tidal waters of the Potomac and the Anacostia rivers and, therefore, are not affected by the other basins in the watershed. The principal Bay segments that were most important for determining the basinwide nitrogen and phosphorus loads were the middle mainstem Bay segments CB3MH, CB4MH, and CB5MH (Maryland and Virginia) and the lower tidal Potomac River segment POTMH_MD because their water quality conditions are influenced by all river basins through the Bay watershed. Therefore, achieving attainment in those segments will necessitate nitrogen and phosphorus reductions from all basins.

The process used for determining the load that will achieve the DO WQS in these segments was to progressively lower the nitrogen and phosphorus loadings simulated in the Bay Water Quality Model and then assess DO WQS attainment for each loading scenario. Numerous iterations of different load scenarios were run until the appropriate nitrogen and phosphorus loadings to achieve WQS could be determined (Appendix M).

Figure 6-9 shows the numerous water quality model runs that were performed at various loading levels and the resulting DO standards attainment results. The water quality measure on the vertical axis is the number of Bay segments that were not attaining the applicable Bay DO WQS. As can be expected, as loadings are lowered throughout the Bay watershed, the number of DO



Note: This graph expands some of the 92 TMDL segments into separate jurisdiction-segments so that the total numbers of open-water, deep-water, and deep-channel designated use segments are 98, 14, and 11, respectively

Figure 6-9. Chesapeake Bay water quality model simulated DO criteria attainment under various TN and TP loading scenarios.

WQS non-attaining segments was reduced. At the loading of 190 million pounds per year of nitrogen and 12.7 million pounds per year of phosphorus, and after considering other lines of evidence beyond the Bay Water Quality and Sediment Transport Model, as presented in Appendix N, only one Bay segment was in nonattainment for DO—lower Chester River. For the lower Chester River segment, nonattainment persisted even to extremely low loading levels. Therefore, Maryland adopted, and EPA approved a restoration variance for that segment. The final allocations for the Bay will attain that restoration variance for DO. It should be noted that the critical segments of CB3MH, CB4MH, and CB5MH for deep-channel and CB3MH, CB4MH, CB5MH, and POTMH for deep-water were among the last segments to come into attainment. Watershed-wide reductions will be needed to attain WQS in these segments. Therefore, EPA determined that basinwide nitrogen loadings of 190 million pounds per year and phosphorus loadings of 12.7 million pounds per year were sufficient to attain the main Bay DO standards; as a result, EPA distributed those loadings among the major river basins and jurisdictions in the Chesapeake Bay watershed.

6.4.3 Allocating Nitrogen and Phosphorus Loads to Jurisdictions within the Bay Watershed

After more than 2 years of discussion and exploration by EPA and the jurisdictions of many different approaches to allocating allowable loads to each of the jurisdictions and major basins, a consensus could not be reached for an approach for allocating loads to all jurisdictions. With the exception of New York and West Virginia, all the watershed jurisdictions agreed to the method described above for allocating loadings to the major river basins and jurisdictions. EPA then chose to use that method as described above to distribute the loadings based on the equity and near consensus of the jurisdictions. Using that method, EPA calculated the relative effectiveness of each of the major river basins in the Bay watershed and plotted as dots on the lines in Figures 6-10 (for phosphorus) and 6-11 (for nitrogen) to determine the basin-jurisdiction allocation represented by each of the points. On the vertical axis is the percent of controllable load (represented in the graph as No Action Minus E3 load) that would correspond to the allocated load for each basin-jurisdiction. For example, 100 percent represents a loading such that all sources would have all control technologies and practices approved by the partnership installed (E3). The horizontal axis represents the relative effectiveness of each of the basin-jurisdictions, a measure of the impact that a pound of nitrogen and phosphorus has on the DO concentrations in the Chesapeake Bay. EPA first constructed the wastewater (WWTP) line (red line in Figures 6-10 and 6-11) on the basis of the removal efficiencies of established treatment technologies.

EPA then constructed the other sources line (blue line in Figures 6-10 and 6-11) by having a difference of 20 percent of controllable load when comparing facilities/lands in the basin-jurisdiction with the highest relative effectiveness with the facilities/lands in the basin-jurisdiction with the lowest relative effectiveness. As can be seen in Figure 6-10 and Figure 6-11, facilities/lands in those basin-jurisdictions that have the highest effectiveness (or impact on the Bay) on a per-pound basis must install the most controls (the basin-jurisdictions on the right of the graph). While it is too cluttered to show each of the basin-jurisdictions on these graphs, see Table 6-3 to identify the relative effectiveness for each basin and then find that point on these graphs. Because the dots represent the various basin-jurisdictions in the watershed, the percent of controllable load can be converted to the actual allocated load to achieve the Bay DO WQS.

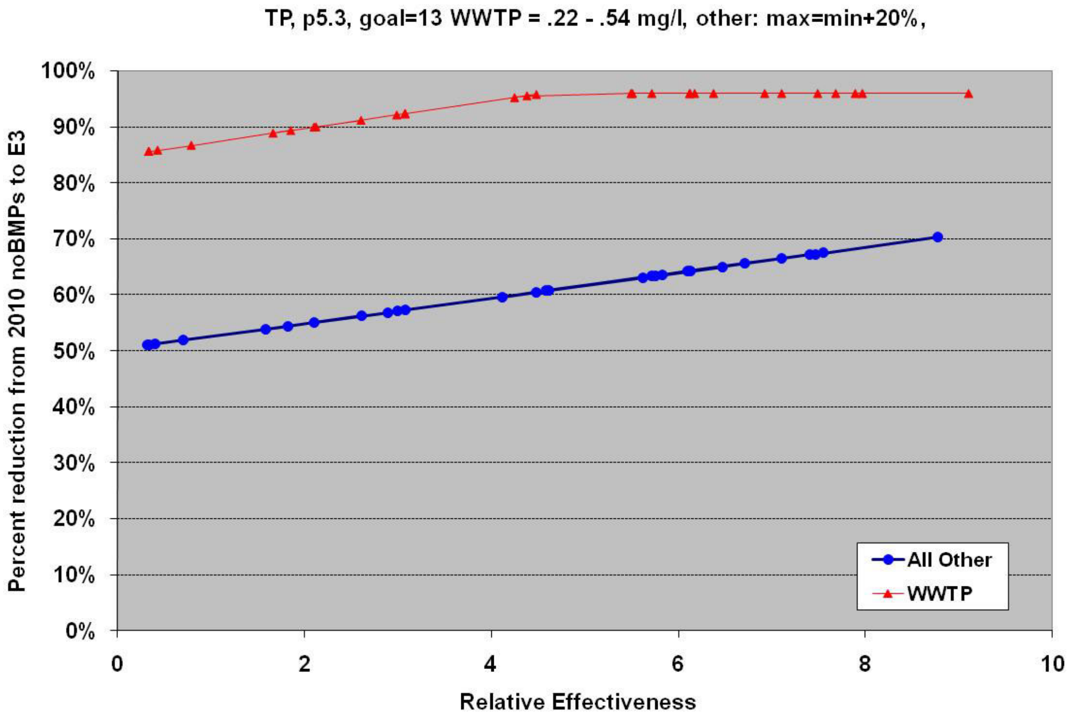


Figure 6-10. Example allocation methodology application for phosphorus.

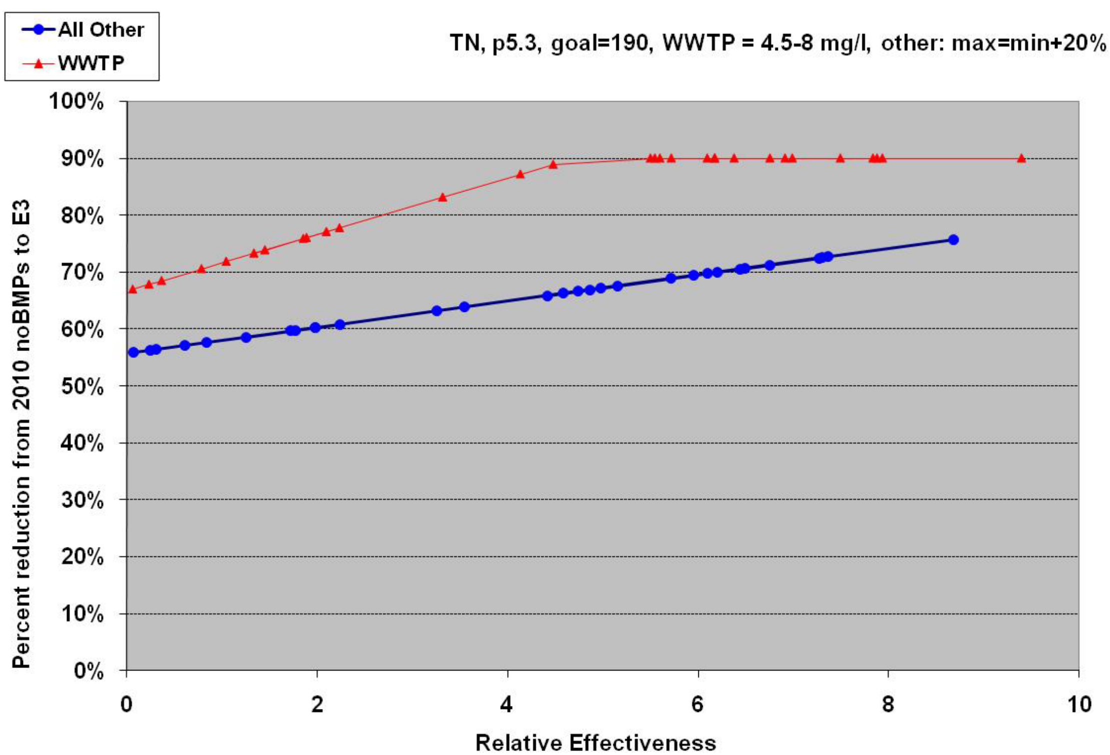


Figure 6-11. Example allocation methodology application for nitrogen.

Finally, EPA added the allocated load for wastewater (WWTP) to the allocated load for other sources to determine the total allocated load for each basin-jurisdiction. It must be noted that although the graph separates wastewater and other sources, this does not necessarily require the jurisdictions to use that separate wastewater or other sources loading in their WIPs for suballocating the loads.

6.4.4 Resolving Dissolved Oxygen and Chlorophyll a Nonattaining Bay Segments

After determining the target basinwide nitrogen and phosphorus allocations and distributing those loads to the major basins and jurisdictions using the methodology illustrated above, EPA identified seven designated-use segments for which the Bay Water Quality Model was predicting nonattainment of the applicable Bay DO WQS (see Table 6-5). Those seven segments out of attainment for the open-water designated use represent less than 1 percent of the total volume of open-water habitats in entire Chesapeake Bay.

The Bay Water Quality Model also predicted nonattainment for numeric chlorophyll *a*. All five Bay segments of the tidal James River in Virginia and the two Bay segments in the District of Columbia (tidal Potomac and Anacostia rivers). On the basis of Bay Water Quality Model runs at the basinwide nitrogen and phosphorus loading of 190 million pounds per year nitrogen and 12.7 million pounds per year phosphorus allocated by major river by jurisdiction the Bay Water Quality Model predicted those seven segments to be in nonattainment of each jurisdiction's respective numeric chlorophyll *a* WQS. This section explores the process by which EPA examined Bay Water Quality Model results showing persistent nonattainment at reduced loading levels and other evidence to make determinations regarding the loadings that would be sufficient to attain the respective WQS for each of the Bay segments.

Dissolved Oxygen Nonattaining Segments

EPA examined the reasons of persistent nonattainment in these segments. Upon further review of the model results for the non-attaining segments, along with other lines of evidence (including water quality monitoring) and application of best professional judgment, EPA determined that 190 million pounds per year TN and 12.7 million pounds per year TP allocated by major river by jurisdiction would be sufficient for these segments to attain the respective DO criteria (see Appendix N). It was generally found that predicted nonattainment in a Bay segment resulted from two or more of the following factors:

1. Less-than-expected change in DO concentrations from the calibration scenario to a given reduced nitrogen and phosphorus load scenario
2. Poor agreement between model-simulated and historically observed DO concentrations for a particular location and historical period
3. A limited number of unusually or very low DO concentrations that the Bay Water Quality Model predicted were very difficult to bring into attainment of the open-water DO criteria even with dramatically reduced loads

Table 6-5. Chesapeake Bay designated use segments showing percent nonattainment of the applicable Bay DO WQS under the basinwide nitrogen and phosphorus target loadings (million pounds per year)

CBSEG	309TN, 19.5TP, 8950TSS '93-'95	248TN, 16.6TP, 8110TSS '93-'95	200TN, 15TP, 6390TSS '93-'95	191TN 14.4TP, 6462 TSS '93-'95	190TN, 13TP, 6123TSS '93-'95	190TN 12.7TP, 6030TSS '93-'95	179TN 12.0TP, 5510TSS '93-'95	170TN 11.3TP, 5650TSS '93-'95	141TN 8.5TP, 5060TSS '93-'95	All Forest '93-'95
Open Water Summer Monthly										
GUNOH	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
MANMH	1%	5%	5%	5%	5%	5%	5%	5%	5%	0%
ANATF_MD	39%	19%	18%	12%	12%	12%	11%	11%	0%	0%
PMKTF	11%	5%	5%	5%	5%	5%	5%	2%	1%	1%
WBEMH	11%	15%	8%	8%	8%	8%	8%	8%	0%	0%
WICMH	11%	11%	15%	5%	5%	5%	5%	5%	5%	4%
Deep Water										
MAGMH	35%	35%	16%	16%	16%	3%	3%	1%	1%	0%

Source: Appendix M
Notes: GUNOH-Gunpowder River, MANMH-Manokin River, ANATF_MD-Anacostia River, Maryland, PMKTF-Upper Pamunkey River, WBEMH-Western Branch Elizabeth River, WICMH-Wicomico River, and MAGMH-Magothy River.
TN - total nitrogen, TP - total phosphorus, and TSS – total suspended solids.

The majority of those segments are in small and relatively narrow regions of the Bay's smallest tidal tributaries. Such conditions constrain the Bay Water Quality Model's ability to effectively integrate multiple drivers of DO concentrations. As a result, the Bay Water Quality Model's ability to simulate the water quality changes in response to dramatically reduced loads was also limited. In such cases, additional lines of evidence were used to determine whether a segment could be expected to achieve the applicable WQS under the reduced nitrogen and phosphorus loads (Appendix N).

EPA evaluated each Bay segment to determine: (1) whether violations of the DO criteria were isolated or widespread; (2) whether nearby Bay segments also exhibited persistent or widespread hypoxia or both; and (3) whether the Bay Water Quality Model predicted sufficient improvements in DO concentrations to achieve DO WQS in nearby deeper, wider segments. Results of the evaluations, documented in detail in Appendix N, are summarized as follows.

Following the comprehensive evaluation of the modeling results, application of the factors described above, and inclusion of alternative lines of evidence, all seven segments were determined to be in attainment of applicable WQS.

Results of the segment-specific evaluations, documented in detail in Appendix N, are summarized as follows.

Gunpowder River (GUNOH)

Monitored DO concentrations over the 10-year period of 1991–2000 were almost universally well above the 30-day mean open-water criterion of 5 mg/L. A single instance of moderate hypoxia, combined with poor model agreement and an almost complete lack of response by the Bay Water Quality Model to load reductions in the monitored location for the relevant month, resulted in persistent nonattainment across all reduced loading scenarios for the month in question. In contrast, nearby Bay segments—Bush River (BSHOH), Middle River (MIDOH), and upper Chesapeake Bay (CB2OH)—all attained their respective DO WQS when loads were reduced to the target basinwide allocation of 190 million pounds per year TN and 12.7 million pounds per year TP (Appendix N). Given those factors, including the poor predictive performance of the model in the Gunpowder River and 10 years of observed attainment of the DO criteria at relatively high nutrient loadings, EPA finds with a reasonable degree of certainty that target loadings of 190 million pounds per year TN and 12.7 million pounds per year TP will be sufficient for the Gunpowder River segment to attain the DO WQS.

Manokin (MANMH), Maryland Anacostia (ANATF_MD), West Branch Elizabeth (WBEMH), Pamunkey (PMKTF), and Wicomoco (WICMH) Rivers

Similar to the Gunpowder River segment, few violations of the open-water DO criteria occurred in these five Bay segments, and Bay Water Quality Model simulations did not match well with historically observed water quality conditions. The Bay Water Quality Model often failed to simulate hypoxia for these locations under observed loads; thus, it was also unable to estimate improved DO concentrations when nitrogen and phosphorus loads were reduced. Nearby deeper, wider regions generally attained DO WQS at or before the target basinwide loadings. For more discussion and data, see Appendix N. Given those factors, observed historic attainment with existing criteria at current high nutrient loadings and limited predictive capacity of the model for those unique segments, EPA finds with a reasonable degree of certainty that target loadings of 190 million pounds per year TN and 12.7 million pounds per year TP will be sufficient for these Bay segments to attain the DO WQS.

Magothy River (MAGMH)

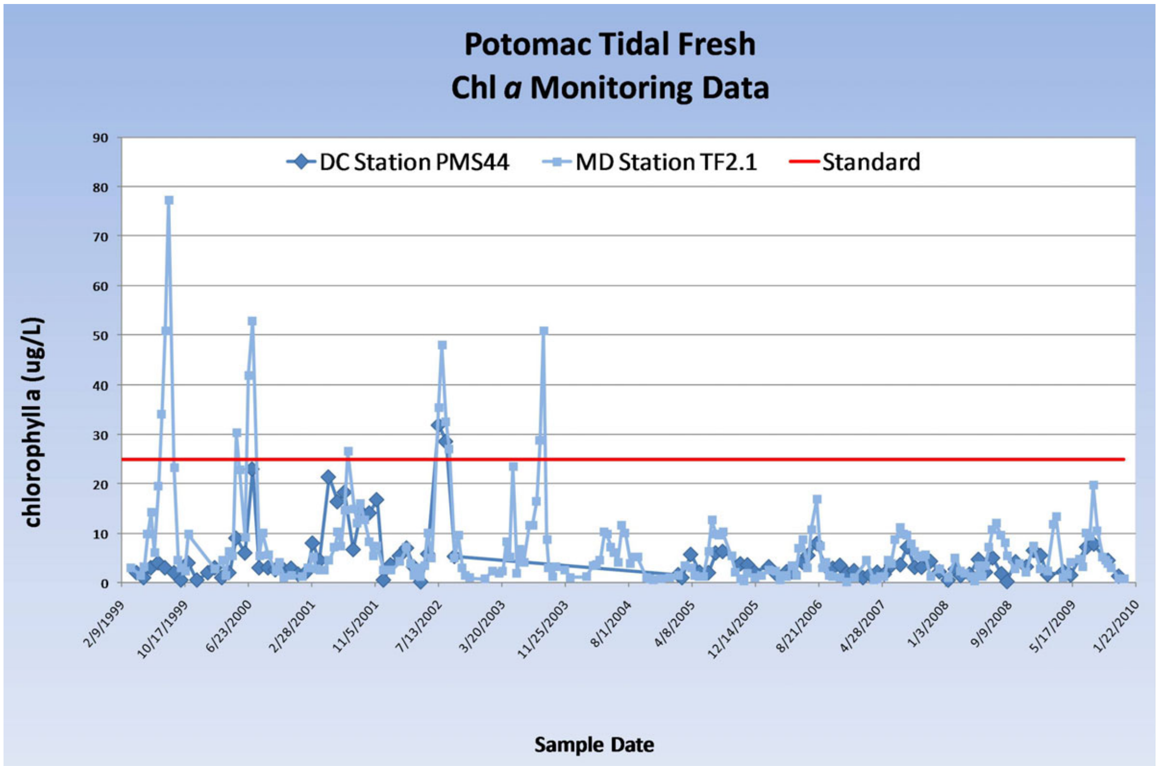
Summer hypoxic conditions were not uncommon in the Magothy River from 1991 to 2000, particularly when episodes of water column stratification prevented mixing of the bottom waters with more oxygenated surface waters. Maryland adopted (and EPA approved) an episodic deep-water designated use applicable to MAGMH to account for periods of water column stratification (USEPA 2010a). However, some violations of the deep-water DO 30-day mean criterion of 3.0 mg/L persisted even when nitrogen and phosphorus loads were reduced to the target basinwide allocation (Appendix N). Because of the small, embayment nature of the Magothy River, the Bay Water Quality Model was unable to reliably simulate observed conditions in MAGMH or consistently estimate a response of sufficiently improved DO in response to load reductions. However, the deep-water region of the adjacent mainstem segment CB3MH attained its DO WQS well before the target basinwide nitrogen and phosphorus LAs (Appendix N). Given the poor simulation of MAGMH conditions by the Bay Water Quality Model, the significant load reductions already required of the Magothy River basin at the target basinwide LAs, the considerable influence of the mainstem Chesapeake Bay on MAGMH water quality conditions, and the predicted attainment of CB3MH deep-water well before the target basinwide loading, EPA determined that MAGMH can reasonably be expected to attain its DO WQS at the target loadings of 190 million pounds per year TN and 12.7 million pounds per year TP.

Chlorophyll *a* Nonattaining Segments

Potomac and Anacostia Rivers in DC

The Bay Water Quality Model projected that the District of Columbia's portions of the Potomac and Anacostia River segments would be in nonattainment of the applicable numeric chlorophyll *a* WQS at the basinwide nitrogen and phosphorus target loads allocated to those two river basins. However, through diagnostic analysis of the modeled chlorophyll *a* simulations for the Potomac and Anacostia rivers in the District of Columbia, EPA determined that the Bay Water Quality Model does not reliably simulate measured chlorophyll *a* levels. Therefore, other lines of evidence (i.e., monitoring data) were weighed more heavily by EPA in the attainment determination (Appendix N). Through further investigation, EPA analyzed recent chlorophyll *a* data for the two segments. The actual monitoring data show that the Potomac River segment is attaining the District's chlorophyll *a* WQS and has been attaining that standard for at least the past 7 years (Figure 6-12). Applying a similar assessment of recent water quality monitoring data to the Anacostia River segment, a 4 percent level of nonattainment was determined (Appendix N).

Because those two segments are at, or near, attainment of the current chlorophyll *a* WQS on the basis of analysis of recent monitoring data and that additional nitrogen and phosphorus loading reductions will occur as a result of the current allocations, EPA has concluded that both of the Bay segments will be in full attainment with the chlorophyll *a* WQS under these nitrogen and phosphorus allocations (Appendix N). Additionally, a TMDL for biochemical oxygen demand



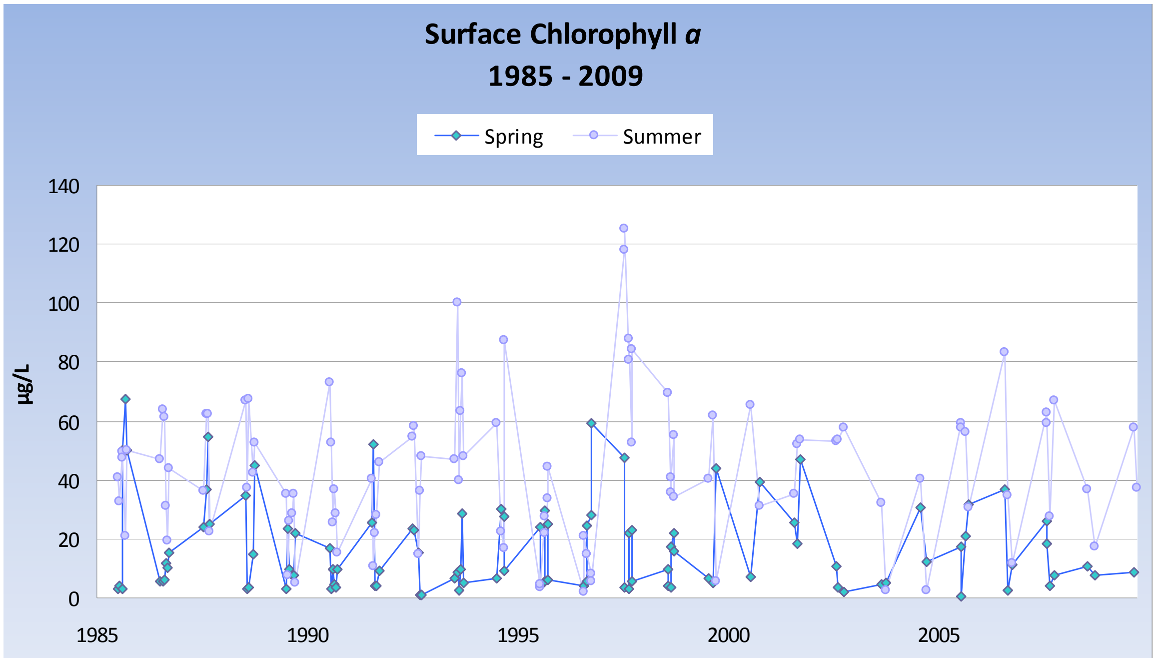
Source: http://www.chesapeakebay.net
Note: The DC station PMS44 is on the tidal Potomac River at the Woodrow Wilson Memorial Bridge (50 meters upstream of the draw span). The MD station TF2.1 is on the tidal Potomac River at Buoy *77* off the mouth of Piscataway Creek.

Figure 6-12. Potomac River chlorophyll a monitoring data compared with the District's summer seasonal mean chlorophyll *a* water quality criteria.

and nitrogen and phosphorus was approved by EPA in 2008 for the *Anacostia River Basin Watershed in Montgomery and Prince Georges Counties, Maryland and the District of Columbia* (MDE and DC DOE 2008). That TMDL for the Anacostia River requires significant reductions that, when implemented, will result in attainment of the chlorophyll *a* WQS.

James River in Virginia

Similar to the EPA analysis of attainment of the District of Columbia's chlorophyll *a* criteria using upper tidal Potomac and Anacostia rivers chlorophyll *a* monitoring data, EPA also assessed attainment using chlorophyll *a* monitoring data for the tidal James River. In contrast to the District's tidal Anacostia and Potomac River segments, EPA found that the past and current monitoring data for most of the tidal James River segments showed significant nonattainment of Virginia's chlorophyll *a* WQS. More recently, the *Virginian-Pilot* on August 12, 2010, reported on algal blooms in the southern Bay region including the James River. An example of the comparative analysis of the monitored data for the James as compared to Virginia's segment-season specific chlorophyll *a* criteria is shown in Figure 6-13. EPA, therefore, has concluded that nutrient controls beyond the present controls are needed in the James and EPA continued to rely on the model results in assessing conditions and determining the appropriate allocations of nitrogen and phosphorus.



Source: http://www.chesapeakebay.net

Figure 6-13. Tidal James River monitoring data for chlorophyll *a* at station TF5.5 (in the upper tidal James River near Hopewell, Virginia) compared to Virginia's James River segment-season specific chlorophyll *a* criteria.

In general, the Bay Water Quality Model is well-calibrated to the tidal James River and effectively simulates average seasonal conditions in the five tidal segments of the river. The Bay Water Quality Model also consistently estimates improved chlorophyll *a* conditions with increasing nitrogen and phosphorus load reductions. At the same time, however, the model does not simulate individual algal bloom events, which are highly variable and caused by numerous factors, some of which are still not well understood by the scientific community (Appendix O). The chlorophyll *a* WQS adopted in Virginia's regulation to protect the tidal James River were set at numerical limits for spring and summer seasonal averaged conditions, not for addressing individual algal bloom events lasting hours to days. Therefore, EPA's determination of nitrogen and phosphorus loadings required to attain chlorophyll *a* WQS in the tidal James River was based on those years and Bay (James River) segments for which the Bay Water Quality Model reliably simulated the water quality monitoring-based chlorophyll *a* calibration data. EPA used that approach to determine the James River basin allocation of 23.5 million pounds per year TN and 2.35 million pounds per year TP.

However, since the Bay Water Quality Model does not accurately simulate short-frequency, individual bloom events, some segment and season-specific nonattainment remains at the target James River allocation. Nonattainment of the summer chlorophyll *a* WQS persisted in the lower tidal fresh James segment (JMSTFL) for the summer periods of 1995–2000 and in the James River mouth segment (JMSPH) for the 1997–2000 summer periods (Appendix O). The Bay Water Quality Model results for those nonattainment areas were not used to establish the allocations for the James River.

Figure 6-14 shows the number of segments and 3-year periods (segment-periods) in nonattainment of Virginia's James River chlorophyll *a* WQS (out of the simulation period of 1991–2000) for the various load scenarios simulated, using those model results where the model is reliably simulating the calibration data. From the graph, it can be seen that the James River does not fully attain the chlorophyll *a* WQS until a loading of 23.5 million pounds per year of nitrogen and 2.35 million pounds per year of phosphorus was achieved. EPA set the necessary load allocations for nitrogen and phosphorus at those levels.

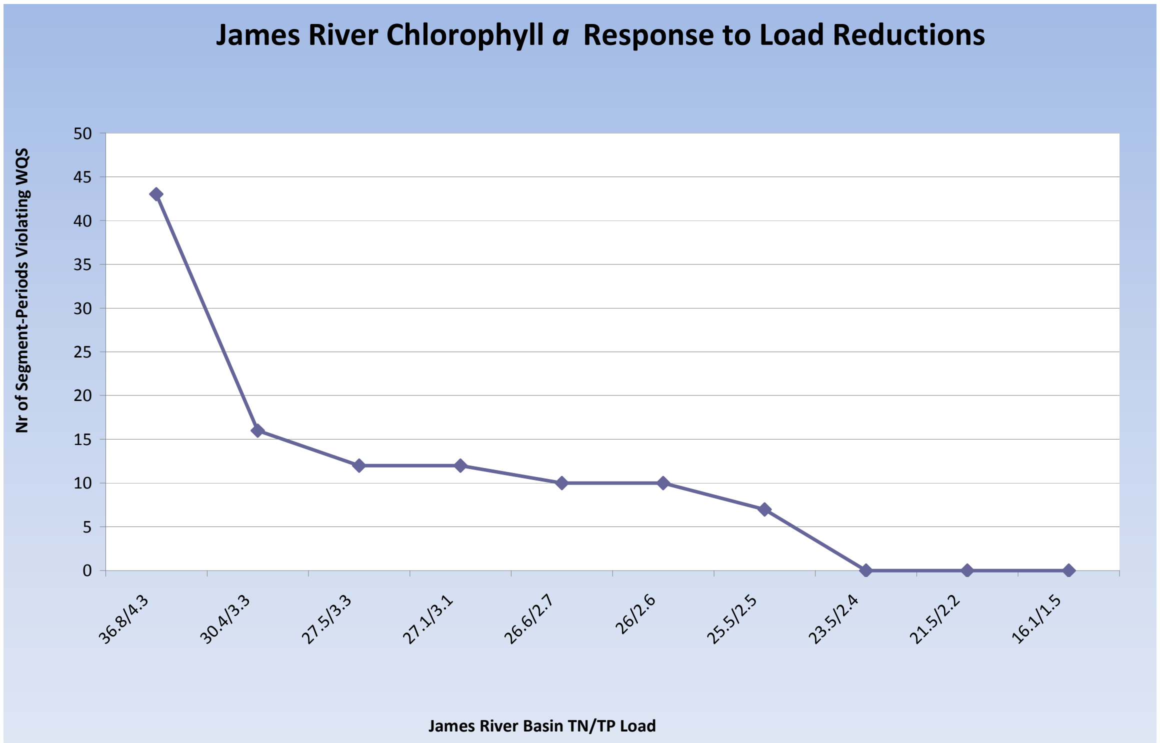


Figure 6-14. James River nonattainment of the chlorophyll *a* WQS at various load scenarios.

6.4.5 Allocation Considerations for the Headwater Jurisdictions (New York and West Virginia)

The methodology described above for distributing the basinwide loading was accepted by all jurisdictions except New York and West Virginia. From an additional Bay Water Quality Model run, EPA determined that small amounts of additional loadings of nitrogen and phosphorus in excess of the 190 million pounds per year TN and 12.7 million pounds per year TP could be allocated and still attain applicable WQS. In the July 1, 2010, letter to the jurisdictions, EPA used its discretionary authority to allocate to New York an additional 750,000 pounds per year of nitrogen (above the allocation calculated for New York using the method used to distribute the basinwide loads of 190 million pounds per year of nitrogen and 12.7 million pounds per year of phosphorus) (USEPA 2010g). With the final TMDL, EPA provided an additional 250,000 pounds per year of nitrogen and 100,000 pounds per year of phosphorus to New York's allocation. In addition, EPA used its discretionary authority to allocate to West Virginia an additional 200,000 pounds per year of phosphorus (above the level allocated to West Virginia using the allocation methodology to distribute the basinwide load of 190 million pounds per year of nitrogen and 12.7 million pounds per year of phosphorus) (USEPA 2010g). EPA, through model analysis, confirmed that those loadings will achieve WQS in the Chesapeake Bay. EPA provided the additional allocations for several reasons, including the following:

- Following the principles and guidelines as expressed in Section 6.3, tributary basins that contribute the most to the Bay water quality problems must do the most to resolve those problems (on a pound-per-pound basis). The headwater jurisdictions of New York and West Virginia contribute small portions of the overall nitrogen and phosphorus delivered to the Bay (5 percent or less) and, therefore, are provided some relief in their allocations.
- The water quality of the Susquehanna River leaving New York appears to be of better quality than that of downstream waters.
- The allocation methodology accommodates to some extent future growth by providing WLAs for wastewater treatment facilities at design flow rather than actual flow, thereby reserving a load for expansion of the facility. Therefore, New York considered the methodology to be biased against Bay watershed jurisdictions that are growing relatively slowly, like New York.
- A cleaner Bay provides greater benefit (in terms of commercial and recreational benefits of a cleaner bay) to the tidal jurisdictions than to the nontidal jurisdictions such as New York and West Virginia.

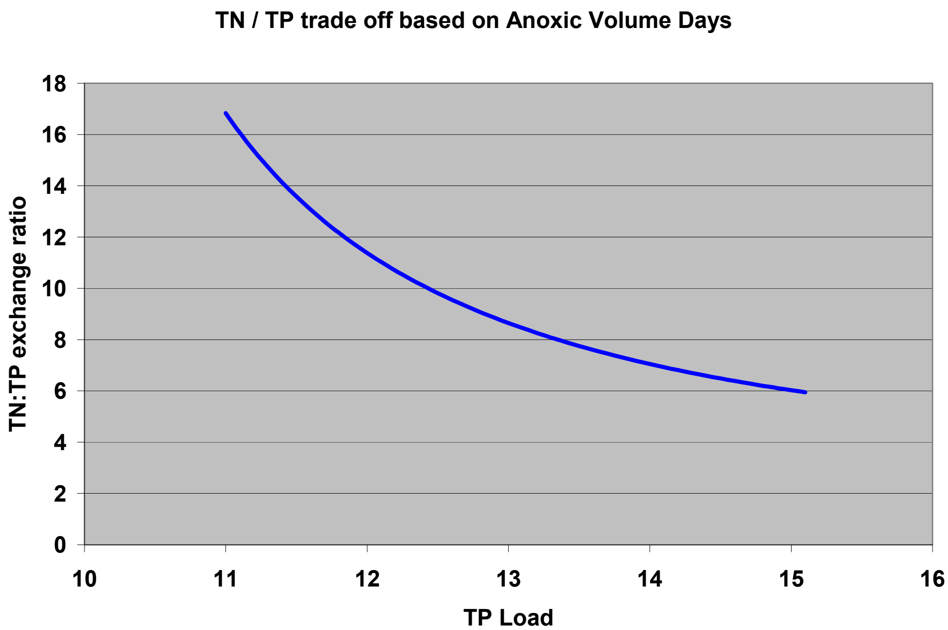
6.4.6 Nitrogen-to-Phosphorus Exchanges

On the basis of recent science regarding the relationship between nitrogen and phosphorus, EPA permitted the jurisdictions to propose the exchange of nitrogen and phosphorus loads within major river basins at a 1:5 ratio for reducing existing allocated phosphorus loads in exchange for increased nitrogen loads; and a 15:1 ratio for reductions in existing allocated nitrogen loads in exchange for increased phosphorus loads. For example, in jurisdiction allocations, for every 1 pound of phosphorus reduced, 5 pounds of nitrogen can be added and for every 15 pounds of nitrogen reduced, 1 pound of phosphorus can be added. This section documents the technical basis for those exchange rates.

Two scientific papers published in recent years specifically address tradeoffs between nitrogen and phosphorus. While those two analyses were completed with earlier versions of the Bay Watershed Model and the Bay Water Quality Model, the results are still meaningful if used to put bounds on the exchanges on a Bay-wide scale.

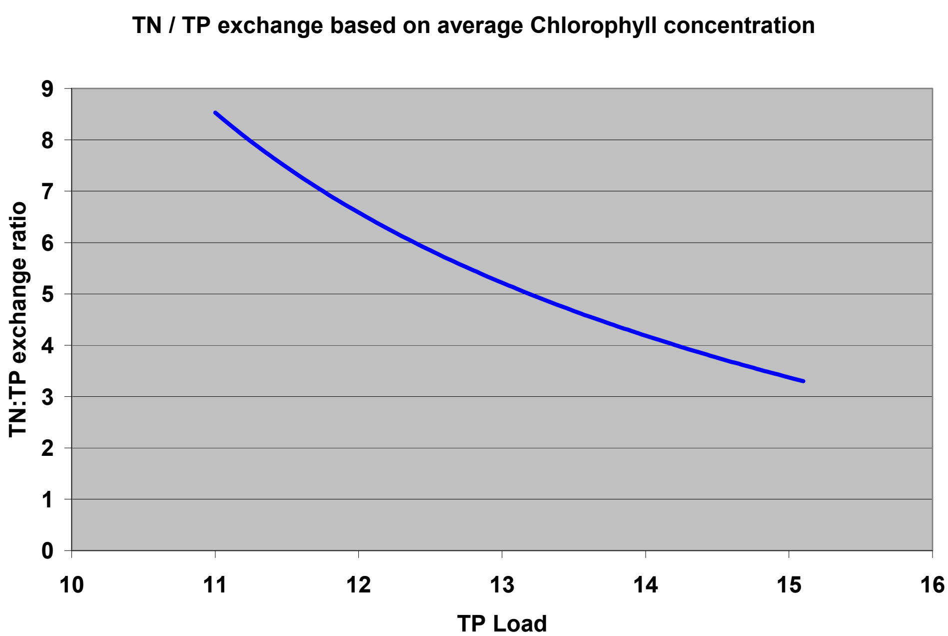
Wang et al. (2006) published response surface plots for chlorophyll *a* concentrations and anoxic volume days using a matrix of nitrogen and phosphorus load reduction scenarios. The response surface plots were generated by applying equations predicting overall chlorophyll *a* concentrations and anoxic volume days as quadratic functions of the nitrogen and phosphorus fraction of 2000 loading levels. Applying the Bay Watershed Model generated values in these same equations to assess the area around the allocation levels of 187.4 million pounds TN and 12.52 million pounds TP, one can use the derivatives of the original published equations to determine estimated TN:TP exchange relationships.

Figure 6-15 illustrates the TN:TP exchange ratio for different levels of TP based on the Anoxic Volume Days metric. At the allocation level of 12.52 million pounds of TP, the calculated exchange ratio is about 9:1, but the ratio has a good deal of variability. Considering that those are earlier versions of the Bay Watershed and Bay Water Quality models applied to the current reduction percentages, the local exchange ratio can vary depending on the location of the basin within the Bay. Given the degree of variability in this graph, EPA adopted a conservative approach. Figure 6-16 is the same analysis, except it uses chlorophyll *a* concentration in place of Anoxic Volume Days. The exchange ratios are lower, putting a greater importance on TP overall.



Source: Wang et al. 2006

Figure 6-15. TN:TP exchanges based on anoxic volume days and varying TP loads.



Source: Wang and Linker 2009.

Figure 6-16. TN: TP exchanges based on chlorophyll *a* concentrations and varying TP loads.

Wang and Linker (2009) documented an application of the earlier Bay models to the deep-water designated use of the upper central Chesapeake Bay segment CB4MH and determined a TN:TP exchange ratio of roughly 5:1 for that region of the mainstem Bay.

Further, the stoichiometric Redfield ratio for algal cell is well established at 16:1 TN:TP. This is the number of nitrogen and phosphorus atoms that approximates the nitrogen needed to make algal proteins and the phosphorus needed to make algal nucleic acids. On a weight basis, which is how one measures nitrogen and phosphorus loads delivered to the Bay, the TN/TP ratio equates to 10:1 TN:TP.

Taking both of those analyses, the two published papers, and EPA's desire to be conservative on these exchanges into account, an asymmetrical exchange ratio of 5:1 TN:TP when allowing more nitrogen loads and lowering the phosphorus load, and a ratio of 15:1 TN:TP when allowing more phosphorus loads and lowering the nitrogen load are applied. All applications of these TN:TP exchanges are confirmed to not affect the attainment of the jurisdictions' Bay WQS through follow-up Bay Water Quality Model scenarios.

Basin-Jurisdiction Nitrogen and Phosphorus Allocations

After performing all the analyses described above, EPA determined the basin-jurisdiction allocations for nitrogen and phosphorus needed to attain the WQS for DO and chlorophyll *a.* EPA sent a letter to the jurisdictions on July 1, 2010, to inform the jurisdictions of the allocations (USEPA 2010g). The table of those allocations are in Section 6.7. The jurisdictions used the allocations to develop their Phase I WIPs that further suballocate the nitrogen and phosphorus loadings to finer geographic scales and to individual sources or aggregate source sectors.

6.5 Establishing the Sediment-Related Model Parameters

In the sampling of particulate material in the streams and rivers of the Chesapeake Bay watershed as well as within the tidal waters, almost all of the measurements are for total suspended solids (TSS). This parameter includes sand, silt, and clay particles of sediment but also includes particulate organics. The Bay Watershed Model is calibrated to the observed TSS values. Since TSS is predominantly sediment, total suspended solids and sediment are often used interchangeably. Throughout the document, most of the references to allocations use the term sediment as that is the pollutant that needs to be reduced, but the formal allocation tables use the term TSS as that's the parameter output from the Bay models and its the parameter causing the aquatic life impairment (e.g., reducing light from reaching SAV).

6.5.1 Critical Conditions for Water Clarity and SAV

Submerged aquatic vegetation or SAV responds negatively to the same suite of environmental factors that result in low to no DO conditions—high-flow periods yielding elevated loads of nitrogen, phosphorus, and sediment (Dennison et al. 1993; Kemp 2004). High levels of nitrogen and phosphorus within the estuarine water column results in high level of algae, which block sunlight from reaching the SAV leaves. The same high concentrations of nitrogen and phosphorus also fuel the growth of epiphytes or microscopic plants on the surface of the SAV leaves, also directly blocking sunlight. Sediment suspended in the water column reduces the amount of sunlight reaching the SAV leaves. Because the critical period for both DO and water clarity/SAV are based on high-flow periods, EPA determined that the same critical period used for DO was appropriate for water clarity/SAV. Therefore, the critical period selected for assessment of the jurisdictions' SAV/water clarity WQS was 1993–1995. Detailed technical documentation is provided in Appendix G.

6.5.2 Assessment Procedures for the Clarity and SAV Standards

The Chesapeake Bay SAV restoration acreage in the jurisdictions' WQS are based on achieving SAV acreage goals set forth in state WQS that were based on the highest SAV acreage ever observed over a 40-year to more than 70-year historical record depending on the records available for each basin (USEPA 2003a; 2003d). Bay-wide, the SAV restoration goal is 185,000 acres.

The linked SAV and water clarity WQS are unique in some respects. Rather than covering the entire Bay as the DO WQS does, the SAV-water clarity WQS applies in only a narrow ribbon of shallow water habitat along the shoreline in depths of 2 meters or less. That presents certain challenges for the Chesapeake Bay model simulation and monitoring systems, both of which have long been more oriented toward the open waters of the Chesapeake Bay and its tidal tributaries and embayments. Scientific understanding of the transport, dynamics, and fate of sediment in the shallow waters of the Chesapeake Bay and understanding and simulating all the factors influencing SAV growth continues to develop. Appendix P provides more details of the Chesapeake Bay Water Quality and Sediment Transport Model-based combined SAV-water clarity attainment assessment procedures used in developing the sediment allocations.

The combined SAV/water clarity WQS can be achieved in one of three ways (see Section 3.3.3). First, as SAV acreage is the primary WQS, the WQS can be achieved by the number of SAV acres measured by way of aerial surveys—the method that is primarily used in CWA section 303(d) assessments. Second, the WQS can be achieved by the number of water clarity acres (divided by a factor of 2.5) added to the measured acres of SAV. Third, water clarity criteria attainment can be measured on the basis of the cumulative frequency distribution (CFD) assessment methodology using shallow-water monitoring data.

Although SAV responds to nitrogen, phosphorus, and sediment loads, DO and chlorophyll *a* primarily respond only to nitrogen and phosphorus loads. Because of that hierarchy of WQS response, EPA developed the strategy to achieve WQS by first setting the nitrogen and phosphorus allocation for achieving all the DO and chlorophyll *a* WQS in all 92 segments, and then making any additional sediment reductions where needed to achieve the SAV/water clarity WQS. That strategy is augmented by management actions in the watershed to reduce nitrogen, phosphorus, and sediment loads.

Just as the SAV resource is responsive to nitrogen, phosphorus, and sediment loads, many management actions in the watershed that reduce nitrogen and phosphorus also reduce sediment loads. Examples include conservation tillage, farm plans, riparian buffers, and other key practices. The estimated ancillary sediment reductions resulting from implementation actions necessary to achieve the nitrogen and phosphorus reductions needed to achieve the allocations are estimated to be about 40 percent less than 1985 sediment loads and 25 percent less than current (2009) load estimates. The sediment reductions associated with the nitrogen and phosphorus controls necessary to achieve the basin-jurisdiction target loads provided on July 1, 2010, are provided in Table 6-6.

Table 6-6. Tributary strategy scenario and nitrogen and phosphorus-based allocation scenario's total suspended solids loads (millions of pounds) by watershed jurisdiction

Jurisdiction	Tributary strategy	Allocation scenario
Maryland	1,195	1,118
Pennsylvania	2,004	1,891
Virginia	2,644	2,434
District of Columbia	10	10
New York	310	291
West Virginia	248	240
Delaware	55	55
Total	6,467	6,040

Using the Bay Water Quality Model, the SAV/water clarity WQS were assessed by starting with measured area of SAV in each Bay segment from the 1993–1995 critical period. On the basis of regressions of SAV versus load, the estimated SAV area, resulting from a particular nitrogen and phosphorus or sediment load reduction, was estimated as described in Appendix P. Then the estimated water clarity acres from the Bay Water Quality Model were added after adjustment by a factor of 2.5 to convert to the water clarity acres to water clarity equivalent SAV acres (Appendix P). Finally the water clarity equivalent SAV acres were added to the regression-estimated SAV acres and compared to the Bay segment-specific SAV WQS.

Note that when assessing attainment using monitoring data, only the SAV acres measurement is generally used because the number of Bay segments assessed with shallow-water clarity data are still limited. When projecting attainment using the Bay Water Quality model, the extrapolated measured SAV acres are added to the model-projected water clarity equivalent SAV acres to determine total SAV acres (Appendix P).

6.5.3 Addressing Reduced Sensitivity to Load Reductions at Low Nonattainment Percentages

Water Clarity

Only one segment displayed a small, yet persistent percentage of model projected water clarity/SAV criteria nonattainment over a range of reduced nitrogen and phosphorus loads—the Appomattox River segment (APPTF) in Virginia's James River Basin. In the case of that segment, while historical records document observed SAV acres in the 1950s, no observed SAV has been mapped since the early 1970s. That tidal fresh segment (salinities from 0 to 0.5 ppt) did not exhibit a positive response (increased water clarity, increased SAV acreage) to model simulated reductions in nitrogen, phosphorus, and sediment as observed in most other Bay tidal fresh segments. For the reasons unique to that Bay segment, EPA would consider it to be in full attainment of its shallow-water bay grass designated use if a 1 percent nonattainment level is achieved.

6.5.4 Explicit Margin of Safety for Sediment

In a TMDL, where there is uncertainty, an explicit MOS may be appropriate. In the Bay TMDL, EPA determined that an explicit MOS is appropriate for sediment because the Bay Water Quality Model was overly optimistic in its simulation of SAV acreages and water clarity attainment in the shallows. Specifically, the Bay Water Quality Model projected that widespread attainment of the SAV/water clarity standards would result at the current (2009) basinwide loading levels of about 8 billion pounds per year. In contrast, however, recent data from the Baywide SAV aerial survey and shallow-water quality monitoring data showed that most Bay segments were not attaining the SAV restoration acreages goals or water clarity criteria. That discrepancy justified the need for an explicit MOS to ensure that the sediment allocations would achieve the Bay jurisdictions' SAV/water clarity WQS.

EPA acknowledges that the science supporting the estuarine modeling simulation of the transport and resuspension for sediment is not as strong as that for nitrogen and phosphorus.[1] It is important to note, however, that many of the conservative assumptions identified in the implicit MOS discussion for nitrogen and phosphorus in Section 6.2.4 also apply to the MOS for sediment. In addition to the conservative assumptions in the modeling and allocation methods, EPA applied an explicit MOS in establishing the sediment allocations.

Since the SAV/water clarity modeling methodology was overly optimistic, and because reducing phosphorus often has the co-benefit of reducing sediment, EPA established sediment allocations on the basis of sediment loads that EPA estimated would result from implementing the phosphorus controls. The basin-jurisdiction sediment allocations initially were expressed as an allocation range reflecting the application of an explicit MOS in order to provide the jurisdictions with some flexibility in preparing their WIPs (USEPA 2010h). That initial allocation range was from 6.1 billion pounds per year to 6.7 billion pounds per year. Using 8 billion pounds per year of sediment as the estimate of the load needed to generally attain at the Baywide SAV/water clarity standards, that allocation range provides a Baywide range for MOS of about 16 to 24 percent.

In the final TMDL, EPA used a singular allocation to the basin-jurisdictions for sediment as opposed to a range. The method used to interpret the WIPs to derive that allocation is described in Section 8. The final Baywide sediment allocation is about 6.5 million pounds per year. So that allocated load yields a Baywide explicit MOS of 19 percent. Of course, the explicit MOS for each of the Bay segments would be expected to be somewhat higher or lower than the Baywide MOS. It is EPA's professional opinion that an explicit Baywide MOS of 19 percent—which is beyond the conservative assumptions identified in the Section 6.2.4 above on the implicit MOS for nitrogen and phosphorus—is appropriate for establishing the sediment allocations.

6.6 Establishing the Basin-Jurisdiction Allocations for Sediment

The methodology used for allocating sediment loads to major river basins and jurisdictions for sediment was much different than the methodology used for nitrogen and phosphorus. Because sediment has a localized water quality effect, the immediate subbasin (e.g., the Chester River) is

[1] Copies of the Chesapeake Bay Water Quality Sediment Transport Model Review Panel's (convened by the CBP's Scientific and Technical Advisory Committee) reports are at http://www.chesapeakebay.net/committee_msc_projects.aspx?menuitem=16525#peer.

usually the dominant controlling influence on water clarity and SAV growth. Therefore, a methodology is not needed to further suballocate the loading to contributing jurisdictions or neighboring basins. On August 13, 2010, the EPA Region 3 Administrator sent a letter to the jurisdictions identifying the sediment allocations (USEPA 2010g).

6.6.1 Methodology for Determining Sediment Allocations

To identify the sediment loads needed to achieve the SAV/water clarity WQS, the following key steps were taken:

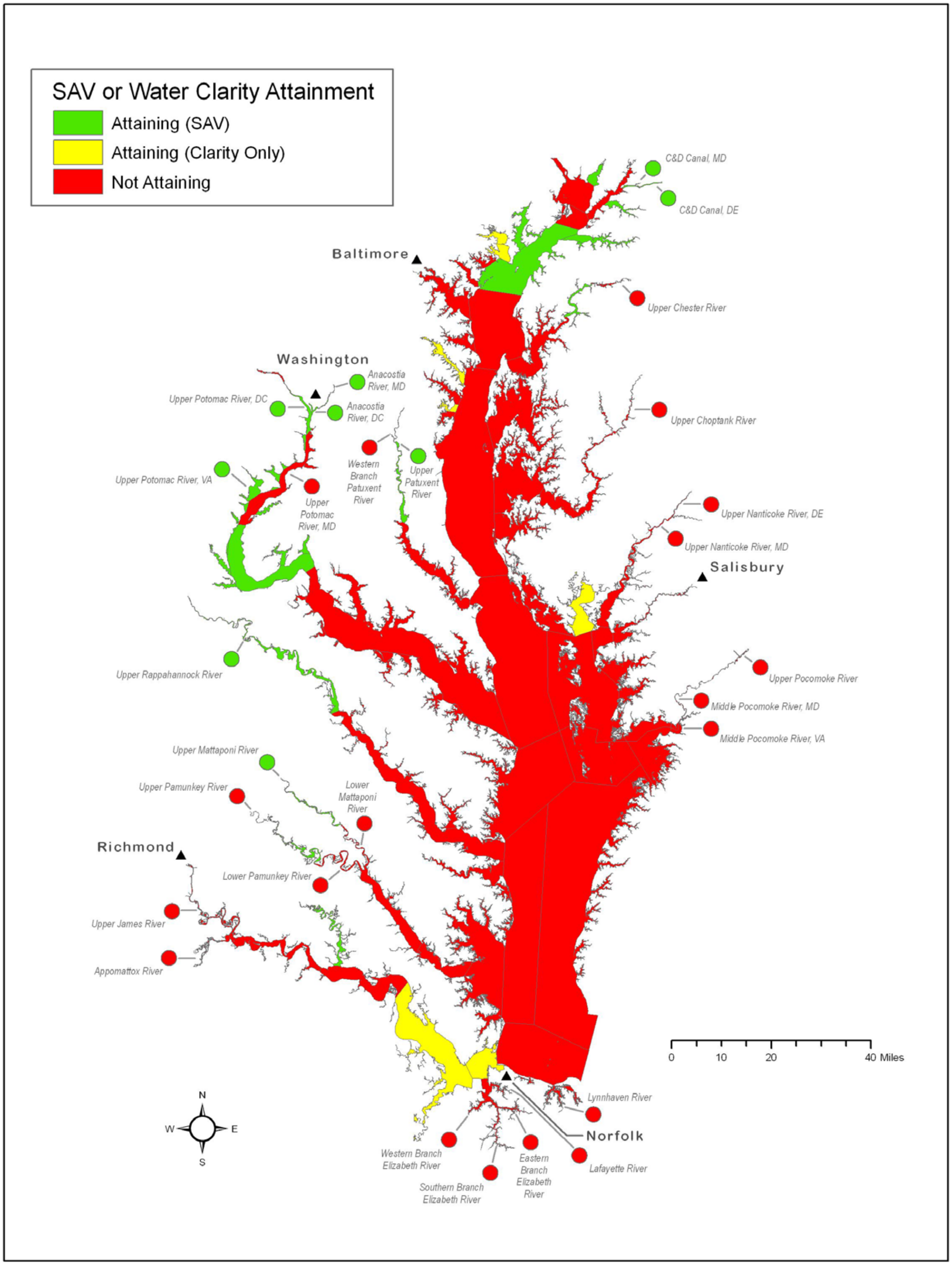
- Determine the sediment loading for each Bay segment that would be expected from installing the controls needed to meet the phosphorus allocations but have the co-benefit of reducing sediment (as described above).
- Using the Bay Water Quality Model, determine the number of acres in each segment that would attain the clarity standards for that segment and divide that number by 2.5 to determine the SAV equivalent acres.
- Add the SAV equivalent acres determined above to the expected SAV acreage on the basis of observed acres to determine the total SAV acreage expected under that nitrogen, phosphorus, and sediment loading scenario.
- Compare the expected SAV acres to the SAV goal for that segment to determine attainment with the WQS.
- For the non-attaining segments, go back to step 1.

Of the 92 tidal Bay segments assessed by Maryland, Virginia, Delaware, and the District of Columbia, 26 achieve the respective jurisdiction's SAV/water clarity WQS according to available monitoring data (Appendix P). Twenty segments have mapped SAV acreages meeting the segment-specific SAV restoration acreage in the jurisdiction's WQS (single best year of the past 3 years). Of the 12 water clarity acre assessments that were performed, an additional 6 segments were found to attain the jurisdiction's water clarity criteria on the basis of an analysis of shallow-water monitoring data (Figure 6-17).

However, the Bay Water Quality Model projected widespread attainment at existing loading levels, yet the existing SAV water quality data show SAV/water clarity WQS nonattainment in 66 of 92 segments with only 46 percent of the Bay-wide restoration acreage achieved (Appendix P). The existing state of scientific understanding has resulted in the Bay Water Quality Model being optimistic in its simulation of SAV acreage in the Bay under current (2009) pollutant loads.

6.6.2 Addressing Water Clarity/SAV Nonattaining Segments

After applying the sediment loads described above, four segments were initially found to be in nonattainment of the SAV-water clarity WQS. Those segments are the Mattawoman Creek (MATTF), the Gunpowder River (GUNOH), the Appomattox River (APPTF), and the Virginia's portion of the lower Potomac River (POTMH_VA). A detailed assessment of those nonattaining segments are in Appendix N, but a brief review is provided below.



Sources: DC DOE 2008; DE DNREC 2008; MDE 2008; VA DEQ 2008; Appendix Q.

Figure 6-17. Chesapeake Bay SAV/Water Clarity WQS attainment from monitoring data assessment.

Mattawoman Creek (MATTF)—Recent aerial surveys have shown a remarkable recovery of the acreage of SAVs in the Mattawoman Creek. In fact, for the years 2006–2009 the acres of observed SAV was higher than the SAV goal. Furthermore, with the implementation of the allocations in this TMDL, further nitrogen, phosphorus, and sediment reductions are expected, which will likely encourage additional SAV growth. So from the observed SAV line of evidence, EPA concludes that the allocated sediment load to Mattawoman Creek will attain the SAV goals.

Gunpowder River (GUNOH)—Similar to the Mattawoman Creek, substantial regrowth of SAV has occurred in the Gunpowder River since 2000. While the SAV goal is not being exceeded consistently, there have been several recent years where the goal is essentially met. On the basis of observed SAV information, combined with the fact that the TMDL allocations will result in additional nitrogen, phosphorous, and sediment reductions, EPA concludes that the allocated sediment load to the Gunpowder River will attain the SAV goals.

Appomattox River (APPTF)

No reported SAV acres are in the Appomattox River in the recent record. Therefore, attainment in this segment will need to be based on attainment for the clarity WQS alone. On the basis of modeling results at the allocation levels, the clarity levels barely attain applicable WQS. So an overall sediment allocations for the James may not be specific enough to assure attainment of the SAV standards in the Appomattox River. Therefore, while the basin-jurisdiction allocation for sediment for the James has been established, it is important to closely track the regrowth of SAV in the segment and use that information to provide needed updates to the assessment for the segment.

Virginia's portion of the lower Potomac River (POTMH_VA)

This segment covers the embayments on the Virginia side of the lower tidal Potomac River. The embayments are well isolated from the Potomac River and, therefore, respond primarily to the inputs from the subwatershed and not the Potomac itself. Recent SAV observations for the segment are much improved over the past but still far short of the WQS. Therefore, attainment determinations for the segment rely largely on the clarity attainment. As a reminder, the predicted SAV levels can be calculated as a combination of the measured SAV levels plus acres of clarity attainment (divided by 2.5). If one uses the critical period 1993–1995 SAV observed acreage and combines this acreage with the expected clarity attainment at the allocation loadings, the segment does not attain the SAV goal at the sediment allocation level. Furthermore, at much higher levels of controls (lower loadings), beyond the sediment allocation, the calculated nonattainment for this segment persists. There is simply not enough shallow water habitat in the segment to attain the standard on the basis of water clarity alone. On the other hand, all neighboring Bay segments in the tidal Potomac River are expected to achieve the SAV standards with the implementation of the sediment allocations. Therefore, having limited basis for which to establish a sediment allocation, and in consideration that neighboring Bay segments are expected to attain the SAV standards, EPA retained the sediment allocations for the Potomac basin. However, EPA considers it important, similar to the Appomattox River, to closely track the regrowth of SAV in this segment and use that information to provide needed updates to the assessment for this segment.

6.7 Basin-Jurisdiction Allocations to Achieve the Bay WQS

On the basis of all the methods and analyses described above, EPA identified allocations for the major basins within each jurisdiction called the basin-jurisdiction allocations. Those allocations were the beginning point for developing the Bay TMDL and are provided below.

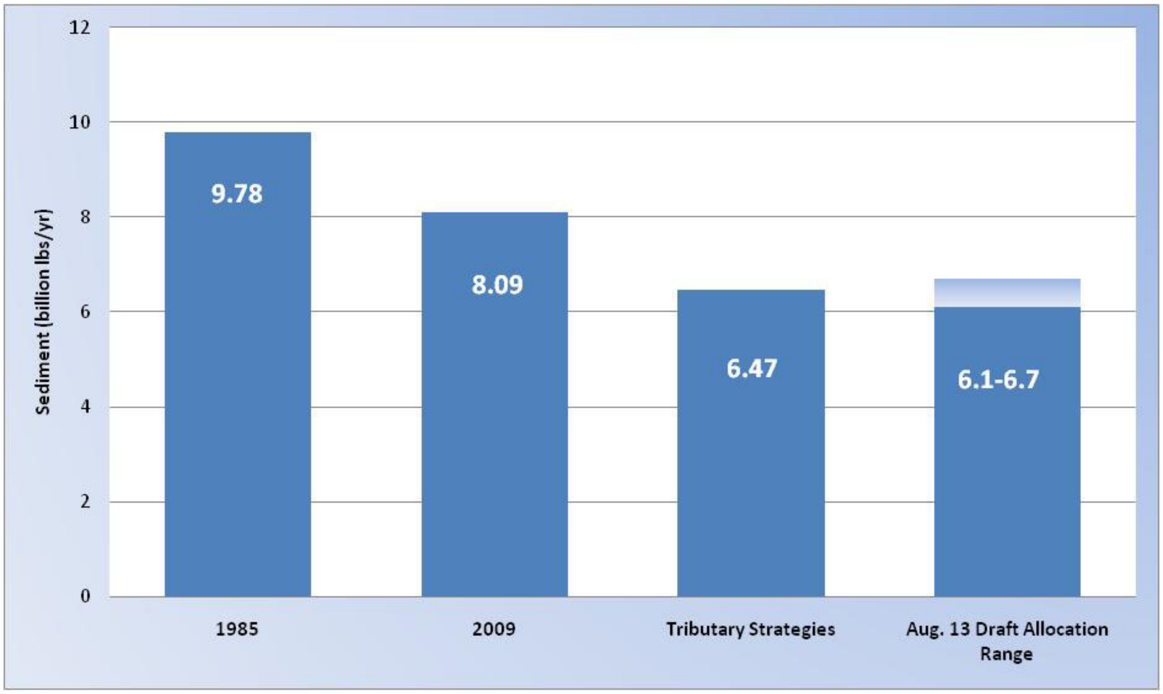
6.7.1 Basin-Jurisdiction Allocations Tables

Throughout 2009 up until the summer of 2010, EPA and its watershed jurisdictional partners worked together to develop the major river basin/jurisdiction allocations. From those collaborative efforts, EPA shared an initial set of major river basin/jurisdiction nitrogen and phosphorus target loads on November 3, 2009, on the basis of decisions at the October 23, 2009, PSC meeting (USEPA 2009b). Then, after a 2-day PSC meeting on April 29-30, 2010, EPA shared in a letter to the partners an updated Bay TMDL schedule and further outlined a long-term commitment to an adaptive management approach to the Bay TMDL (USEPA 2010f).

The basin-jurisdiction allocations were based on attaining the adopted (but proposed at the time) amendments to the jurisdictions' Bay WQS. On July 1, 2010, EPA shared the nitrogen and phosphorus allocations (USEPA 2010g) and the sediment allocations on August 13, 2010 (USEPA 2010h). Those were the allocations that jurisdictions used to develop their Phase I WIPs that further suballocate the nitrogen, phosphorus, and sediment loadings to finer geographic scales and to individual sources or aggregate source sectors and EPA used to evaluate those WIPs. By initially expressing the sediment allocations as a range, EPA allowed the jurisdictions some flexibility in developing their Phase I WIPs while assuring with confirmation Water Quality Model runs that all the WQS would be met (Figure 6-18) (USEPA 2010h). The allocations were calculated as delivered loads (the loading that actually reaches tidal waters) and as annual loads. The loads are provided in Tables 6-7 and 6-8. The allocations were further refined through the jurisdictions' WIPs by exchanges of loadings for some basins in Maryland and exchanges of nitrogen to phosphorus or phosphorus to nitrogen within a basin. Those adjusted allocations are provided in Section 8.

6.7.2 Correction of the West Virginia Sediment Allocation

The allocation for sediment for West Virginia, listed in Tables 6-7 and 6-8, was corrected subsequent to the distribution of the sediment allocation letter to the jurisdictions on August 13. 2010. Recall that the sediment range of allowable loads was based on the expected sediment loading that would result as a co-benefit to reducing phosphorus. So the sediment range was highly dependent on the phosphorus allocation. The reason the sediment allocation for West Virginia needed to be corrected was that the previous sediment allocation in the EPA letter of August 13, 2010, was not based on the supplemental phosphorus load that was provided to West Virginia. When the full phosphorus allocation for West Virginia is considered, the updated sediment load range for West Virginia was 309–340 million of pounds per year. For the Potomac River in West Virginia, the updated sediment load range is 294–324 million pounds per year**.** The sediment allocation range for the James River Basin in West Virginia remains unchanged.



Source: USEPA 2010h

Figure 6-18. Model simulated sediment loads by scenario compared with the range of sediment allocations (billions of pounds per year as total suspended sediment).

6.8 Attainment of the District of Columbia pH Water Quality Standard

After the development of the nitrogen, phosphorus and sediment allocations to achieve the Bay DO, chlorophyll *a*, SAV/water clarity WQS, EPA conducted an analysis to explore whether these allocations were sufficient to remedy the pH impairment in the District of Columbia portion of the Potomac River Estuary. The upper Potomac River Estuary from Key Bridge to Haines Point has been on the District of Columbia's 303(d) list of impaired waters for pH from 1998 to present. EPA believes that the high pH levels are indirectly caused by the relationship between high nitrogen and phosphorus levels and algal growth. Readily available nitrogen and phosphorus in surface waters supports the growth of algae, which can become prolific when nitrogen and phosphorus levels are high. During photosynthesis, algae use carbon dioxide, resulting in high pH conditions (Sawyer et al. 1994). In water, carbon dioxide gas dissolves to form soluble carbon dioxide, which reacts with water to form undissociated carbonic acid. Carbonic acid then dissociates and equilibrates as bicarbonate and carbonate. Generally, as carbon dioxide is used up in photosynthesis, pH rises because of the removal of carbonic acid (Horne and Goldman 1994). It is expected that the high pH levels in this segment of the tidal Potomac River are due to primary productivity (algal growth). Algal growth is fueled by excess nitrogen and phosphorus inputs. On the basis of a reasonable degree of scientific certainty, as further explained below, EPA finds that the reduced nitrogen and phosphorus loads resulting from implementation of the Chesapeake Bay TMDL will also result in decreased algae levels and, thus, meet the District of Columbia pH numeric WQS.

Table 6-7. Chesapeake Bay watershed nitrogen and phosphorus and sediment allocations by major river basin by jurisdiction to achieve the Chesapeake Bay WQS

Basin	Jurisdiction	Nitrogen allocations (million lbs/year)	Phosphorus allocations (million lbs/year)	Sediment allocations (million lbs/year)
Susquehanna	New York	8.48 [b]	0.62 [b]	293–322
	Pennsylvania	71.74	2.31	1,660–1,826
	Maryland	1.08	0.05	60–66
	Total	81.31 [b]	2.98 [b]	2,013–2,214
Eastern Shore	Delaware	2.95	0.26	58–64
	Maryland	9.71	1.09	166–182
	Pennsylvania	0.28	0.01	21–23
	Virginia	1.21	0.16	11–12
	Total	14.15	1.53	256–281
Western Shore	Maryland	9.74	0.46	155–170
	Pennsylvania	0.02	0.001	0.37–0.41
	Total	9.76	0.46	155–171
Patuxent	Maryland	2.85	0.21	82–90
	Total	2.85	0.21	82–90
Potomac	Pennsylvania	4.72	0.42	221–243
	Maryland	15.70	0.90	654–719
	District of Columbia	2.32	0.12	10–11
	Virginia	17.46	1.47	810–891
	West Virginia	4.67	0.74	294–324 [c]
	Total	44.88	3.66	1,989–2,188 [c]
Rappahannock	Virginia	5.84	0.90	681–750
	Total	5.84	0.90	681–750
York	Virginia	5.41	0.54	107–118
	Total	5.41	0.54	107–118
James	Virginia	23.48	2.34	837–920
	West Virginia	0.02	0.01	15–17
	Total	23.50	2.35	852–937
Total Basin/Jurisdiction Allocation		187.69	12.62	6,135–6,749
Atmospheric Deposition Allocation[a]		15.70	--	--
Total Basinwide Allocation		203.39	12.62	6,135–6,749

a. Cap on atmospheric deposition loads direct to Chesapeake Bay and tidal tributary surface waters to be achieved by federal air regulations through 2020.
b. This allocation to New York does include the additional (beyond the draft) allocation of 250,000 pounds per year of nitrogen and 100,000 pounds per year of phosphorus that EPA added to the New York allocation (see Section 6.4.5)
c. This allocation includes a correction of the sediment allocations to West Virginia to account for the increase in phosphorus allocation provided to West Virginia (see Section 6.7.2)

To support that assumption, continuous monitoring data from the District of Columbia's Department of the Environment long-term monitoring station at the Roosevelt Island Bridge were evaluated. This location falls within the impaired tidal Potomac River segment (POTTF_DC) and is the only location for which continuous data are available for trend analysis. Plots of pH vs. chlorophyll *a* for the period of record indicate a distinct relationship between the two parameters; increased chlorophyll *a* levels are associated with increased levels of pH. That relationship is particularly apparent for April through June of 2010 (Figure 6-19).

Table 6-8. Chesapeake Bay watershed nitrogen and phosphorus and sediment allocations by jurisdiction by major river basin to achieve the Chesapeake Bay WQS

Jurisdiction	Basin	Nitrogen allocations (million lbs/year)	Phosphorus allocations (million lbs/year)	Sediment allocations (million lbs/year)
Pennsylvania	Susquehanna	71.74	2.31	1,660-1,826
	Potomac	4.72	0.42	221-243
	Eastern Shore	0.28	0.01	21-23
	Western Shore	0.02	0.001	0.37-0.41
	PA Total	76.77	2.74	1,903-2,093
Maryland	Susquehanna	1.08	0.05	60-66
	Eastern Shore	9.71	1.09	166-182
	Western Shore	9.74	0.46	155-170
	Patuxent	2.85	0.21	82-90
	Potomac	15.70	0.90	654-719
	MD Total	39.09	2.72	1,116-1,228
Virginia	Eastern Shore	1.21	0.16	11-12
	Potomac	17.46	1.47	810-891
	Rappahannock	5.84	0.90	681-750
	York	5.41	0.54	107-118
	James	23.48	2.34	837-920
	VA Total	53.40	5.41	2,446-2,691
District of Columbia	Potomac	2.32	0.12	10-11
	DC Total	2.32	0.12	10-11
New York	Susquehanna	8.48 [b]	0.62 [b]	293-322
	NY Total	8.48 [b]	0.62 [b]	293-322
Delaware	Eastern Shore	2.95	0.26	58-64
	DE Total	2.95	0.26	58-64
West Virginia	Potomac	4.67	0.74	294-324 [c]
	James	0.02	0.01	15-17
	WV Total	4.68	0.75	309–341 [c]
Total Basin/Jurisdiction Allocation		187.69	12.62	6,135-6,749
Atmospheric Deposition Allocation[a]		15.70	--	--
Total Basinwide Allocation		203.39	12.62	6,135-6,749

a. Cap on atmospheric deposition loads direct to Chesapeake Bay and tidal tributary surface waters to be achieved by federal air regulations through 2020.
b. This allocation to New York does include the additional (beyond the draft) allocation of 250,000 pounds per year of nitrogen and 100,000 pounds per year of phosphorus that EPA added to the New York allocation (see Section 6.4.5)
c. This allocation includes a correction of the sediment allocations to West Virginia to account for the increase in phosphorus allocation provided to West Virginia (see Section 6.7.2)

For the most recent 2-year period (September 2008 to November 2010), pH levels at that location have regularly exceeded the maximum criterion level of 8.5; however, they never exceeded 9.0.[2] Those pH levels are similar to those observed at other tidal Potomac River Estuary monitoring stations.

[2] In 9VAC25-260-50, Virginia requires that estuarine waters fall within the acceptable pH range of 6.0 to 9.0.

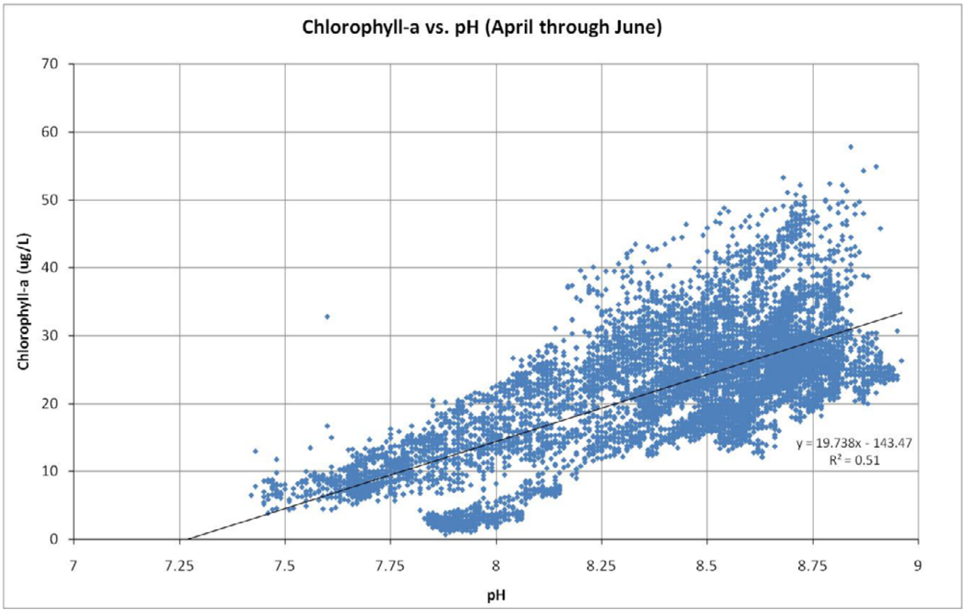


Figure 6-19. District of Columbia's Roosevelt Island station pH versus chlorophyll *a* monitoring data regression.

It is also important to note that no known wastewater discharges are expected to contribute to high pH levels along this stretch of the Potomac. Only one nonsignificant industrial facility discharges to the tidal Potomac River above this location, the Washington Aqueduct. Flow from the facility is relatively small (13.2 million gallons per day) when compared to the flow rate of the Potomac (about 7 billion gallons per day) in the vicinity. Permit limits for the facility require that pH is between 6.0 and 8.5. Examination of discharge monitoring report (DMR) data from May 2003 to May 2010 for the facility indicates one pH violation on August 31, 2003, for pH of 9.22 at Outfall 004. No other outfalls had violations between May 2003 and February 2006, and pH ranged from 6.5 to 8.0 during that time. A second violation, failure to report DMR data, occurred in May 2010.[3] A second facility, Walter Reed Army Medical Center, discharges approximately 0.09 million gallons per day to the tidal Potomac River via Rock Creek. Because of its upstream location, discharge characteristics (process water from heating and cooling system and rooftop runoff), and small size, it is not a source of high pH waters. Because the next segment upstream is the POTTF_MD, and it is not impaired for pH, no further upstream discharge facilities were evaluated.

Flow and pH data for the most recent 2-year period show that high flows generally do not correspond to pH exceedances. That evidence strongly suggests that nonpoint sources are not a direct cause of the pH exceedances. For those reasons, it is EPA's best professional judgment that pH exceedances are caused by the high nitrogen and phosphorus and resultant algae growth and that the reductions expected to result from implementing the Chesapeake Bay TMDL will also ensure attainment of the pH criterion in this segment of the Potomac.

[3] EPA reviewed DMR records from both PCS and ICIS. Actual data were available from the PCS review (2003 to early 2006), whereas the ICIS review (2006 to May 2010) provided information regarding whether a violation occurred and the type of violation.

The Washington Ship Channel is another waterbody segment in the District that was listed as impaired on the District of Columbia's 1998 303(d) list and was part of EPA's Consent Decree. In 2004 the District established, and EPA approved, a TMDL to address the pH impairment that requires phosphorus reductions expressed in annual loads. Since the 2004 Washington Ship Channel TMDL, the District's final 2008 303(d) list and its draft 2010 303(d) both indicate that the Washington Ship Channel's aquatic life use is no longer impaired due to pH. It is EPA's best professional judgment that this supports the conclusion that implementing the Chesapeake Bay TMDL's nitrogen and phosphorus reductions will address the District of Columbia's pH impairments and that implementing the Chesapeake Bay TMDL will continue to protect the Washington Ship Channel from pH impairment. The Chesapeake Bay TMDL supersedes the Washington Ship Channel's 2004 pH TMDL.