8 Section 8: Direct Loads

8.1 Introduction

Figure 8-1 shows the calculation of delivered loads for a land use in a land segment. Spatially-averaged nutrient loading rates in pounds per acre are modified first for local nutrient application rates and then by management practices, location within the watershed, and physical characteristics. This chapter deals with direct loads to streams which bypass calculations other than stream and river delivery.

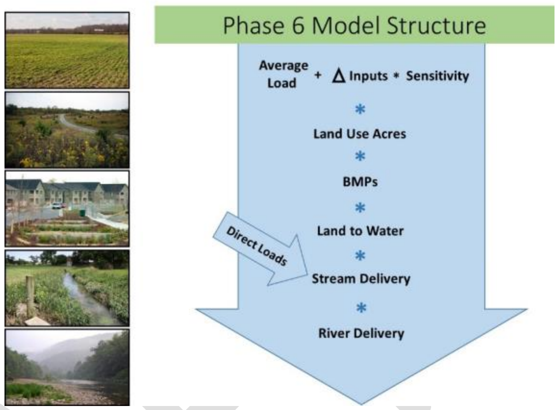


Figure 8-1: Phase 6 Model Structure

8.2 Atmospheric Deposition

Review responsibility - MWG

Chapter 3 contains a detailed description of the atmospheric deposition calculation. Loads that are delivered to the land surface are also delivered to the surface of the water. The loading rate of atmospheric deposition in pounds per acres is multiplied by the water acres in each land-river segment as described in chapter 5 on land use. Stream delivery and river delivery are applied as described in chapters 9 and 10.

8.3 Diversions

Review responsibility for this entire section - MWG

Guidelines previously established for Phase 5 model development were followed throughout the data collection process for the expansion of the diversion dataset in Phase 6. Essentially, the categories of water withdrawals were limited to Public Water Supply and Irrigation & Agricultural withdrawals. While data collection began with only reported surface water withdrawals, the potentially substantial influence of groundwater withdrawals on the surface water regimen in some regions (particularly karst dominated landscapes of West Virginia) prompted the collection of groundwater withdrawal information as well. While these data were not utilized in this dataset, they are readily available should decisions to use them change.

The contacts and processes for data acquisition in different states and watersheds are described below, followed by the methodology used to connect water withdrawals to Phase 6 river segments.

8.3.1 Data Acquisition

- Delaware
    - Data were gathered with the help of Allison Diggins of DE DNREC after completing a request for water data through a FOIA Form on the DNREC website. In Delaware the coordinates of public water supply intakes is confidential information and cannot be

released, although it was possible to receive information concerning the county in which the public supply intakes are located.

- Maryland
  - Water use data was collected with the assistance of John Smith of MDE who shared a spreadsheet containing information about water withdrawal permits and values at the county level extending from dates prior to 1984 through 2013.
- Pennsylvania
  - Data requests are available for PA by submitting a query through a web portal which contains information about primary facility reports, sub-facility reports, as well as different categories. Instructions concerning how to utilize the web portal can be found here. Additional help was provided by Raksha Varanasi of PADEP when the web portal did not function properly. Information that Pennsylvania uses in relation to consumptive coefficients are provided in a PDF file at this website.
- Susquehanna River
  - Instead of utilizing NYDEC data for water withdrawals, Michael Holt with the Division of Water in Albany directed data acquisition efforts to the Susquehanna River Basin Commission. Paula Ballaron worked extensively to provide data for the entire basin, helping to provide overlap in Pennsylvania.
- Virginia
  - VADEQ data for all basins within the Bay watershed were gathered with the assistance of Curt Thomas. Monthly data were collected with coordinates for the period 2004-2013. An initial dataset provided for 2010 withdrawal data suggested discrepancies between VADEQ and the five year county level reports provided for the all counties nationally by USGS. After further evaluations, an additional dataset spanning the years 1984-2003 was incorporated.
- West Virginia
  - WVDEP data were collected with the help of Brian Carr, whose comments regarding the influence of groundwater on surface water in some locations provided an impetus to collect groundwater withdrawal data for the entire Bay watershed. Data prior to 2010 were deemed unreliable by WVDEP because of inconsistent back-cast reporting methods, so withdrawals previously in place for river segments in WV for the years 2002-03 in the Phase 5 model were copied up to the period of available records beginning in 2010. Annual withdrawal data were provided by WVDEP for the years 2010-13.

8.3.2 Methodology

As the data collection process moved forward, a lack of sufficient GPS coordinate data to link all water withdrawals to specific river segments proved potentially problematic. For an initial stopgap measure, diversion data from the years 2001 and 2002 were copied for the years 2003-2014 in the Phase 6 Beta 1 version of the model. To better define precisely which river segments had withdrawals when the only data available was at a county level, the areas of urban and agricultural spaces were utilized. The area of urban land use (as recorded for 2009, the halfway point between start and end years 2004 and 2014) for each county was first summed. This total area of urban land use was then divided into the urban area for each river segment that exists within the county. These fractional portions of urban area for the river segments within counties were calculated for the entire watershed, and organized into a matrix with dimensions equal to R rows by L columns (R being the number of river segments and L the number of land segments). After organizing the county level data for states that did not provide GPS coordinates of withdrawal locations, the matrix containing the ratios of river segment urban area per land segment was multiplied by the state-provided county data. The result of this matrix multiplication was an array that contained an approximation of public supply diversion data for river segments with urban area. An identical technique was employed for agricultural withdrawals using watershed model defined agricultural areas within river segments.

Several inconsistencies were noted after this original method was employed between the Phase 5.3.2 dataset of withdrawals and the updated Phase 6 dataset. Efforts were made to update the older dataset, but this could only be done for the entire period extending back to 1984 for Virginia and Maryland because of policy artifacts and poor reporting. Still, the revision of data in these states helped to correct the majority of problems seen with large withdrawals.

Issues that necessitated further attention involved manual manipulations of withdrawals to maintain consistency in large volumes diverted to particular river segments. Analyses were completed to ensure that these large diversions (typically greater than 25 MGD) were not misattributed to neighboring river segments or sufficiently broken apart as to mask their relative impact on local hydrology. For those state-supplied datasets that did not temporally match the extended calibration period of Phase 6, diversion data were interpolated on an annual basis between 2003 (the final year of data provided in Phase 5.3.2) and the first year of data provided for new data (unless noted otherwise, see West Virginia above). Datasets that did not extend to 2014 were completed by copying the annual withdrawals from the last year of data supplied for each year remaining.

8.4 Wastewater

This section describes development of the wastewater input for the Phase 6 Model including a description of the data sources, methods, and assumptions

The Phase 6 Watershed Model wastewater database includes information for about 522 significant and 6,870 non-significant industrial and municipal wastewater facilities discharging directly to the surface waters in the Chesapeake Bay watershed during 1984-2016 The exact number of operational dischargers changes from year to year as new facilities are added and old facilities closed. For each facility outfall, the database includes monthly average flow (mgd, million gallons per day) and monthly average concentrations (mg/l)for total nitrogen (TN), ammonia (NH_3), nitrate and nitrite (NO_3+NO_2), total organic nitrogen (TON), total phosphorus (TP), orthophosphate (PO_4), total organic phosphorus (TOP), total suspended solids (TSS), biological oxygen demand (BOD_5), and dissolved oxygen (DO). The wastewater data cover the 1984 to 2016 time frame and is updated annually as data becomes available. This database also contains facility information, such as facility type (municipal or industrial), significant or non-significant, county served and SIC code as well as the latitude and longitude at the end of pipe.

In the Phase 6 Watershed Model, the river segments are simulated as a completely mixed reactor and all the wastewater monthly loads within a reach are summed for each of the 800 receiving river segments and input as a daily load.

The complete time series of wastewater inputs as applied in the Phase 6 river-segments from 1984 to 2015 are available for review at https://archive.chesapeakebay.net/VT/Phase_6_Calibration_Data_Review/.Also available on this site are data analyses and summarized data to assist the data review.

8.4.1 Wastewater Flows and Loads

From 1984 to 2015, wastewater flows throughout the Chesapeake watershed have increased in the early years and stabilized with slightly down trend in recent years (Figure 8-1). In contrast, wastewater loads have generally decreased because of increased wastewater treatment upgrades, which have been driven by advances in techno logy, enforceable Clean Water Act (CWA) National Pollutant Discharge Elimination System (NPDE S) permits and funding from multiple local, state and federal sources – along with phosphorus detergent bans and operational reforms. and treatment technology improvement. Figure 8-2 shows the decrease in total Chesapeake wastewater nitrogen and phosphorus end of pipe loads. Flow for the eight major basins is shown in Figures 8-3, and equivalent plots are shown for the nitrogen and phosphorus loads in Figures 8-4 and 8-5(to be updated).

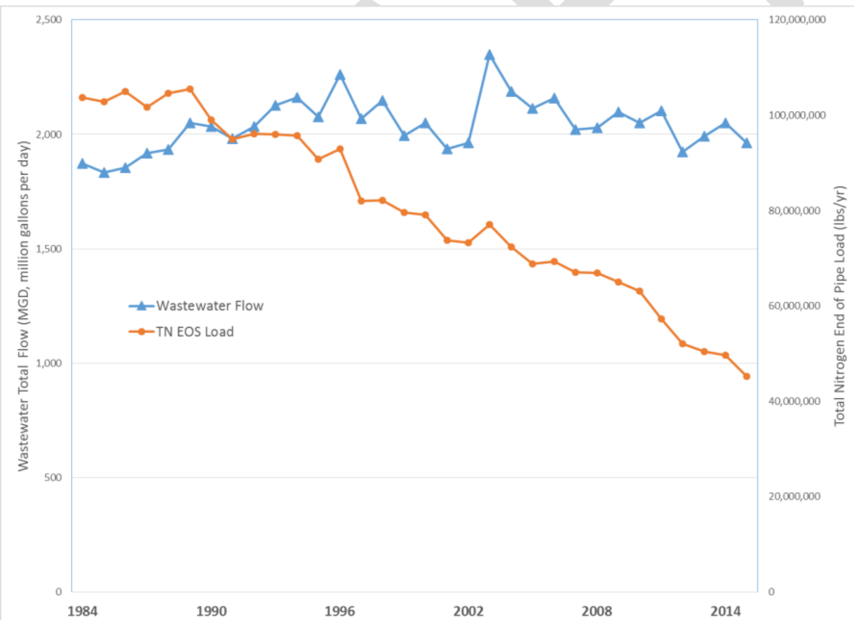


Figure 8-2. Wastewater flow vs TN load

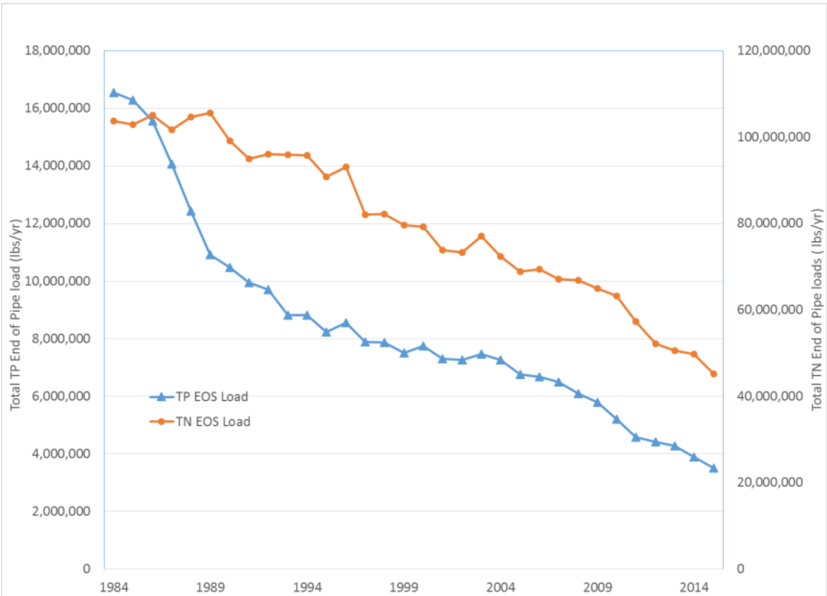


Figure 8-3. Wastewater total nitrogen (orange) and total phosphorus (blue) loadings.

In 1985, wastewater represented 28 percent of total nitrogen loading to the Bay and 39 percent of the total phosphorus loading. In 2015, however, WWTPs represent a much smaller proportion of the total load, only 16 % for both TN and TP as indicated on the following charts.

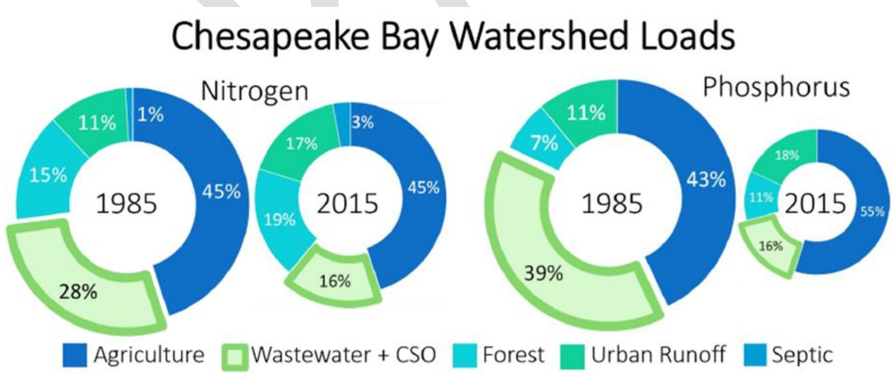


Figure 8-4. Changes of wastewater load contributions among all sources

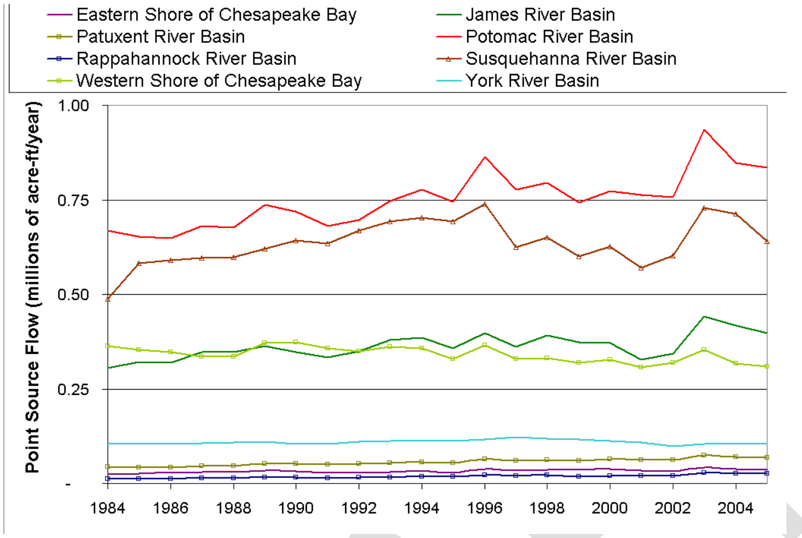


Figure 8-5. Chesapeake Bay eight major basins wastewater flow.

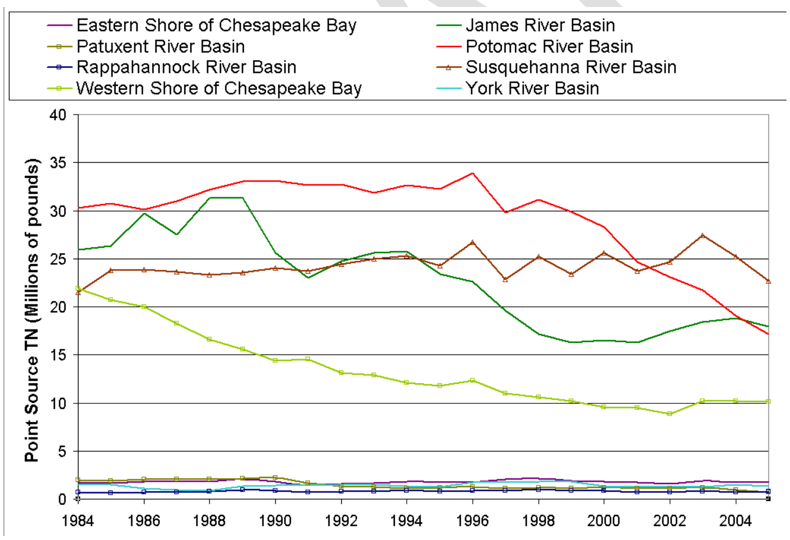


Figure 8-6. Chesapeake Bay eight major basin's total nitrogen load.

8.4.2 Wastewater input constituents in the Phase 6 watershed model

The table below shows the Wastewater input constituents in the CBP wastewater database. Total Nitrogen, Total Phosphorus, and Total Kjeldahl Nitrogen are not directly used in the Phase 6 watershed model since they are calculated by summing their constituent parts. The Phase 6 watershed model accepts Ammonia, Nitrate-Nitrite, Total Organic Nitrogen, Phosphate, and Total Organic Phosphorus along with non-nutrient constituents of Dissolved Oxygen and Total Suspended Solids. Biochemical Oxygen Demand is used to split Total Organic Nitrogen and Total Organic Phosphorus into labile and refractory components and it not used as an addition of nutrients to the loads mentioned above. For this reason, Carbonaceous Biochemical Oxygen Demand is preferred over Biochemical Oxygen Demand, where available.

Table 8-1. Parameters included in the wastewater database.

	Units	
Parameter	**Database**	**Phase 6 input**
Flow	Million gallons per day (mgd)	Million gallons per day (mgd)
Total Nitrogen (TN)	mg/l	N/A
Ammonia Nitrogen (NH_3)	mg/l	lbs/day
Nitrate-Nitrite Nitrogen ($NO_{2,3}$)	mg/l	lbs/day
Total Organic Nitrogen (TON)	mg/l	lbs/day
Total Kjeldahl Nitrogen (TKN)	mg/l	N/A
Total Phosphorus (TP)	mg/l	N/A
Phosphate (PO_4)	mg/l	lbs/day
Total Organic Phosphorus (TOP)	mg/l	lbs/day
Biochemical Oxygen Demand (BOD_5)	mg/l	lbs/day
Dissolved Oxygen (DO)	mg/l	lbs/day
Total Suspended Solid (TSS)	mg/l	lbs/day

8.4.3 Significant and Non-significant Dischargers

On the basis of minimum flow rates, significant and nonsignificant municipal and industrial dischargers were defined and grouped separately in the early 1990s by each jurisdiction. Those two groups of significant and nonsignificant dischargers are the basis for differences in annual progress reporting in the CBP. All significant facilities in most Bay jurisdictions are targeted for nutrient reduction and required to have nutrient permit limits to meet their Bay TMDL targets, while nonsignificant plants have no such requirements though many jurisdictions have started to include nutrient monitoring requirements or limits in permits for some of their nonsignificant plants.

Note: The term *nonsignificant* is defined by a minimum flow for lower priority in nutrient reduction effort and does not imply any quantification of importance to water quality. To avoid confusion over the term, the acronym NSF for NonSignificant Facilities will be used in text that follows.

Almost all NSF information was incorporated into the Phase 6 wastewater input files. However, the information on NSFs is generally not as well characterized as the significant dischargers due to no monitoring requirements on NSFs historically. Most of the NSFs' load estimates were developed through special studies by jurisdictions.

A significant discharger is a facility that is on the significant facility list in a jurisdictional Watershed Implementation Plan and meets one of the following criteria:

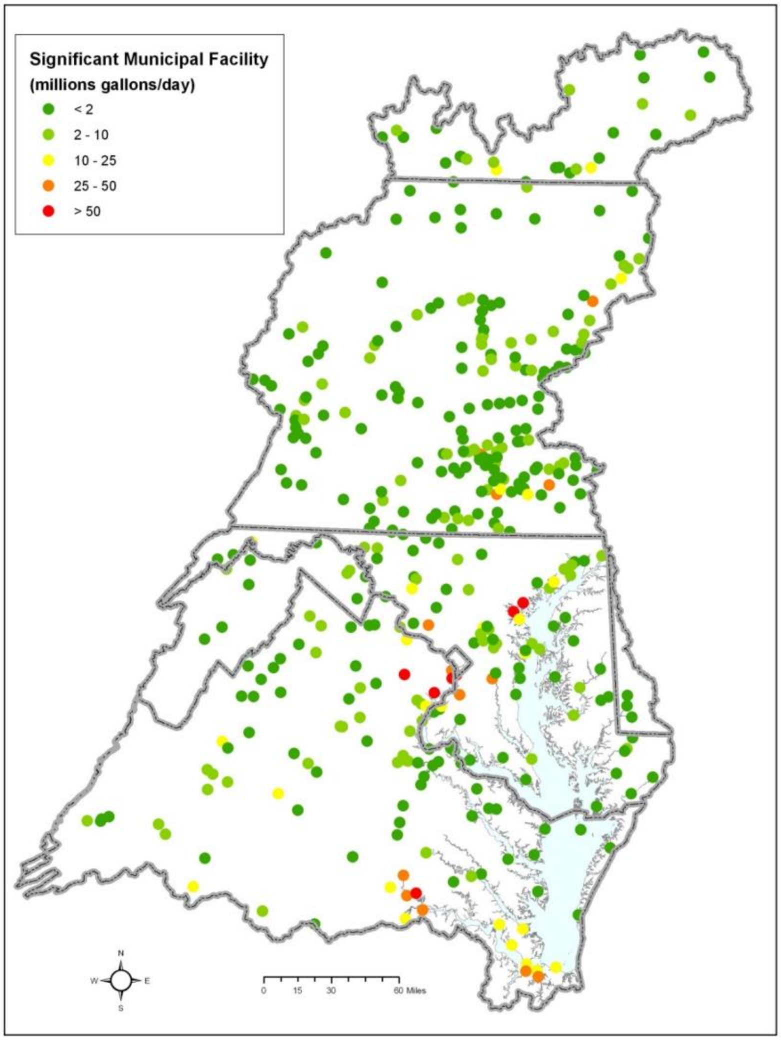
- In West Virginia, Delaware, Pennsylvania and New York - Facility treating domestic wastewater and the design flow is greater than or equal to 0.4 million gallons per day (MGD).
- In Maryland - Facility treating domestic wastewater and the design flow is greater than or equal to 0.5 MGD.
- In Virginia - Facility treating domestic wastewater and the existing design flow is greater than or equal to 0.5 MGD west of the fall line or 0.1 MGD east of the fall line.
- In the District of Columbia – Blue Plains is the only significant facility located in the District.
- Industrial facilities with a nutrient load equivalent to 3,800 total phosphorus (TP) lbs/year or 27,000 total nitrogen (TN) lbs/year.
- Any other municipal and industrial wastewater facilities assigned with individual waste load allocations within a jurisdictional Watershed Implementation Plan.

The definition of the significant facility listed above is described in the Chesapeake Bay Program Wastewater Facility and BMP Implementation Data Submission Specifications and Requirements, which is an attachment of the U.S. Environmental Protection Agency Chesapeake Bay Program Grant and Cooperative Agreement Guidance (https://www.epa.gov/restoration-chesapeake-bay/chesapeake-bay-program-grant-guidance).

Table 8-2 summarizes the number of current, active significant facilities in each jurisdiction. There are 468 significant facilities reported in the database.

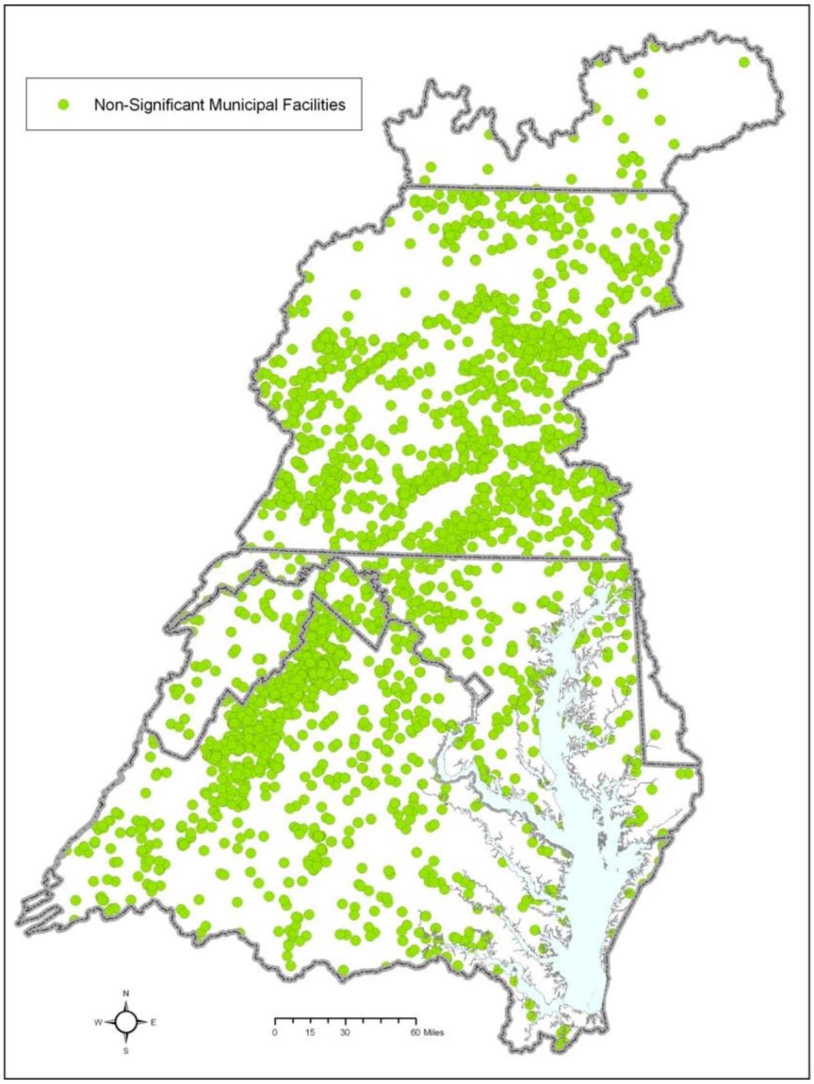
Table 8-2. Significant Wastewater Plants in the Chesapeake Bay Watershed (as of May 2017)JURISDICTION	NUMBER OF SIGNIFICANT FACILITIES		
	MUNICIPAL	INDUSTRIAL	TOTAL
DC	1	0	1
DE	3	1	4
MD	76	9	85
NY	26	4	30
PA	188	23	211
VA	94	22	116
WV	13	8	21
Total	401	67	468

Note: Blue Plains wastewater treatment plant serves DC and portions of Maryland and Virginia, but is counted only once in this table as a DC plant.



Source: Phase 5.3 Chesapeake Bay Watershed Model 2009 Scenario (to be updated)

Figure 8-7. Significant municipal wastewater treatment facilities in the Chesapeake Bay watershed.



Source: Phase 5.3 Chesapeake Bay Watershed Model 2009 Scenario (to be updated)

Figure 8-8. Nonsignificant municipal wastewater treatment facilities in the Chesapeake Bay watershed.

Table 8-23 summarizes the number of current, active non-significant facilities in each jurisdiction. There are 5,729 non-significant facilities reported in the database.

Table 8-3. Non-significant Wastewater Plants in the Chesapeake Bay Watershed (as of May 2017)

JURISDICTION	NUMBER OF NSF FACILITIES		
	MUNICIPAL	INDUSTRIAL	TOTAL
DC	1	6	7
DE	0	1	1
MD	119	1,074	1,193
NY	101	76	177
PA	1,545	365	1,910
VA	1,634	653	2,287
WV	134	20	154
Total	3,534	2,195	5,729

The model calibration included not only currently active facilities, but also any plants that are currently closed, but operated during the model calibration time period: 1984-2015. There were 61 significant and 1,152 nonsignificant facilities counted as off-lined facilities in the database and included with their historical loading data or estimates in the model calibration.

In addition to pollutant and flow parameters, listed in Table 8-1, descriptive information about each facility including information such as facility name, National Pollutant Discharge Elimination System (NPDES) permit number, location (county, state, river segment, latitude and longitude), and facility type (industrial or municipal) are tabulated in the following spreadsheet https://archive.chesapeakebay.net/VT/Phase_6_Calibration_Data_Review/ P6_Seg_Cell_WWTP_Latlo ngs_CAST.xlsx

Table 8-4, and Table 8-5 summarize Phase 6 Model wastewater flow and nutrient loading estimates by jurisdiction and major river basin, respectively. Modeled sediment loads for those facilities are not presented because wastewater discharging facilities represent a *de minimis* source of sediment (i.e., less than 0.5 percent of the 2009 total sediment load).

Table 8-4. Model estimated 2016 wastewater loads by jurisdiction delivered to Chesapeake BaySTATE	Flow (mgd)	Edge of Stream Load		Delivered Load	
		TN (lbs/yr)	TP (lbs/yr)	TN (lbs/yr)	TP (lbs/yr)
DC	116	1,130,234	36,921	1,130,234	36,917
DE	2	39,009	5,552	39,009	5,552
MD	6,259	12,479,344	630,600	11,664,669	558,612
NY	76	3,457,483	239,409	1,607,166	91,527
PA	4,327	11,433,550	1,340,513	6,969,870	539,729
VA	6,613	16,322,883	1,264,312	13,412,467	1,097,928
WV	64	775,447	87,986	261,129	40,753

Source: Phase 5.3 Chesapeake Bay Watershed Model 2016 Progress

Table 8-5. Model estimated 2016 wastewater loads by major river basin delivered to Chesapeake BaySTATE		Edge of Stream Load		Delivered Load	
	Flow (mgd)	TN (lbs/yr)	TP (lbs/yr)	TN (lbs/yr)	TP (lbs/yr)
JAMES RIVER	2,566	11,173,482	885,450	10,213,251	818,704
MD EASTERN SHORE	45	523,135	43,837	506,142	42,462
MD WESTERN SHORE	3,978	8,997,310	375,689	8,803,514	372,573
PATUXENT RIVER	688	513,442	53,176	431,039	46,464
POTOMAC RIVER	2,200	8,641,244	563,795	5,489,847	333,634
RAPPAHANNOCK RIVER	31	513,033	51,955	406,303	45,680
SUSQUEHANNA RIVER	4,384	14,289,784	1,503,363	8,400,964	596,161
VA EASTERN SHORE	4	70,406	5,833	70,406	5,833
YORK RIVER	3,568	962,957	126,897	799,978	113,565

Source: Phase 5.3 Chesapeake Bay Watershed Model 2016 Progress

8.4.4 Data Sources

The sources of wastewater information for previous watershed models include the following:

- EPA's Permit Compliance System (PCS), based on state NPDES Discharge Monitoring Reports (DMRs)
- Data files from Pennsylvania Department of Environmental Protection including a 1994 sampling study data and the Pennsylvania Voluntary Monitoring data since 1998
- Data files from the Virginia Department of Environmental Quality based on PCS, DMRs, and the Virginia Voluntary Nutrient Monitoring Program
- Data files from the Metropolitan Washington Council of Governments (MWCOG)
- The final tributary strategies from Pennsylvania, Maryland, DC, and Virginia
- Data from the Maryland Department of the Environment
- Data from Delaware Department of Natural Resources and Environmental Control
- Data from West Virginia Department of Environmental Protection
- Data from New York Department of Environmental Conservation

Data source information is documented in USEPA (1998, 2000). Because of a lack of data format consistency among the data received from the jurisdictions and PCS, extensive data compiling was required.

During the phase 6 model input development, all Bay jurisdictions agreed to and participated in the historical data clean-up effort. The phase 6 model wastewater database was developed from the contributions from all Bay jurisdictions.

8.4.5 Current Wastewater Data Reporting Requirements

As described in the *Data Submission Specifications and Requirements*, an attachment of the CBP grant guidance(https://www.epa.gov/sites/production/files/2016-01/documents/attachment6pointnonpointsourcedata.pdf), jurisdictions are required to submit monthly concentration and flow data for all parameters listed below for significant discharges.

1. At Facility Level: Data must be provided for those municipal, industrial, and federal facilities as defined above as *significant dischargers* of TN and TP to the Chesapeake Bay watershed. The jurisdictions must annually update their list of significant dischargers with additional facilities that meet one of the criteria of the significant facility definition. The location (county, latitude/longitude) of each facility's *discharge* point must be reported.

2. At the Monthly Level: *12 individual months* of concentration and flow data for the nine identified parameters must be provided for each outfall. Jurisdictions must submit all parameters in each month's data record for each facility. They must submit data for the following parameters: average monthly flows and average monthly concentrations of NH_3, TKN, NO_2+NO_3, TN, PO_4, TP, BOD_5 ($CBOD_5$ is preferred), and DO. All nitrogen species must be reported as nitrogen; all phosphorus species must be reported as phosphorus.

If no monthly monitored concentration data exist for one or more of the nine parameters for a facility, the jurisdiction submits the default concentration data or calculated data on the basis the species relationship listed in Table 8-6. All default or calculated data are flagged with explanatory information. Industrial facility data are reported as average monthly flow and concentrations. A flow diagram of the wastewater nutrient data processing is shown in Figure 8-.

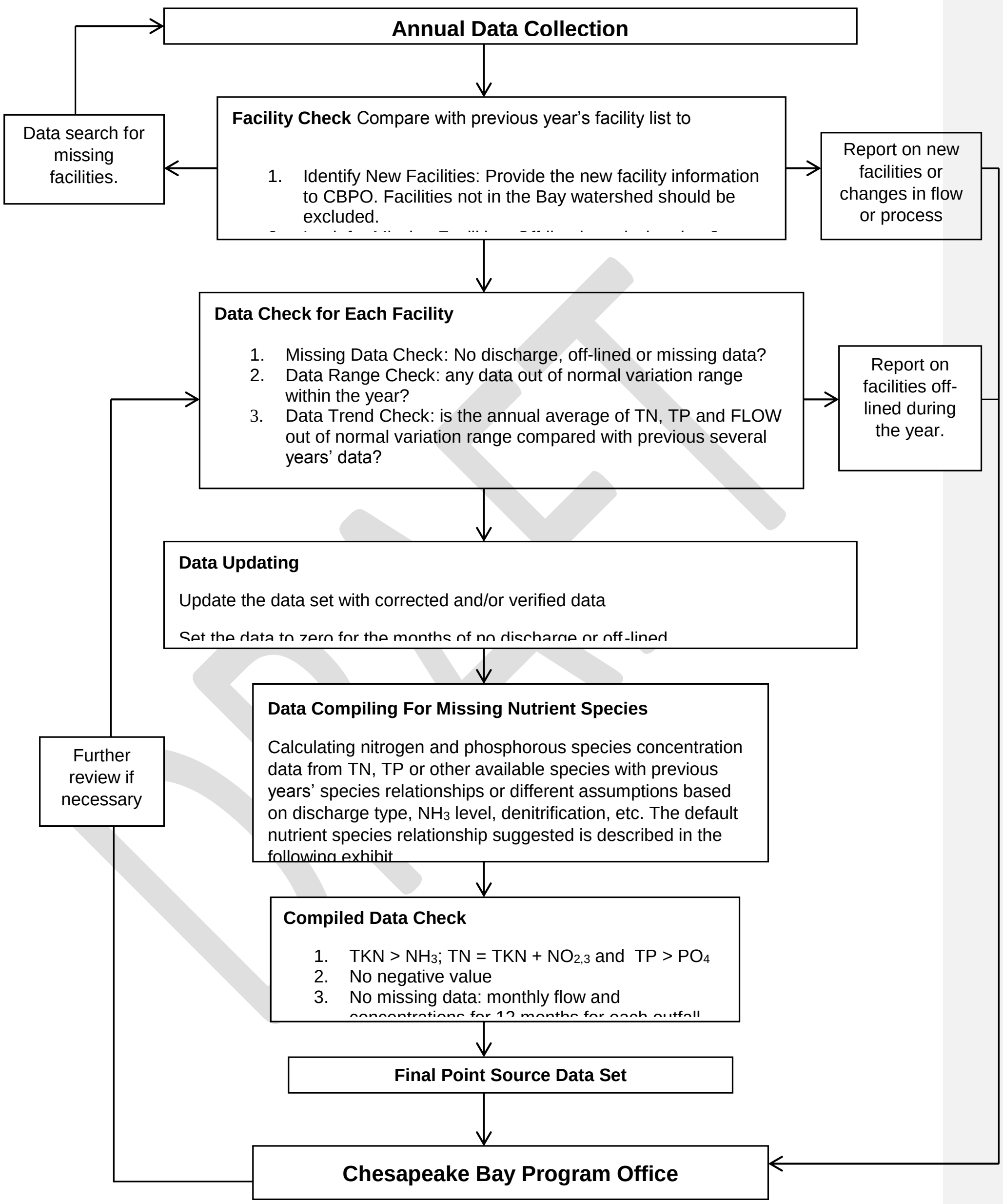


Figure 8-9 Wastewater nutrient data processing flow diagram.

8.4.6 Nutrient Species Defaults

The nutrient species calculation must be done for any data record for which nutrient species data were insufficient or missing (Table 8-6).

Table 8-6. Nutrient species default relationships for wastewater data

Type of wastewater		$NH_3/NO_{2,3}$/OrgN[a] (w/o nitrification)	$NH_3/NO_{2,3}$/OrgN (w/ nitrification)[c]	$NH_3/NO_{2,3}$/OrgN (w/ denitrification)
Municipalities		80/3/17[b]	7/80/13[b]	12/73/15
Industries	Chemical	7/85/8+		
	Pulp & Paper	1/0/99[b]		
	Poultry Facilities w/ BNR			8/75/17[b]
	Nonchemical (includes seafood, poultry, & food processors w/out BNR)[e]	80/3/17[b]	7/85/8[d]	8/75/17[b]

a. Organic nitrogen

b. Updated on the basis of an analysis of actual data from plants operating in Virginia.

c. Apply this relationship wherever NH_3 limits apply.

d. Assumed by performing an analysis of Maryland chemical industry wastewater effluents, which showed it is very close to the relationship for nitrifying sewage. This would apply to all chemical discharges and assumes that wastewaters are treated chemically and, thus, would not vary as for sewage relationships.

e. Biological nutrient removal

Type of wastewater	Facilities w/out TP reduction (PO_4/TOP ratio)	Facilities with TP reduction (PO_4/TOP ratio)
All	71/29[e]	67/33[e]

e. Determined by averaging the actual data from MD and VA plants (including Blue Plains for *with TP Reduction*. A facility with TP reduction is defined as a facility having a permit limit for TP.

Period	TSS default (all jurisdictions)	TSS default w/out NRT*	TSS default w/ NRT*
1985–1990[f]	45		
1990–2000	25		
2000–2010		15	8

* Nutrient reduction technology.

Type of wastewater	DO concentration 1985–1990	DO concentration 1990–2010
All	4.5 mg/l[f]	5.0 mg/l

f. The TSS and DO default numbers take into account a number of Nutrient Management Plan (NMP) facilities operating across the watershed from 1985-1990. In the early years of CBP nutrient reduction the state NMPs for POTWs focused primarily on phosphorus reductions.

8.4.7 Wastewater Nutrient Load Calculation

The following equation was applied by the Chesapeake Bay Program Office when using concentrations and flow to calculate monthly average daily loads:

Load (lbs/day) = Concentration (mg/l) x Flow(MGD) x Constant (8.344)

The annual loads were calculated by summing the monthly loads in the year:

Load (lb/yr) = SUM(Load (lbs/day) x Days in the month)

The constant 8.344 is a conversion factor used by the Chesapeake Bay Program Office, which converts millions gallons per day (MGD) and mg/l into loads in pounds (lbs). There are different values of this conversion factor that have been used in other places.

Year round (365 days) operation of wastewater dischargers was assumed for the load calculation unless otherwise specified.

8.4.8 Mead Westvaco Industrial Facility in Covington Virginia

A consistent under simulation of phosphorus load in James River in an early Beta version of Phase 6 model prompted a careful examination of model performance and input datasets. It was found that the under simulation for most part limited to the early decade in the model calibration period of years 1985 to 2014. Furthermore, the under simulation of phosphorus concentration in James river were traced back to the Jackson River monitoring station below Dunlop Creek in Covington Virginia (Figure 8-10).

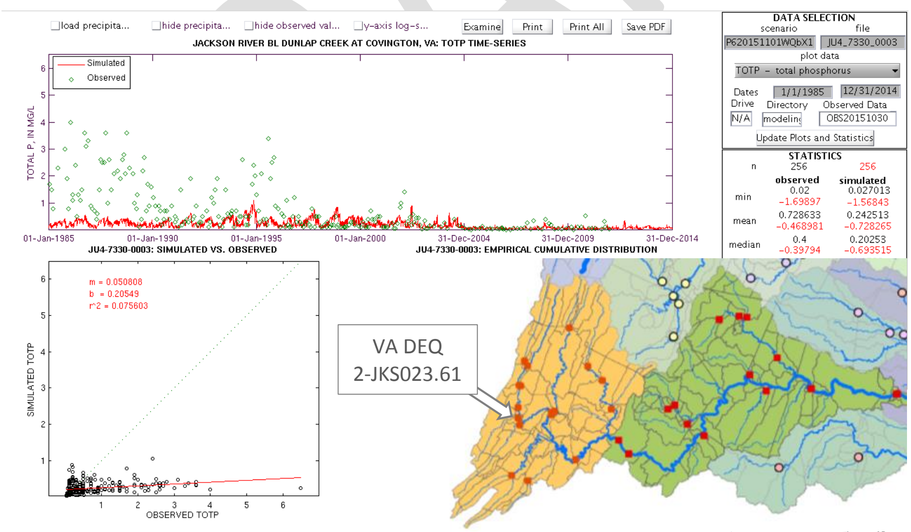


Figure 8-10: A comparison of simulated (an early Phase 6 beta) and observed phosphorus concentration at Jackson River below Dunlap Creek in Covington, VA. Monitoring data show high phosphorus concentration levels reported in 1980s and 1990s.

The close investigation of the geographic setting along with the monitoring data provided a strong and compelling evidence for the linkage between the high levels of phosphorus concentrations in the river and the wastewater discharge from the Mead Westvaco industrial facility. The wastewater input dataset for the facility revealed that an estimate of phosphorus discharge from the facility were not available until 1996. And for that reason, a phosphorus concentration of 3.5 mg/l was assumed to remedy missing data over the period of 1984 to 1996 in the Phase 5 Watershed model (Figure 8-).

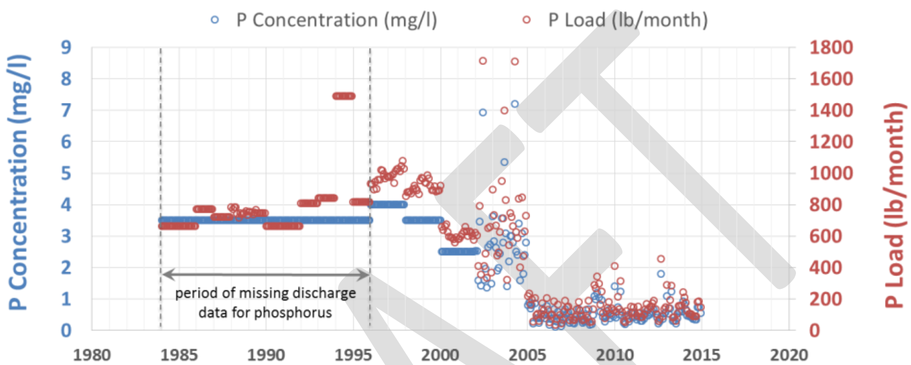


Figure 8-11: Reported discharge of phosphorus from Mead Westvaco industrial wastewater facility. Phosphorus discharge were not reported for the period 1984 to 1996, and 3.5 mg/l concentration was assumed.

USGS WRTDS (Hirsch et al., 2010; Hirsch and Di Cicco, 2014) was used for revising the assumptions made for removing missing phosphorus discharge records for the facility. The WRTDS uses monitoring information for concentrations and flow for estimating loads through multivariate regression. Estimates of load using WRTDS will provide an improved estimates of loads that will be consistent with the monitoring information. Monitoring data of daily flow and phosphorus concentrations for the monitoring station 2-JKS023.61 were used as input for WRTDS. Figure 8-(a) shows that estimate of daily phosphorus concentration from WRTDS matched well with the monitoring samples. Furthermore, estimates of phosphorus loads for the period 1984 to 1996 from WRDTS, as shown in Figure 8-(b), were used to revise the prior assumptions that were used in filling the missing data.

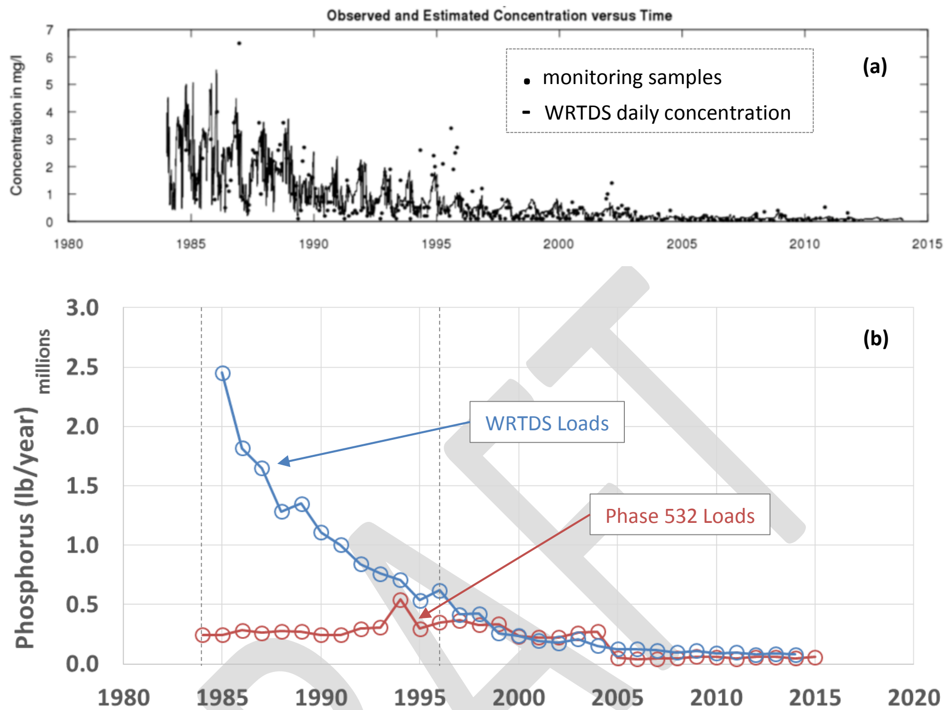


Figure 8-12: (a) Comparison of monitored and WRTDS estimated daily phosphorus concentration. (b) Comparison of annual phosphorus loads for the Mean Westvaco facility used input Phase 532 model with the estimated using WRTDS. Inputs loads for the 1984 to 1996 were revised using WRTDS.

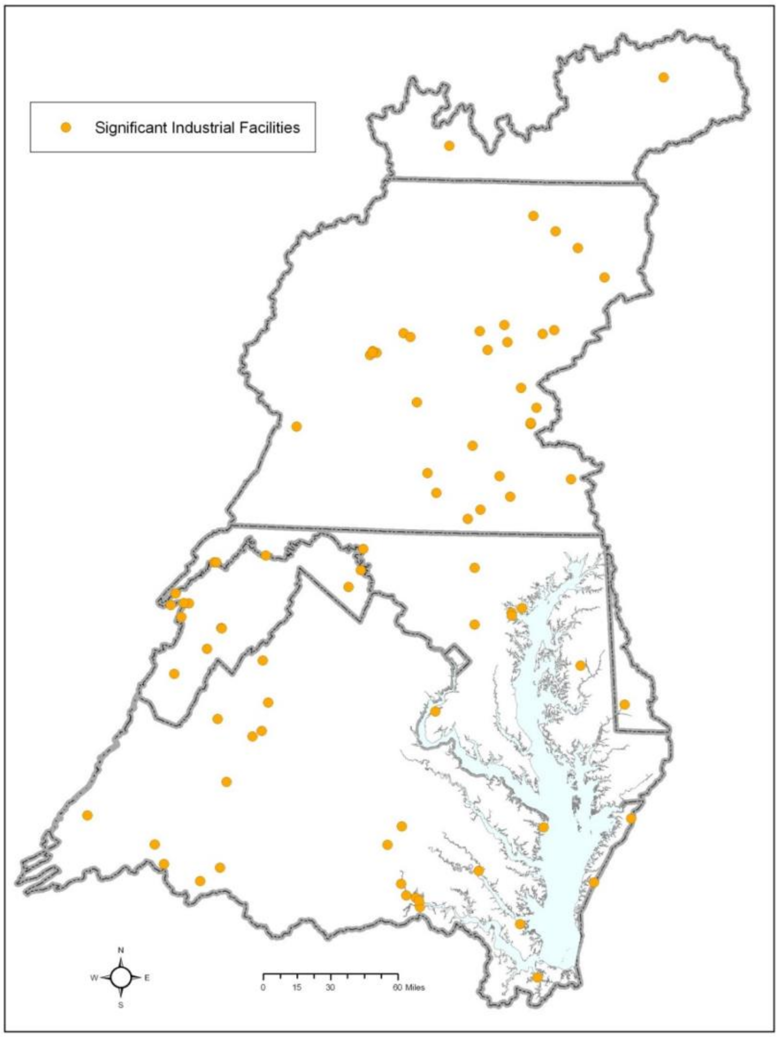
Email from VA DEQ 6/22/16

"WestRock was adding Phosphorus to their wastewater process in excess thinking it helped them treat the wastewater, They conducted a study and determined they did not need to do that anymore in the timeframe when you indicated they reduced the load they discharge. They also did some process modifications at the carbon plant to recycle/capture spent phosphoric acid that they wasted to the wastewater plant. At the same time our TMDL group developed a "local" TMDL for nutrients in the Jackson river that spurred further reductions at POTWs and WestRock. I would have to do some research on the timing of each step or phase of reductions but I think it coincides with the timing you mention. "

8.4.9 Industrial Sources

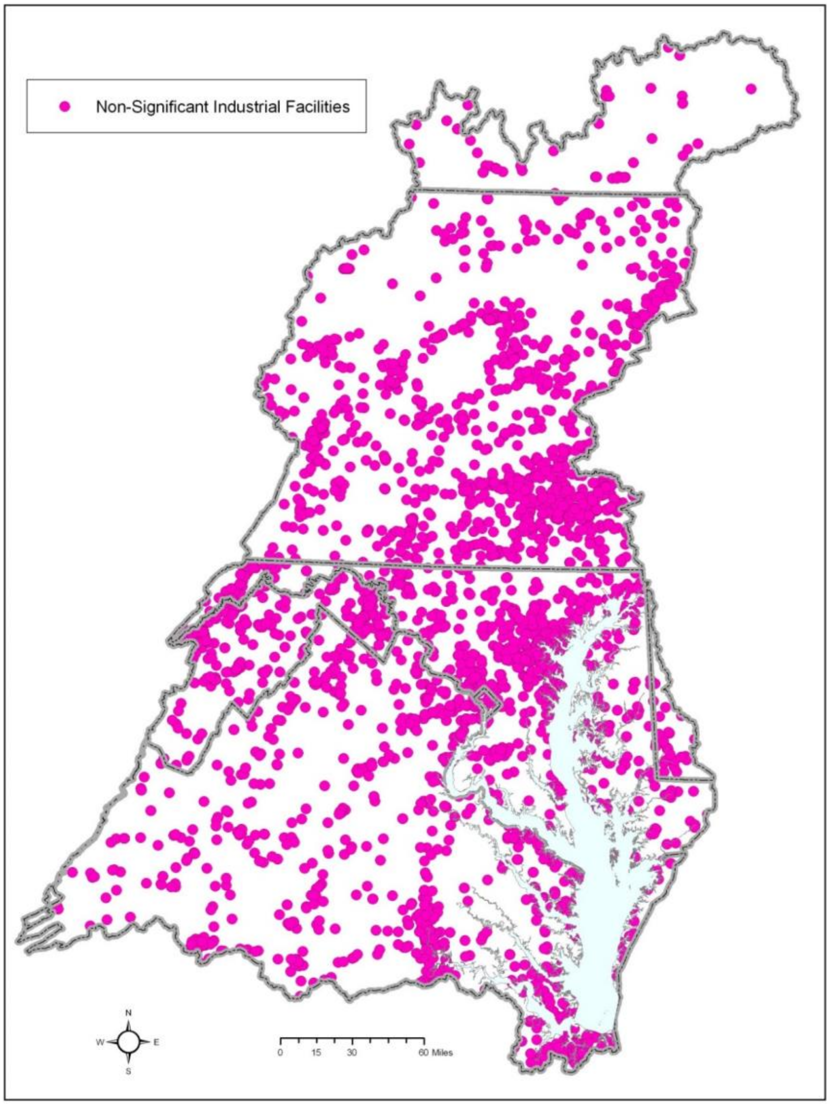
Some wastewater industrial dischargers use river uptake as the only water source. As the facility both withdraws and discharges water in the same model segment, no flow discharge is assumed to come from these industrial facilities, only loads. Other industrial wastewater dischargers use city or well water, or a percentage of city or well water that makes up the total flow discharged. In such cases, the portion of the effluent from the city or well water source is included as a flow contribution to the river segment Other industrial plants not in the survey list were assumed to use 100 percent city or well water.

Industrial discharge facilities are facilities discharging process water, cooling water, and other contaminated waters from industrial or commercial sources. (Table 8-7). EPA identified 2,262 currently active facilities discharging industrial wastewaters in the Chesapeake Bay watershed, with 67 significant facilities (Figure 7-2) and 2,195 non-significant ones (Figure 7-3).



Source: Phase 5.3 Chesapeake Bay Watershed Model 2009 Scenario

Figure 8-13. Significant industrial wastewater discharge facilities in the Chesapeake Bay watershed.



Source: Phase 5.3 Chesapeake Bay Watershed Model 2009 Scenario.

Figure 8-14. Nonsignificant industrial wastewater discharge facilities in the Chesapeake Bay watershed.

Table 8-7. Sources of industrial water withdrawal based on survey results (to be updated)

State	Facility	NPDES	2003 Flow (mgd)	Water source distribution: River water (%)	Water source distribution: City or well water (%)
DE	Invista (Dupont-Seaford)	DE0000035	30.73	99.95	0.05
MD	ISG Sparrows Point (Bethlehem Steel)	MD0001201	49.08		100
MD	Upper Potomac River Commission	MD0021687	20.47	100	0
MD	W R Grace	MD0000311	3.73		100
MD	Westvaco Corporation-Luke	MD0001422	1.54	100	0
NY	Pollio Dairy	NY0004308	0.86		100
NY	South Otselic State Fish Hatch	NY0244431	0.89		100
PA	Appleton Paper Springmill	PA0008265	4.39		100
PA	Empire Kosher Poultry-Mifflint	PA0007552	0.94		100
PA	Merck & Company	PA0008419	12.83		100
PA	Osram Sylvania Products, Inc.	PA0009024	0.83		100
PA	PA Fish & Boat Commission-Bellefonte	PA0040835	6.40		100
PA	PA Fish & Boat Commission-Benner Springs	PA0010553	6.00		100
PA	PA Fish & Boat Commission-Pleasant Gap	PA0010561	4.87		100
PA	PA Fish & Boat Commission-Typlersville	PA0112127	13.00		100
PA	P-H Glatfelter Company	PA0008869	12.00		100
PA	Pope & Talbot Wis Inc.	PA0007919	1.57		100
PA	Proctor & Gamble Paper Products	PA0008885	7.44		100
PA	USFW-Lamar National Fish Hatchery	PA0009857	4.40		100
VA	Brown & Williamson	VA0002780	0.83		100
VA	Coors Shenandoah Brewery	VA0073245	0.79		100
VA	Dupont-Spruance	VA0004669	23.96	100	0
VA	Dupont-Waynesboro	VA0002160	3.27		100
VA	George's Chicken Inc	VA0077402	1.27		100
VA	Georgia Pacific Corporation	VA0003026	6.25	100	0
VA	Giant Refinery-Yorktown	VA0003018	52.38		100
VA	Greif Bros Corp-Riverville	VA0006408	5.03	100	0
VA	Honeywell	VA0005291	117.64	95	5
VA	Merck -Stonewall Plant-Elkton	VA0002178	7.84		100
VA	Omega Protein Inc	VA0003867	2.55	100	0
VA	Phillip Morris-Park 500	VA0026557	2.14		100
VA	Pilgrim's Pride-Hinton	VA0002313	0.91		100

				Water source distribution	
State	**Facility**	**NPDES**	**2003 Flow (mgd)**	**River water (%)**	**City or well water (%)**
VA	Smurfit Stone	VA0003115	18.61		100
VA	Tyson Foods, Inc.	VA0004031	0.97		100
VA	Tyson Foods, Inc.-Temperanceville	VA0004049	1.06		100
VA	Westvaco Corporation-Covington Hall	VA0003646	30.41	100	0
WV	Pilgrim's Pride	WV0005495	1.59		100
WV	Virginia Electric & Power	WV0005525	9.16	100	0

Net load was assumed by EPA CBPO for all the industrial effluent data reported/submitted. However, there was no consistency basin-wide either in where it was applied or the methodology used for net load calculation. For the Phase 6 watershed model calibration, in order to distribute loads to the proper sources, net discharges of nutrients from industrial facilities should be used by all jurisdictions under the following conditions: 1) intake and discharge are the same water body; and 2) flow and nutrient concentrations are known for intake and effluent (i.e. measured for a long enough period of time to establish daily/monthly/seasonal trend). It was recommended by the CBP Wastewater Workgroup that net discharge concentrations should be reported for all industrial facilities meeting the criteria.

One major change in historical data for

8.4.10 Wastewater Data Changes between phase 5.3.2 and phase 6 model.

The wastewater data collection for the Phase 6 model calibration was a result of collectively effort on historical data clean-up by the Chesapeake Bay Program Wastewater Treatment Workgroup. The data clean-up effort mainly includes:

1) Corrections to know data errors in the historical dataset
2) Updating the default values based on the latest information
3) Adding or generating the historical data for newly added facilities
4) Updating and correcting the starting and off-line dates for facilities, especially for nonsignificant plants added to the database in recent years.
5) Removing facilities that are not wastewater dischargers.

Many jurisdictions submitted entire new datasets for the 30 years or corrections to partial data, and some states provided instructions and the CBP wastewater data manager modified and/or generated new data according to the state instructions. The Bay jurisdictions, represented by the Wastewater Treatment Workgroup, have reviewed and approved of this database update. All the changes and updates from the Bay jurisdictions have been included in the updated database for phase 6 model and resulted in overall improvement in model performance.

Table 8-8 summarized the changes in number facilities included in model calibration between phase 5.3.2 and phase 6.

Table 8-8: Total numbers of facilities (both active and inactive) during 1984-2015

STATE	TYPE	SIG/INSIG	Phase 5	Phase 6	Difference
DC	MUNICIPAL	Significant	1	1	0
	INDUSTRIAL	Non-significant	9	9	0
DE	MUNICIPAL	Significant	3	3	0
		Non-significant	1	1	0
	INDUSTRIAL	Significant	1	1	0
		Non-significant	5	5	0
MD	MUNICIPAL	Significant	87	87	0
		Non-significant	245	245	0
	INDUSTRIAL	Significant	11	11	0
		Non-significant	1,071	1,575	504
NY	MUNICIPAL	Significant	26	26	0
		Non-significant	107	105	-2
	INDUSTRIAL	Significant	4	4	0
		Non-significant	86	86	0
PA	MUNICIPAL	Significant	197	197	0
		Non-significant	1,643	1,710	67
	INDUSTRIAL	Significant	25	25	0
		Non-significant	395	358	-37
VA	MUNICIPAL	Significant	114	114	0
		Non-significant	1,654	1,654	0
	INDUSTRIAL	Significant	31	31	0
		Non-significant	655	654	-1
WV	MUNICIPAL	Significant	16	16	0
		Non-significant	154	154	0
	INDUSTRIAL	Significant	8	8	0
		Non-significant	123	112	-11

The results of the all changes are reflected in the loading number differences throughout the calibration time period between phase 5 and phase 6 wastewater databases as displayed in Table 8-9.

Table 8-9: % Difference in Bay wide wastewater loads between phase 5 and 6 databases

Year	TN Load	TP Load	TSS Load
1984	-0.69%	18.76%	-7.16%
1985	-0.80%	16.55%	-8.11%
1986	-0.72%	13.95%	-7.86%
1987	-0.81%	9.94%	-7.90%
1988	-0.64%	10.02%	-7.62%

1989	-0.17%	7.85%	-7.82%
1990	-0.11%	9.30%	-8.72%
1991	-0.05%	7.10%	-8.86%
1992	0.30%	6.34%	-8.49%
1993	0.17%	4.26%	-8.67%
1994	0.01%	0.30%	-8.15%
1995	-0.70%	1.79%	-8.53%
1996	-0.78%	-0.65%	-7.82%
1997	-0.96%	0.12%	-8.83%
1998	-1.25%	-3.51%	-9.19%
1999	-1.15%	-0.52%	-10.81%
2000	-1.25%	-3.07%	-12.03%
2001	-1.33%	-4.20%	-12.68%
2002	-1.46%	-4.86%	-11.98%
2003	-0.96%	-5.73%	-10.71%
2004	-1.08%	-6.16%	-9.29%
2005	-0.70%	-6.17%	-9.72%
2006	0.92%	-5.72%	-9.84%
2007	-1.52%	-7.00%	-10.30%
2008	-0.83%	-5.77%	-7.96%
2009	-0.88%	-6.32%	-6.52%
2010	-0.62%	-7.68%	-6.86%
2011	-0.08%	-3.32%	-9.75%
2012	0.17%	3.40%	-11.57%
2013	-1.26%	0.49%	-11.99%
2014	-0.96%	1.53%	-12.66%
2015	31.60%	44.72%	17.21%

The phase 5 dataset included the data up to the 2015 progress that contained only half of 2015 for many jurisdictions; but, the phase 6 database was updated with the 2016 progress, which completed the 2015 data for all jurisdictions and caused the significant difference for 2015 in Table 8-9. The following two charts: Figure 8-15 and Figure 8-16 present these changes over the calibration time period.

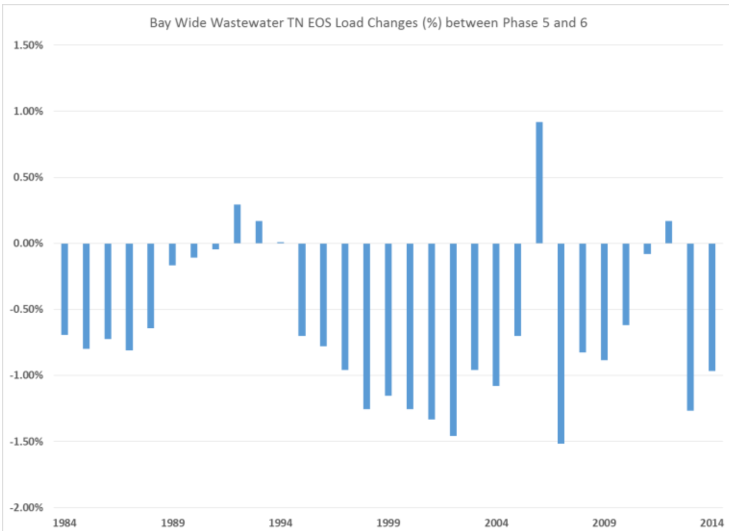


Figure 8-15. Bay wide wastewater TN EOS load changes between the phase 5 and phase 6 databases.

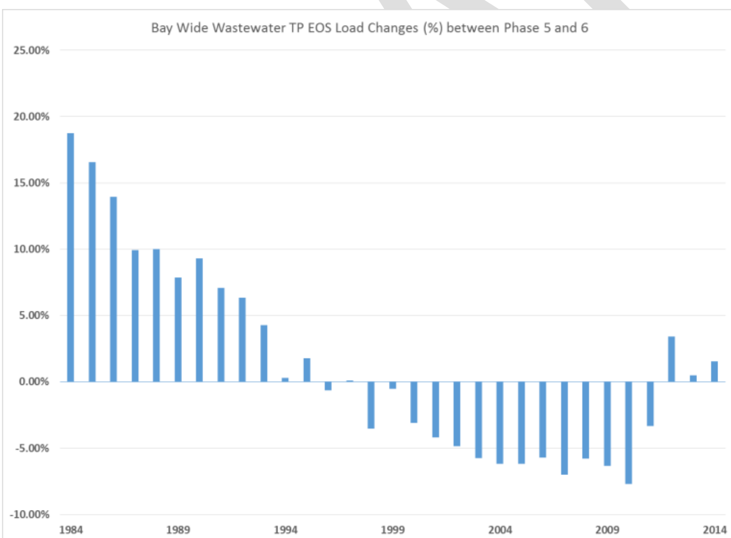
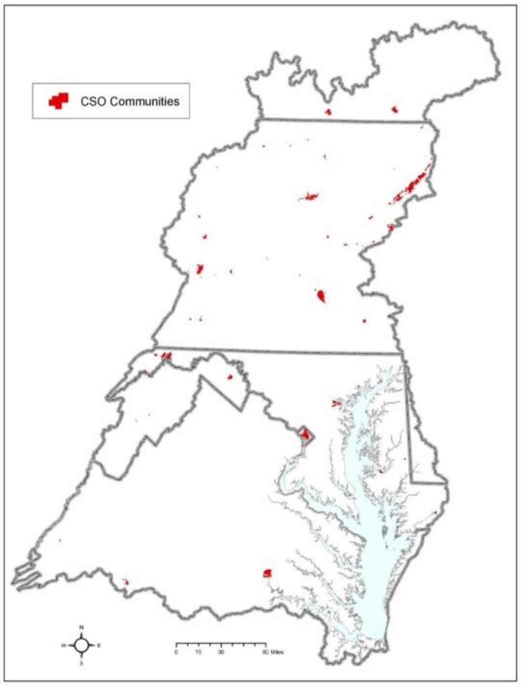


Figure 8-16. Bay wide wastewater TP EOS load changes between the phase 5 and phase 6 databases.

8.5 Combined Sewer Overflows

Combined sewer systems are sewage collections systems that also carry stormwater runoff. In dry weather and during small rainfall events, all flow is routed to a waste water treatment plant. In wet weather, the amount of water in the system is too great for the treatment plant to handle and a large portion of the combined sewage and stormwater is routed directly to a receiving water. This event is known as a combined sewer overflow (CSO). The Chesapeake watershed has 64 communities with combined sewer systems.



Initial work in this area was performed by TetraTech for the Phase 5 CBWM. This work is preserved in Phase 6 and automated by CBPO staff for scenarios and extensions of the simulation period.

For four of the largest CSO communities in the watershed — Alexandria, Lynchburg Richmond, Virginia; and the District of Columbia — The CBP relied heavily on readily available and relatively detailed Long-Term Control Plans (LTCPs) to characterize overflows. In addition, TetraTech ran simulations of existing sewer models for those communities to support developing overflow and water quality estimates. TetraTech used the District of Columbia's combined sewer system (CSS) model to develop loading estimates for the CSOs. For the Alexandria, Richmond, and Lynchburg CSSs, various versions of EPA's Storm Water Management Model (SWMM) were used to estimate overflows. CSO discharge monitoring data were available for the Alexandria and Richmond CSOs, but no samples were available from Lynchburg because the LTCP calls for complete separation of the storm sewers from sanitary sewers.

Figure 8-2. CSO communities in the Chesapeake Bay watershed.

Information related to loading from the other 60 CSO communities in the watershed includes spatial data collected as a result of a direct survey of the communities to support the TMDL, limited water quality and overflow data from some of the CSO communities in the watershed, and representative water quality concentrations available in the literature. Overflow volume and pollutant loading from CSO communities are heavily dependent on the service area or catchment area of the combined system. Service area data obtained from the communities were used to calculate the loading from each community during high-flow events. Precipitation data observations were also obtained from weather monitoring stations proximate to each community to derive runoff volumes. Overflows and associated pollutant loads from CSO communities were then developed using various sources of water quality data including monitoring data and literature values.

For the full list of CSO communities, see Table 8-18.

8.5.1 District of Columbia CSOs

Data provided by the District of Columbia Department of the Environment was used for CSO flows and concentrations in the District of Columbia. Combined sewer overflow estimates were determined by simulating the combined sewer system (CSS) model developed by the District of Columbia Water and Sewer Authority (DCWASA) for the development of the Long Term Control Plan (LTCP) for DC CSOs (DCWASA 2002).

DCWASA maintains a MIKE URBAN H&H model to simulate its collection system. The model used the MOUSE hydrologic and hydraulic model engines to estimate overflows from CSO outfalls. For 1991–2005, CSO flows were based on model simulation of individual rainfall events. The model was not simulated for the period 1985–1990. The 1993 model-simulated flows, which represented an average condition, were repeated for that period. Average concentrations were derived from the average EMC (event mean concentration) for CSO overflows taken from monitoring data collected for the LTCP. Those values are shown in Table 8-7. Figure 8-3 presents the time series TN and TP loads for DC CSOs.

Table 8-7. CSO water quality constituent EMCs developed by DCWASA (2002)

	EMCs (mg/L)					
Water quality constituent	**CSO 10**	**CSO 021**	**CSO 12**	**CSO 19 (location 1)**	**CSO 19 (location 2)**	**Outfall 001 (CSO bypass)**
TKN	6	3.8	4	4	2.4	17
NH_3-N	2.9	0.96	0.66	0.69	0.46	8.7
NO_3+NO_2-N	0.6	0.85	0.81	0.79	0.78	0.7
TP	1.31	1	0.98	0.85	0.83	2.4
DIP (PO_4)	0.37	1.04	0.11	0.23	0.15	0.8
TSS	147	130	186	96	182	130.1

Note: CSO 19 was monitored at two locations.

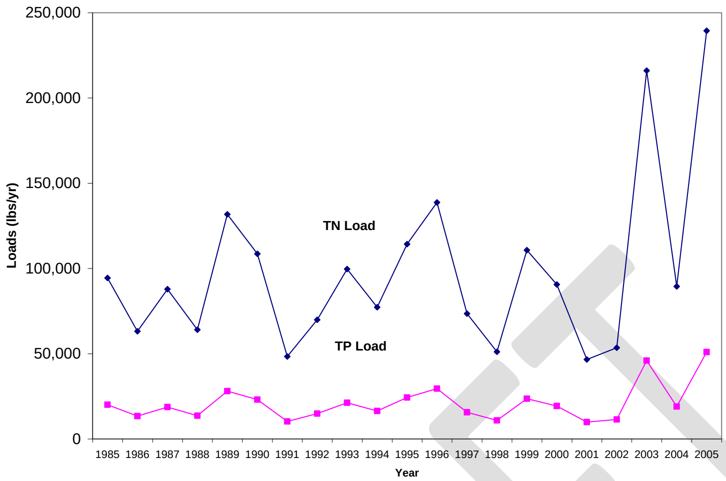


Figure 8-3. District of Columbia CSO loads for 1985–2005.

8.5.2 Alexandria, Lynchburg, and Richmond, Virginia

The Virginia communities of Alexandria, Richmond, and Lynchburg. All three communities estimate CSO overflows using EPA's SWMM system. Alexandria and Richmond use the built-in RUNOFF module for hydrologic modeling on the basis of detailed service area information, and the TRANSPORT module for hydraulic modeling. The overflows calculated by SWMM for Alexandria and Richmond were directly used in the Phase 5.3 Model and area directly carried over to Phase 6.

The SWMM model developed for Lynchburg is circa 1989 (updated in 1995, 1998, 2000, and 2002) and it does not explicitly model real-time rainfall and hydrology. Instead, the model is used to regress current rainfall events with a range of calibrated events with known overflows. The Lynchburg overflow estimates were supplemented with data from a linear regression of rainfall to overflow volume, because that model is not a continuous simulation.

CSO discharge water has been monitored in the Alexandria and Richmond CSOs, but no samples are available from Lynchburg because the Long Term Control Plan (LTCP) calls for complete separation of the system. Table 8-8 summarizes the CSO EMCs for the baseline, pre-LTCP condition from 1985 to 2005. They were derived from site-specific EMCs, regulatory considerations (i.e., tributary strategy), and application of recommended EMCs (or constituent fractions) to fill data gaps.

Table 8-8. CSO water quality constituent EMC summary for Alexandria, Richmond, and Lynchburg, Virginia

	Water quality constituent (mg/L)[a]					
Member	**TN**	**NH_3-N**	**NO_2-N + NO_3-N**	**PO_4-P**	**TP**	**TSS**

Alexandria CSO	5.88	1.53	0.79	0.16 [b]	0.78	70.5
Richmond CSOs (Virginia Tributary Strategy)	8	1.4	1.1	0.2	1	130
Lynchburg[c] (Virginia Tributary Strategy)	8	1.4	1.1	0.2	1	130

a. Total organic nutrient forms can be derived by subtracting the inorganic forms from the total nutrient concentrations.

b. The Alexandria EMC for orthophosphate-P is estimated as 20% of TP as per the recommendations for filling these types of data gaps.

c. The Lynchburg EMCs correspond to the selected Richmond EMCs and the Virginia tributary strategy.

8.5.3 All Other Combined Sewer Systems

The remaining 60 communities with Combined Sewers were assessed using an average concentration and a relationship between rainfall and overflow depth derived from the available data. Thirty-two of the 60 communities submitted data in one form or another (e.g., hard copy data, ESRI shapefiles, PDF files, JPEG files, or KML files). Twenty-eight facilities either did not respond to the request for data or did not provide any usable data. Data received from communities were digitized into ESRI shapefile format. For the 28 communities that did not provide service area information, service area data from USGS were used.

Once the CSO service areas were delineated, flow and load contributions from the areas were estimated. Rainfall data from a nearby climate station were obtained for each CSO community. To select a proximate climate station (the population of daily total rainfall stations, with a minimum percentage of completeness of data between 1985 and 2008, was used), a Thiessen polygon method was applied to assign the appropriate station to a given CSO community (Figure 8-4). Table 8-9 shows the assignment of the weather stations to the NPDES discharges.

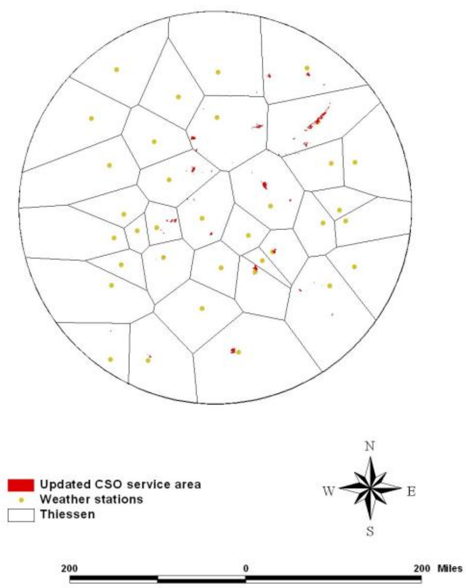


Figure 8-4. Theissen polygon method applied to daily rainfall stations.

Table 8-9. Weather stations assigned to CSO communities (by NPDES ID)

Weather stations-coop ID	NPDES ID	Weather stations-coop ID	NPDES ID
8906	DC0021199	9705	PA0026557
3570	DE0020265	9933	PA0026743
3570	MD0020249	9705	PA0026921
3570	MD0021571	0132	PA0027014
8065	MD0021598	0132	PA0027022
0465	MD0021601	8469	PA0027049
3570	MD0021636	8469	PA0027057
3570	MD0022764	9705	PA0027065
8065	MD0067384	9705	PA0027081
8065	MD0067407	9705	PA0027090
8065	MD0067423	9933	PA0027197
8065	MD0067547	9705	PA0027324
0687	NY0023981	8469	PA0028631
0687	NY0024406	0132	PA0028673
0687	NY0035742	8469	PA0036820
9705	PA0020940	4030	PA0037711
9933	PA0021237	8469	PA0038920
0132	PA0021539	0132	PA0043273
9933	PA0021571	8469	PA0046159
8469	PA0021687	0106	PA0070041
9072	PA0021814	0106	PA0070386
4030	PA0022209	9705	PAG062202
9705	PA0023248	9933	PAG063501
0106	PA0023558	5120	VA0024970
0687	PA0023736	8906	VA0025160
0687	PA0024341	7285	VA0025542
9705	PA0024406	7201	VA0063177
9705	PA0026107	6163	WV0020150
0132	PA0026191	6163	WV0021792
8469	PA0026310	4030	WV0023167
9705	PA0026361	8065	WV0024392
9705	PA0026492	8065	WV0105279

Overflow data from 8 of the 60 communities were available. The data were regressed with rainfall data from the local precipitation stations to identify the relationship between rainfall and overflows. Table 8-10 shows the coefficient of determination (R^2) for each of the community comparisons with rainfall.

Table 8-10. R^2 of the developed linear regression using rainfalls and CSO discharges for NPDES

NPDES ID	R^2
MD0067407	0.6
PA0023558	0.85
PA0022209	3.00E-06
MD0021598	0.67
PA0026361	0.56
PA0070386	0.13
PA0070041	0.03
PA0026107	0.18

The data sets with R^2 values higher than 0.5 (MD0067407, PA0023558, MD0021598, and PA0026361) were selected for further analysis. CSO discharge data from those communities were divided by the corresponding community areas (described above) to calculate unit area flows (gallon/day-acre). Once flows were derived, correlations were sought between the unit-area flows and the associated rainfall data by generating a best fit line. The best fit line is shown in Figure 8-5.

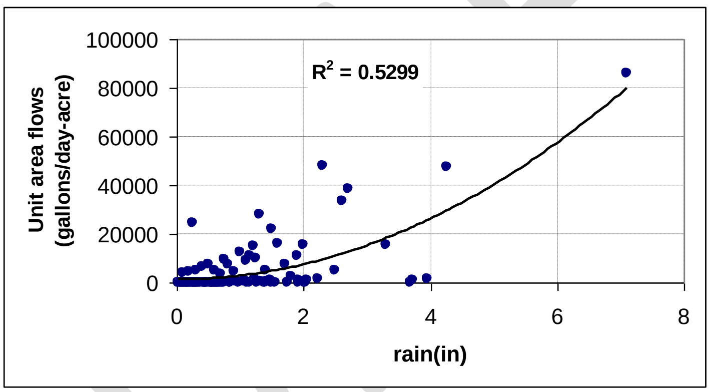


Figure 8-5. Best fit line; rainfall vs. unit area flow.

The best fit line suggests that smaller rainfall amounts produce small overflows. To address that issue, a cutoff rainfall rate was forced to explicitly eliminate the CSO events for small rainfalls. That rate was assigned on the basis of the lowest observed rainfall data generating an overflow at any of the four communities used to develop the best fit line. The best fit equation and the cutoff rate were then applied to the assigned rainfall data for each CSO community and results were multiplied by the community areas to generate the estimated CSO discharges for each community. Several communities' CSOs were taken offline during the 1985–2008 period, as identified during the data request effort. The communities' flows (and subsequent loads) were removed for offline periods.

Water quality data were available for 3 of the 60 CSO communities, as shown in Table Table 8-11. The data were applied to the three communities at times of overflow (see above) to derive the loads.

Table 8-11. Averaged water quality data from CSO communities in the Chesapeake Bay watershed

NPDES ID	NH_3 (mg/L)	BOD_5 (mg/L)	TSS (mg/L)	TP (mg/L)	TKN (mg/L)	NO_2+NO_3 (mg/L)	TN (mg/L)	Nitrate as N(mg/L)	Phosphorus as P (mg/L)	Nitrite as N (mg/L)	NH_3 as N (mg/L)
MD0021598	1.324	26.620	84.960	0.437	4.324	1.552	5.876	--	--	--	--
PA0026361	--	24.219	96.418	--	--	--	--	1.433	0.629	0.088	--
PA0026107	--	52.249	143.547	3.179	--	--	--	0.866	--	0.601	3.778

* Parameter names were left as originally described in the original data sets.

To calculate loads for the remaining communities, national average values were used according to Novotny and Olem's (1994) nationwide average characteristics of CSOs (Table 8-12) were multiplied by the overflow for each community.

Table 8-12. Nationwide average characteristics of CSOs

	BOD_5 (mg/L)	Suspended solids (mg/L)	TN (mg/L)	TP (mg/L)
Nationwide average characteristics of CSOs	115	370	9 to 10	1.9

Source: Novotony and Olem 1994

Table 8-13. Combined sewer system (CSS) communities in the Bay watershed

Jurisdiction	River basin	NPDES ID	Facility name
DC	Potomac	DC0021199	Washington, District of Columbia
DE	Eastern Shore	DE0020265	Seaford Waste Treatment Plant
MD	Eastern Shore	MD0020249	Federalsburg WWTP
MD	Eastern Shore	MD0021571	City of Salisbury WWTP
MD	Potomac	MD0021598	Cumberland WWTP
MD	Patapsco	MD0021601	Patapsco WWTP
MD	Eastern Shore	MD0021636	Cambridge WWTP
MD	Eastern Shore	MD0022764	Snow Hill W & S Dept.
MD	Potomac	MD0067384	Westernport CSO
MD	Potomac	MD0067407	Allegany County CSO
MD	Potomac	MD0067423	Frostburg CSO
MD	Potomac	MD0067547	Lavale Sanitary Commission CSO
NY	Susquehanna	NY0023981	Johnson City (V) Overflows
NY	Susquehanna	NY0024406	Binghamton (C) CSO
NY	Susquehanna	NY0035742	Chemung Co Elmira SD STP
PA	Susquehanna	PA0020940	Tunkhannock Boro Mun. Auth.
PA	Susquehanna	PA0021237	Newport Boro STP
PA	Susquehanna	PA0021539	Williamsburg Municipal Auth.
PA	Susquehanna	PA0021571	Marysville Borough WWTP
PA	Susquehanna	PA0021687	Wellsboro WWTP
PA	Susquehanna	PA0021814	Mansfield Boro WWTP
PA	Susquehanna	PA0022209	Bedford WWTP
PA	Susquehanna	PA0023248	Berwick Area Joint Sewer Auth. WWTP
PA	Susquehanna	PA0023558	Ashland WWTP
PA	Susquehanna	PA0023736	Tri-Boro Municipal Authority WWTP
PA	Susquehanna	PA0024341	Canton Boro Auth. WWTP
PA	Susquehanna	PA0024406	Mount Carmel WWTF
PA	Susquehanna	PA0026107	Wyoming Valley Sanitary Authority WWTP
PA	Susquehanna	PA0026191	Huntingdon Borough WWTF
PA	Susquehanna	PA0026310	Clearfield Mun. Auth. WWTP
PA	Susquehanna	PA0026361	Lower Lackawanna Valley San. Auth. WWTP
PA	Susquehanna	PA0026492	Scranton Sewer Authority WWTP
PA	Susquehanna	PA0026557	Sunbury City Mun. Auth. WWTP
PA	Susquehanna	PA0026743	Lancaster City WWTP
PA	Susquehanna	PA0026921	Greater Hazelton Joint Sewer Authority WWTP
PA	Susquehanna	PA0027014	Altoona City Auth. - Easterly WWTP
PA	Susquehanna	PA0027022	Altoona City Auth. - Westerly WWTF
PA	Susquehanna	PA0027049	Williamsport Sanitary Authority – West Plant
PA	Susquehanna	PA0027057	Williamsport Sanitary Authority – Central Plant
PA	Susquehanna	PA0027065	LRBSA - Archbald WWTP
PA	Susquehanna	PA0027081	LRBSA - Clinton WWTP
PA	Susquehanna	PA0027090	LRBSA - Throop WWTP
PA	Susquehanna	PA0027197	Harrisburg Advanced WWTF

Jurisdiction	River basin	NPDES ID	Facility name
PA	Susquehanna	PA0027324	Shamokin Coal Twp Joint Sewer Auth.
PA	Susquehanna	PA0028631	Mid-Cameron Authority
PA	Susquehanna	PA0028673	Gallitzin Borough Sew and Disp. Auth.
PA	Susquehanna	PA0036820	Galeton Borough Authority WWTP
PA	Susquehanna	PA0037711	Everett Area WWTP
PA	Susquehanna	PA0038920	Burnham Borough Authority WWTP
PA	Susquehanna	PA0043273	Hollidaysburg STP
PA	Susquehanna	PA0046159	Houtzdale Boro Municipal Sewer Authority
PA	Susquehanna	PA0070041	Mahanoy City Sewer Auth. WTP
PA	Susquehanna	PA0070386	Shenandoah Mun. Sewer Auth. WWTP
PA	Susquehanna	PAG062202	Lackawanna River Basin Sewer Auth.
PA	Susquehanna	PAG063501	Steelton Boro Authority
VA	James	VA0063177	Richmond
VA	James	VA0024970	Lynchburg
VA	James	VA0025542	Covington Sewage Treatment Plant
VA	Potomac	VA0087068	Alexandria
WV	Potomac	WV0020150	City of Moorefield
WV	Potomac	WV0021792	City of Petersburg
WV	Potomac	WV0023167	City of Martinsburg
WV	Potomac	WV0024392	City of Keyser
WV	Potomac	WV0105279	City of Piedmont

8.5.4 Automation of the CSO method

The method for estimating CSOs described in the previous section was adapted for automated runs in order to explore action scenarios and to extend the simulation period with updated rainfall data. The automated method shares most of the assumptions made under the original method, with the main adjustments of new meteorological inputs. The action scenario method for CSO estimates was designed with the following major goals: 1) to be flexible enough to model different action scenarios 2) ideally have the capability to run scenarios in past, present, and future temporal space and 3) to run mostly automatically, providing the user with a simple and effective method scalable to many scenarios. The R language was chosen as the development platform for this method due to previously created functions sourced both from the author and from packages available on the Comprehensive R Archive Network (CRAN) under one or more permutations of the general public license. These functions greatly reduced development time and significantly increased the functionality of the final product. In addition, R is widely used and portable to multiple computational platforms and operating systems including parallel computing, which characterizes the current range of development and production environments at the Chesapeake Bay Program Office.

Two categories of precipitation input data were used in this analysis: 1) A set of station data from the Global Historical Climate Network (GHCN) were used in an attempt to recreate as closely as possible the original CSO results provided by Tetra Tech, but lacking in its ability to generalize to future climate scenarios and 2) modeled rainfall used as inputs to the Chesapeake Bay Model were applied to the CSO estimation framework in order to make possible management action scenario runs with temporal scalability to past, present, and future. Both datasets required collection, formatting, and processing. The collection of modeled precipitation for action scenarios was obtained from data and their corresponding spatial distribution to land segments. However, station data had to be collected at least loosely following the method followed above in the work by TetraTech. In order to automatically gather precipitation data from a large group of stations with the necessary spatial and temporal coverage an R function designed to access the GHCN network was used. This function is currently available at the GitHub repository: http://github.comn/andrewsommerlot/precipitation-mapping. This repository holds additional functions necessary to repeat this method. The modifications and implementation of these functions for the CSO estimation method is located a script file on the Chesapeakebay.net system at: /bluefish/archive/modeling/cso/cso_scenario_modeling.R.

The analysis was completed in 3 stages. Figure 7-15 illustrates the evolution of the global environment in R during the process and highlights different types of pertinent data as meteorological and spatial inputs are processed into a CSO estimate table. In the first stage, all meteorological data were collected and prepared for spatial processing, the second stage includes processes that separately overlaid each precipitation set to CSO community location polygons (Figure 7-14) , returning a precipitation time series for each of these areas. Finally in stage three, both precipitation data sets were used as an inputs to the CSO estimation regression equation in Figure 7-12. The resulting two outputs were 1) a CSO estimate table derived from station data used for verification of the automated process and 2) a CSO estimate table derived from modeled land segment level precipitation data, which is interchangeable with other land segment defined meteorological data sets from past, present, and future including different climate scenarios. Figure 7-16 illustrates the workflow of the CSO scenario modeling method.

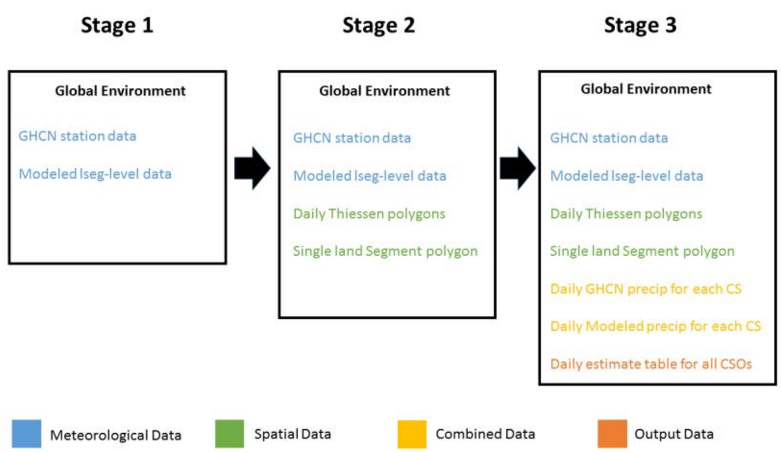


Figure 7-15: Illustration of pertinent data within the R global environment at the end of each major stage of the process.

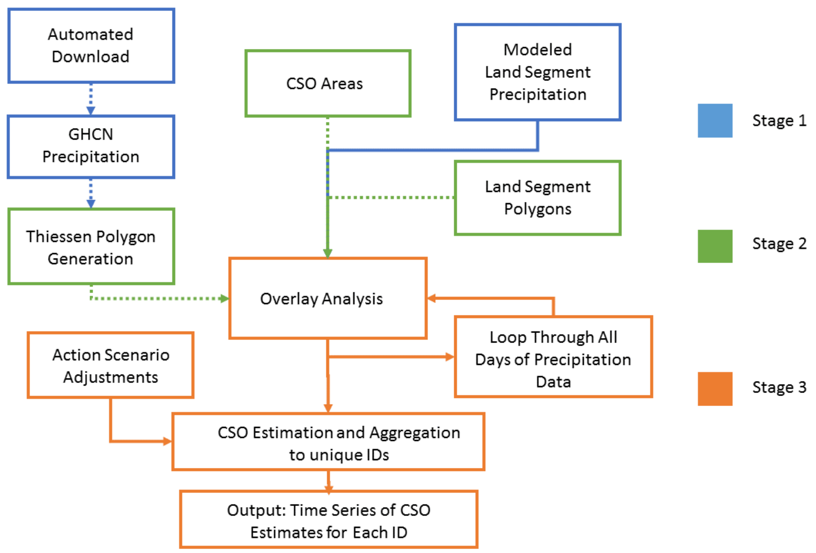


Figure 7-16: CSO Estimation method Workflow. Solid pathways show portion of process repeated for action scenario modeling

Box 1 below describes in pseudo code the processing the GHCN station data into CSO estimations for each NPDES ID for method verification, and box 2 describes the processing of the land-segment-defined modeled rainfall for scenario analysis. The main difference in processing the two data sets is that spatially defined distribution surfaces do not need to be created for the modeled rainfall data, as they are already defined at the land segment scale and have no missing data. However, in this case the CSO regression was applied to a system with a different spatial precipitation distribution then the one from which is was derived, which could lead to error propagating through the equation, reducing the accuracy of the final estimates. Although applied to a new distribution, precipitation in CSO areas are still defined as the corresponding value, or mean aggregate of multiple corresponding values, of a non-overlapping polygon-defined surface distribution within each CSO boundary. This approach is a conceptually similar to the station data derived estimates as the nearest source of precipitation data is still used as the best source for each CSO area. Thus, the assumption was made that the CSO regression could be applied to both precipitation data sets and spatial distributions, allowing for action scenario modeling within the Chesapeake Bay Model framework.

Box 1. Pseudo code applied to station data for verification of automated method

For each day:

Remove missing values from precipitation dataset

Make Thiessen polygons from remaining stations

For each CSO service area:

Take mean of rainfalls from Thiessen polygons with areas in CSO areas

Apply regression equation and CSO acreage to calculate flow estimates

Aggregate CSO service area flow estimates by NPDES ID with summation

Return table of all data combined

Box 2. Pseudo code applied to modeled rainfall data for scenario modeling

For each day:

For each CSO service area:

Take mean of rainfalls from land segment polygons with areas in CSO areas

Apply regression equation and CSO acreage to calculate flow estimates

Aggregate CSO service area flow estimates by NPDES ID with summation

Return table of all data combined

In the case of measured precipitation, Thiessen polygon surfaces were made uniquely for each day in the time series. This was done in order to address missing data, as daily time series of meteorological station data over the relatively long time are likely to have some missing data and a simple imputation—such as a mean fill—may be inappropriate, as missing large precipitation events could significantly affect the final aggregate CSO estimates by underestimating monthly or yearly totals. The automated GHCN download selects stations with densely populated data within defined spatial and temporal scales. The bounding box for this analysis was defined as: west -80.5 deg longitude, east -74.2 deg longitude, north 42.9 deg latitude, and south 36.9 deg latitude. Within these bounds, 55 stations were found with dense precipitation data sets in the necessary temporal range. For each day, consisting of 55 precipitation measurements, NA values were removed before creating a Thiessen polygon surface. In this way, a station drops out of the polygon creation when it does not have data for that day, and the surface is constructed without it. So the station from which a CSO community area is assigned precipitation may change through time, but only if its ideal value in reference to the surface with all available stations is missing. When this occurs, the polygon surface is adjusted and the next-best value is used. Thus, no day for the final CSO community area precipitation dataset contained missing values, and using statistical metrics such as the mean or median, which may grossly misrepresent the rainfall at a daily time scale, were avoided. At most, four stations had missing data in the same day, or alternatively, the minimum number of stations used to create a polygon surface was 49, or about 89% of the maximum number of stations. Figures 7-17 and 7-18 show two selected days of GHCN Thiessen polygon surfaces one with 49 and another with 55 stations and overlaid CSO community areas for reference. The figure shows the average size and distribution of the polygons is similar to that of Figure 7-11, suggesting the automated process may be acceptable at least in spatial recreation of the original precipitation analysis. In addition, the difference in the surfaces is not great, with the biggest changes being a loss of station polygons North-east of Washington DC and West of Philadelphia in Pennsylvania.

Precipitation results were further processed by converting to area-normalized inches and applying the equation from Figure 7-12 to each unique CSO community area / day combination to obtain MMgal/day-acre estimates. Each result was then multiplied by its corresponding CSO community area sourced from the shapefile illustrated in Figure 7-14. The results were further processed by aggregating them to unique NPDES ID / day combinations, as multiple CSO communities can be defined under a single NPDES ID. The resulting outputs were two separate data tables, one from each type of meteorological forcing, containing CSO estimates for each CSO community area defined by unique NPDES ID per day, mirroring the format of the results purchased from Tetra Tech. The pre-aggregated, precipitation outputs are available at G:\Modeling\SBMODELING\Phase6\Point Sources\precipitation_cso\unaggregated_pcp_outputs, giving all the necessary information and maximum flexibility to the user applying action scenarios.

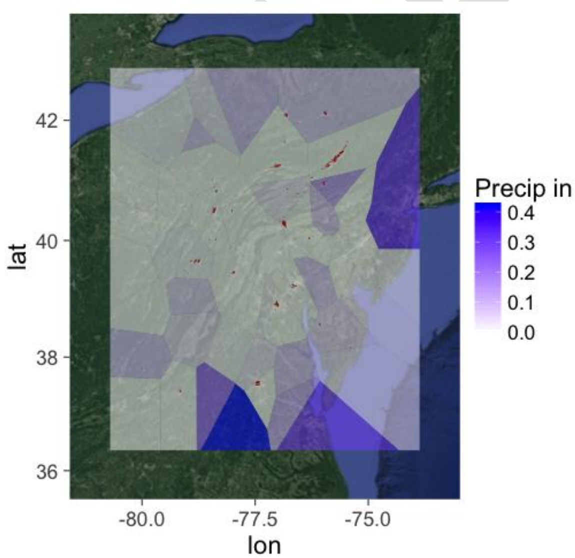


Figure 7-17: GHCN precipitation Thiessen polygon surface with the maximum of 55 stations for December 31, 2015

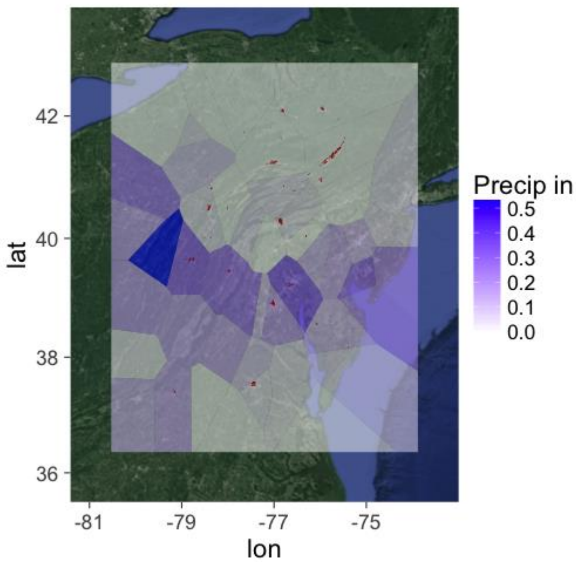


Figure 7-18: GHCN precipitation Thiessen polygon surface with the minimum of 49 stations for November 29, 2015

Since action scenarios are concerned with monthly or greater aggregates of CSO outputs, the data tables were aggregated to monthly outputs in MMgal/month overflow for the following analysis. CSO estimates from Tetra Tech are treated as ground truth in the results, as the goal of both station and modeled precipitation driven CSO estimations was to re-create this data in a manner repeated applicable to scenario modeling including different meteorological forcings. The resulting CSO estimates from both station and modeled precipitation data provided close values to the original Tetra Tech CSO estimates when aggregated to monthly flow outputs (Figure 7-19). The Nash-Sutcliff efficiency (NSE), a commonly used metric to compare time series data in the hydrologic sciences was chosen to quantitatively assess the recreation of the Tetra Tech data. NSE varies from negative infinity (poor) to 1 (perfect) measure of simulated recreation of observed data. A general guideline common in NPS literature is NSE greater than or equal to 0.5 on a monthly time scale can be considered satisfactory. The time period shown is the overlap between the most recent estimates received from Tetra Tech (2010 through 2015), and the available modeled precipitation data (1984 through 2014), resulting in a temporal range of 2010 through 2014. The station forced estimates provided the best recreation of the Tetra Tech estimates, with a Nash-Sutcliff efficiency (NSE) of 0.91 on a monthly time scale, closely followed by the modeled precipitation forced estimates with an NSE of 0.87. Both results are well above the general guideline of 0.5. The empirical cumulative distribution functions show similarities between all data sets (Figure 7-20) with the modeled precipitation forced CSO estimates having a slight tendency to over predict compared with the Tetra Tech estimates, while the station precipitation forced estimates tend to over predict high flows and slightly under predict low flows. Despite these discrepancies, both methods recreated the Tetra Tech estimates well at the monthly scale.

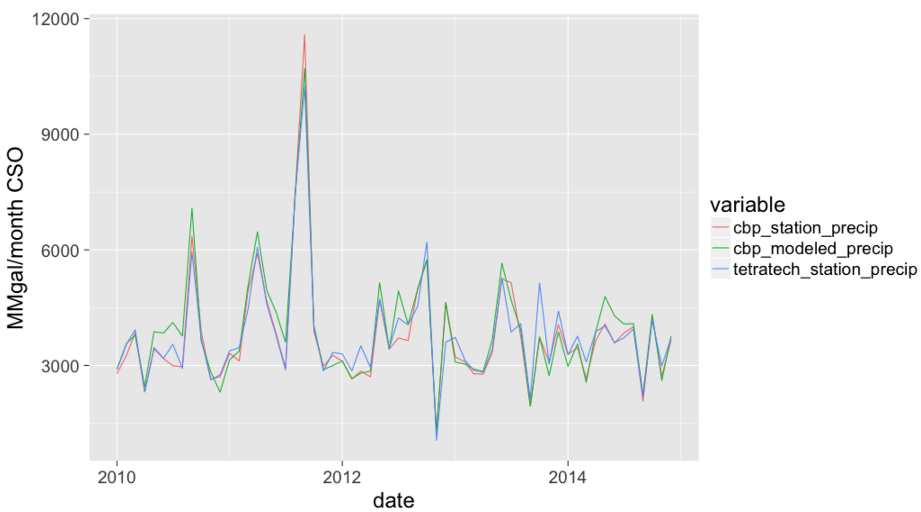


Figure 7-19: Monthly aggregation of CSO estimates from Tetra Tech, CBP station precipitation forced, and CBP modeled precipitation forced methods over the time period from 2010 through 2014.

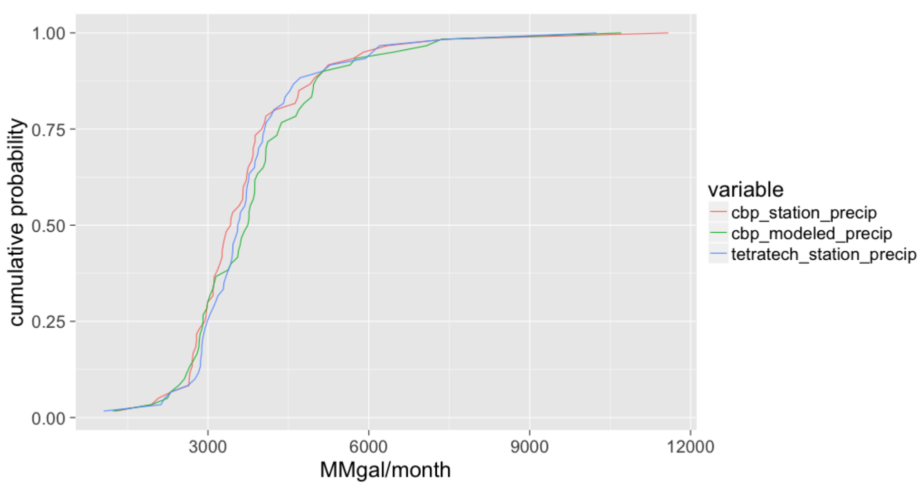


Figure 7-20: Empirical Cumulative Distribution Functions (ECDFs) for all three methods.

In summary, two methods were used to recreate the CSO estimates received from Tetra Tech 1) a station precipitation forced estimate and 2) a modeled precipitation forced estimate. The station driven estimates provided the best recreation of Tetra Tech data, however the model driven estimates provided similar and satisfactory results as well. It is worth noting that none of these methods (including the Tetra Tech estimates) have been vetted for operational purposes at a daily time scale. Chesapeake Bay Program decisions are based on the static Phase 6 model which operates on long-term annual average loads. For use in the dynamic model, daily predictions that correlate with rainfall are used to avoid CSO loads creating high concentrations during low-flow periods.

The station precipitation forced estimates are the best recreation of historical CSO estimates in accordance with the report from Tetra Tech. Since the station driven estimates cannot be generalized to future climate scenario however, the modeled precipitation forced estimates are used for all scenarios.

8.6 Sanitary Sewer Overflows and WWTP Bypasses

Properly designed, operated, and maintained sanitary sewer systems are meant to collect and transport all the sewage that flows into them to a POTW. Frequent SSOs are indicative of problems with a community's collection system and can be due to multiple factors:

- Infiltration and inflow contributes to SSOs when rainfall or snowmelt infiltrates through the ground into leaky sanitary sewers or when excess water flows in through roof drains connected to sewers, broken pipes, or badly connected sewer service lines. Poor service connections between sewer lines and building service lines can contribute as much as 60 percent of SSOs in some areas.
- Undersized systems contribute to SSOs when sewers and pumps are too small to carry sewage from newly developed subdivisions or commercial areas.
- Pipe failures contribute to SSOs as a result of blocked, broken, or cracked pipes; tree roots growing into the sewer; sections of pipe settling or shifting so that pipe joints no longer match; and sediment and other material building up causing pipes to break or collapse.
- Equipment failures contribute to SSOs because of pump failures or power failures.

SSOs represent a typical source of nutrients from urban area to the Chesapeake Bay, but not captured by current model, especially in areas not covered by CSO collection system. For example, City of Baltimore eliminated its CSO in 2007, but the storm driven sewer overflows has continued as a major issue for the city.

SSO is considered as illegal discharge and has traditionally been avoided in the Bay Models due to limited data availability. Bypass has been reported as storm driven bypass and not included in the effluent data for many plants. Only Blue Plains bypass outfall has reported data for the Bay model currently. . however, information available to characterize their contribution to the overall nutrient loads delivered to the Bay is limited largely because of their illegality and infrequency. Although the Phase 6 Model does not specifically account for SSOs and Bypasses, the nutrient load contributions from SSOs and Bypasses are part of the background conditions incorporated into the Phase 6 Watershed Model. Therefore, SSO and Bypass loads are accounted for in the data used for calibration of the model.

8.7 On-site Wastewater Disposal Systems

Review responsibility for this entire section - USWG

On-site Wastewater Disposal Systems (OSWDS), commonly called septic systems, represent an estimated 6 percent of the total nitrogen load from the Chesapeake watershed in 2000 (Phase 4.3 Model—Base Scenario). Information of the loads from these systems are generally sparse. Detailed descriptions of data procedures, source information, and assumptions used in estimating the loads are in Palace et al. (1998).

Loads from OSWDS are compiled from census data using the methodology suggested in Maizel et al. (1995). OSWDS are simulated as a nitrate load discharged to the river. Phosphorus loads are assumed to be entirely attenuated by the OSWDS. The OSWDS loads are determined by assessing the census records of waste disposal systems associated with households. Standard engineering assumptions of per capita nitrogen waste and standard attenuation of nitrogen in the septic systems are applied. Overall, the assumption of a load of 4.0 kg/person-year is used at the edge of the OSWDS field, all in the form of nitrate (Metcalf and Eddy. 1979).

Using an average water flow of 75 gallons/person-day for a septic tank (Salvato 1982), a mean value of 3,940 grams/person-year for groundwater septic flow, 4,240 grams/person-year for surface flow of septic effluent, and typical surface/subsurface splits as reported by Maizel et al. (1995), a total nitrogen concentration of about 39 mg/L at the edge of the septic field was calculated. That concentration compares favorably with Salvato (1982) who calculated on-site wastewater management system total nitrogen concentrations of 36 mg/L. It is assumed that attenuation of the nitrate loads between the septic system field and the edge-of-river nitrate loads represented in the Phase 5.3 Model is due to (1) attenuation in anaerobic saturated soils with sufficient organic carbon (Robertson et al. 1991; Robertson and Cherry 1992), (2) attenuation by plant uptake (Brown and Thomas 1978), or (3) attenuation in low-order streams before the simulated river reach. Overall, the total attenuation is assumed to be 60 percent (Palace et al. 1998).

OSWDS loads are input as a daily load in the river reach. For coastal plain OSWDS loads where there is no simulated reach, the OSWDS nitrate loads are delivered directly to the tidal Bay.

Two potential sources of error are in the estimate of nitrogen loads from septic systems. After 1990, the U.S. Census Bureau survey no longer enumerates the number of household served by septic systems.

The fraction of the population on septic systems and the number of people per system are based on the 1990 Census estimates and are therefore unable to be updated through the 1985 to 2005 simulation period of Phase 5.3. The fraction of the population on septic and the number of people per system as used in the Phase 5.3 Model, therefore, do not change over the simulation period. The assumption of a 60 percent attenuation between the septic field and the edge-of-river for nitrogen loads applied over the entire Bay watershed could also introduce errors in the estimation of septic loads.

Septic systems are commonly designed so that the waste goes into a tank, where solids sink to the bottom, and liquids flow through to a septic field. While some phosphorus can become soluble, the Partnership assumes that only nitrogen is distributed to the septic field.

To calculate the amount of nitrogen generated from septic systems, the USGS provides Scenario Builder with an estimate of the number of septic systems within each land-river segment and the average number of people contributing waste to each system. More detailed methods for estimating population served by septic and the number of septic systems will be provided by USGS at a later date. From this estimate, Scenario Builder then calculates nitrogen load from the edge of septic drainfields within a land-river segment using Equation 8-1. This equation contains both an average nitrogen load per person per year and an assumption of 60% nitrogen attenuation. Both these values are being reviewed by the Wastewater Workgroup.

Equation 8-1: total nitrogen septic loads

Total Persons on Septic X 8.92 Lbs N/Person/Year X 0.4

8.7.1 Maryland soils for On-site Waterwater

MDE conditionally approved the report, Nutrient Attenuation in Chesapeake Bay Watershed Onsite Wastewater Treatment Systems, at the WWTWG conference call on September 13, 2016, pending the resolution of questions including the approach for classifying drainfield soils. This document outlines the approach proposed by MDE to the WWTWG on December 20, 2017 and approved by the partnership for defining septic system drainfield soil texture in Maryland.

To estimate the soil characteristics of septic drainfields, MDE conducted surveys of county health departments in late-2016. This approach offered advantages over the use of watershed-wide data sets, in particular due to the age and variability in construction practices used in Maryland's systems. In terms of septic classification, many of Maryland's older septic systems discharge at a depth below six feet, where the Soil Survey Geographic database, SSURGO, provides little data. In addition, many of the newer systems in Maryland are mounded, meaning that the drainfield soils would not be captured in the SSURGO database.

Results from the surveys are summarized as follows:

- Anne Arundel County: Clayey soils in the north of the county and sandier soils on top of clay to the south, with many drywells in the east
- Baltimore County: Systems installed between 5 and 10 feet deep mostly in the piedmont region in the north of county
- Calvert County: Systems in sandy to loamy soil at 5 to 10 feet deep

- Caroline County: Shallow systems in sandy to loamy soils
- Charles County: Many systems below 10 feet deep
- Carroll County: Deep systems in the southeast and mounded systems in the northwest
- Harford County: Deep systems installed in loamy soils in the north, shallower systems in more cohesive soils in the south
- Talbot County: Shallow systems, with many older systems close to water table
- Somerset County: Mounded systems inland and shallow systems closer to the coast, with many older systems close to water table
- Wicomico County: Shallow systems installed in sandy soils

Because of the variety of responses—including factors like depth, distance from water table and construction method—it was difficult to translate the survey into a model data set, so the following decision rules were applied to the categories.

- Areas with significant numbers of mounded systems were assigned to the Sandy group. Based on best professional judgment, it was determined that the fill material would be chosen based largely on its hydraulic conductivity, meaning that it should be predominated by sandier soils.
- Areas with a lot of deep systems—those greater than 8 feet—were assigned to the Sandy classification. Based on best professional judgment, it is expected that these systems would be installed at a depth where a hydraulically-conductive soil was located, and that there would be less available oxygen at these depths to promote nitrification, meaning that the low level of attenuation in the Sandy group was most appropriate.
- Any areas where the majority of systems were located within or close to the groundwater table or discharged into drywells, the soil type was assigned to the Sandy group, as this would provide minimal treatment within the context of the expert panel report.

Due to the qualitative nature of this study and the absence of readily-available spatial information and data showing quantities of systems installed in specific soil types, the drainfield soid types were generalized across counties. In counties with significant areas covered by municipal sewers, soil type was defined based on the non-sewered area of the county.

The result of applying the decision rules to Maryland's counties was that all of the counties in the watershed were determined to be in the Sandy soil class, as they were either constructed in Sandy soil, or would have a treatment potential most similar to the Sandy classification. Having most systems located in sandy soils is an intuitive result, since systems would typically be constructed in soils that would maximize their conductivity rather than their nutrient attenuation potential. Systems discharging to sandier soil could have a smaller footprint than those discharging to cohesive soil, meaning that they would be less expensive to install.

Given the schedule constraints involved with this project, it was not possible to conduct as thorough a survey as would be necessary for characterizing the drainfield soils. The systems in a given county would vary significantly based on factors like the era of construction, the local geology, the proximity of the groundwater table and the size of the lot, to name a few. This approach is highly qualitative in nature, and could be enhanced by coupling it to a thorough quantitative analysis using county-level septic system records.

8.8 Rapid Infiltration Basins

A small number of municipal wastewater treatment facilities across the watershed discharge wastewater to permeable earthen basins designed to provide nutrient treatment of wastewater through soil infiltration rather than discharging wastewater directly to a nearby stream. The Chesapeake Bay Program's Phase 5.3.2 Watershed Model did not explicitly simulate rapid infiltration basin discharges as a nutrient source. This memo recommends a way to explicitly simulate this nutrient source as part of the Phase 6 Watershed Model.

The Phase 6 Watershed Model will use a simple nutrient balance simulation to estimate the loads from rapid infiltration basins at each location. The following equation will be used:

Yearly RIB Nitrogen Load to Nearby Stream = (Total G of RIB X Average Lb/G Nitrogen) – (Total Lbs Nitrogen Removal by RIB)

The resulting load will be simulated as a discharge to the modeled stream similar to the discharge from septic, and will be subject to further retention within the stream during simulated transport to the Chesapeake Bay.

Model Load Results: The resulting discharge to the simulated stream will be reported by the Chesapeake Bay Program models as a municipal wastewater discharge to the land, or "MWL."

Total lbs removal was estimated using Zone 1 and Zone 3 septic attenuation factors.

8.9 Non-agricultural spray irrigation

Many municipal wastewater treatment plants have permits to discharge effluent directly to nearby waters only during certain months of the year. For the remainder of the year (most typically the growing season), these plants discharge their effluent to nearby herbaceous lands (including golf courses, turf grasses and other non-agricultural herbaceous areas), thereby removing the direct discharge pathway to nearby waters. These discharges are most often made to grassy areas to take advantage of the natural nutrient uptake and retention ability of grasses, thus reducing, but not altogether eliminating nutrient runoff to nearby waters. The Chesapeake Bay Program's Phase 5.3.2 Watershed Model did not explicitly simulate municipal spray irrigation on non-ag land as a source of nutrients to the watershed. This memo recommends a way to explicitly simulate this nutrient source as part of the Phase 6 Watershed Model.

The Phase 6 Watershed Model will use a simple nutrient balance simulation to estimate the loads from spray irrigation at each location. The following equation will be used:

Yearly Spray Irrigation Nitrogen Load to Nearby Stream =(Total G of Spray Irrigation X Average Lb/G Nitrogen) – (Total Lbs Nitrogen Uptake + Total Lbs Nitrogen Soil Retention)

The resulting load will be simulated as a discharge to the modeled stream similar to the discharge from a septic, and will be subject to further retention within the stream during simulated transport to the Chesapeake Bay.

Model Load Results: The resulting discharge to the simulated stream will be reported by the Chesapeake Bay Program models as a municipal wastewater discharge to the land, or "MWL."

Total lbs removal from uptake and nitrogen soil retention was estimated using Zone 1 and Zone 3 septic attenuation factors.

8.10 Animal Loafing and Feeding Areas

Review responsibility - AgWG

The method to calculate the total available nutrients to the barnyard are included in Section 3: Terrestrial Inputs. Section 3 also details the method by which this is separated into manure nutrients applied to crops, lost to volatilization, and lost to the environment. Manure nutrients lost to the environment are considered a direct load to streams after appropriate land-to-water factors are applied.

8.11 Direct Deposition into streams

Review responsibility - AgWG

The method to calculate the total available nutrients directly deposited to the stream are included in section 3 and discussed in appendix 3B: Pasture Subgroup Recommendations for Direct Deposition in Riparian Pasture Access Area. All nutrients deposited are considered a load to the stream with no attenuation.

8.11.1 Attenuation in near-pasture area

The Partnership reviewed existing TMDL models developed for VA which assessed the impact of riparian area deposition. Each model had an assumption of the amount of manure deposited within the riparian area that was actually deposited in the stream itself, representing 0 attenuation of the manure nutrients by the land. These assumptions varied, with many models assuming 100 percent. The Partnership has chosen to use the average of these models, which was approximately 70 percent, to represent the amount of manure deposited within a riparian area which has 0 attenuation. That leaves 30 percent of manure deposited within nearby riparian areas which should have some attenuation factor applied to it. Butler et. al, 2008 found that of the TN and TP from manure applied to simulated, heavy use riparian areas, approximately 33 percent and 34 percent respectively was exported. These findings and assumptions can be combined in the following manner to estimate manure runoff to streams:

- TN Fraction Runoff from Riparian Pasture = 0.70 X 1 + 0.30 X 0.33, or 0.80
- TP Fraction Runoff from Riparian Pasture = 0.70 X 1 + 0.30 X 0.34, or 0.80

8.11.2 Sediment loads near deposition areas

The Pasture Subgroup did not comment on sediment in riparian areas for the report denoted in this documentation as Appendix 3B. CBWM Phases 4 and 5 did have sediment loads from riparian pasture, however. Physically, these areas have little or no vegetation and heavy hoof traffic. They are therefore susceptible to washoff of sediment. Sediment loads from these areas were determined to be about an order of magnitude higher than for pasture in the phase 5 CBWM (USEPA 2010a-09). This assumption cannot be carried forward from Phase 5 since RPA does not have associated acres in Phase 6.

To keep the edge-of-stream load the same in Phase 6 as it was in Phase 5, the Phase 5 watershed-wide sediment load of 553017 tons (p532cal_102413 scenario) is divided by the p6 RPA TN load from 1991-2000. This gives a ratio of (Sed tons) / (N lbs). Each LRseg N load is multiplied by this ratio to get the sediment load.

8.12 Tidal Shoreline Loads

Commented [GS1]: This section is FFR ready

Loads that originate within the tidal boundaries or at the tidal margins were not considered in the previous versions of the CBWM. For Phase 6 these loads are being considered so that that actions taken in the tidal water to reduce or increase nutrients and sediment can be included in the accounting of watershed management. Tidal shoreline loads are those loads caused by the erosion of fastland and nearshore erosion caused by wave action.

The shoreline length was found through the following GIS analysis. A new polygon representing tidal water was created as the inverse of the land-river segments. The land-river segments were converted from polygon to polylines and then to lines. Lines that intersect with the tidal water are considered to be shoreline. Land-river segments that drain to tidal water but do not have tidal shoreline were removed from the loading calculation.

Shoreline loads were calculated for the Chesapeake Bay Program's estuarine Water Quality and Sediment Transport Model (WQSTM) (Cerco and others 2010) which referenced calculations discussed in Halka and Hopkins 2006. The loads from the WQSTM that were generated by Halka and Hopkins are available and are used in the Phase 6 watershed model. These loads contain the BMPs that were in place at the time the loads were generated. According to Appendix C, question 13, of the shoreline BMP panel report (Forand and others 2015) the base loads in the calibration are to be loads that include BMP effects without the requirement that states report the pre-2008 BMPs.

The following analysis translated loads at the WQSTM cell level to loads at the land-river segment level. To be designated as having shoreline loads, land-river segments must have assigned shoreline length in the analysis above and must be loading WQSTM cells that have shoreline loads. The weights relating land-river segments to cells were used to partition shoreline length to cell/land-river segment combinations. The total cell loads were then apportioned among the land-river segments according to the length associated with each cell/land-river segment combination for a given cell.

Shoreline loads and lengths are assigned to the nonfederal portion of the LRseg. A new analysis of federal shoreline would not be consistent with the method described above given the difficulty of determining shoreline length, a classic problem in fractal geometry. A future GIS-based re-analysis of shoreline lengths and loads will be required to apportion loads to federal partners.