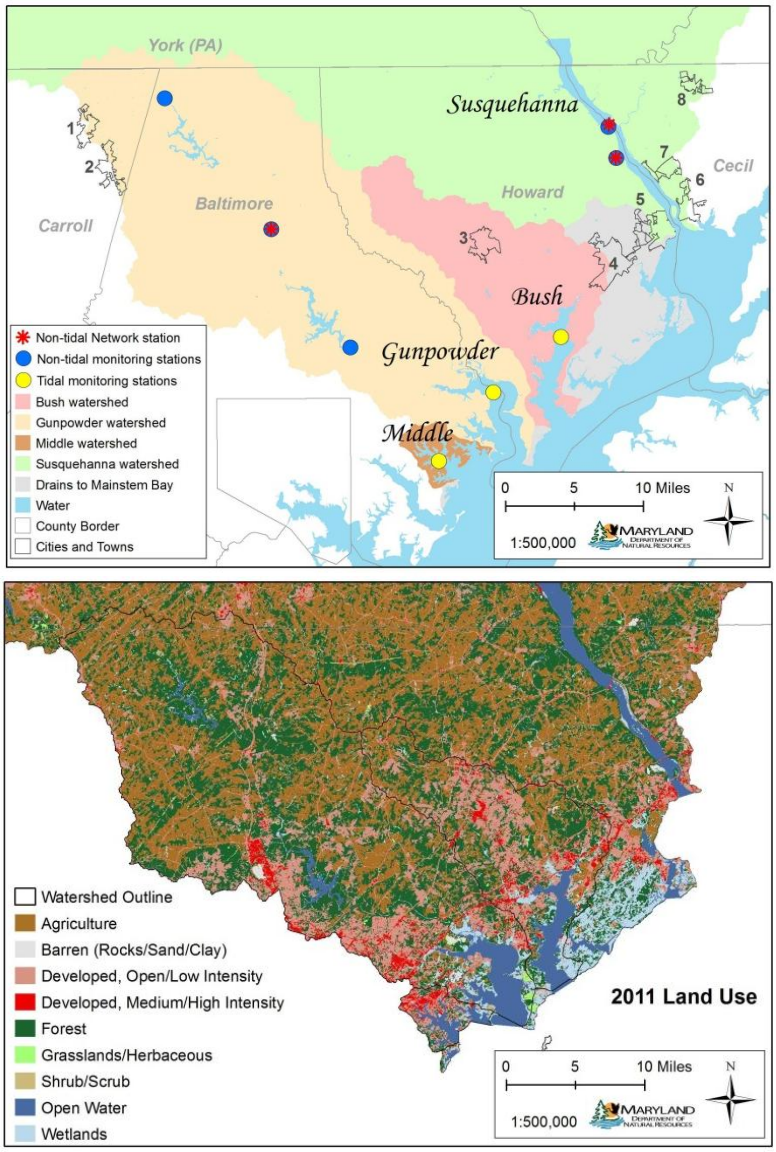
Upper Western Shore
Water Quality and Habitat Assessment
Overall Condition 2012-2014

The Upper Western Shore Basin includes the Bush, Gunpowder and Middle rivers (Figure 1). This basin includes areas in Carrol, Baltimore, Howard and Cecil Counties in Maryland. The upper eastern region of the basin drains to the Susquehanna River, but due to the overwhelming influence of the portions of the river's watershed that are in Pennsylvania and New York, the Susquehanna River is not included in this report.



In the Bush River watershed, land use was estimated as 38% developed, 33% forested, and 20% agriculture (Figure 1).[1] Impervious surfaces covered 12% of the watershed.[2] Stormwater and wastewater sources are the most important contributor of nitrogen and phosphorus loadings; stormwater and agricultural are the largest sources of sediment loadings.[3]

In the Gunpowder River watershed, land use was estimated as 22% developed, 39% forested, and 32% agriculture. Impervious surfaces covered 8% of the watershed. Stormwater and agriculture are the largest sources of nitrogen, phosphorus and sediment loadings.

In the Middle River, land use was estimated as 66% developed and 19% forested. Impervious surfaces covered 30% of the watershed. Stormwater is the largest source of nitrogen and sediment loadings and wastewater is the largest source of phosphorus loadings to Middle River.

Figure 1 Upper Western Shore Basin.
Top panel shows the individual watersheds and locations of long-term non-tidal and tidal water quality monitoring stations. Gray areas of the basin drain to the mainstem Bay. Cities and towns (numbered left to right) are 1-Manchester, 2- Hampstead, 3- Bel Air, 4-Aberdeen, 5- Havre de Grace, 6- Perryville, 7- Port Deposit, 8- Rising Sun. Lower panel shows the land use throughout the basin for 2011.[1]

How healthy are the Upper Western Shore Rivers?

Maryland Department of Natural Resources (MDDNR) measures water and habitat quality at three non-tidal long-term monitoring stations on the Gunpowder River and at three tidal long-term monitoring stations, one in each of the rivers in the basin (Figure 1). Current conditions are determined from the most recent three years of data; trends are determined from the 1999-2014 data.

Maryland DNR also participates in the Non-tidal Network, a partnership with the United States Geologic Survey (USGS), the Chesapeake Bay Program, and the other states in the Chesapeake Bay watershed, to measure non-tidal water quality using the same sampling and analysis methods. One of Maryland's long-term non-tidal stations on the Gunpowder is also part of the Non-tidal Network (Figure 1, Table 2); two additional stations in the Susquehanna basin in Maryland are part of the Non-tidal Network. USGS completes the trends analysis for all Non-tidal Network stations. USGS combines river flow data and the nutrient and sediment data for the most recent 10-year period. The USGS method accounts for changes in river flow so that underlying changes in nutrient and sediment levels can be determined.[4]

Gunpowder River: Non-tidal areas: Measured nitrogen levels at the two upper long-term non-tidal stations increased, and nitrogen levels still had increased when changes in river flow are accounted for. Measured phosphorus levels decreased at all three stations and measured sediment levels decreased at the lowest station.

Tidal areas: Water quality in the tidal Gunpowder River is fair due to sediment levels that are too high and is worsening due to increasing nitrogen levels. Habitat quality for underwater grasses is poor due to high algal density and poor water clarity, and both are getting worse. Underwater grasses covered 39% of the restoration goal area during this period.[5] Summer bottom dissolved oxygen levels at the monitoring station located in the middle portion of the river are good. Bottom dwelling animals are healthy the middle portion of the river but degraded in areas sampled near the mouth of the river during this period.

Table 1. Summary of non-tidal water quality trends.
Trends for nitrogen (N), phosphorus (P) and sediment (Sed). Trends at MD DNR long-term non-tidal monitoring stations (columns labeled 'MDDNR') are determined for 1999-2014; analysis does not include use of flow data. Trends at Non-tidal Network stations (columns labeled 'USGS') are determined by USGS for 2005-2014 (at some stations there is no 2005 data); analysis includes use of flow data.[4] Non-tidal Network stations include the corresponding USGS gage number. Stations in bold typeface are MD DNR long-term non-tidal monitoring stations that are also part of the Non-tidal Network. Decreasing trends ('Dec') are improving trends and shown with green typeface. Increasing trends ('Inc') are degrading trends and shown with red typeface. Blanks indicate no significant trend. Grey shading indicates that the station does not have data for that parameter. Stations are ordered from upstream to downstream.

				MDDNR 1999-2014 (without flow)			USGS 2005*-2014 (with flow)		
Watershed	**USGS Gage #**	**MD DNR Station**	**River/Creek**	**N**	**P**	**Sed**	**N**	**P**	**Sed**
Gunpowder		GUN0476	Gunpowder	Inc	Dec				
	01582500	**GUN0258**	**Gunpowder**	Inc	Dec		Inc		
		GUN0125	Gunpowder		Dec	Dec			
Susquehanna	**01578310**	**CB1.0**	**Susquehanna**					Inc	
	01580520	**DER0015**	**Deer Creek**	Inc	Dec				

Table 2. Summary of tidal water quality and habitat quality indicators.
Annual trends for 1999-2014 for nitrogen (total nitrogen), phosphorus (total phosphorus), sediment (total suspended solids), algal densities (chlorophyll *a*), and water clarity (Secchi depth). Summer bottom dissolved oxygen (DO) trends are for June through September data only. Trends are either 'Increasing' or 'Decreasing' if significant at $p \leq 0.01$; blanks indicate no significant trend. Improving trends are in green, degrading trends are in red. Nitrogen (dissolved inorganic nitrogen) levels below the level for nitrogen limitation 'Meet' criteria, otherwise 'Fail' criteria for 2012-2014 data. Phosphorus (dissolved inorganic phosphorus), sediment (total suspended solids), algal densities (chlorophyll *a*) and water clarity (Secchi depth) either 'Meet' or 'Fail' submerged aquatic vegetation (SAV) habitat requirements for 2012-2014 data. Summer (June through September) bottom dissolved oxygen levels either 'Meet' or 'Fail' EPA open-water 30-day dissolved oxygen criteria.

	Water Quality			Habitat Quality		
River	Nitrogen	Phosporus	Sediments	Algal Densities	Water Clarity	Summer Bottom DO
Bush	Meet	Increasing Meet	Fail	Increasing Fail	Fail	Meet
Gunpowder	Increasing Meet	Meet	Fail	Increasing Fail	Decreasing Fail	Meet
Middle	Meet	Meet	Meet	Meet	Decreasing Fail	Meet

Bush River: Water quality in the tidal Bush River is fair due to high sediment levels and is worsening due to increasing phosphorus levels (Table 2). Habitat quality for underwater grasses is poor due to poor water clarity and high algal densities; algal densities are also increasing. Underwater grasses covered 72% of the restoration goal area during this period. Summer bottom dissolved oxygen levels are good. Bottom dwelling animals are healthy in the upper river areas that were sampled during this period.

Middle River: Water quality in the Middle River is good. Habitat quality for underwater grasses is poor due to high algal densities and poor water clarity, and water clarity has decreased. Underwater grasses covered 40% of the restoration goal area during this period. Summer bottom dissolved oxygen levels at the monitoring station located in the middle portion of the river are good. Bottom dwelling animals are healthy in some of the smaller tributaries sampled during this period but are not healthy in areas near the mouth of the river.

How do the Upper Western Shore basin Rivers compare to other Maryland rivers?

The Bush River is in the 'Low Agriculture/High Development' land use category. Nitrogen and phosphorus levels are high compared with other high development systems (Figure 2). Sediment levels are the highest and algal densities are among the highest of all Maryland rivers and bays. Water clarity is among the worst of all rivers. Summer bottom dissolved oxygen levels are moderate.

The Gunpowder River is in the 'High Agriculture/High Development' land use category. Compared to other similar systems, the Gunpowder has moderate nitrogen and phosphorus levels. Sediment levels are high and algal densities are moderate. Water clarity is among the worst of all rivers. Summer bottom dissolved oxygen levels are high.

The Middle River is in the 'Low Agriculture/High Development' land use category. Nitrogen, phosphorus and sediment levels and algal densities are low compared with other high development systems. Water clarity is low and summer bottom dissolved oxygen levels are moderate.

What has been done to improve water and habitat quality in the Upper Western Shore Rivers?

Wastewater, Stormwater and Septic Loads

Wastewater treatment plant nitrogen loadings to the Bush River have been reduced by 22%, but phosphorus loadings increased 52%. Upgrades to all four major wastewater treatment plants that discharge to the basin were completed by 2015 (though loadings data is only available through 2012).[6]

Wastewater treatment plant nitrogen loadings to the Gunpowder River have been reduced by 85%, and phosphorus loadings have been reduced by 89%. Upgrades to one of the two major wastewater treatment plants that discharge to the basin have been completed, and the second facility will be upgraded by 2018.

Stormwater retrofits have reduced nitrogen loadings and prevented 58,554 pounds of nitrogen from entering the rivers since 2003, and 248 septic system retrofits were completed between 2008 and 2013.[7]

Agricultural Loads[7]

In 2014 there were 24,361 acres of cover crops planted in between growing seasons to absorb excess nutrients and prevent sediment erosion. Fencing on 16,258 acres of farmland was used to keep livestock out of streams and prevent streambank erosion. More than 530 containment structures had been built to store animal wastes and allow these nutrients to be applied to the land in the most effective manner at the appropriate time. More than 4,110 acres of stream buffers were also in place, allowing areas next to streams to remain in a natural state with grasses, trees and wetlands.

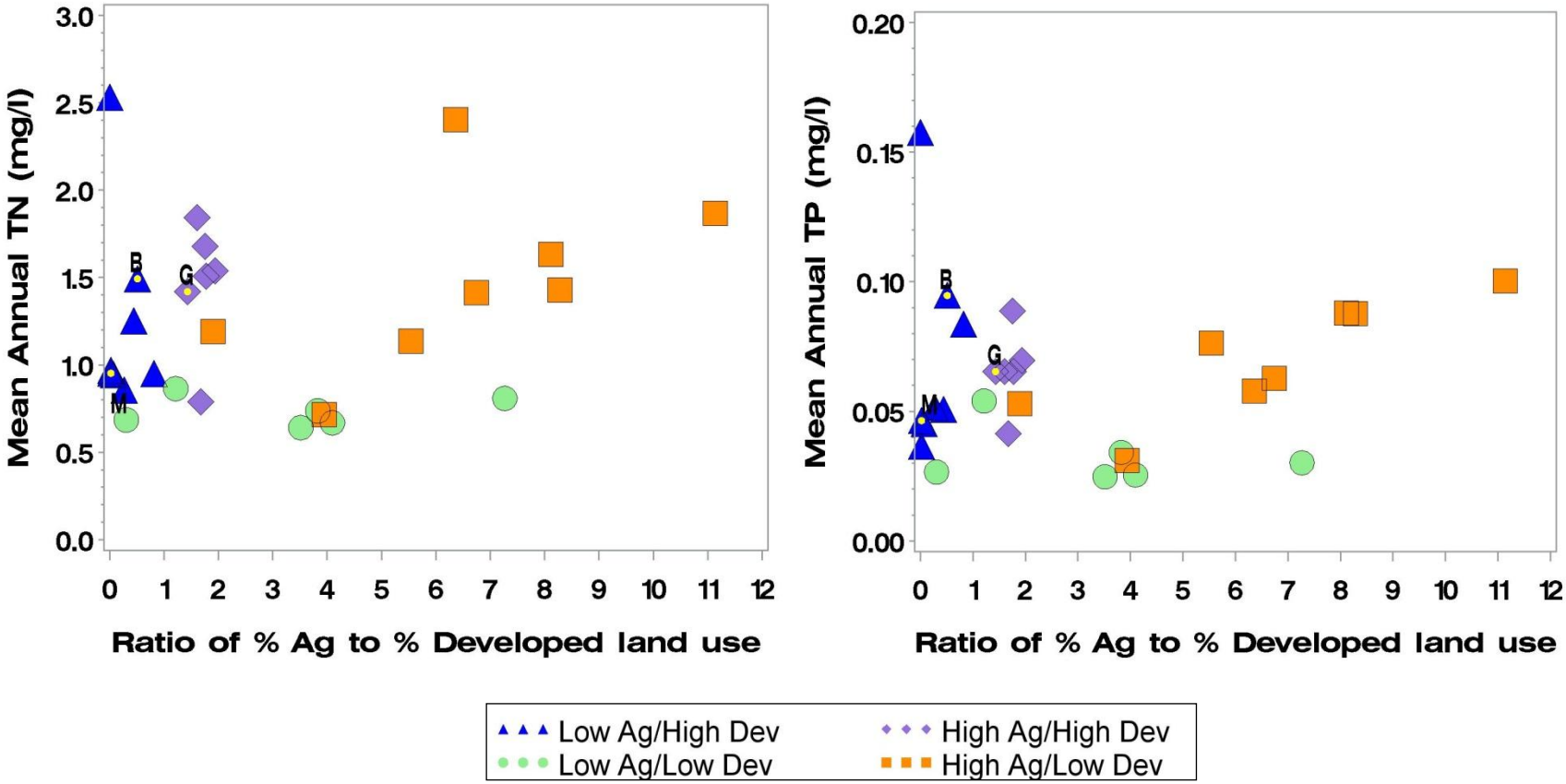


Figure 2. Water quality conditions versus land use.
Water quality is shown relative to the ratio of % Agriculture (Ag) to % Developed (Dev) land use. Data for 2012-2014 are summarized as mean annual concentration (in mg/L) for total nitrogen (TN) and total phosphorus (TP). Rivers are color coded by their land use categories (see legend). Yellow dots highlight the data for the Bush (B), Gunpowder (G) and Middle (M) rivers.

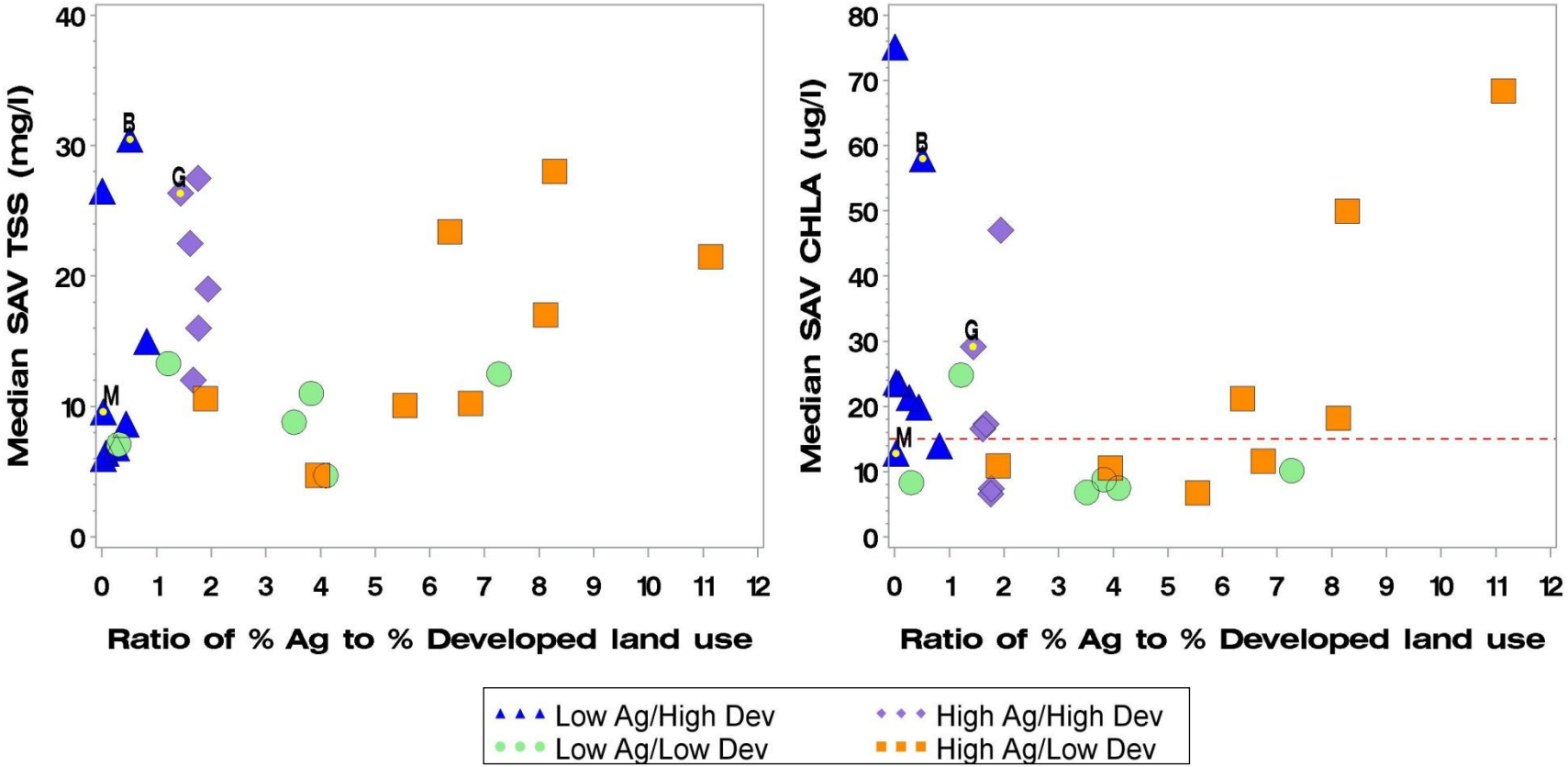


Figure 2 (cont.). Water quality conditions versus land use.
Water quality is shown relative to the ratio of % Agriculture (Ag) to % Developed (Dev) land use. Data for 2012-2014 are summarized as submerged aquatic vegetation (SAV) growing season (April-October) median for total suspended solids (TSS, in mg/L), chlorophyll *a* (CHLA, in µg/L). Reference lines are included on the CHLA graph. Rivers are color coded by their land use categories (see legend). Yellow dots highlight the data for the Bush (B), Gunpowder (G) and Middle (M) rivers.

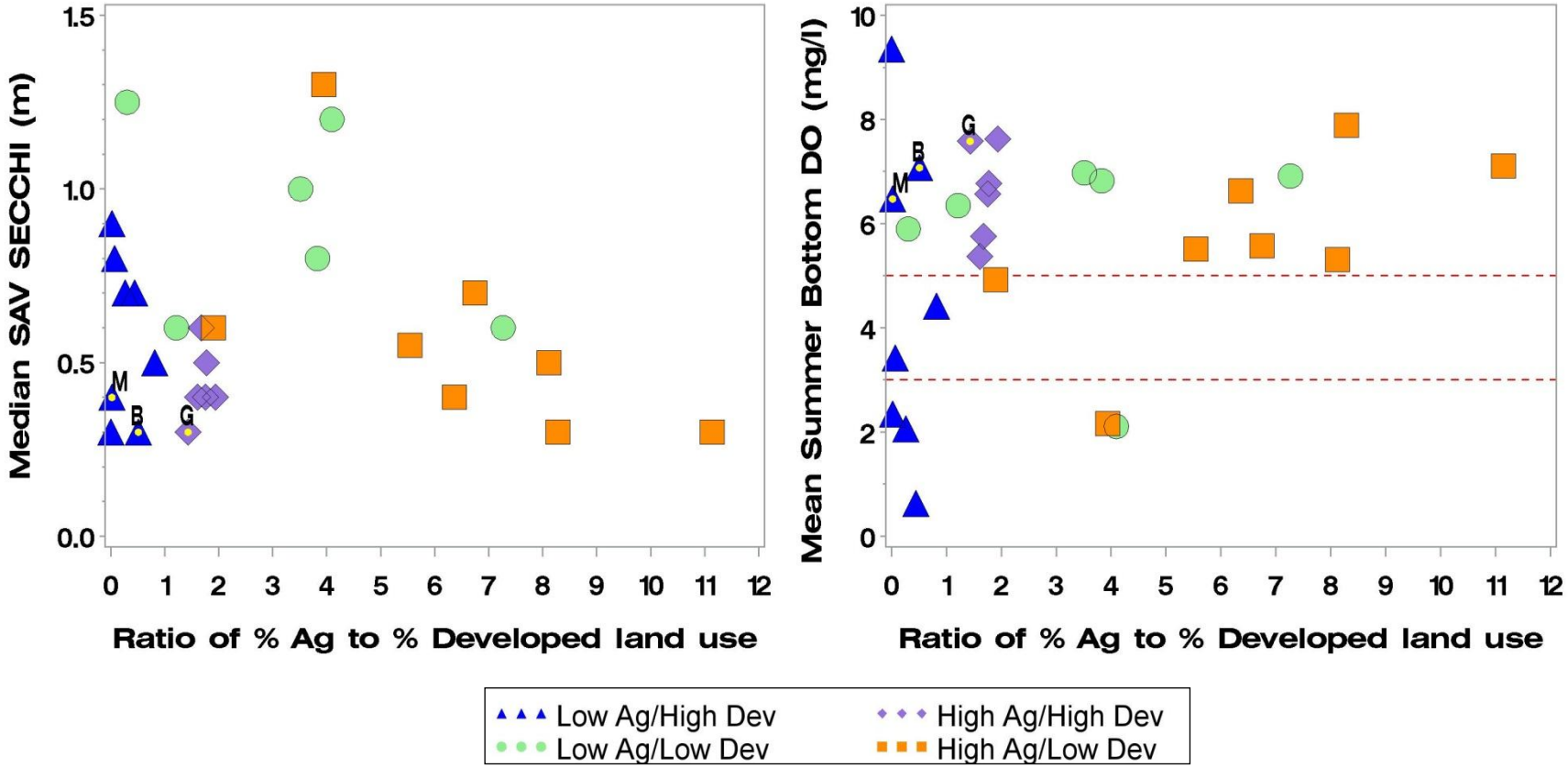


Figure 2 (cont.). Water quality conditions versus land use.
Water quality is shown relative to the ratio of % Agriculture (Ag) to % Developed (Dev) land use. Data for 2012-2014 are summarized as submerged aquatic vegetation (SAV) growing season (April through October) median for Secchi depth (in m) and as mean for summer (June through September) bottom dissolved oxygen (DO, in mg/L). Reference lines are included on the DO graph. Rivers are color coded by their land use categories (see legend). Yellow dots highlight the data for the Bush (B), Gunpowder (G) and Middle (M) rivers.

For more information

An integrative assessment of the water and habitat quality of the Upper Western Shore Rivers for 1985-2010 is available online at http://eyesonthebay.dnr.maryland.gov/eyesonthebay/tribsums.cfm. Current water and habitat quality information is also available from Maryland DNR's Eyes on the Bay website www.eyesonthebay.net.

References and Data Sources

Data not collected and/or analyzed by the Maryland Department of Natural Resources include:

[1] Land use by basin determined from 2011 National Land Cover Database (NLCD).
Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K., 2015, Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing, v. 81, no. 5, p. 345-354
GIS layer downloaded on 11/24/2015 from http://www.mrlc.gov/nlcd11_data.php

[2] Impervious surfaces data downloaded from Maryland Department of the Environment (MDE) website on 12/1/2015
http://www.mde.state.md.us/programs/Water/TMDL/DataCenter/Pages/phase6_development.aspx

[3] Nutrient and sediment loads data for Progress 2014 model run downloaded on November 16, 2015 from http://baytas.chesapeakebay.net/. Source categories from BayTas website were renamed to conform to those used on the ChesapeakeStat website http://stat.chesapeakebay.net/?q=node/130&quicktabs_10=1 as follows: Agriculture = Ag; Agriculture_Regulated = Ag_Reg; Non Regulated Stormwater = Urban; Regulated Stormwater = Stormwater; WasteWater-CSO = CSO; PS = Wastewater; Forest = Forest; Non-Tidal Water Deposition = NT_Dep; Septic = Onsite.

[4] Nutrient and sediment non-tidal concentrations trends results are through WY2014 from USGS website http://cbrim.er.usgs.gov/trends_query.html file dated 2/02/2016, downloaded 2/4/2016. Trends are determined using the Weighted Regressions on Time, Discharge, and Season (WRTDS) model, Hirsch and others, Environmental Modelling & Software 2015, http://www.sciencedirect.com/science/article/pii/S1364815215300220. Results are reported in the text if the trend was 'Extremely Likely' (Likelihood values ≥ 0.95) or 'Very Likely' (Likelihood values $0.95 > p \geq 0.90$).

[5] Underwater grasses (submerged aquatic vegetation, or SAV) data are available from the Virginia Institute of Marine Sciences SAV in Chesapeake Bay and Coastal Bays webpage, Tables tab http://web.vims.edu/bio/sav/SegmentAreaTable.htm#.

[6] WWTP loadings data were downloaded from the Chesapeake Bay Program Nutrient Point Source Database website on 10/14/2015 (http://www.chesapeakebay.net/data/downloads/bay_program_nutrient_point_source_database). Changes in loadings determined from the difference of the average of the first three and last three years of data. Data for calendar year available for 1985-2012.

[7] Data are from Maryland's 2014 - 2015 Milestone Goals and Progress Report website http://baystat.maryland.gov/solutions-map/.

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Chesapeake Bay Program
A Watershed Partnership

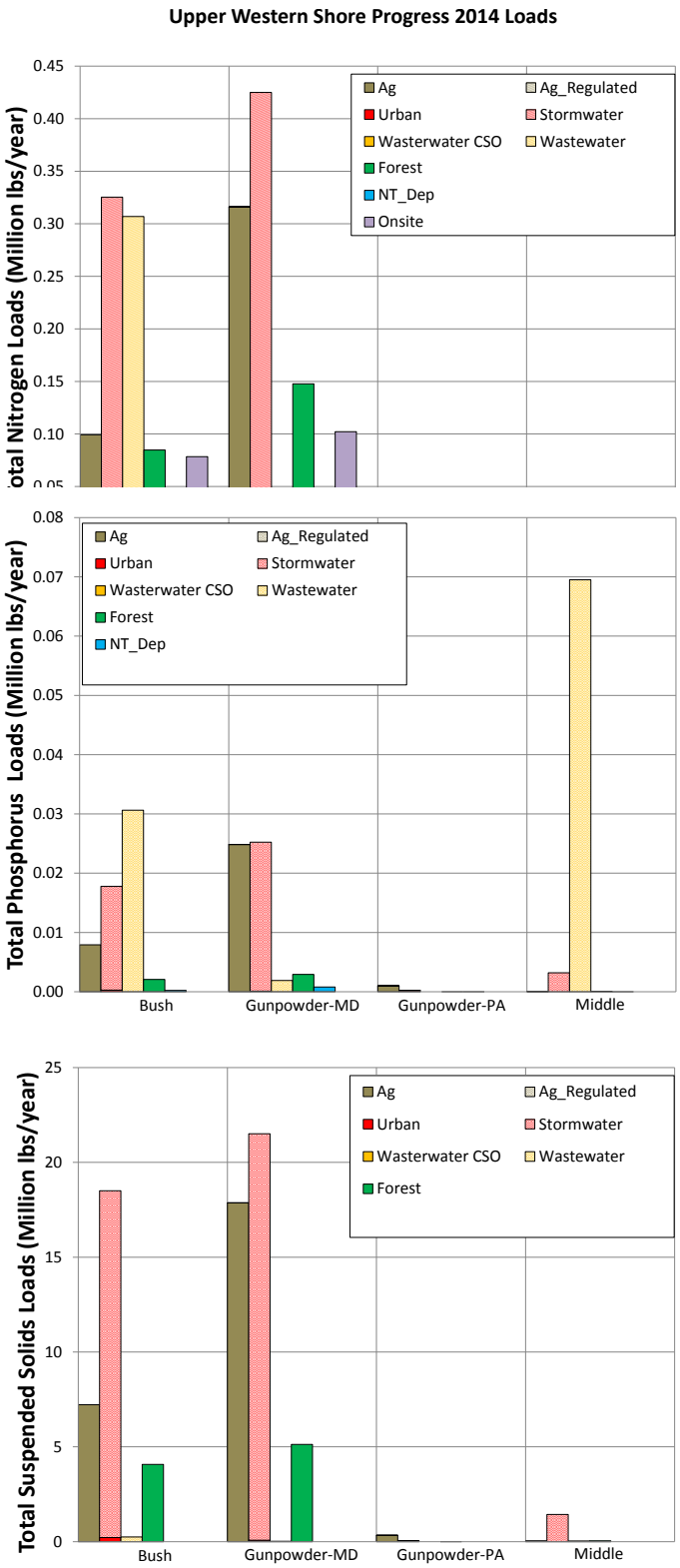

Figure 3. Nitrogen, phosphorus and sediment loads to Upper Western Shore rivers. Loads (in million lbs/year) are summarized by Chesapeake Bay Program model segment and by source category. Data for Progress 2014 model run downloaded on November 16, 2015 from http://baytas.chesapeakebay.net/. Source categories from BayTas website were renamed to conform to those used on the ChesapeakeStat website http://stat.chesapeakebay.net/?q=node/130&quicktabs_10=1 as follows: Agriculture = Ag; Agriculture_Regulated = Ag_Reg; Non Regulated Stormwater = Urban; Regulated Stormwater = Stormwater; WasteWater-CSO = CSO; PS = Wastewater; Forest = Forest; Non-Tidal Water Deposition = NT_Dep; Septic = Onsite.

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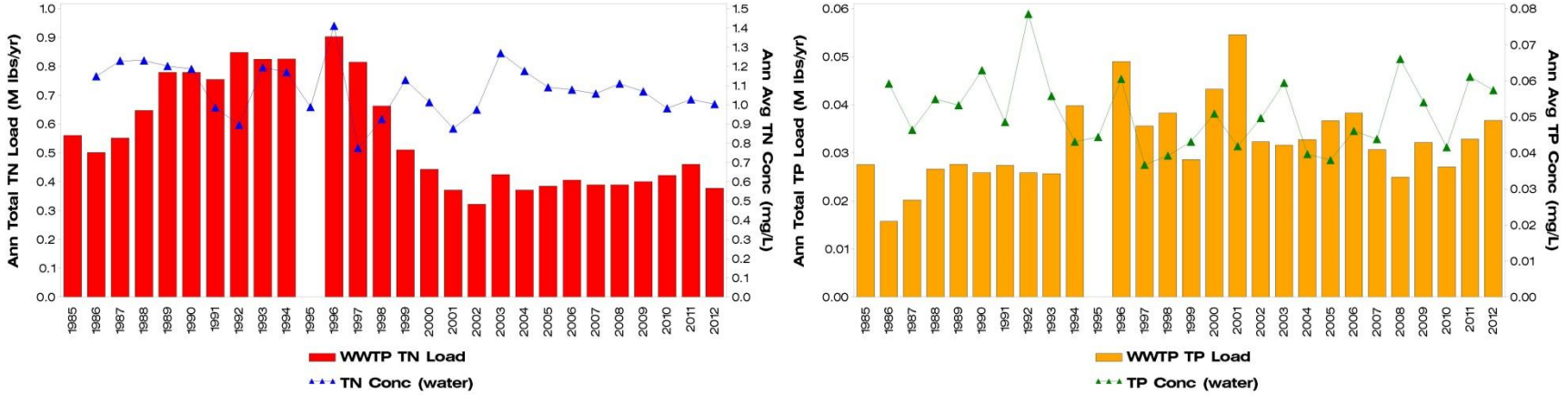
River	Segment	State	Source	TN Load (delivered)	% TN load	TP Load (delivered)	% TP load	Sed. Load (delivered)	% Sed. Load
Bush	BSHOH	MD	Ag	0.099	11.0%	0.0079	13.5%	7.22	**24.0%**
			Ag_Reg						
			Urban	0.002	0.2%	0.0003	0.4%	0.21	0.7%
			Stormwater	0.324	**36.1%**	0.0175	**29.9%**	18.29	**60.9%**
			CSO						
			Wastewater	0.307	**34.2%**	0.0306	**52.2%**	0.25	0.8%
			Forest	0.085	9.4%	0.0021	3.5%	4.07	13.5%
			NT_Dep	0.004	0.4%	0.0002	0.4%		
			Onsite	0.078	8.7%				
			Total Load	**0.898**		**0.0586**		**30.04**	
Gunpowder	GUNOH	MD	Ag	0.316	**31.1%**	0.0248	**44.6%**	17.86	**40.1%**
			Ag_Reg	0.000	0.0%	0.0000	0.0%	0.00	0.0%
			Urban	0.001	0.1%	0.0001	0.2%	0.07	0.2%
			Stormwater	0.424	**41.8%**	0.0251	**45.1%**	21.43	**48.1%**
			CSO		0.0%		0.0%		0.0%
			Wastewater	0.013	1.2%	0.0019	3.4%	0.02	0.0%
			Forest	0.148	14.5%	0.0029	5.2%	5.12	11.5%
			NT_Dep	0.013	1.2%	0.0008	1.4%		0.0%
			Onsite	0.102	10.1%		0.0%		0.0%
			Total Load	**1.016**		**0.0557**		**44.52**	
Gunpowder	GUNOH	PA	Ag	0.014	**75.3%**	0.0010	**82.6%**	0.33	**86.8%**
			Ag_Reg	0.000	0.1%	0.0000	0.4%	0.00	0.0%
			Urban	0.003	18.2%	0.0002	14.9%	0.04	11.6%
			Stormwater	0.000	0.3%	0.0000	0.8%	0.00	0.5%
			CSO		0.0%		0.0%		0.0%
			Wastewater		0.0%		0.0%		0.0%
			Forest	0.001	3.1%	0.0000	1.3%	0.00	1.1%
			NT_Dep	0.000	0.0%	0.0000	0.0%		0.0%
			Onsite	0.001	3.0%		0.0%		0.0%
			Total Load	**0.019**		**0.0012**		**0.38**	
Middle	MIDOH	MD	Ag	0.001	1.1%	0.0001	0.1%	0.02	1.3%
			Ag_Reg	0.000	0.0%	0.0000	0.0%	0.00	0.0%
			Urban		0.0%		0.0%		0.0%
			Stormwater	0.037	**79.8%**	0.0032	4.4%	1.43	**93.5%**
			CSO		0.0%		0.0%		0.0%
			Wastewater	0.000	0.0%	0.0695	**95.4%**	0.04	2.4%
			Forest	0.003	5.9%	0.0001	0.1%	0.04	2.8%
			NT_Dep	0.001	1.8%	0.0000	0.1%		0.0%
			Onsite	0.005	11.4%		0.0%		0.0%
			Total Load	**0.047**		**0.0728**		**1.54**	

Bush River



Gunpowder River

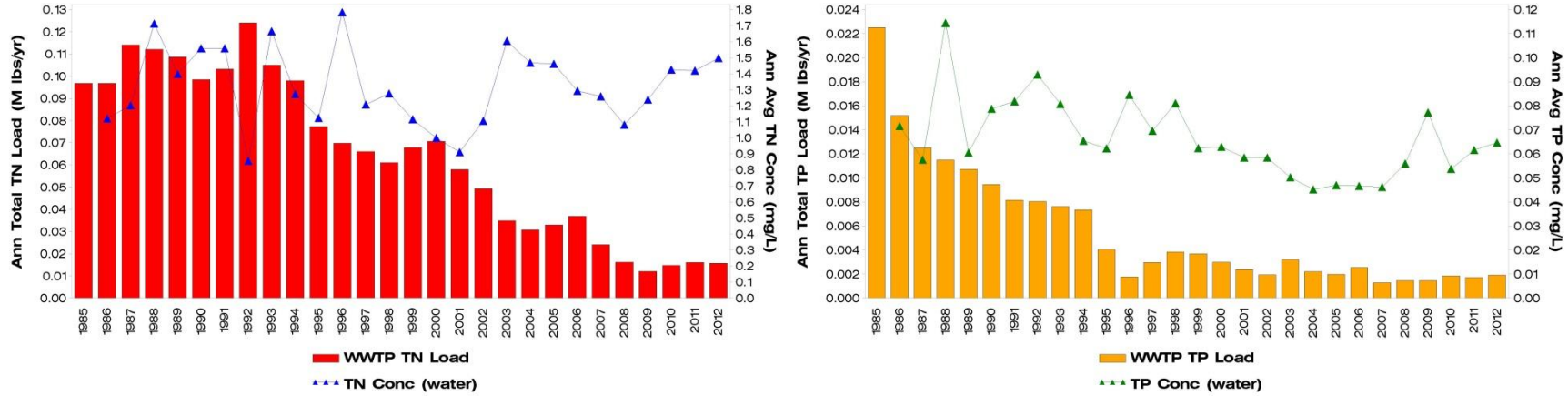


Figure 4. Total Wastewater Treatment Plant loads versus water quality. Summed total of loads from all major wastewater treatment plants (in million pounds per year, M lbs/yr) that discharge into the Bush River (top graphs) and Gunpowder River (bottom graphs) compared to annual mean nutrient concentrations (in mg/L) at the long-term monitoring site in each river. Total nitrogen loads (red bars) compared to total nitrogen concentrations (blue triangles) are shown in the left side graphs; total phosphorus (orange bars) compared to total phosphorus concentrations (green triangles) are shown in the right side graphs. Full calendar year loadings data is only available through 2012, and was downloaded from the Chesapeake Bay Program Nutrient Point Source Database website on 10/14/2015 (http://www.chesapeakebay.net/data/downloads/bay_program_nutrient_point_source_database). There are no major wastewater treatment plants on Middle River. Note that there was no loadings data for one of the three major wastewater treatment plants in the Bush River for 1995, so the total load could not be determined.