MODELED DEPOSITION IN THE CHESAPEAKE BAY REGION: CONEMAUGH, HOMER CITY, AND HARRISON

prepared for

Chesapeake Bay Foundation

prepared by

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INTRODUCTION

An air quality dispersion modeling exercise was conducted to estimate the long-term deposition of nitrogen, sulfur, fine particulate matter, and mercury due to emissions from the Conemaugh and Homer City Generating Stations, both located in Indiana County in Western Pennsylvania, and from the Harrison Power Station, located in Northern West Virginia. This modeling was conducted to provide important data and context for the EPA's review of Clean Air Act section 126(b) petitions filed by Maryland and Delaware. See 83 Fed. Reg. 26,666 (June 8, 2018).

To effectively control the hazards of mercury contamination in our waterways, it is essential to understand the pathways that transport mercury from emission sources to contaminated watersheds, or "sensitive receptors." A key element of this process is the transport of mercury through the atmosphere, whereby directly emitted mercury is mixed with and dispersed through the ambient air by meteorological processes until the material is either carried away or deposited to the surface. A dispersion modeling study was conducted to assess the amounts of airborne mercury deposited at sensitive receptors throughout the Chesapeake Bay Region that can be attributed to specific coal-fired power plants. Power plants are also significant sources of oxides of nitrogen (NO_X) and sulfur dioxide (SO_2), which contribute to acid rain and increased nitrogen loading of waterways. The emission and fate of these pollutants, as well as fine particulate matter (PM), were also tracked with the dispersion model.

The CALPUFF air quality dispersion model (v5.8.5) was used to account for the hourly emissions of NO_X, SO_2, H_2SO_4, fine PM, and mercury from each of the coal-fired power plants' units, and the subsequent transport through the atmosphere, including the chemical conversion of NO_X and SO_2 into nitric acid, nitrate and sulfate.[1] The model was used to estimate the total deposition of nitrogen, sulfur, fine PM, and mercury for an entire year at numerous receptors within the Chesapeake Bay Watershed.

The model considered three species of emitted mercury: gaseous elemental mercury (Hg(0)), reactive gaseous mercury (RGM), and particle-bound mercury (Hg(p)). The lifetime of elemental mercury in the atmosphere is very long (approximately one year), whereas oxidized forms of mercury (RGM and Hg(p)) have a lifetime of only a few days due to higher solubility and particle settling. Hg(0) can be transported over continental distances, whereas RGM and Hg(p) are typically deposited closer to their source. The modeled sources can emit varying proportions of the three mercury species due to differences in coal used, leading to variability in the relative amounts of deposited mercury near each source.

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[1] The CALPUFF modeling for the Conemaugh, Homer City, and Harrison power plants employed similar modeling procedures, CALPUFF modeling options, and POSTUTIL and CALPOST postprocessing procedures as was followed in previous CALPUFF modeling assessments. For details of the modeling protocol, see Appendix A of Gray, H.A., *Cypress Creek Power Plant Modeling: Pollutant Deposition to the Chesapeake Bay and Sensitive Watersheds within the Commonwealth of Virginia*, report prepared for the Chesapeake Bay Foundation (August 2009).

The dry deposition rates for gases and particles are computed within CALPUFF as a function of geophysical parameters and meteorological conditions using a multi-layer resistance model. The rate of deposition to the surface depends on properties of the depositing material (particle size and density for particles; molecular diffusivity, solubility and reactivity for gases), the characteristics of the surface (surface roughness, and vegetation), and atmospheric variables (stability, turbulence intensity). An empirical scavenging coefficient approach is used to compute wet deposition fluxes for gases and particles during precipitation. Pollutant depletion is a function of the hourly precipitation rate and an empirically-derived pollutant-specific scavenging coefficient, which is based on characteristics of the pollutant species (reactivity and solubility) and precipitation type (liquid or frozen).[2]

For each source modeled, the annual wet and dry deposition rates of nitrogen, sulfur, fine PM, and the three mercury species were estimated at each of 8096 locations (spaced every 9 km on a 88 x 92 gridded array) within the modeling domain shown in Figure 1. The CALPUFF inputs, options, and model results are described below.

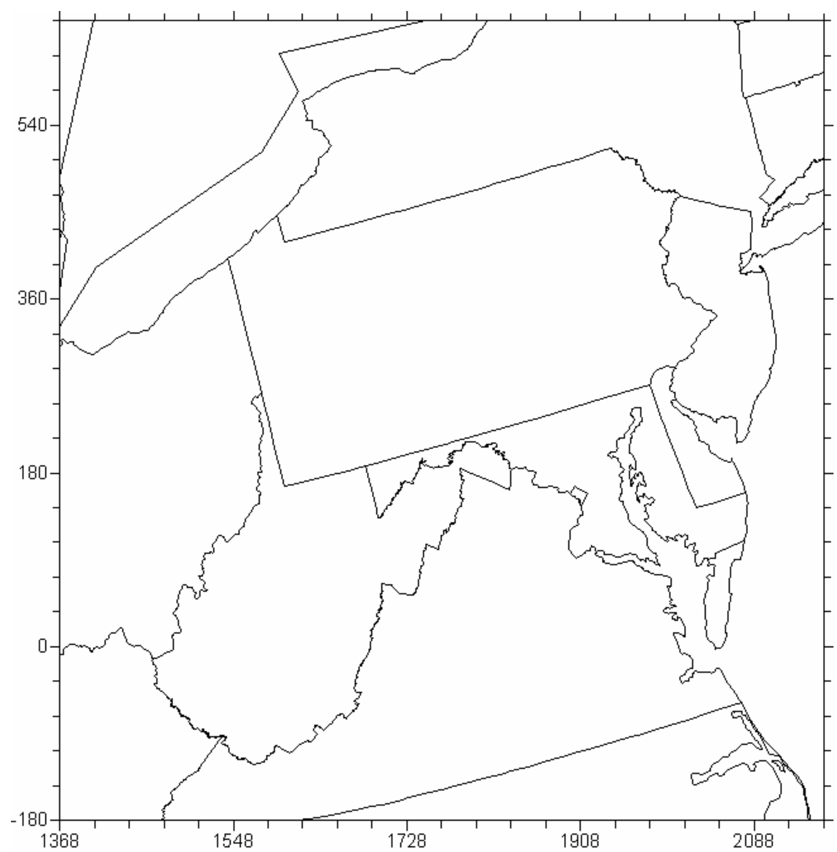

Figure 1. CALPUFF modeling domain

[2] For further details, see Scire, et al., *A User's Guide for the CALPUFF Dispersion Model (Version 5)*. Earth Tech, Inc., Concord, MA, 2000. http://src.com/calpuff/download/CALPUFF_UsersGuide.pdf

SOURCE AND EMISSIONS DATA

The CALPUFF model requires a number of stack parameters to be input to the model in order to properly locate the release of pollutant emissions, and to estimate the plume rise for each hour of the simulation. The stack parameters for the three modeled sources were obtained from various sources[3], and are shown in Table 1, below.

Table 1. Stack Parameters

Source	Base Elev. (m)	Stack Height (m)	Diameter (m)	Velocity (m/s)	Temperature (K)
Conemaugh Unit 1	332.2	160.0	8.53	21.3	324.3
Conemaugh Unit 2	332.2	160.0	8.53	21.3	324.3
Homer City Unit 1	365.8	243.8	7.32	26.0	427.6
Homer City Unit 2	365.8	243.8	7.32	26.0	427.6
Homer City Unit 3	365.8	260.3	8.23	19.1	324.8
Harrison Unit 1	298.0	305.1	7.92	16.8	338.7
Harrison Unit 2	298.0	305.1	7.92	16.8	338.7
Harrison Unit 3	298.0	305.1	7.92	16.8	338.7

Two different emission scenarios were modeled for each power plant. The first scenario assumed that each unit was operating at 85 percent of maximum capacity for each modeled hour. Emission rates were estimated by assuming that each unit operated at 85 percent of its full load, (MMBtu heat input), and then applying the appropriate emission factors (lb/MMBtu) for NO_X, SO_2, fine PM and mercury.

For the second scenario, each hour's emissions were set equal to the average hourly emission rate that occurred during 2016. Annual average emission rates of NO_X and SO_2 for 2016 were obtained from the US EPA's Clean Air Markets Database.[4] Mercury emissions data were obtained from the initial MATS Notice of Compliance Status (NOCS) documents submitted by the power plants to EPA. Fine PM emission data were obtained from a number of different sources.[5] Direct emissions of H_2SO_4 were assumed to be 1 percent of the SO_2 emissions rate (adjusted for molecular weight) for each modeled unit.

[3] For Conemaugh and Homer City, stack parameters were taken from each plant's Title V permit application. Stack parameters for Harrison were obtained from a response to a FOIA request by the state of West Virginia, and were cross-checked against 2017 RATA data. Base elevations were confirmed with Google Earth.

[4] https://ampd.epa.gov/ampd/

[5] For Conemaugh and Harrison, fine PM emissions data were from MATS Notice of Compliance Status (NOCS). A combination of 2014, 2015, 2016 RATA and the Title V permit application, along with the MATS NOCS, were used to construct the Homer City fine PM data.

Table 2 shows the modeled annual average emission rates of NO_X, SO_2, fine PM, and mercury for each modeled unit and for each emission scenario. The split between the three emitted mercury species, Hg(0):RGM:Hg(p), was assumed to be 84:14:2 percent for all three power plants.[6] Figure 2 shows the locations of the three modeled power plant sources.

Table 2. Modeled Emission Rates

Source	Modeled Emission Rate (lb/hr)			
	NO_X	**SO_2**	**Fine PM**	**Mercury**
SCENARIO 1: 85% CAPACITY				
Conemaugh Unit 1	1,803.87	496.05	20.55	0.00195
Conemaugh Unit 2	1,433.23	567.34	27.40	0.00231
Homer City Unit 1	1,634.39	1,159.73	4.97	0.00195
Homer City Unit 2	2,016.00	8,379.15	6.18	0.00306
Homer City Unit 3	1,772.37	1,558.47	50.00	0.00501
Harrison Unit 1	809.66	709.93	66.86	0.00233
Harrison Unit 2	1,296.75	899.80	66.86	0.00233
Harrison Unit 3	995.68	567.37	66.86	0.00233
SCENARIO 2: 2016 ACTUAL				
Conemaugh Unit 1	1,557.24	428.23	17.74	0.00168
Conemaugh Unit 2	1,021.42	404.33	19.53	0.00165
Homer City Unit 1	804.25	570.68	2.45	0.00096
Homer City Unit 2	804.26	3,342.77	2.46	0.00122
Homer City Unit 3	867.57	762.86	24.47	0.00245
Harrison Unit 1	829.31	727.16	68.48	0.00238
Harrison Unit 2	917.38	636.56	47.30	0.00165
Harrison Unit 3	1,029.08	586.40	69.10	0.00240

[6] The mercury speciation for the three modeled power plants was assumed based on the type of coal used (eastern bituminous) and the emission controls implemented as a result of the MATS rule (scrubbers).

Figure 2. Location of the modeled power plants within the CALPUFF modeling domain

RECEPTOR DATA

The CALPUFF simulation was conducted within the 792 km x 828 km rectangular modeling domain shown in Figures 1 and 2, above. The CALPUFF computational grid consisted of 8,096 (88 x 92) modeled receptor locations, spaced every 9 km within the modeling domain. Terrain (elevation) data and surface characteristics data (land-use data, necessary for meteorological data development) were prepared for the gridded modeling domain using the recommended CALPUFF preprocessors.[7]

[7] The preparation of the required geophysical data for use in the CALPUFF modeling is described in Appendix A of Gray, H.A., *Cypress Creek Power Plant Modeling: Pollutant Deposition to the Chesapeake Bay and Sensitive Watersheds within the Commonwealth of Virginia*, report prepared for the Chesapeake Bay Foundation (August 2009).

METEOROLOGICAL DATA

The meteorological data that were input to the CALPUFF dispersion model for modeling of the three coal-fired power plants were identical to the meteorological data that were developed for use in previous CALPUFF modeling assessments of numerous sources in the Chesapeake Bay area.[8] Detailed meteorological data for 1996 were obtained from the Penn State/NCAR Mesoscale Modeling System, Version 5 (MM5), a prognostic model with four-dimensional data assimilation. The 36 km MM5 data were augmented by ambient surface meteorological measurements, including wind speed and direction, temperature, and precipitation data. The resulting CALMET-derived data set for 1996 represents a typical annual cycle of meteorology and was used to estimate the long-term ambient concentration and deposition impacts due to emissions from each of the modeled power plants.[9]

OZONE DATA

The chemical mechanism within the CALPUFF model requires that hourly estimates of background ambient ozone concentration be input to the model.[10] Ozone data from 190 monitoring stations for 1996 were assembled for use in the current CALPUFF modeling application.[11]

MODEL RESULTS

The CALPUFF model was used to calculate both wet and dry deposition to the surface for the emissions from each of the sources listed in Table 2. The annual wet deposition (which occurs during precipitation) and the dry deposition were summed within each model grid cell. The gridded model results were then aggregated spatially to determine total annual deposition within various geographical areas (subsets of the entire modeling domain), including the Chesapeake Bay Watershed (Figure 3), the mainstem

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[8] See, for example, (1) Gray, H.A., *The Deposition of Airborne Mercury within the Chesapeake Bay Region from Coal-fired Power Plant Emissions in Pennsylvania* (March 2007), (2) Gray, H.A., *Deposition in the Chesapeake Bay Region* (February 2009), and (3) Gray, H.A., *Cypress Creek Power Plant Modeling: Pollutant Deposition to the Chesapeake Bay and Sensitive Watersheds within the Commonwealth of Virginia*, report prepared for the Chesapeake Bay Foundation (August 2009).

[9] A detailed description of the meteorological modeling can be found in Appendix A of Gray, H.A., *Cypress Creek Power Plant Modeling: Pollutant Deposition to the Chesapeake Bay and Sensitive Watersheds within the Commonwealth of Virginia*, report prepared for the Chesapeake Bay Foundation (August 2009).

[10] The MESOPUFF II chemical mechanism within CALPUFF uses ozone concentrations and solar radiation intensity as surrogates for the OH- radical concentration during the day when gas-phase free radical chemistry is active.

[11] The ozone data used for the current modeling application are described in Appendix A of Gray, H.A., *Cypress Creek Power Plant Modeling: Pollutant Deposition to the Chesapeake Bay and Sensitive Watersheds within the Commonwealth of Virginia*, report prepared for the Chesapeake Bay Foundation (August 2009).

of the Chesapeake Bay, Commonwealth of Pennsylvania, and a number of other sensitive watersheds.

Total nitrogen (N) deposition due to each modeled power plant was determined as the sum of the nitrogen present in the deposited NO_X, nitric acid, ammonium nitrate, and ammonium sulfate. Similarly, total sulfur (S) deposition due to each source was computed as the sum of sulfur present in the deposited SO_2 and ammonium sulfate. Total mercury (Hg) deposition was determined as the sum of the three emitted Hg species. Tables showing the modeled annual deposition of N, S, fine PM, and total Hg within a number of sensitive receptor areas for each modeled scenario (85% capacity, and 2016 actual emissions) are in Appendix A.

Deposition to the Chesapeake Bay Watershed

The Chesapeake Bay Watershed includes all the streams and tributaries that ultimately flow into the bay, including all the land area in which rainfall and snowmelt would channel (drain) into creeks, streams, and rivers, and eventually into the Chesapeake Bay. The watershed extends through six states (and D.C) from Virginia northward into New York, encompassing an area of approximately 170,000 km2, as shown in Figure 3 (shaded region). A number of major and secondary rivers empty into the Chesapeake Bay, including the James, York, Rappahannock, Potomac, Patuxent, and Patapsco to the west, the Gunpowder, Bush, Susquehanna, Northeast, Elk, and Sassafras to the north, and the Chester, Choptank, Nanticoke, Wicomico, and Pocomoke to the east.

The CALPUFF model was used to estimate the deposition of N, S, fine PM, and Hg within the Chesapeake Bay Watershed due to emissions from the Conemaugh power plant. Under the "2016 Actual' emissions scenario, the model estimated that the Conemaugh power plant was responsible for the deposition of approximately 397 metric tons of N, and about 287 metric tons of S within the watershed. The model results in Tables A1 and A2 indicate that about 13 percent of the emitted NO_X and about 17 percent of the emitted SO_2 from the Conemaugh power plant are ultimately deposited to the Chesapeake Bay Watershed.[12] Similarly, the model predicted that about 15 percent of the fine PM emitted from the Conemaugh power plant would be deposited in the Chesapeake Bay Watershed. Although significant proportions of the RGM (23 percent) and Hg(p) (16 percent) were deposited to the watershed, only about 1.2 percent of the Hg(0) was deposited. Hg(0) accounted for the majority (84 percent) of the total Hg emissions, and therefore less than 5 percent of the total Hg emitted from Conemaugh was deposited to the Chesapeake Bay Watershed, accounting for about 615 grams/yr of Hg deposition under the "2016 Actual" emissions scenario.

[12] Obtained by dividing the total deposition totals in Table A1 or Table A2 by the emission rates in Table 2, and correcting for molecular weights.

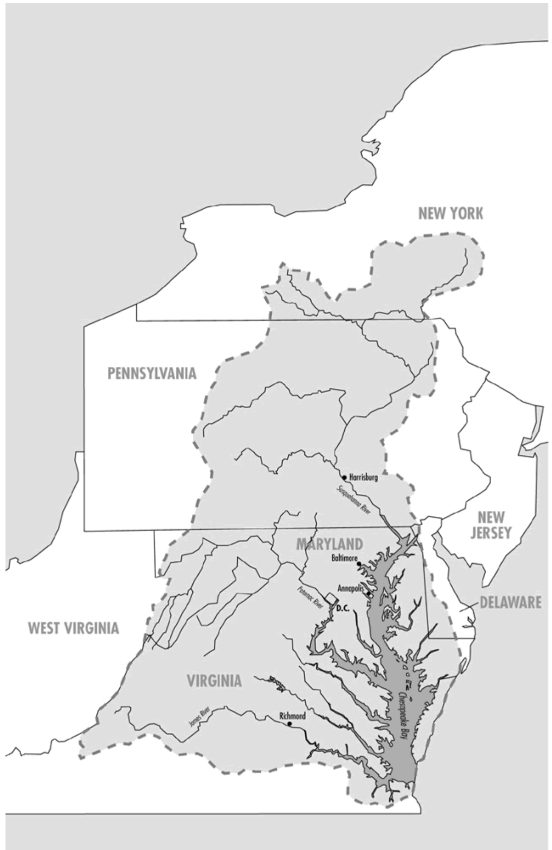

Figure 3. Chesapeake Bay Watershed

Under the "2016 Actual" emissions scenario, the CALPUFF model estimated that the Homer City power plant was responsible for depositing 412 metric tons of N, and 1,317 metric tons of S within the Chesapeake Bay Watershed. The model results in Tables A3 and A4 indicate that about 14 percent of the emitted NO_X and SO_2 from the Homer City power plant is ultimately deposited to the Chesapeake Bay Watershed. The CALPUFF model also predicted that about 13 percent of the fine PM emitted from the Homer City power plant would be deposited in the Chesapeake Bay Watershed. Although significant proportions of the RGM (19 percent) and Hg(p) (14 percent) were deposited to the watershed, less than one percent of the Hg(0) was deposited. Hg(0) accounted for 84 percent of the total Hg emissions, and therefore only about 4 percent of the total Hg emitted from Homer City was deposited to the Chesapeake Bay Watershed, accounting for 681 grams of Hg annually (under the "2016 Actual" emissions scenario).

The Harrison power plant was responsible for depositing 399 metric tons of N, and 542 metric tons of S within the Chesapeake Bay Watershed, under the "2016 Actual" emissions scenario. The model results in Tables A5 and A6 indicate that about 12 percent of the emitted NO_X and about 14 percent of the emitted SO_2 from the Harrison power plant are ultimately deposited within the Chesapeake Bay Watershed. The

CALPUFF model also predicted that about 13 percent of the fine PM emitted from the Harrison power plant would be deposited in the Chesapeake Bay Watershed. Although significant proportions of the RGM (18 percent) and Hg(p) (14 percent) were deposited to the watershed, less than one percent of the Hg(0) was deposited. Hg(0) accounted for 84 percent of the total Hg emissions, and therefore only about 3.5 percent of the total Hg emitted from Harrison was deposited to the Chesapeake Bay Watershed, accounting for about 895 grams/yr of Hg deposition (under the "2016 Actual" emissions scenario).

Deposition to the Chesapeake Bay

The Chesapeake Bay is the largest estuary in the United States, with an approximate area of 11,600 km^2, as shown in Figure 4. The bay and its shoreline (total shoreline: 18,800 km) are home to a diverse ecosystem of vegetation, fish, and other wildlife. The bay is quite shallow in many places; about one quarter of the area of the bay is less than 2m in depth.

Figure 4. Chesapeake Bay

The CALPUFF model was used to estimate the amount of airborne nitrogen, sulfur, fine PM, and mercury that was directly deposited to the surface waters of the Chesapeake Bay (including the mainstem of the bay and the inlet/mouth of the major rivers) due to emissions from each of the modeled power plants. The results are shown in the "Chesapeake Bay" row in the Appendix A tables. Under the "2016 Actual" emissions scenario, the model estimated that emissions from Conemaugh would be responsible for 7,546 kg/yr of N deposition, 6,883 kg/yr of S deposition, and 13 gram/yr of Hg deposition directly into the Chesapeake Bay. The model also predicted, for the same emissions scenario, that the Homer City power plant would account for 9,916 kg of N deposition, 334,267 kg of S deposition, and 16 grams of Hg deposition directly into the Chesapeake Bay annually. Similarly, the model estimated that, under the "2016 Actual" emissions scenario, emissions from Harrison would account for 8,666 kg of N deposition, 13.554 kg of S deposition, and 21 grams of Hg deposition to the surface of Chesapeake Bay annually.

Deposition within each State

The model results were used to estimate the amount of sulfur, nitrogen, fine PM, and mercury that would be deposited within the borders of the entire state of Maryland (modeled area: 31,124 km^2), within the Commonwealth of Virginia's borders (modeled area: 100,861 km^2, accounting for almost the entire state), and deposited to the surface of the entire Commonwealth of Pennsylvania (total area: 117,347 km^2, not including Lake Erie). The estimated annual deposition rates appear in the third through fifth rows of the Appendix A tables. For example, the model results indicate that, under the "2016 Actual" emissions scenario, Conemaugh would be responsible for over 45 metric tons of N deposition and about 75 grams of total Hg deposition annually within the borders of Maryland. Emissions from Homer City would account for almost 49 metric tons of N deposition and 84 grams of total Hg deposition per year within Maryland. Harrison would contribute over 62 metric tons of N deposition and 147 grams of Hg deposition within Maryland each year.

Deposition to Sensitive Watersheds: Virginia

The model results were used to estimate the annual rates of deposition within a number of sensitive watersheds located in Virginia, Pennsylvania, and West Virginia. Many of these sensitive watersheds are described below. Model results, showing the estimated annual deposition rates of N, S, fine PM, and Hg due to each modeled source, for each emission scenario, can be found in Appendix A

Pamunkey River Basin. The Pamunkey River is a tributary of the York River. The Pamunkey River drains the North Anna, South Anna and Little Rivers in Louisa and Hanover Counties, flowing past the Pamunkey Indian Reservation to the town of West

Point, where it meets the Mattaponi River to form the York River. The total area of the Pamunkey River Basin is 3,818 km2, or about 4 percent of Virginia. The Pamunkey River Basin represents about 2 percent of the total Chesapeake Bay Watershed.

Dragon Run Watershed. The Dragon Run is a forty-mile stream, located at the headwaters of the Piankatank River, characterized by extensive non-tidal and tidal cypress swamp. The stream, along with the surrounding Dragon Run Swamp, is almost entirely undeveloped and is recognized by the Smithsonian Institute as Virginia's most pristine water body to empty into the Chesapeake Bay. The Dragon Run Watershed consists of 363 km^2, of which 10 percent are wetlands.

Figure 5. Dragon Run

Great Dismal Swamp. The Great Dismal Swamp National Wildlife Refuge (NWR) is a largely inaccessible marshy region located in southeastern Virginia and northeastern North Carolina. The refuge consists of 444 km^2 of forested wetlands, including the Dismal Swamp Canal and Lake Drummond, a 13 km^2 lake located in the heart of the swamp (the largest of only two natural freshwater lakes in Virginia). The waters of Lake Drummond and the Great Dismal Swamp naturally flow southward into North Carolina, emptying into the Pasquotank River and Albemarle Sound. However, the Feeder Ditch and the Dismal Swamp Canal connect the lake (and Albemarle Sound) with the Elizabeth River which empties into the Chesapeake Bay, via the Deep Creek Locks, to the north.

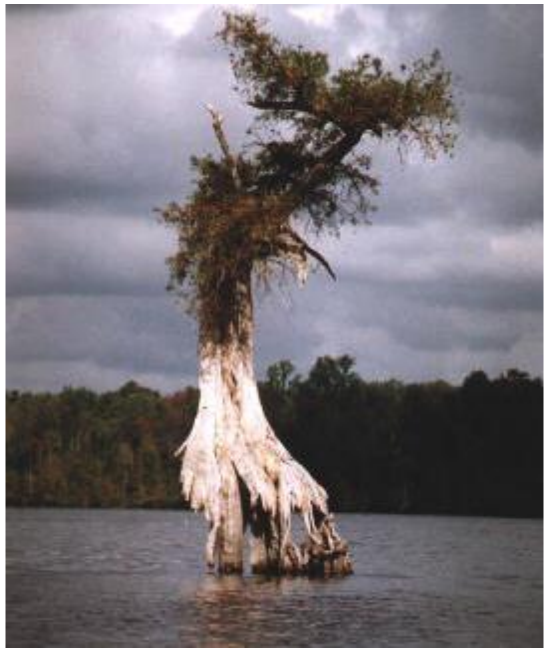

Figure 6. Lake Drummond, Great Dismal Swamp NWR

Deposition to Sensitive Watersheds: Pennsylvania

Precipitation in Pennsylvania drains to the north Atlantic via one of four main pathways. Stream and rivers in the eastern part of the state flow to the ocean via the Delaware River. The Susquehanna River Basin, along with the Potomac River (and Elk, Northeast and Gunpowder Rivers), drain almost half of the Commonwealth's area to the Chesapeake Bay. The Ohio River Basin drains the western third of the Commonwealth, ultimately reaching the Gulf of Mexico. Small areas of northern Pennsylvania drain to the Great Lakes (via Lake Erie and the Genessee River). The major drainage basins in Pennsylvania are shown in different colors on the map in Figure 7.

The Pennsylvania DEP has divided the major drainage basins into twenty sub-basins, each of which contains from one to eleven watersheds. The 104 resulting watersheds are also shown in Figure 7. Three of these watersheds have been selected for determination of the deposition impacts due to emissions from the modeled power plant sources.

Many waterways in the Chesapeake Bay region have been found to be contaminated with mercury. In 2005, Pennsylvania issued fish consumption advisories for mercury in 80 waterways throughout the Commonwealth due to measured unhealthful levels of mercury. These contaminated waterways include the Black Moshannon State Park Lake in Centre Co. (fish tissue concentration measured between 0.48 – 0.97 ppm, wet weight), the Tioga and Cowanesque Rivers and both the Cowanesque and Hammond Reservoirs in Tioga Co. (0.32 - .97 ppm), and the Beaver Run Reservoir in

Westmoreland Co. (0.32 – 0.48 ppm). Results of the CALPUFF dispersion model were used to estimate the deposition of mercury (and sulfur, nitrogen and fine PM) to each of these three “sensitive receptors,” consisting of the watersheds surrounding the contaminated waterways. The locations of these three watersheds are identified in lighter colors in Figure 7.

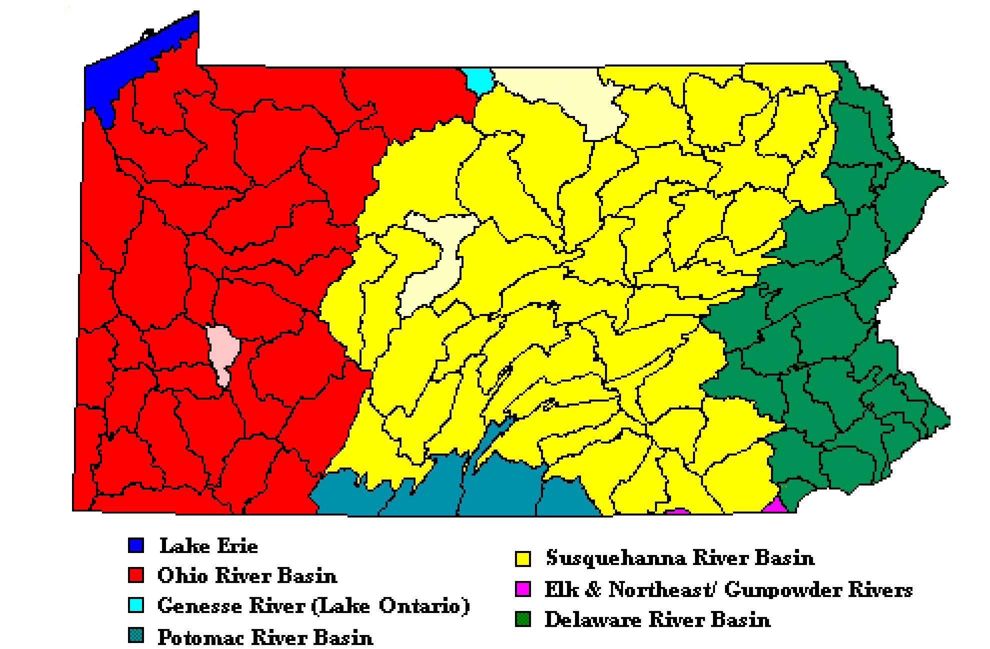

Figure 7. Pennsylvania’s Major Drainage Basins and Watersheds.

Moshannon – Mosquito Creeks Watershed. The Upper West Branch of the Susquehanna River flows through north-central Pennsylvania, creating sub-basin Number 08, as shown in Figure 8a. Watershed 08D (Figure 8b), consists of the 484 square mile combined drainage areas for Moshannon Creek (flowing into the Susquehanna from the south) and Mosquito Creek (located to the north of the Susquehanna).

Situated on the top of the Allegheny Plateau in Centre County, the Black Moshannon State Park features the Black Moshannon Bog Natural Area. The park, covering 3,394 acres of forests and wetlands, contains unique, natural environments and provides recreational opportunities for thousands of visitors. More than 43,000 acres of the Moshannon State Forest surround the park, adding to the remote and wilderness setting. The 250-acre Black Moshannon Lake is fed by clear springs and small streams which flow through the bogs (darkening the water) that stretch in most directions from its shores.

The Mosquito Creek watershed is located in Clearfield and Elk Counties, adjacent to the Moshannon Creek watershed. The watershed consists of largely undeveloped, forested public lands traversed by forest roads and hiking trails. The watershed was once known for its abundance of naturally reproducing wild brook and brown trout. However, since the early 1960's, the creek's water quality has become more acidic, causing wild brook trout to become scarce and wild brown trout to virtually disappear.

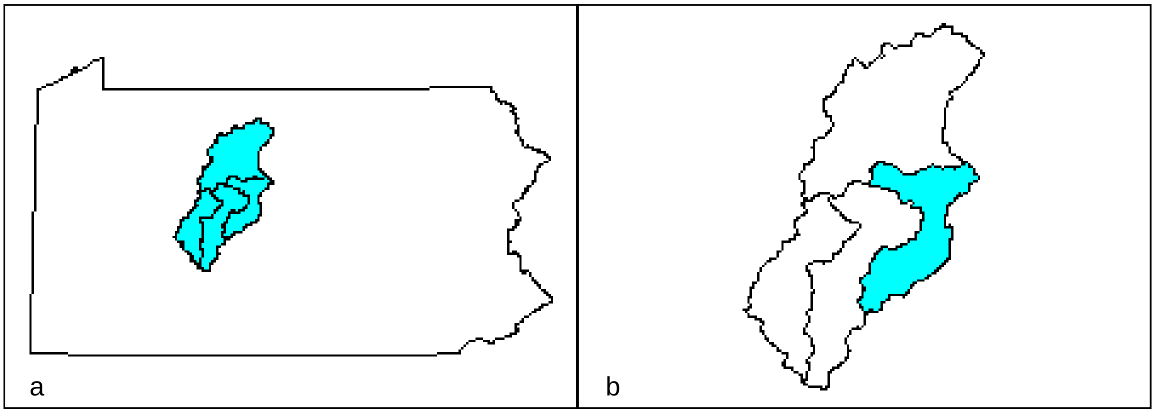

Figure 8. (a) Sub-basin Number 08: Upper West Branch Susquehanna;

(b) Watershed 08D: Moshannon – Mosquito Creeks Watershed

Figure 9. Black Moshannon Lake

Tioga – Cowanesque Rivers Watershed. The headwaters of the Tioga River are in the mountains of western Bradford County, where the river flows southwest into Tioga County, passing through the Tioga State Forest before turning northward towards

Steuben County, New York. The Tioga River drains a region of ridges in the northern Allegheny Plateau of the Susquehanna River, collecting the waters of Mill Creek from the east then Crooked Creek from the west at the town of Tioga, where adjoining dams have created the Hammond Lake and Tioga Reservoir. The Cowanesque River flows into the Tioga just north of the New York state line. Further north, the Tioga joins the Cohocton River to become the Chemung, a tributary of the Susquehanna.

Watershed 04A, the Tioga – Cowanesque Rivers Watershed, with a total drainage area of 676 square miles in Pennsylvania (figure 10b), is part of the Upper Susquehanna River Sub-basin (Figure 10a). The heavily forested watershed is popular as a wilderness destination, offering recreational opportunities including camping, fishing, hunting, bird watching, boating, and hiking. Despite the fact that this watershed is far removed from large coal-fired power plants, it still has received enough mercury to have fish advisories issued for many of its waterways, including the 1,090 acre Cowanesque Lake.

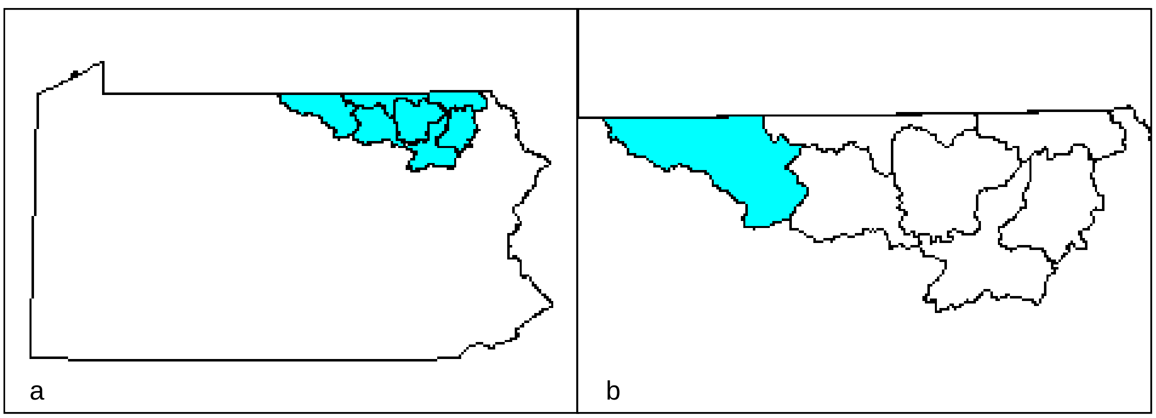

Figure 10. (a) Sub-basin Number 04: Upper Susquehanna;

(b) Watershed 04A: Tioga – Cowanesque Rivers Watershed

Figure 11. Tioga River

Kiskiminetas River Watershed. Within the Lower Allegheny Sub-basin (Number 18, Figure 12a), the Kiskiminetas River drains the three eastern watersheds (total area: 1,723 sq. mi) of the sub-basin, transporting the waters of the Conemaugh and Stonycreek Rivers, and the Loyalhanna, Blacklegs, Two Lick, and Blacklick Creeks to the Allegheny River about 40 km northwest of Pittsburgh. Along the way, the Kiskiminetas River passes through the 164 square mile Watershed Number 18C, known as the Kiskiminetas River Watershed (Figure 12b), where it further collects local creeks and streams, such as Beaver Run. While traversing the watershed, the Kiskiminetas River creates the boundary between Westmoreland County (to the south) and Armstrong County (to the north).

The 4½ mile long Beaver Run Reservoir, located in northwestern Westmoreland County, is owned and operated by the Westmoreland County Municipal Authority. Boating and fishing are currently not allowed in the reservoir; however the area has become popular in recent years as a bird watching sanctuary, with avocet present and nesting bald eagles also being spotted. The reservoir empties into Beaver Run which then flows northward to the Kiskiminetas River.

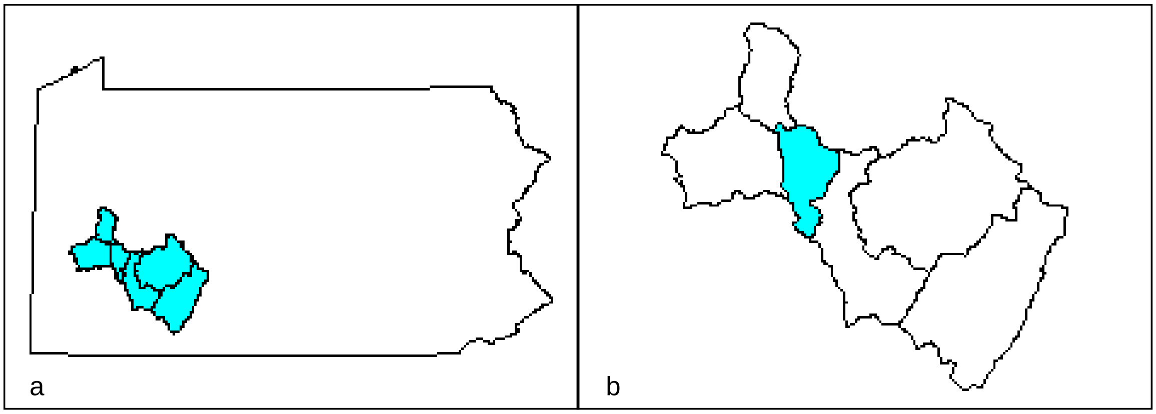

Figure 12. (a) Sub-basin Number 18: Lower Allegeheny;

(b) Watershed 18B: Kiskiminetas River Watershed

Figure 13. Beaver Run, Westmoreland County

Deposition to Other Watersheds

A number of additional watersheds have been added to the modeling analysis. Results for each watershed (estimated annual deposition of N, S fine PM, and Hg due to each modeled source) are tabulated in Appendix A. The following watersheds have been added: In Virginia: Roanoke River, N. Fork Holston River, Blackwater River, Nottoway River, James River, Chester River, Patuxent River, Shenandoah National Park. In Pennsylvania: Conewago Creek. In West Virginia: Mill Creek.

APPENDIX A

CALPUFF MODEL RESULTS

Table A1. Total Annual Deposition (kg/yr): Conemaugh @ 85% Capacity

Receptor Area	SULFUR	NITROGEN	MERCURY	PMF
Chesapeake Bay Watershed	366,040	497,980	0.77665	28,126
Chesapeake Bay	8,791	9,532	0.01682	568
Maryland	43,854	57,884	0.09456	2,933
Virginia	70,434	97,786	0.14682	4,777
Pennsylvania	468,280	615,830	1.01570	38,076
Pamunkey River	4,514.9	6,235.6	0.00952	296.0
Dragon Run	274.1	364.9	0.00060	18.3
Great Dismal Swamp	165.9	216.5	0.00036	10.2
Moshannon-Mosquito Creeks	8,468.4	11,339.0	0.01753	807.9
Tioga-Cowanesque Rivers	4,859.2	7,218.8	0.00939	485.8
Kiskiminetas River	1,791.3	2,137.3	0.00374	171.3
Roanoke River	7,111.0	11,223.0	0.01451	615.6
N. Fork Holston River	49.1	67.3	0.00012	2.8
Blackwater River	1,008.5	1,307.8	0.00223	56.6
Nottoway River	2,835.6	3,887.3	0.00619	161.9
James River	18,671.0	27,473.0	0.03806	1,375.6
Chester River	1,133.0	1,515.7	0.00239	89.9
Patuxent River	2,603.3	3,507.6	0.00564	164.5
Conewago Creek	201.0	289.3	0.00043	13.6
Shenandoah NP	1,288.0	1,941.8	0.00277	82.5
Mill Creek	277.9	391.9	0.00056	15.4
Max Dep Rate (kg/ha-yr)	1.471	1.662	3.36E-06	0.139

Table A2. Total Annual Deposition (kg/yr): Conemaugh @ Actual 2016 Emissions

Receptor Area	SULFUR	NITROGEN	MERCURY	PMF
Chesapeake Bay Watershed	286,580	393,590	0.61514	21,861
Chesapeake Bay	6,883	7,546	0.01331	441
Maryland	34,334	45,782	0.07485	2,280
Virginia	55,144	77,317	0.11616	3,713
Pennsylvania	366,630	487,240	0.80495	29,596
Pamunkey River	3,534.8	4,931.1	0.00754	230.1
Dragon Run	214.6	289.0	0.00048	14.2
Great Dismal Swamp	129.9	171.4	0.00028	7.9
Moshannon-Mosquito Creeks	6,630.1	8,950.2	0.01390	627.9
Tioga-Cowanesque Rivers	3,804.4	5,699.1	0.00744	377.6
Kiskiminetas River	1,402.5	1,688.8	0.00297	133.1
Roanoke River	5,567.4	8,863.5	0.01148	478.5
N. Fork Holston River	38.4	53.2	0.00010	2.1
Blackwater River	789.6	1,035.3	0.00177	44.0
Nottoway River	2,220.1	3,075.8	0.00490	125.9
James River	14,618.0	21,724.0	0.03011	1,069.2
Chester River	887.0	1,200.0	0.00189	69.9
Patuxent River	2,038.2	2,774.3	0.00446	127.9
Conewago Creek	157.3	228.5	0.00034	10.5
Shenandoah NP	1,008.4	1,536.1	0.00219	64.1
Mill Creek	217.6	310.5	0.00045	12.0
Max Dep Rate (kg/ha-yr)	1.152	1.322	2.67E-06	0.108

Table A3. Total Annual Deposition (kg/yr): Homer City @ 85% Capacity

Receptor Area	SULFUR	NITROGEN	MERCURY	PMF
Chesapeake Bay Watershed	3,121,100	944,930	1.48210	31,898
Chesapeake Bay	81,303	22,735	0.03570	638
Maryland	374,170	111,930	0.18327	3,152
Virginia	639,220	207,740	0.30485	5,264
Pennsylvania	3,900,000	1,050,800	1.89730	47,860
Pamunkey River	38,701.0	12,297.0	0.01874	295.5
Dragon Run	2,573.3	808.6	0.00129	22.2
Great Dismal Swamp	1,673.7	481.9	0.00084	10.6
Moshannon-Mosquito Creeks	84,783.0	23,691.0	0.03989	1,246.5
Tioga-Cowanesque Rivers	52,018.0	18,668.0	0.02244	653.9
Kiskiminetas River	22,763.0	5,079.6	0.01106	352.1
Roanoke River	67,875.0	26,845.0	0.03220	705.6
N. Fork Holston River	605.8	214.6	0.00033	3.4
Blackwater River	9,613.5	2,870.5	0.00483	59.5
Nottoway River	26,501.0	8,688.3	0.01321	192.4
James River	171,590.0	59,789.0	0.08067	1,479.1
Chester River	9,495.0	3,118.7	0.00469	86.5
Patuxent River	22,711.0	7,109.7	0.01124	173.8
Conewago Creek	1,774.6	590.8	0.00088	14.8
Shenandoah NP	10,783.0	3,503.2	0.00529	88.3
Mill Creek	2,515.9	740.8	0.00117	15.3
Max Dep Rate (kg/ha-yr)	12.431	1.094	7.35E-06	0.376

Table A4. Total Annual Deposition (kg/yr): Homer City @ Actual 2016 Emissions

Receptor Area	SULFUR	NITROGEN	MERCURY	PMF
Chesapeake Bay Watershed	1,316,500	411,900	0.68067	15,326
Chesapeake Bay	34,267	9,916	0.01638	306
Maryland	157,810	48,925	0.08418	1,515
Virginia	269,560	90,727	0.13999	2,530
Pennsylvania	1,646,400	459,120	0.87189	22,996
Pamunkey River	16,320.0	5,380.7	0.00861	142.0
Dragon Run	1,085.0	354.6	0.00059	10.7
Great Dismal Swamp	705.0	211.0	0.00038	5.1
Moshannon-Mosquito Creeks	35,788.0	10,310.0	0.01833	599.1
Tioga-Cowanesque Rivers	21,922.0	8,079.3	0.01029	314.0
Kiskiminetas River	9,630.7	2,227.4	0.00509	169.4
Roanoke River	28,636.0	11,677.0	0.01480	339.5
N. Fork Holston River	254.8	93.1	0.00015	1.6
Blackwater River	4,050.4	1,257.0	0.00222	28.6
Nottoway River	11,173.0	3,802.5	0.00607	92.5
James River	72,362.0	26,114.0	0.03704	711.3
Chester River	4,008.0	1,362.7	0.00216	41.6
Patuxent River	9,576.7	3,104.4	0.00516	83.5
Conewago Creek	748.5	257.3	0.00040	7.1
Shenandoah NP	4,550.0	1,534.3	0.00243	42.4
Mill Creek	1,063.9	327.8	0.00054	7.4
Max Dep Rate (kg/ha-yr)	5.248	0.489	3.36E-06	0.180

Table A5. Total Annual Deposition (kg/yr): Harrison @ 85% Capacity

Receptor Area	SULFUR	NITROGEN	MERCURY	PMF
Chesapeake Bay Watershed	605,310	447,950	0.98062	105,490
Chesapeake Bay	15,121	9,717	0.02302	2,079
Maryland	99,219	69,738	0.16141	15,624
Virginia	253,120	179,060	0.42177	37,614
Pennsylvania	495,080	350,800	0.79285	98,298
Pamunkey River	12,537.0	8,681.2	0.02163	1,781.3
Dragon Run	692.8	470.8	0.00121	93.1
Great Dismal Swamp	492.6	330.7	0.00078	65.9
Moshannon-Mosquito Creeks	5,584.1	4,081.8	0.00848	1,110.3
Tioga-Cowanesque Rivers	4,883.8	4,170.1	0.00744	1,097.6
Kiskiminetas River	2,133.5	1,322.6	0.00353	516.8
Roanoke River	28,094.0	20,935.0	0.04611	3,615.4
N. Fork Holston River	503.4	281.7	0.00093	35.5
Blackwater River	2,867.5	2,059.4	0.00484	399.3
Nottoway River	7,867.0	5,450.0	0.01374	960.2
James River	73,740.0	52,336.0	0.12656	9,846.4
Chester River	1,440.2	1,060.1	0.00237	223.1
Patuxent River	4,053.5	3,028.2	0.00654	591.5
Conewago Creek	389.5	330.6	0.00061	74.6
Shenandoah NP	5,339.5	3,779.7	0.00893	852.1
Mill Creek	2,178.1	1,486.0	0.00389	381.2
Max Dep Rate (kg/ha-yr)	2.309	0.881	4.31E-06	0.930

Table A6. Total Annual Deposition (kg/yr): Harrison @ Actual 2016 Emissions

Receptor Area	SULFUR	NITROGEN	MERCURY	PMF
Chesapeake Bay Watershed	542,200	399,270	0.89497	97,229
Chesapeake Bay	13,544	8,666	0.02102	1,916
Maryland	88,875	62,154	0.14731	14,402
Virginia	226,730	159,580	0.38506	34,670
Pennsylvania	443,470	312,720	0.72330	90,604
Pamunkey River	11,230.0	7,741.5	0.01975	1,641.9
Dragon Run	620.6	419.9	0.00111	85.8
Great Dismal Swamp	441.2	295.0	0.00071	60.7
Moshannon-Mosquito Creeks	5,001.9	3,640.0	0.00774	1,023.4
Tioga-Cowanesque Rivers	4,374.5	3,719.3	0.00679	1,011.6
Kiskiminetas River	1,911.1	1,179.6	0.00322	476.4
Roanoke River	25,165.0	18,663.0	0.04212	3,332.3
N. Fork Holston River	450.9	250.6	0.00085	32.7
Blackwater River	2,568.5	1,836.8	0.00442	368.1
Nottoway River	7,046.8	4,860.9	0.01255	885.0
James River	66,052.0	46,649.0	0.11556	9,075.8
Chester River	1,290.0	945.3	0.00217	205.7
Patuxent River	3,630.9	2,699.5	0.00598	545.2
Conewago Creek	348.9	294.6	0.00055	68.8
Shenandoah NP	4,782.9	3,368.0	0.00815	785.4
Mill Creek	1,951.0	1,323.8	0.00355	351.4
Max Dep Rate (kg/ha-yr)	2.068	0.807	3.93E-06	0.857