

CHAPTER 5 NONPOINT SOURCE ASSESSMENT, PRIORITIZATION, AND ACTIVITIES

This section of the Virginia Water Quality Assessment 305(b) Report includes an assessment of nonpoint source (NPS) pollution potential at the 6th level (12-digit) hydrologic units of the [National Watershed Boundary Dataset \(NWBD\)](#) (hereafter referred to as either hydrologic units, or just units). It also includes indicators for prioritizing NPS corrective actions at the hydrologic unit level and a summary of NPS reduction activities currently underway. It has been prepared by the Virginia Department of Conservation and Recreation (VADCR) and the Virginia Department of Environmental Quality (VADEQ) to provide a comparative evaluation of the state's waters, on a hydrologic unit basis. This comparative evaluation can be used to target limited resources and funds for NPS pollution protection activities to where they are most needed. The key results of the assessment include quantification of nutrient and sediment loads and a ranking of hydrologic units as high, medium or low based on those loads. The ranking is presented in a series of maps and tables for each major source sector such as; agriculture, forestry, and urban, with an additional series of maps representing the overall or combined ranking.

The 2016 NPS Assessment and Prioritization study summarizes existing sources of information, as referenced, and data provided by the following organizations: VADCR, VADEQ, Virginia Department of Forestry (VDOP), U.S. Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS), local Soil and Water Conservation Districts (SWCDs), the Department of Biological Systems Engineering (BSE) at Virginia Tech (VT), the Virginia Department of Health (VDH), the Virginia Department of Game and Inland Fisheries (VDGIF), the Virginia Department of Mines, Minerals, and Energy (VDMME), the Center for Environmental Studies (CES) at Virginia Commonwealth University (VCU), the US Environmental Protection Agency (EPA), the Chesapeake Bay Program (CBP), the U.S. Geological Survey (USGS), the Multi-Resolution Land Characteristics Consortium (MRLC), Conservation Technology Information Center (CTIC), the US Department of Interior – Census Bureau, the American Community Survey, and the Climate Forecast System Re-analysis (CFSR).

There are four major components to the 2016 NPS Assessment and Prioritization study - potential pollutant loadings, water quality impairments, measures of biological health, and NPS reduction activities. The main focus of this chapter is the determination of potential loadings of total nitrogen (TN), total phosphorus (TP), and total sediment (TS), hereafter referred to as NPS pollutants, by hydrologic unit and agricultural, urban, and forest generalized land use classes. The evaluation of hydrologic units by aquatic species' health represents water quality measures not necessarily related to the potential NPS pollutant loads. In order to prioritize clean-up and protection activities, hydrologic units of prime importance for the protection of public surface water supplies were also determined. Details of these components follow.

NPS POLLUTION LOADINGS

The NPS Assessment estimation of pollutant loadings is based on a calculation of the estimated [edge of stream](#) (EOS) loadings of nitrogen, phosphorus, and sediment per hydrologic unit using the Generalized Watershed Loading Functions (GWLF) model.

The estimation of loads of NPS pollutants as a basis for assessing water quality by hydrologic unit is consistent with Virginia's participation as a partner with the EPA's CBP in the calculations of NPS pollutant loads using the Chesapeake Bay Watershed Model (CBWM). Although Virginia uses CBWM results (particularly in CBP related activities), they have only been obtainable for that portion of Virginia that is in the Chesapeake Bay Watershed (James, York, Rappahannock, Potomac, and Bay Coastal basins). Other state programs can benefit from having measures similar to the CBWM loads but for the non-Bay portion of the state. As has been done since 2002, Virginia has produced statewide NPS pollutant load results similar to those of the CBWM by using the GWLF model¹.

¹ GWLF was chosen because it was configured for continuous simulation and could produce EOS loads based on land-based loadings, fate, and the transport of pollutants as does the CBWM. Both models also simulate seasonal variations, include both surface and subsurface components, and can represent both dissolved and particulate forms of pollutants. The GWLF model used in the 2016 assessment is an update of the model developed for the 2014 and previous assessments.

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NPS pollutant load estimations were performed by taking into consideration the relevant best management practice (BMP) installations in Virginia over the previous sixteen year period (1998-2014) by VADCR, VADEQ, VDOF, USDA-NRCS, local stormwater management agencies, and private nutrient management plan writers. Table 5-1 lists the generalized land use classifications and details the contributing specific land uses utilized for this assessment.

Table 5-1 Descriptions of Nonpoint Source Assessment Generalized Land Uses

Nonpoint Source Assessment Land Classifications	Source Data Descriptions
Forest	Pine, Hardwood, Mixed Harvested/Disturbed Forest
Agriculture	Crop: Conventional Tillage, Conservation Tillage, Bare Soil, Hay Livestock: Unimproved Pasture, Pasture Cattle-Grazed, Pasture Poultry Litter Applied, Pasture/Forest/Field Manure Applied
Urban	Impervious (Pavement, Sidewalks, Roof Area, Compacted Areas, High Density Residential) Pervious (Grassland, Low to Medium Density Residential, Industrial, Bare Soil)

As would be anticipated, there are loading estimation changes between the 2014 and 2016 assessment calculations. These changes are the result of updated and improved data along with model recalibration and corrections made to the model code.

For consistency with previous NPS assessment reports and maps and with the manner in which this data is used, the ranking of hydrologic units for the NPS pollutant unit area load (UAL) components for the 2016 NPS Assessment has maintained the division of UALs into previously used categories - the highest 20% of the values for each component are classified as high, the next 30% are classified as medium, and the remaining 50% are classified as low. This ranking methodology applies to the NPS pollutant loads only. These range definitions are not absolute, since units with equal or very similar loading values were not divided into different classes.

Table 5-2 reports the final statewide loadings by pollutant and the amount of land in Virginia by general land use class. Loading values in this table reflect the loads after the reductions are applied from active BMPs installed over the previous sixteen years. More information regarding model development, land use classification details, and methodology for estimating pollutant loading per land use and per pollutant, is provided in the final section of this chapter.

Table 5-2 2016 Statewide NPS Pollutant Loads – Post BMP Reduction

	Units	Agricultural Class	Urban Class	Forestry Class	Other (Barren, Extractive, Channel Erosion, Septic)
Total VA Land Area #	Acres	5,722,303	2,528,960	16,714,994	
%of VA Land	%	22.83	10.09	66.69	0.39
Total Nitrogen	10 ⁶ Kg/year	10.70	5.42	7.77	
%of all NPS N ^	%	33.92	17.20	24.63	24.25
Total Phosphorus	10 ⁶ Kg/year	1.09	0.51	0.51	
% of all NPS P ^	%	49.13	22.98	23.04	4.85

Total Sediment	10 ⁶ Kg/year	1,278.27	0.12	1,134.9	
% of all NPS S ^	%	41.96	4.04	37.26	16.74

Value does not include acres of non-forested wetlands and barren land (see Table 5-7).

^ Includes loads from barren, channel erosion, and extraction.

Agricultural NPS Pollution Loads

Agriculture is a large and diverse industry in Virginia and accounted for almost 23% of Virginia's land use in the year being assessed. While this percentage is significantly lower than the national average and continues to decline in Virginia, agricultural activities remain the most significant source of nonpoint source pollution in the state. As shown in Table 5-2 and as the current and all past assessment model results suggest, agricultural land in Virginia contributes NPS pollutant loads in greater proportion to the area they comprise than do the other land use classes.

Nonpoint source pollutants from agriculture originate from several different sources with different associated impacts. Deposition to agricultural lands in the form of fertilizers and animal manures affect water quality when they reach groundwater reserves, are directly deposited to streams, or are washed into surface waters during rain events in either a dissolved state or with eroding soils. These pollutants include pathogens as well as nutrients. Farming practices can contribute to or retard runoff and can certainly affect the amount of soil lost from fields which can potentially end up in water features.

This assessment estimated the nutrient and sediment loads from agricultural areas but not pathogen loadings. Factors in this assessment which affect the amount of nutrient loads reaching water from agricultural lands include the soil erodability, types of agricultural practices, types and numbers of farm animals, land cover, stream density, rainfall, seasonal variations in plant growth and nutrient applications, existence and type of agricultural BMPs, soil saturation, and slope.

The ranked UALs by hydrologic unit of nitrogen, phosphorus, and sediment from agricultural land uses are displayed in Figures [5-1](#), [5-2](#), and [5-3](#) respectively. The rankings are also listed in [Table 5-3](#)

There are a few factors that are specific to changes in loadings, and thus ranks, of the agricultural NPS pollutants between the current and past assessment products. Perhaps the most significant factor is that the model itself was recalibrated with new data, parameters, and procedures. Otherwise, the updating of the land use is usually the primary contributor to changing loads. Additional factors are noted below.

Urban NPS Pollution Loads

Around 10% of the land in Virginia was considered urban for the year being assessed. Urbanized land produces NPS pollutants as the result of precipitation washing nutrients, sediment, and other substances from the impervious surfaces found in these areas. The sources of these surface contaminants include: air and rain deposition of atmospheric pollution; littered and dirty streets; traffic by-products such as petroleum residues, exhaust products, heavy metals and tar residuals from the roads; chemicals applied for fertilization, control of ice, rodents and other pests; and sediment from construction sites. Improper industrial, commercial and domestic hook-ups to storm sewers also contribute various pollutants to waterways, as do inadequate and/or improperly maintained sewage disposal systems both for municipalities and individual homes.

This assessment estimated only the nutrient and sediment loads from urban areas and no other urban NPS pollutants as described above. Factors that affect the amount of surface and channel erosion loads reaching water from urban lands include the degree of imperviousness of the urban land use, impervious area NPS pollutant build-up rates, stream density, rainfall, septic system use, direct discharges, soil saturation, and slope.

The main factors to changes in loadings, and thus ranks, of the urban NPS pollutants between the current and past assessment products are the same as for agricultural loads. These were updated land use, as well as updated model data, parameters, and procedures. Also of relevance septic loads were excluded from the reported urban load, as they had been in the past. This is because septic loadings are not Final 2016

exclusive to the urban environment and so they were simulated as an individual loading source in this assessment.

The ranked UALs by hydrologic unit of nitrogen, phosphorus, and sediment from urban land uses (as described in Table 5-2) are displayed in Figures [5-4](#), [5-5](#), and [5-6](#) respectively. The rankings are also listed in [Table 5-3](#). Urban load measures are based on pollution potential and do not compensate for many of the urban runoff control measures that may be in place in some areas. Such reduction measures are primarily installed by the private sector.

Forestry NPS Pollution Loads

Almost 67% of Virginia's land area was forested in the year being assessed. Forestland in general produces lower NPS pollutant loads² per unit area than other land uses. Certain forest disturbing activities such as tree harvesting, site preparation, and reforestation, however, do make a load contribution. As [Table 5-2](#) shows, these activities contribute more to the sediment load than they do to other NPS pollutants.

Forestland can be harvested as part of a land use change such as residential development, clearing for agricultural fields, or surface mining. Due to the similar spectral signatures in classified land cover imagery of these land activities, as well as those of non-temporary land covers such as bare rock and beaches, it can be difficult to discern them from one another without other associated data. Fortunately, the VDOF tracks forest harvesting activities to facilitate the proper management of Virginia's forest resources relative to water quality.

Whereas agricultural activities operate on a yearly or seasonal cycle on agricultural lands, a single cycle of forest harvesting, site preparation and reforestation occurs over many years. Due to temporal and spatial overlap in silvicultural cycles, measurement of these forest disturbing activities in this assessment is more of a snapshot than a trend. As such, the ranking of hydrologic units for forest based loads varies more between NPS Assessments for forest harvesting units than do the loads of other land use classes when model code and parameters are kept constant.

Factors in this assessment that affect the amount of loads reaching water from forestlands include soil erodability, existence of disturbed forestlands, stream density, rainfall, existence and effectiveness of forest (silviculture) BMPs, soil saturation, and slope.

The ranked UALs by hydrologic unit of nitrogen, phosphorus, and sediment from forestland uses are displayed in Figures [5-7](#), [5-8](#), and [5-9](#) respectively. The rankings are also listed in [Table 5-3](#).

The factors most responsible for the changes in loadings, and thus ranks, of the forest NPS pollutant loads in this assessment are the same as for agriculture and urban uses. Additional factors include updated forest harvesting information from VDOF, and improved accounting of silviculture BMPs effectiveness.

NPS Pollution Loads of Other Land Uses

Extraction and non-urban barren lands have not been lumped into any of the output land use classes with regard to reporting loads or unit area loads (see [Table 5-2](#)). Therefore, they do not influence the ranking of units for any of the specific land use load classes. Likewise, loads from the non-sewered population and channel erosion are not reported in any specific land use class load.

Using resource extraction spatial data from the VDMME helped isolate true extraction activities from reforestation sites, urbanization, or other land disturbing activities. The spatial distribution of extraction land use was used in conjunction with county level recordings of extraction activity.

²Airborne nutrient pollution is accounted for as part of the load of the land use it falls upon. The majority of the airborne nutrient load falls on forestland in Virginia and is therefore associated more with forestland than with other uses.

Approximately 4.85% of the phosphorous, 24.25% of the nitrogen, and 16.75% of the sediment load in the 2016 NPS Assessment was associated with loads from the non-sewered population, channel erosion, barren, and extractive land uses. The largest contributor of this group is the nitrogen load from failing septic systems and straight pipes (untreated). The most significant extraction use loads occurred in the Big Sandy basin. In general, barren land only contributed minor loads.

Total Loads by NPS Pollutant

Calculated total nitrogen, total phosphorus, and total sediment unit area loads from all land uses combined, including the other uses noted above, are displayed in Figures [5-10](#), [5-11](#), and [5-12](#), respectively and listed in [Table 5-3](#). Total nitrogen is composed of septic nitrogen, groundwater nitrogen, dissolved nitrogen from various land uses, wash-off of nitrogen from impervious surfaces, and sediment-attached nitrogen. Total phosphorus is composed of septic phosphorus, groundwater phosphorus, dissolved phosphorus from various land uses, wash off of phosphorus from impervious surfaces, and sediment attached phosphorus. Total sediment is the sediment yield from all land uses and instream erosion.

The summing of NPS pollutant loads by land use into total NPS pollutant loads in this NPS assessment is simply the addition of values with equivalent units (kg/ha/yr of nitrogen or phosphorus, Mg/ha/yr of sediment). Accordingly, the relative weight of the estimated NPS pollutants coming from one land use versus another is directly comparable. This comparison shows that NPS pollutants from agricultural lands dominate the total NPS pollutant loads although barren lands can be heavy contributors where they occur in some concentration.

IMPAIRED WATERS

In accordance with US EPA Clean Water Act (CWA) guidance and protocol, the VADEQ assembled a list of the water quality limited riverine, lacustrine, and estuarine waters of Virginia in 2014 (303d report). That list and associated assessment geodatabase of water quality limited waters are the basis for the impaired waters portion of the 2016 NPS Assessment. Similar to the rankings of estimated pollutant loads, the impaired waters ranking presents a series of maps depicting, by hydrologic unit, the relative proportion of waters that appear to be impaired due to nonpoint source pollution.

Among the many defined attributes in the impaired waters assessment geodatabase are the names of the impaired waters, the beginning and ending spatial limits of the impaired portions, impairment causes, and impairment sources. Following is a brief overview of the generation of this prioritization ranking list and the evaluation of NPS impacted waters, a subset of this assessment geodatabase. Included first, were all the waters identified by VADEQ staff as having NPS related sources. Additionally, this ranking included those impaired waters which did not list any point source related causes or listed sources as unknown, provided visual inspection of high resolution imagery of the surrounding watershed(s) could corroborate that the source was likely NPS (i.e. urban or natural)³. Excluded from the ranking list are those waters listed as impaired for toxics or occurring in primarily estuarine influenced areas.

Waters in the impaired waters layer that are suspected of being impaired due to nonpoint sources were divided by the hydrologic unit boundaries into segments to allow for the summation of impaired water lengths or areas by these units. The same process was performed on all waters in the state and determined the total available miles of riverine, acres of lacustrine, and square miles of estuarine waters per hydrologic unit that occur for comparison against the impaired portions.

Whereas the 2016 NPS Assessment focuses on nutrients and sediment, most of the NPS impaired waters from the 2014 303(d) report are listed due to the existence of pathogens. Total Maximum Daily Load (TMDL) studies have shown that pet wastes can have a role in high pathogen counts in some urban streams. Concentrations of wildlife can have a similar effect in various land use / land cover settings.

³ This included all fecal causes of unknown sources since approximately 90% of non-urban fecal problems are surmised to be due to agricultural or natural animal loadings. Similarly, because about 85% of benthic impairments are believed to be sediment related, and because VADEQ personnel are more likely to know and document point sources of benthic impairments, all benthic impairments of unknown sources are considered to be NPS related. Impairments with nutrient sources were also included.

Likewise, human wastes, arising from the existence of straight pipe disposal, failing septic systems, or malfunctioning water treatment plants and their permitted collection system infrastructure, can all contribute to the impairment of waters due to high levels of pathogens. Based on TMDL studies completed to date, a significant number of the waters impaired due to the existence of pathogens are believed to be impaired because of farm animal wastes.

The number of farm animals by type and by unit is part of the nutrient load calculation, since most farm animal wastes are recycled back to the ground by the animals or in a more controlled mode by farmers who want to fertilize fields and/or remove wastes from confined animal sites. The controlled dispersal of wastes is a goal of nutrient management planning and a practice that DCR cost-shares with farmers to implement. The fencing off of stream banks and construction of alternative water sources are two such practices, in this case designed to keep livestock out of and away from streams so as to avoid sediment loading from eroded stream banks and also avoid direct deposition of manure and its associated pathogen load.

The following rankings of hydrologic units by water regime consider only non-shellfish NPS-associated impairments.

Riverine Impairments

Summed lengths of NPS impaired riverine water features in 2014 as miles per hydrologic unit were compared to the total miles of riverine systems available per unit at the same scale⁴ to determine the percentage of the total available riverine water miles per unit that were NPS impaired. The ranking of this value is based on the value itself and not on a pre-set distribution of the range of calculated percentage values. The rankings of units for impaired riverine waters are displayed in [Figure 5-13](#) and listed in [Table 5-3](#).

Estuarine Impairments

Most of the impaired main-stem estuarine water bodies in Virginia have listed impairment causes that are not considered to be due to practices occurring in the immediate units that they flow through. There may be, in fact, very little land associated with some of these units. Estuarine waters are also tidal and may show pollution effects from multiple areas, even if they are not main-stem estuarine water bodies. For these reasons the estuarine waters are not being used to rank the hydrologic units in which they pass through in this assessment. Although there are NPS impaired estuarine waters it is difficult to associate them with specific upland NPS pollutant sources.

Lacustrine Impairments

Summed areas of impaired lacustrine waters in 2014 as acres per hydrologic unit were compared to the total acres of lacustrine waters available per unit to determine the percentage of lake waters in a unit that were impaired. Although the land area of these units can be a source of NPS pollutants, so too can the incoming streams.

The ranking of this value is based on the value itself and not on a pre-set distribution of the range of calculated percentage values. The vast majority of the hydrologic units in Virginia contained no impaired lake or reservoir waters in 2014. However, most of the remaining units had very high percentages of impaired lacustrine waters. This distribution is in part due to the decreased unit sizes of the 6th level NWBD units but also due to the call regarding their impairment source. The rankings of hydrologic units for impaired lacustrine waters are displayed in [Figure 5-14](#) and listed in [Table 5-3](#).

BIOLOGICAL HEALTH

Additional components for evaluating the effects of nonpoint source pollution include the VDH public surface water sources and their protection zones and an evaluation of the health of aquatic species

⁴ In 2014 the scale was 1:24,000, augmented by the inclusion of smaller streams designated as impaired.
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in the state's waters conducted by the Center for Environmental Studies at VCU. These components provide an additional means to prioritize water quality protection - the protection of the sources of public drinking water and of natural aquatic communities respectively.

Public Source Water Protection

As part of their Source Water Area Protection (SWAP) Program, the VDH determined the area upstream of public surface water intakes that must be investigated for threats to water quality. The most immediate area of their concern is referred to as the Zone 1 for each intake. Zone 1 areas extend out to a five mile radius upstream from a water supply intake or five miles around a lake containing an intake, without crossing watershed boundaries except those upstream. The population served by an intake, provided by VDH, and the portion of a hydrologic unit that is within a Zone 1 area has been used by VADCR to calculate the concentration of persons served per unit by these public surface water supplies. The concentration values serve as a measure of the importance of high water quality by hydrologic unit for public drinking water supply protection.

Concentration values are the summation by hydrologic unit of all Zone 1 areas or combinations of Zone 1 areas in that unit times one one-thousandth of the effective population each serves. In cases where a municipality owned several intakes, the single recording of population served was divided amongst each intake to create an effective population served. In cases of overlapping intake reaches the effective population of each reach was summed for the portion of overlap.

The categorized values and rankings for indicating concentration by unit are displayed in [Figure 5-15](#) and listed in [Table 5-3](#). Unlike the NPS loading variables in this assessment, where high ranked units represent units of concern, the high ranking public source water units are just units with a greater need for water quality protection. A significant amount of their area lies immediately upstream from surface water intakes that are used extensively for public drinking use by many people.

The vast majority of hydrologic units contained no Zone 1 protection zones or portions of Zone 1 protection zones. Of those with some Zone 1 content, the majority had low levels (< 10) of the calculated measure for concentrations of people served within a watershed. Of the remaining units, a few had significantly higher value measures (> 100) and were therefore classified as having a "Very High" need for source water protection. The rest were divided amongst a moderate category (10-30) and a high category (30-100).

Aquatic Species Measures

The presence or absence of certain aquatic species can serve as an indication of the overall quality of a particular waterway. They can also indicate where the most biological damage can occur from water quality degradation. Accordingly, the NPS Assessment and Prioritization study provides a ranking of hydrologic units for stream-dependent living resources (including fish, mollusks, and crayfish) using a multi-metric index calculated by the CES at VCU as part of their [Interactive Stream Assessment Resource \(INSTAR\)](#).

These indexes (referred to as the mIBI - a modified version of the Index of Biological Integrity) are calculated by the CES using databases originally developed by VADCR, the VDGIF, and VCU⁵. More than 162,000 database records from over 2000 aquatic collections have been gathered since INSTAR's Inception. As a result it is possible to calculate a mIBI value for more than 93% of the 6th level units of the NWBD. An equally beneficial result from having more records available for any unit is the decreased likelihood of a false prioritization indication based on minimal information.

By associating a hydrologic unit code with each of the stream segments for which aquatic species information was available in the various databases, metric scores by unit were developed for each of six metrics. These metrics are as follows:

⁵ More information about the mIBI and the other components of INSTAR can be found at <http://gis.vcu.edu/instar/>.
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- Metric 1 Number of Intolerant Species: refers to the total number of unique water quality intolerant species found in a unit.
- Metric 2 Native Species Richness: refers to the number of indigenous (local) species present in a unit.
- Metric 3 Number of Rare, Threatened and Endangered Species: refers to the number of species that are considered rare, threatened or endangered due to their low population levels that are present in a unit.
- Metric 4 Number of Non-indigenous Species: refers to the number of non-native species present in a unit. These are introduced species that would not normally be found in this particular location.
- Metric 5 Number of Critical Species: refers to the number of species found in a unit that are considered critical because of some important role that they play, such as being a food source or a major recreational fishery.
- Metric 6 Number of Tolerant Species: refers to the number of species found in a unit that are tolerant to degraded stream conditions and can survive even in these sub-optimal conditions.

A score of 0 – 5 was assigned by the CES for each metric based on the metric’s values. In general, high metric values were assigned high metric scores - indicative of high stream health. A score of zero was given if insufficient data were available. Of the 1251 hydrologic units, 86 (7%) were assigned a zero for this reason. Metrics 4 and 6 were reversed in the scoring, since a low value for either of these metrics would indicate high stream health. Therefore a high metric score was given for low metric values for these two metrics. Lower values are more desirable in metrics 4 and 6 because a high number of non-native species and/or a high number of species that are tolerant to stream degradation are less desirable characteristics for a stream.

Scores for each metric for each unit were totaled to give an overall total mIBI score per hydrologic unit. These summed scores per hydrologic unit were then tiered relative to the summed scores of the other units in the same basin by assigning a category value of High (score of 5), Medium (score of 3), or Low (score of 1) on per metric per basin basis. The resulting total mIBI scores are used to place each hydrologic unit into ranked categories reflecting biotic integrity and resource importance.

Since there were six metrics and a maximum score of 5 could be obtained for each metric, the overall maximum score a unit could receive was 30 (6 x 5). Fewer than 8% of the units (100) are considered to have very high biodiversity, with total mIBI scores of 20 or more. Another 198 units have total mIBI scores of at least 18. At the other end of the spectrum, 24% of the units (301) with sufficient data have total metric scores of 12 or less – indicative of low biodiversity. These units most probably contain waters with some degree of degradation.

The categorization of the mIBI scores by hydrologic unit is displayed in [Figure 5-16](#), and listed in [Table 5-3](#). In this figure and table, high mIBI scores equate to areas of high biotic integrity. Whereas, low mIBI ranked units represent units of concern in regard to low water quality based on aquatic species measures, high ranked units represent areas of importance for the protection of the state’s streams with exceptional biodiversity. There has been very little change in total mIBI scores over the past few years.

While the maintenance or enhancement of water quality for the protection of all native aquatic life is the preferred goal, these aquatic species priorities should help direct NPS pollution mitigation efforts and other water quality improvement projects toward hydrologic units with the most important aquatic resources.

COLLECTIVE USE OF RANKINGS

The twelve rankings assigned to hydrologic units for NPS pollutants by land use class, the two rankings for impaired waters occurrence, and the two rankings of units for biological health can be used in various combinations to evaluate statewide conditions and prioritize NPS reduction activities. Which measures are included in each prioritization process, and how one weighs in comparison to another, depends on the activity to be prioritized. For instance, VADCR uses the agricultural NPS pollution

rankings as variables in the targeting of agricultural best management practices (see Agricultural Cost Share Program below).

There are several considerations to keep in mind when constructing prioritization processes using these rankings. Perhaps the most important is that some factors are measures potentially being produced at the hydrologic unit of interest, such as the NPS pollutant loadings. Other measures reflect existing conditions at the unit of interest, such as aquatic species health, and may in part be due to activities occurring in upstream units. The source water concentration values directly account for the upstream effect by virtue of their being based on a designated upstream zone.

Another consideration is the possible incorrect inference of cause and effect. Waters in a hydrologic unit may be impaired due to nonpoint sources but the cause of these waters being listed as impaired is not necessarily related to the nitrogen, phosphorus, and sediment that are potentially being loaded to them in either the unit of concern or upstream of it. Likewise point source loadings can be the reason for the streams in a unit to collectively produce a low mIBI score and aquatic species rank.

In the 2016 NPS Assessment and Prioritization some units have been flagged for conditions that can be determined by comparing the rankings of measures in this report. The flags have been entered into [Table 5-3](#). The conditions are:

Exceptional aquatic biodiversity.

1> Units (11) with mIBI scores of 24 or greater.

High aquatic biodiversity with high potential NPS pollutant loads.

2> Units (12) with mIBI scores of 18 or greater and all high ranked total NPS pollutant loads.

High public water supply protection need with high potential NPS pollutant loads.

3> Units (8) with source water concentration values greater than 30 and any high ranked total NPS pollutant load.

High public water supply protection need with NPS impaired surface water at intake.

4> Units (35) with NPS impaired waters immediately upstream of the source water intake.

Excessive agricultural loadings.

5> Units (11) with potential agricultural nutrient loads (either N or P) greater than four times the standard deviation from the mean agricultural nutrient load.

6> Units (7) with potential agricultural sediment load greater than four times the standard deviation from the mean agricultural sediment load.

NPS REDUCTION ACTIVITIES

Efforts to reduce NPS pollution in Virginia have been undertaken by government agencies - federal, state, regional, and local, as well as by citizen action. In many cases the activities are cooperatively performed and funded. Descriptions of the cooperative NPS reduction activities can be found at the [NPS Management Plan website](#) and document. Most of these efforts target particular watersheds. Among them and elaborated upon at this site are TMDL studies and Implementation Plans, Nutrient Management, Agricultural Cost Share incentive programs for BMP installations, and incentives for the set aside of agricultural land.

Total Maximum Daily Loads

TMDLs, described elsewhere in this 305(b) report, are developed for waters that have been determined to be impaired and are so listed in Virginia's EPA approved 2014 303(d) report. Streams are not listed as impaired however due to high concentrations of nitrogen, phosphorus, or sediment, but rather because they cannot support, or can only partially support, one or more of the five designated uses. This is because water quality standards do not exist for concentrations of these pollutants for free-flowing waters. Nevertheless, certain impairment causes are primarily due to nonpoint source pollutants

(see Impaired Waters in this chapter) and VADEQ staff has often determined that there are nonpoint sources for these impairments. This section of the NPS Assessment provides an analysis and presents a map characterizing TMDLs, by hydrologic unit, where NPS sources appear to be dominant.

For TMDLs currently being developed, the hydrologic units were divided between those with and those without a predominant nonpoint source. Most of the water quality impairments in Virginia are due to nonpoint source pollution. Consequently, most of the TMDLs that are being undertaken have a nonpoint source component. These studies are focused on identifying the sources of the impairment causes, quantifying the loadings of these sources to the water, and determining the load reduction needed to meet the use criteria. The development of an Implementation Plan is expected following the completion of a TMDL study for a particular watershed. Implementation of the plan's course of action then follows.

The number of TMDL implementation projects underway or completed is continually increasing. [Table 5-4a](#) lists the NPS TMDL Study Reports (excluding estuarine, shellfish, and those developed for toxic pollutants), and [Table 5-4b](#) lists the NPS TMDL Implementations Plans as of December 31, 2016, by their status, which is a temporal condition. At that time, there were 74 completed, NPS dominated TMDL Implementation Plans covering 894 unique impaired waters. These plans represented 4,842 impaired segment miles and 1,477 impaired reservoir acres (ID305b Assessment Units, from Virginia's 2014 Integrated Report), which may be addressing more than one pollutant for a water segment. In addition, there were 223 NPS dominated TMDL studies that have been approved by the EPA covering 745 hydrologic units with impaired segments. The number of TMDL Study Reports completed cannot be directly compared to Implementation Plans completed, as the geographic area and impaired waters included may vary. Implementation Plans may be developed for only a portion of a TMDL Study or include areas from multiple adjacent studies with similar land uses, and addressed by similar reduction strategies.

Whereas, streams or water bodies are listed as impaired, it is the watershed of those impaired stream segments and water bodies that are the focus of nonpoint source pollutant reduction activities. The hydrologic units listed in Tables 5-4a and 5-4b are those in which some portion of the unit contains the listed impaired stream segment. Sometimes the entire area of the listed hydrologic unit is the watershed of the impaired stream segment, but often only a portion of that unit must be studied for a TMDL. [Figure 5-17](#), shows the true TMDL study areas and thus gives a better indication of the geographic extent of where the work is being performed. One difficulty in geographically representing the extent of multiple TMDL areas is that they often overlap – the watershed of a TMDL for a headwaters stream becomes part of the watershed of a TMDL for a larger water feature downstream, perhaps with a different pollutant/stressor. In [Figure 5-17](#), the latest EPA approved TMDL work is displayed by impairment type and [Figure 5-18](#) likewise shows the true TMDL Implementation Plan areas, which also include geographic overlap.

Agricultural Cost Share Program

The [Virginia Agricultural Cost Share Program](#) (VACS) offers incentives to farmers and agricultural landowners to encourage the installation and use of a number of approved techniques (BMPs) for reducing agricultural related nonpoint source runoff. While the program aims to address nonpoint source pollutants statewide, specific hydrologic units are targeted based on the agricultural loads estimated from the NPS Assessment (see Agricultural NPS Pollution Loads) and other factors. Soil and Water Conservation Districts further target the practices to individual needs within their district within these load priority areas.

Funding support for the implementation of these practices has been borne by the state and the federal government since the program's inception in 1985. The number of installations per year has varied widely over the years, correlating with the variation of funds available to the program. At this time the primary funding source is the Virginia Natural Resources Commitment Fund, a sub-fund of the Water Quality Improvement Fund (WQIF) established by the Commonwealth's Water Quality Improvement Act (WQIA). Other state and federal funds may be used however, such as Chesapeake Bay Implementation Grants.

Table 5-5 contains a summation of the installation or practice of several of the more common NPS BMPs

initiated in the 2014 and 2015 program years of the VACS (July 2013 – June 2015). Other NPS BMPs in this period addressed the use of conservation tillage, nutrient management planning, terracing, sinkhole protection, wetland restoration and conversion, irrigation water recycling, strip cropping, and the capping of abandoned wells. Still other NPS BMPs addressed the installation of water table control structures, runoff impoundments, agricultural chemical and fertilizer handling facilities, composter facilities, water diverters, animal waste and mortality facilities, and the installation, repair, and pump-outs of septic tanks.

Additional information on agricultural best management practices and the cost-share program can be found at http://www.dcr.virginia.gov/soil_and_water/costshare.shtml. Other efforts to reduce NPS pollutants include local and state stormwater controls, BMP installations by the USDA, and silviculture BMP installations by the VDOF. These and other efforts reduce estimated initial loads as calculated in the NPS pollution loadings of this assessment.

Table 5-5 NPS BMP Installations and Metrics, Program Years 2014 & 2015 (July 1, 2013 through June 30, 2015)

Basin	Acres of Riparian & Wildlife Buffer	Miles of Fencing**	Acres of Erosion Stabilization	Acres of Grazing Land Managed	Acres of Cover Crop	Acres of Sod Filters and Waterways
Potomac *	7,064	89	552	1,017	1,378	18
Shenandoah	9,478	56	1,254	701	12,281	1,993
Rappahannock	6,833	115	1,438	2,727	10,286	21
York	1,570	31	318	657	5,834	7
James	11,327	164	1,231	3,090	18,742	11
Bay Coastal	619	3	64	20	13,085	10
Ocean Coastal	388				8,329	
Albemarle Sound	1,224				2,766	
Chowan	8,671	12	176	167	2,633	747
Roanoke	5,862	190	541	2,850	2,234	677
Yadkin	54	3	4	14	84	1,003
New	3,538	41	393	738	3,832	
Clinch/Powell	2,727	38	107	1,254	201	2
Holston	3,576	25	6,178	822	2,309	1
Big Sandy		8	33	211		
TOTAL	62,931	775	12,289	14,268	83,994	4490

*excludes the Shenandoah

** fencing may be for stream exclusion and/or grazing management

Conservation Reserve Enhancement Program

The USDA's Conservation Reserve Program (CRP) provides incentives for the removal of agricultural land from production to protect environmentally sensitive land alongside rivers and streams. The [Virginia Conservation Reserve Enhancement Program](#) (CREP) augments CRP by providing for state enhanced cost-share and rental payments for conservation practices focused on the restoration of riparian buffers and wetlands. The Virginia CREP also funds the purchase of conservation easements on the restored riparian buffers.

Most, but not all areas of the state qualify for CREP assistance. Maps showing where CREP assistance is available can be found at <http://www.dcr.virginia.gov/soil-and-water/crep-areas>. The metrics reported in [Table 5-5](#) include the impact of CREP practices during this period. The USDA's CRP increases the reported results. Information about CRP can be found at <https://www.fsa.usda.gov/programs-and-services/conservation-programs/index>.

Nutrient Management

The Virginia Nutrient Management Program which is administered by Code of Virginia §10.1-104.2 is designed to detail the most efficient use of fertilizers and manures on farms and urban lands in the Commonwealth. Plans are customized to fit a particular operation. The potential productivity of each field is considered along with an inventory of available nutrients from the soil, crop residues, manures, and commercial fertilizers. Nutrient management plans are flexible, based upon crop responses to nutrients, and focus on efficiently using those nutrients.

In Virginia, nutrient management plans are created by nutrient management specialists employed by VADCR. These specialists offer hands-on assistance with soil and tissue sampling, the use of soil surveys, equipment calibrations, and interpreting results to improve farmer efficiency. VADCR has 14 staff specialists who assist farmers, mostly of animal operations, in developing and implementing nutrient management plans.

There is also a private sector involvement in nutrient management activities. Statewide, there are currently 474 certified agricultural nutrient management plan writers, who record the majority of the acreage being managed each year. In addition, Virginia has an Urban Certification program with 174 certified urban plan writers. These plans are written for urban lands consisting of state owned lands, golf courses, businesses, and other urban areas. For the period ending in 2014 there are now over 905,000 acres statewide with a current nutrient management plan. Table 5-6 contains an accounting of the active plans in 2014.

Table 5-6 Acres Placed Under a Nutrient Management Plan As of 6/30/2014

Basin	Crop Acres	Hay Acres	Pasture Acres	Specialty Crop Acres	Turf & Landscape Acres
Albemarle Sound	23940	7		50	
Atlantic Coastal	25936			1420	
Big Sandy		155	299		
Chowan	87179	5714	3841	854	978
New	7552	5831	7519	157	22
Roanoke	26003	29084	8000	206	87
Clinch/Powell	1128	2617	5164		
Holston	3899	4710	7891		
Yadkin	97	24	7	243	
Non-Bay Total	175735	48143	32720	2930	1086
Bay Coastal	75975	474	251	1942	311
James	72415	34115	14881	1309	3181

Potomac **	49878	16060	6618	67	3191
Shenandoah	46639	38746	31959	121	101
Rappahannock	121020	15948	3325	466	127
York	94967	6787	2409	68	1264
Bay Total	460895	112130	59442	3973	8174
Grand Total	636630	160273	92162	6903	9261

** excludes the Shenandoah

Additional information on the Commonwealth's nutrient management program can be found at http://www.dcr.virginia.gov/soil_and_water/nutmgt.shtml.

Model Development and Estimation of Pollutant Loadings

The GWLF NPSA2016 model was calibrated for use in Virginia's NPS Assessment by the VT BSE prior to the 2016 assessment model runs. Since 10 years had elapsed without major changes to the modeling procedures, the modeling procedures were updated along with traditional model input data updates. The same database structure from the 2002 and 2006 calibrated models was used to evaluate a multiple-year period with output categories based on agricultural, urban, and forest land uses. Explicit 2016 version revisions to GWLF modeling, calculations, and approach include:

1. Model code corrections to the daily erosivity equations
2. A correction to the KLSCP (K – erodibility factor, LS – slope length factor, C – cover and management factor, P – support practice factor) calculation in a pre-model data processing spreadsheet (reducing sediment and attached nutrient loads by a factor of 5.8)
3. A unit conversion correction to the 'Soil Test' total P Concentration (reducing current soil P values to approximately 20% of previous ones)
4. Use of CFSR rainfall, which generates time-series at the centroid of each VAHU6 watershed
5. Updated model simulation period from 1985-2003 climate data to 1995-2014 climate data
6. Inclusion of a channel erosion component (reported as part of total load only) based on daily flow, channel depth, perennial stream length, and other hydrologic unit characteristics for which data had not previously been available
7. Improved representation of area-based parameters for hydrologic units along the state's boundary, referred to as 'fringe' watersheds, through inclusion of their out-of-state drainage areas
8. Septic loads were removed from the urban load category and are only reported in the total loads and rankings
9. Parameter algorithms or values were revised for LS-factor (topographic), manure nutrients, and C-factors (cover management), to reflect updates from the literature and from expert panel analysis for the Phase 6 Chesapeake Bay watershed model

Model input data updates for the simulation period included:

1. Land uses from information compiled from the MRLC National Land Cover Database (NLCD), USDA-NASS cropland data layer, Ag census, VADCR, VDMME, VDOF, and CTIC
2. Farm animal numbers and corresponding manure generated
3. Version 5 of the 6th level hydrologic unit system for Virginia
4. Average soil K factors (soil erodibility) (with inclusions) by updated land uses by updated hydrologic units
5. Soil Phosphorus (P) content from more recent and more resolute Virginia Tech Soil Testing Lab results
6. BMP generalized pass through factors from information provided by localities, VADCR, and NRCS

Hydrologic calibration was performed using the observed conditions at 113 monitoring sites across Virginia as assembled by the CBP Office primarily from the USGS and the VADEQ for the CBWM. Calibration watersheds were created that corresponded to these monitoring station points and were as consistent as possible with existing NWBD unit boundaries. There are portions of Virginia that are Final 2016

downstream of these monitoring sites, however, that could not be calibrated in this manner. To calibrate the model for these portions of the state, the BSE defined six physiographic regions covering Virginia. Regions were comprised of aggregated 6th level NWBD units that were adjusted to coincide with the aforementioned calibration points. A limited set of parameter values were then modified by region during the calibration process of the upstream calibration watersheds until flows simulated by the GWLF model output were sufficiently similar to the observed data. Final parameter values per region were then assigned to the downstream portion of each region. The GWLF assessment runs used and produced data for the 6th level hydrologic units (1237 units) in Virginia; 11 other units that are all water and three small units added to the hydrologic unit system after model calibration were not modeled. GWLF assessment runs in 2016 used a land use / land cover data set developed by VADCR from a number of sources⁶ to represent 2012 conditions. The 2012 conditions were simulated to align with dates of the latest land cover data and agricultural census (2012) data available when the 2016 NPS Assessment occurred.

Table 5-7 lists the land use classification system used in the GWLF assessment runs and the equivalent generalized model output land use classes. Spatially attributed BMP and nutrient management plan effects are measured as both land use changes⁷ to the aforementioned 2012 land use/land cover data set and as fractional reductions to the loadings by modeled land use.

Table 5-7 Land Use Classification

<u>Original Class</u>	<u>Derived Class</u>	<u>Modeled Class</u>	<u>NPS Assessment</u>
Pine Forest Hardwood Forest Mixed Forest		Forest	Forest
Forest Harvest		Disturbed Forest	
Crop Bare Soil (Portion)	Conventional Tillage Conservation Tillage Hay Unimproved Pasture Pasture Cattle-Grazed Pasture Poultry Litter Manure Acres	Conventional Tillage Conservation Tillage Hay Unimproved Pasture Pasture Cattle-Grazed Pasture Poultry Litter Manure Acres	Agriculture
Pavement Rooftop		Impervious Urban	
Residential/Industrial Grassland Bare Soil (Portion)		Pervious Urban	Urban
Natural Barren Extraction		Barren	
Open Water Salt Marsh		Not Modeled	

Output from the GWLF assessment runs are in the form of average annual loads (L) of each NPS

⁶ The base spatial layer for the 2012 land use / land cover data set was the 2011 NLCD. Agricultural uses were modified using the USDA 2012 Census of Agriculture and the 2012 USDA NASS, as well as tillage practice surveys by VADCR (2015) and the National Crop Residue Management Survey (2007) from the CTIC. Barren classes were modified using data from the VDMME. Disturbed forest was determined with the help of VDOF timber harvesting data. Additional classes were based on processes developed for VADCR by The Academy of Natural Sciences of Philadelphia (1997) using data from Virginia's confined animal databases.

⁷ It was not necessary to change the land use to represent land use change NPS BMPs in this assessment because they were already captured in the source data.

pollutant (p: TN, TP, and TS) per modeled land use⁸ per unit. From this, two forms of unit area loads were calculated – per hectare (h) of general output land use class (l: agriculture, urban, and forest) per hydrologic unit (w) load (luUAL) and per hectare of total modeled land (a) per hydrologic unit (w) load (UAL).

The luUAL value is preferable to the load values themselves when comparing the loading impacts of the individual output land use classes between hydrologic units. They are normalized in that the size of the hydrologic unit does not impact this value. This measure can isolate high loading rates of the general land use classes. It is calculated as:

$$\text{luUAL}(plw) = L(plw) / h(lw)$$

While the above calculation is useful it does not necessarily identify those hydrologic units in which NPS reduction activities should be focused⁹. Therefore, the UAL was used for ranking hydrologic units in this assessment report but significant luUAL values were used in flagging units in need of attention. The UAL per output land use class per pollutant for each hydrologic unit is calculated as follows:

$$\text{UAL}(plw) = L(plw) / h(aw)$$

The output loadings provide a statewide equivalent of the types of results that Virginia has been able to obtain from the CBWM for the Chesapeake Bay drainage area of the Commonwealth over the last twenty seven years. [Table 5-2](#) reports the final statewide loadings by pollutant by general land use class and the amount of land in Virginia by general land use class. Loading values in this table reflect the loads after the reductions are applied from active BMPs installed over the previous sixteen years

⁸ Not all possible land uses were modeled (see Table 5-7). The area of a particular unit as used in these calculations would not include the hectares of non-modeled land uses occurring in that unit.

⁹ For instance, units with high loading rates for agricultural land may have only a small amount of this land use and therefore small total loads of pollutants from agricultural uses. Furthermore, any action (if possible) in any year could encompass all reasonable reduction activities, thus making this hydrologic unit less worthy of further attention.