Ohio River Valley Water Sanitation Commission

Ohio River Basin Mercury Loading Analysis

June 2020

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Acronyms and Abbreviations

ADCP	Acoustic Doppler Current Profiler
AL	Alabama
AMLE	Adjusted Maximum Likelihood Estimation
AMNet	Atmospheric Mercury Network
BAF	Bioaccumulation Factor
BCCs	Bioaccumulative Chemicals of Concern
DL	Detection Limit
DMR	Discharge Monitoring Report

ECHO	Enforcement & Compliance History Online
EPA	Environmental Protection Agency
GEM	Gaseous elemental mercury
GIS	Geographic Information System
GOM	Gaseous oxidized mercury
GA	Georgia
Hg	Mercury
ICIS	Integrated Compliance Information System
ID	Identification
IDW	Inverse-Distance Weighting algorithm
IL	Illinois
IN	Indiana
Km	Kilometers
Km^2	Square kilometers
lbs	Pounds
L&D	Lock and Dam
MD	Maryland
MDN	Mercury Deposition Network
MeHg	Methylmercury
mm	Millimeters
MO	Missouri
ng/L	Nanograms per liter
NADP	National Atmospheric Deposition Program
No.	Number
NPDES	National Pollutant Discharge Elimination System
NWS	National Weather Service
OH	Ohio
OR	Ohio River
ORB	Ohio River Basin
ORM	Ohio River Mile point
ORSANCO	Ohio River Valley Water Sanitation Commission
PBM	Particulate-Bound Mercury
PA	Pennsylvania
SIC	Standard Industrial Classification
TN	Tennessee
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WV	West Virginia
µg/m2/yr	Microgram per square meter per year
%	Percentage
I	Integer
lnQ	ln(streamflow)-center of ln(streamflow)
dtime	decimal time – center of decimal time
per	period, 1 or 0 depending on defined period

EXECUTIVE SUMMARY

Mercury (Hg) in the environment poses human health and ecological concerns. Methylated forms of mercury bioaccumulate up through the food chain and various forms are found commonly in Ohio River water, sediment, and fish. Mercury is a ubiquitous contaminant which is transported globally through the atmosphere from both anthropogenic and natural sources. It is recognized that local atmospheric sources may also be significant. Every state in the U.S. has issued fish consumption advisories to the public due to levels found in fish tissue.

In 2015, in response to public concern about mercury levels in Ohio River water and fish, the Ohio River Valley Water Sanitation Commission (ORSANCO) established an Ad-Hoc committee on mercury studies to determine what information would be needed to further address this contaminant. The Ad-Hoc committee determined that a basin-wide source apportionment study was a top priority to understand mercury contributions to the Ohio River. Since atmospheric deposition of mercury (from both global and local sources) has been identified as a source of watershed contamination, the Commission's source apportionment study was to focus on the possible relative contributions of mercury loading to the Ohio River from atmospheric deposition and point source discharges.

The main study objectives were (1) to develop mercury loadings to the Ohio River from point sources and atmospheric deposition for the one year study period, and (2) evaluate those loadings relative to instream mercury loadings in the Ohio River Basin for the one year study period. The study period in which loadings were evaluated was from November 1, 2015 through October 31, 2016. All mercury loads are for total mercury, not methylmercury. ORSANCO conducted monthly water quality monitoring at four Ohio River main stem stations and 15 major tributaries for one year. The data were used to estimate instream mercury loads at each of these river stations for the project period. Mercury loads for point sources were calculated using NPDES discharge monitoring report data for the study period. Data from the National Atmospheric Deposition Network were used in a GIS framework to estimate wet and dry atmospheric mercury deposition within the 15 major tributaries and five smaller, Ohio River local watersheds, comprising the entire Ohio River Basin.

This report approximates instream mercury loads, point source mercury loads, atmospheric mercury deposition (wet and dry forms), and an overall mercury loading analysis for the basin for the one year project period. Overall mass contributions of mercury from the Ohio River Basin were evaluated at ORM 912 (ORM 912 is the most downstream Ohio River station and references Ohio River mile point 912). The main conclusions from the report are as follows:

ATMOSPHERIC DEPOSITION

- It was estimated about 25,000 pounds of mercury from atmospheric deposition to the Ohio River basin occurred during the one year study period.

- It was estimated about 17,000 pounds of mercury from atmospheric deposition to the Ohio River basin above Ohio River mile point (ORM) 912 occurred during the one year study period.
- How much of this atmospheric deposition of mercury reached the Ohio River main stem or its tributaries during the study period was unknown.
- The quantity of atmospheric deposition of mercury to the watershed was about 6 times the instream load at ORM 912.

INSTREAM LOAD

- The estimated instream mercury load at ORM 912 was estimated to be 2,961 pounds for the one year study period. This load represents contributions from all sources, including atmospheric deposition, point sources, and non-point sources.
- Mercury loads from the 13 major tributaries upstream of ORM 912 account for about half (1,461 pounds) of the mercury load at ORM 912 (2,961 pounds) for the one year study period.

POINT SOURCE LOAD

- Mercury loads from monitored point sources was 63 pounds. This represents about 2 percent of the total mercury load (2,961 pounds) to the Ohio River at ORM 912. Note that each state has different monitoring requirements for point sources depending on that state's NPDES implementation procedures.
- Monitored Ohio River outfalls discharging directly to the main stem accounted for about 40 percent (25 pounds) of the estimated total point source load (63 pounds) at ORM 912.
- Since all point sources were not monitored for mercury, it is recognized that mercury loads from point sources were somewhat higher than estimated.

OTHER

- Ohio River mercury water data used in the study related very well to long term historical Ohio River mercury water data from ORSANCO's clean metals monitoring program.
- As with most research, ORSANCO identified some limitations within the study that could affect estimates included in the conclusions.
- Several topics are suggested for continued mercury related research.

The USEPA, ORSANCO and its member states will continue to be vigilant about mercury levels in the biota and water of the Ohio River. Water quality and fish tissue monitoring will continue. As commercial and industrial uses of mercury decline, downward trends of basin-wide mercury loadings are expected with concomitant decreases of mercury in the water column and fish tissue. While concern about mercury will continue, the Ohio River water quality and its fish should not be perceived as in a "crisis state". With respect to mercury, the Ohio River is safe to swim in, safe to consume potable water from after treatment, and safe to consume fish from in accordance with state issued advisories.

Chapter 1: Introduction

The Ohio River Valley Water Sanitation Commission (ORSANCO) is an interstate agency for water pollution control in the Ohio River Basin, representing Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia, West Virginia, and the federal government. On June 30, 2015, then ORSANCO Chairman Tom Easterly appointed the Ad-Hoc Committee on Mercury (Hg) Studies to evaluate what is known about the sources of mercury that impact fish in the Ohio River and to make recommendations to the Commission on the need for any additional information and proposed methods for obtaining such information. Steps utilized by the Ad-Hoc Committee included:

1) Gathering and evaluating what is currently known about the sources of mercury that impact fish in the Ohio River;

2) Identifying what we do not know about the sources of mercury that Impact fish in the Ohio River;

3) Identifying the potential value of addressing what we do not know about this issue and alternative methods dealing with the missing information; and

4) Making recommendations to the Commission for future needed information.

The Ad-Hoc Committee prepared a Mercury Background Report that was distributed to the Commission prior to its October 16, 2016 Commission Meeting. Mercury contamination of aquatic systems and its effects on humans and wildlife are very complex issues. The global nature of the distribution of mercury in the atmosphere makes regulation and measuring the success of regulations or localized reduction efforts difficult. Understanding the mercury sources and loadings in a watershed can be a useful first step in making better management decisions. While more comprehensive syntheses of mercury issues exist for other regions of the country, the Mercury Background Report's summary of mercury and how it affects the Ohio River basin environment provided ORSANCO Commissioners and the Ad-Hoc Mercury Committee members with a common understanding of the issues surrounding mercury contamination in the Ohio River. The ultimate objective of the report was to help achieve consensus to focus ORSANCO's next steps and overall goals regarding mercury concerns.

Some key observations resulted through the research that was completed to develop the Mercury Background Report. In aquatic ecosystems, some inorganic mercury is converted to methylmercury (MeHg), the form that ultimately accumulates in fish [6, 51]. The net rate of mercury methylation (i.e. the amount of methylmercury produced less the amount broken down), varies spatially and temporally and is dependent upon on numerous environmental factors (e.g. temperature, dissolved oxygen, organic matter, and sulfates). Methylmercury enters the aquatic food web when it is taken up from water by algae and other microorganisms [27]. Methylmercury concentrations increase with successively higher trophic levels in the food web, a process known as bioaccumulation. In general, predatory fish at the top of the food web tend to accumulate the highest methylmercury concentrations [9]. Aquatic organisms may biomagnify methylmercury to more than 1,000,000 times the water column concentration [51, 43].

High methylmercury concentrations in fish are the primary cause of fish consumption advisories, which exist in every State in the Nation [44]. The predominant source of mercury in fish is deposition of atmospheric inorganic mercury produced by coal combustion. In response to the widespread contamination of fish, mercury has been effectively removed from many products and waste streams, resulting in about a 60 percent decrease in emissions in the United States since 1990 [4]. However, to reduce mercury levels in fish to fully meet human health criteria, further reductions in mercury in the environment are necessary.

Since the 1970s, North America and Europe have significantly decreased mercury emission through air and water pollution awareness, regulations, and enhanced technology [4]. Off-setting this desirable trend, however have been significant increases in mercury emissions from developing areas such as China, India, and parts of Africa.

After completing the Mercury Background Report, the Ad-Hoc Committee systematically considered the potential value of addressing what we do not know about mercury in the Ohio River, and a strong consensus developed for conducting a mercury source loading apportionment on the main stem (i.e. direct, local) of the Ohio River. Alternative means to conduct such a study were considered, the intent being to better quantify where and how mercury is entering the main stem of the river and to link where mercury is entering the river with measured and computed in-stream mercury loadings.

The resulting study estimates atmospheric deposition to the watershed since it is known to be a significant source of mercury in surface waters. The main objective of the study was to estimate the mercury loads from point sources and atmospheric deposition, and to relate mass contribution to instream loads in the Ohio River. The committee emphasized that the study should rely on existing studies to the extent practical to minimize the necessary resources to complete the study. This primarily involved using existing mercury data from Ohio River mercury bioaccumulation factor studies. This study is the first step in helping to meet the Ad Hoc Committee Charge and is meant to help guide the Commission and the Ad Hoc Committee on potential additional steps needed to meet the Ad Hoc Committee on Mercury Studies charge.

1.1 Final Work Plan and Scope

The four main components to the project were (1) estimation of instream mercury loads for the one year project period, (2) estimation of mercury loads from point sources for the one year project period, (3) estimation of atmospheric deposition for the one year project period, and (4) comparison of instream mercury loads to point source loads and atmospheric deposition. Legacy contaminated sediments were not included in the scope of this study.

The Ohio River Basin was divided into 15 major sub-watersheds and five Local watersheds in which tributaries drain directly to the Ohio River (OR Local 1-5, Fig. 1). Cumulative, instream and point source mercury loads, and atmospheric deposition were calculated for each of the 15 major tributary watersheds and five local watersheds for the period November 1, 2015 through October 31, 2016. The entire set of tributaries, along with the four Ohio River main stem stations, were sampled monthly for one year over that period. Any data gaps were filled by modeling existing data to match the same timeframe as described in Section 2.2. Instream mercury loads were calculated for the 15 major tributaries and four Ohio River main stem stations.

Atmospheric mercury deposition over the same timeframe was calculated for each watershed using data from the National Atmospheric Deposition Network. Wet and dry mercury deposition was calculated within a GIS-based framework for each of the 15 tributary watersheds and five Local watersheds during the project period. Mercury deposition represents total quantities to the entire watershed (land and water). The report does not address the timing, rate, or proportion of mercury from air deposition that enters into surface waters.

Point source mercury loads were calculated for each watershed for the project timeframe using the national U.S. EPA's Enforcement and Compliance History Online (EPA-ECHO) data base, or data provided directly from the state environmental agencies. Mercury concentration and discharge flow data over the time period were averaged and used to calculate a mercury loading for each point source with mercury monitoring data. A cumulative, total point source discharge mercury load was calculated for each watershed. Point source discharge data were reviewed by each of the states issuing the permit. Point sources without mercury monitoring requirements or effluent limitations would not be included in the loadings calculation due to the absence of any data. Storm water discharges were also excluded due to a lack of flow data. Non-contact cooling water discharges were also excluded since these discharges are returning mercury to waters from whence it was withdrawn.

One objective of the project was to evaluate the extent to which point sources may contribute to Ohio River instream mercury loads. In doing so, point source and atmospheric deposition were compared against Ohio River instream mercury loads. The project period was selected to coincide with previously collected instream mercury data. Ohio River mercury loads were calculated at four locations: ORM 126, ORM 282, ORM 782, and ORM 912 (Fig. 1). Cumulative mercury point source loads and atmospheric mercury deposition from every watershed upstream of each Ohio River station were compared to instream mercury loads at that Ohio River station (i.e. total point source mercury loads upstream of an Ohio River station as a percentage of the total Ohio River instream mercury loading at that station).

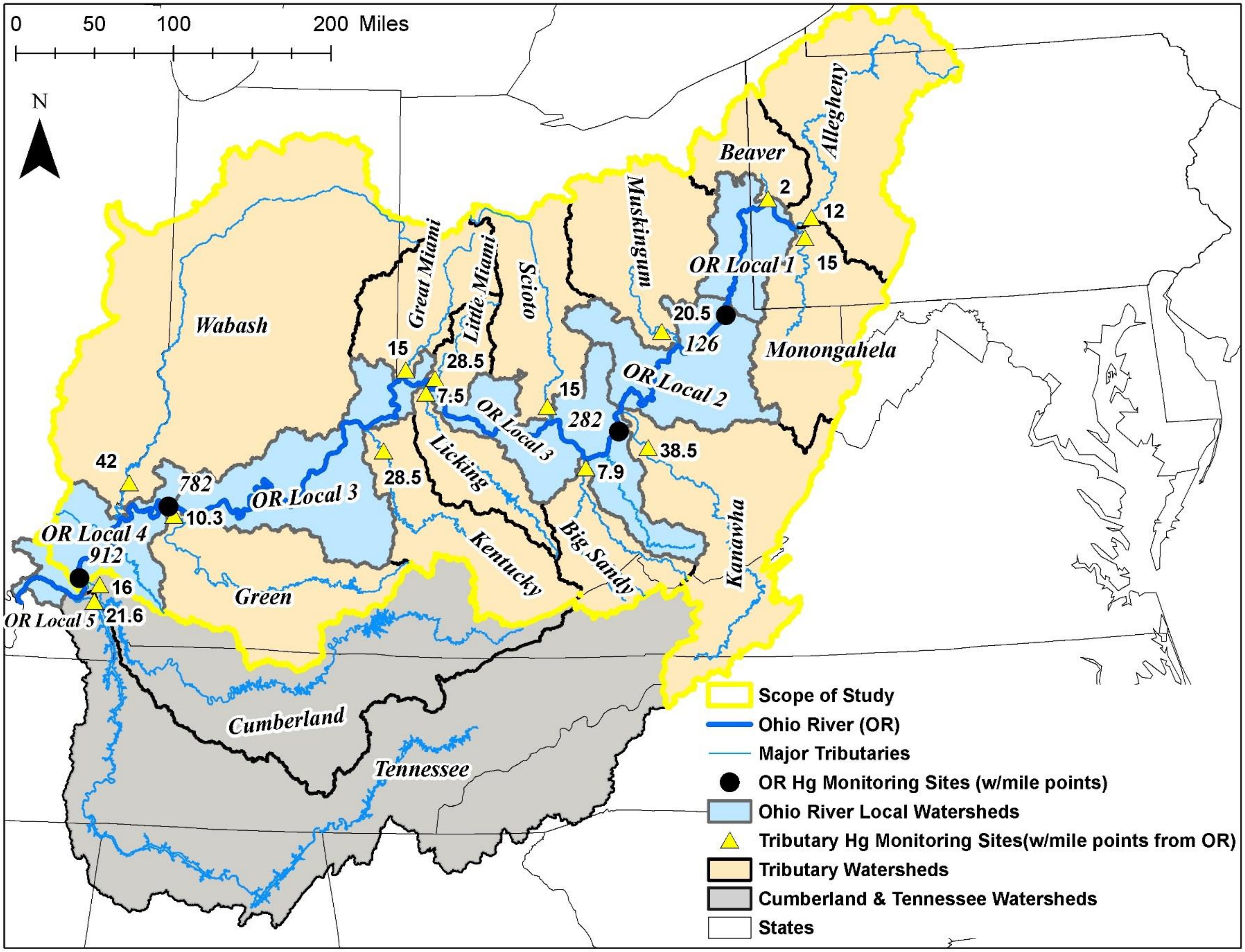


Figure 1. Ohio River Basin Project Area

The Cumberland and Tennessee River Basins both enter the Ohio River downstream of the most downstream Ohio River monitoring station at ORM 912). Their confluence with the Ohio River are between ORM 912 and ORM 981 which is the confluence with the Mississippi River, and mercury data were not collected at ORM 981 as part of this study. Therefore, these two watersheds cannot be compared against Ohio River instream mercury loadings. However, both watersheds were sampled instream and resulting instream mercury loads, point source mercury loads, and atmospheric deposition were calculated (Fig. 1).

1.2 Background on Mercury as a Contaminant

As part of its background work, ORSANCO's Ad-Hoc Committee on Mercury Studies conducted a literature review of mercury in the environment. The following are important concepts that collectively help to define the key issues associated with understanding and addressing mercury contamination in the Ohio River.

Mercury is a global pollutant

Mercury can be transported tens of thousands of kilometers on average in the atmosphere and is therefore accurately considered to be a global pollutant, continuously moving in gaseous and reactive forms between the air, land, and water of the Earth as part of a natural mercury cycle [51]. It is emitted to the atmosphere from three sources:

- Primary natural or gelogenic (volcanic eruptions, geothermal emissions)
- Primary anthropogenic or man-made (coal combustion, precious metal extraction, commercial products containing mercury.
- Re-emissions or secondary sources (portions of previous natural and anthropogenic sources) that have been deposited back to the land, vegetation, and waters, is transferred in gaseous form back to the atmosphere. This can also be referred to as "legacy" mercury.

Mercury is a widespread contaminant

Although mercury is a natural trace element found everywhere in the Earth's air, land, and water, it is also a widespread environmental contaminant that can accumulate to harmful concentrations in aquatic ecosystems and has documented toxicological risks to humans and wildlife (Fig. 2) [4, 44, 49, 51, 53].

Methylmercury concentrated in fish presents a human health hazard

Due to the ability of methylmercury to accumulate to levels exceeding various established thresholds in fish, as of 2011 all 50 U.S. states had fish consumption advisories in place for mercury which was responsible, at least in part, for 81% of all advisories [42].

The atmosphere is generally the greatest source of mercury entering water environments

Deposition from the atmosphere has been found by many researchers to be the primary source of mercury in aquatic systems, although direct point sources can also contribute significantly [4, 8-9, 14, 52]. Atmospheric deposition (wet plus dry) is the predominant pathway of anthropogenic mercury to most aquatic ecosystems in the U.S. [51, 32].

To be bioavailable, inorganic mercury is converted to methylmercury

Upon transport to a river or stream, inorganic mercury must first be methylated in order to be bioavailable. Methylation of inorganic mercury is typically conducted by microbial actions and has been shown to be correlated with warmer temperatures, limited dissolved oxygen, abundant organic matter, increased sulfates, and the presence of sulfides in the sediment among other factors [1, 5, 15, 29, 38, 51-52]. The ratios of methylmercury to total mercury within streams have been found to be low, and Brigham et al. concluded that benthic, in channel methylation of mercury is not important to the mass balance of methylmercury within the studied stream basins [3]. Likewise, methylation is thought to be as low (or lower) in the Ohio River main stem [12, 29, 38, 26].

Methylmercury bioaccumulates in the food chain

Algae are thought to be the major contributors of methylmercury to the food chain, as they can concentrate the contaminant from the aqueous phase at a rate of 100-10,000+ times and are fed on by zooplankton, crayfish, some fish, and other herbivores or omnivores [27]. Overall, aquatic organisms may bioaccumulate environmental contaminants to more than 1,000,000 times the concentrations detected in the water column [40, 43].

USEPA's recommended fish tissue criterion of 0.3 ppm

ORSANCO has adopted USEPA's recommended methylmercury criterion of 0.3 ppm (mg/kg) as a fish tissue criterion for determining attainment of the fish consumption use of the Ohio River [44]. While this is the most commonly used value by states, criteria range from 0.04-0.5 ppm in fish tissue.

Figure 2 depicts the main processes and sources of mercury in the environment.

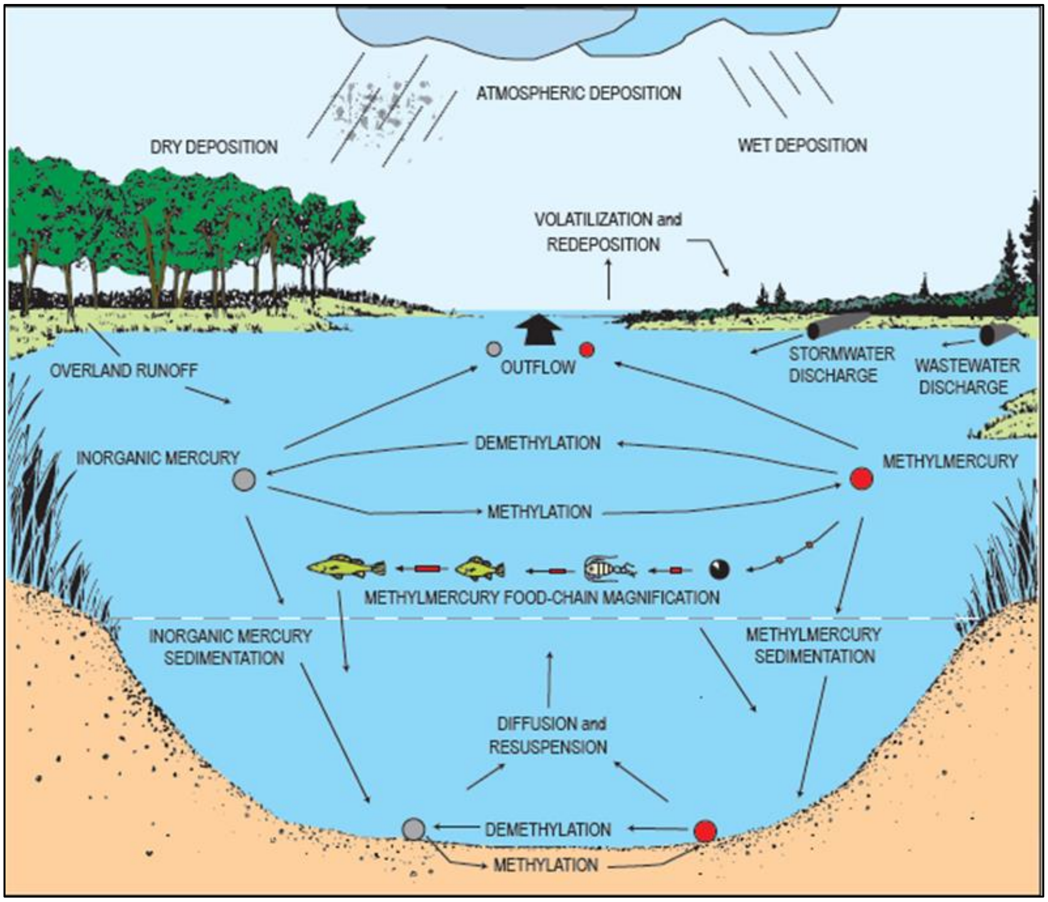


Figure 2. The major sources and processes involved with mercury as a contaminant in the environment [from Risch et al. 30].

1.3 Study Area

The Ohio River Basin is 527,884 square kilometers (km^2) and the 20 tributary and Local watersheds have drainage areas that range in size from the Ohio River Local 5 (2,392 km^2) to the Tennessee River (105,947 km^2) (Table 1). Land cover in the Basin as a percentage of the total area is primarily deciduous forest (52%), cropland (34%), and urban (9.4%), although the percentages of land cover types vary widely among the 20 watersheds (Fig. 3, Fig. 16) [19]. For the purposes of this study, the Ohio River Basin was divided into 15 major watersheds and five Ohio River Local watersheds (Fig. 1) which serve as the reporting units for the project. The 15 major tributaries combined account for approximately 85% of the total flow to the Ohio River.

Four Ohio River main stem stations were selected to assess mercury loads in the Ohio River. These stations were used in a previous ORSANCO study. The four sites include Hannibal L&D (ORM 126), RC Byrd L&D (ORM 282), Newburgh L&D (ORM 782) and Smithland L&D (ORM 912) at the separation of the five Ohio River Local watersheds (Fig. 1).

There were 653 point source facilities with 752 outfalls within the Ohio River Basin that contain mercury limitations and/or mercury monitoring requirements in their NPDES discharge permits which were included in this report. Intermittent storm water discharges were excluded from the analysis due to a lack of flow data needed to estimate loadings. Those 653 individual entity sources were categorized in 48 different areas classified by Standard Industrial Classification (SIC) codes. Industry types with the most outfalls were sewerage system SIC code 4952, electrical services excluding nuclear SIC code 4911, coal surface mining SIC code 1221, steel works SIC code 3312, coal underground mining SIC code 1222, and industrial organic chemicals SIC code 2869 (Table 2). The number of point source facilities varies per watershed from 3 (Licking watershed) to 94 facilities (Muskingum watershed, Table 3). Some facilities have more than one monitored outfall, but all facilities have at least one. The number of point source outfalls varies per watershed from 3 outfalls (Licking watershed) to 97 outfalls (Muskingum watershed). It is noted that states have different monitoring requirements for mercury discharges.

Table 1. Characteristics of Ohio River Basin study area watersheds

	Area in square kilometers					
Watershed	**Drainage**	**Forest**	**Cropland**	**Urban**	**Grassland**	**Water**
Allegheny	30,368	21,757	5,440	2,246	370	339
Monongahela	19,102	13,790	2,814	2,053	83	189
Beaver	8,177	3,586	2,626	1,497	189	250
OR Local 1	9,059	5,317	1,924	1,468	184	113
Muskingum	20,848	9,347	8,295	2,542	340	253
Kanawha	31,720	24,375	4,114	2,169	596	200
OR Local 2	17,450	13,386	2,468	1,280	132	161
Big Sandy	11,119	8,860	329	746	916	48
Scioto	16,866	4,426	9,755	2,246	264	143
Little Miami	4,553	1,080	2,527	854	36	44
Licking	9,597	4,808	3,727	689	294	58
Great Miami	13,900	2,287	9,147	2,121	171	139
Kentucky	18,040	10,532	4,766	1,528	960	84
OR Local 3	42,209	24,434	11,440	4,078	1,448	635
Green	23,916	11,184	10,136	1,450	780	241
Wabash	85,350	17,131	57,998	8,211	924	904
OR Local 4	10,884	4,361	5,188	764	181	282
Cumberland	46,389	27,310	11,774	4,252	1,969	903
Tennessee	105,947	65,645	24,500	9,416	3,382	2,657
OR Local 5	2,392	760	1,253	220	4	129
Ohio River Basin	**527,884**	**274,376**	**178,968**	**49,608**	**13,219**	**7,642**

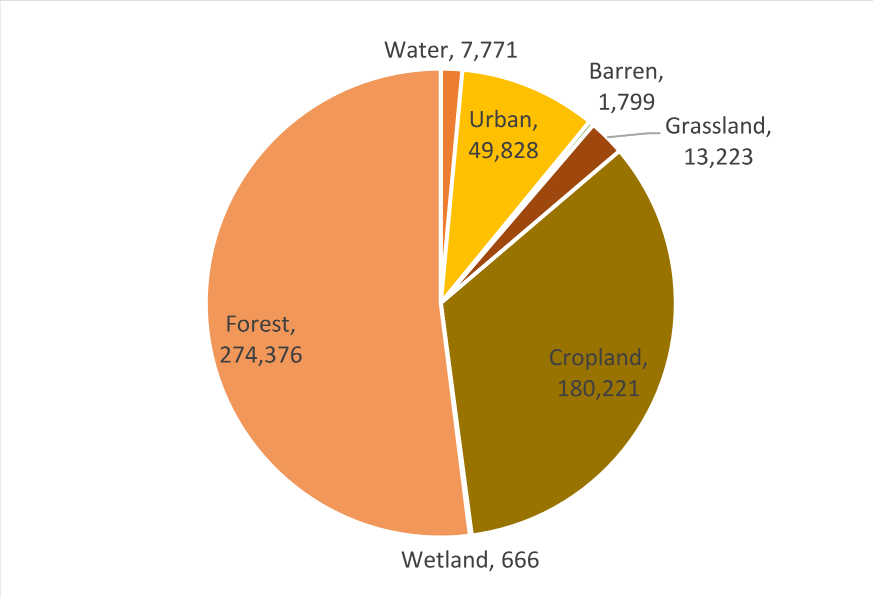


Figure 3. Land cover in Ohio River Basin (in square kilometers)

Table 2. Number of mercury monitoring facility's point source discharges per watershed (SIC code) in Ohio River Basin during study period. {displaying the SIC codes with the most facilities; Not all the SIC codes are shown}

[SIC, Standard Industrial Classification; shaded cells have no data]

Watershed	Sewerage System (4952)	Electrical Services excluding Nuclear (4911)	Coal Surface Mining (1221)	Steel Works (3312)	Coal Underground Mining (1222)	Industrial Organic Chemicals (2869)
Allegheny		3				
Monongahela	6	4			1	
Beaver	22			3		
OR Local 1	32	5	1	1	3	1
Muskingum	80	4	1	2	1	
Kanawha	23	2				
OR Local 2	22	5				3
Big Sandy	2		15			
Scioto	61					
Little Miami	27					
Licking	3					
Great Miami	54			1		
Kentucky	8					
OR Local 3	58	10	1	1		
Green	10	1	2			
Wabash	41	10			3	
OR Local 4	6	2	1			
Cumberland	8	2	13			
Tennessee	15	5				
OR Local 5	2					
Ohio River Basin	**480**	**52**	**33**	**8**	**7**	**4**

Table 3. Number of mercury monitored facilities and outfalls per watershed during the study period November 2015 thru October 2016

[Hg, mercury; Shaded cells are accumulation to that mile point]

Watershed	Number of Hg Monitored Outfalls	Number of Hg Monitored Facilities
Allegheny	7	5
Monongahela	15	12
Beaver	29	27
OR Local 1	55	48
ORM 126	106	92
Muskingum	97	94
Kanawha	37	29
OR Local 2	49	35
ORM 282	289	250
Big Sandy	33	18
Scioto	63	63
Little Miami	27	27
Licking	3	3
Great Miami	60	58
Kentucky	9	9
OR Local 3	91	78
ORM 782	575	506
Green	21	14
Wabash	74	66
OR Local 4	15	13
ORM 912	685	599
Cumberland	34	23
Tennessee	27	25
OR Local 5	6	6
Ohio River Basin	**752**	**653**

Chapter 2: Instream Mercury Loads

2.1 Approach

Instream mercury loads were calculated using mercury monitoring data collected by the Ohio River Valley Water Sanitation Commission (ORSANCO), daily mean flow data consistent with the time period of monitoring from United States Geological Survey (USGS), and the U.S. Army Corps of Engineers (USACE). A USGS FORTRAN program for estimating constituent loads in streams and rivers (LOADEST) was used to combine these data and estimate mercury loads. The method for calculating the mercury loads is presented and the results are discussed in the following section.

2.2 Methods

2.2.1 Stream Water Sample Collection, Analysis, & Quality Assurance

ORSANCO sampled the 15 major tributaries near their confluence with the Ohio River on a monthly basis during the study time period November 1, 2015 through October 31, 2016. Monthly water samples were also collected for a year at four Ohio River main stem locations during differing time periods (Fig. 4, Table 4).

- ORM 126; July 1, 2012 through June 20, 2013.
- ORM 282; June 1, 2015 through May 31, 2016.
- ORM 782; July 1, 2015 through June 30, 2016.
- ORM 912; Nov. 1, 2016 through October 31, 2017.

These sites were adjusted to the study period November 1, 2015 through October 31, 2016 using LOADEST as discussed in section 2.2.3. Monitoring was conducted at these four main stem sites for another project, but these existing data were used in this project, which resulted in significant resource savings.

All the samples were collected from boats except where boat access was limited (e.g. the Scioto, Little Miami, and Great Miami rivers) and were instead collected from bridges (Table 4). The samples collected from boats were collected using the USGS flow-weighted cross-sectional composite method (Equal Discharge Increment method) for collecting water samples, and flow was measured with an Acoustic Doppler Current Profiler (ADCP) unit. The samples collected from bridges utilized a mid-stream, mid-depth grab sample, and the flow was assigned from USGS daily flow data based on the day they were collected. All the water samples were analyzed by Pace Analytical using EPA 245.7, with a reporting limit of 1.5 ng/L. Quality Assurance (QA) and Quality Control samples were collected in addition to the ambient stream samples collected. Stream samples were collected in duplicate for approximately 20% of the samples collected. Additionally, field blanks were collected and analyzed for quality assurance purposes. The samples were analyzed for total mercury concentration, including dissolved and particulate mercury and methylmercury (MeHg). Total mercury was used for the project (Appendix Table A1-Table A5). No significant quality assurance issues were noted based on QA results.

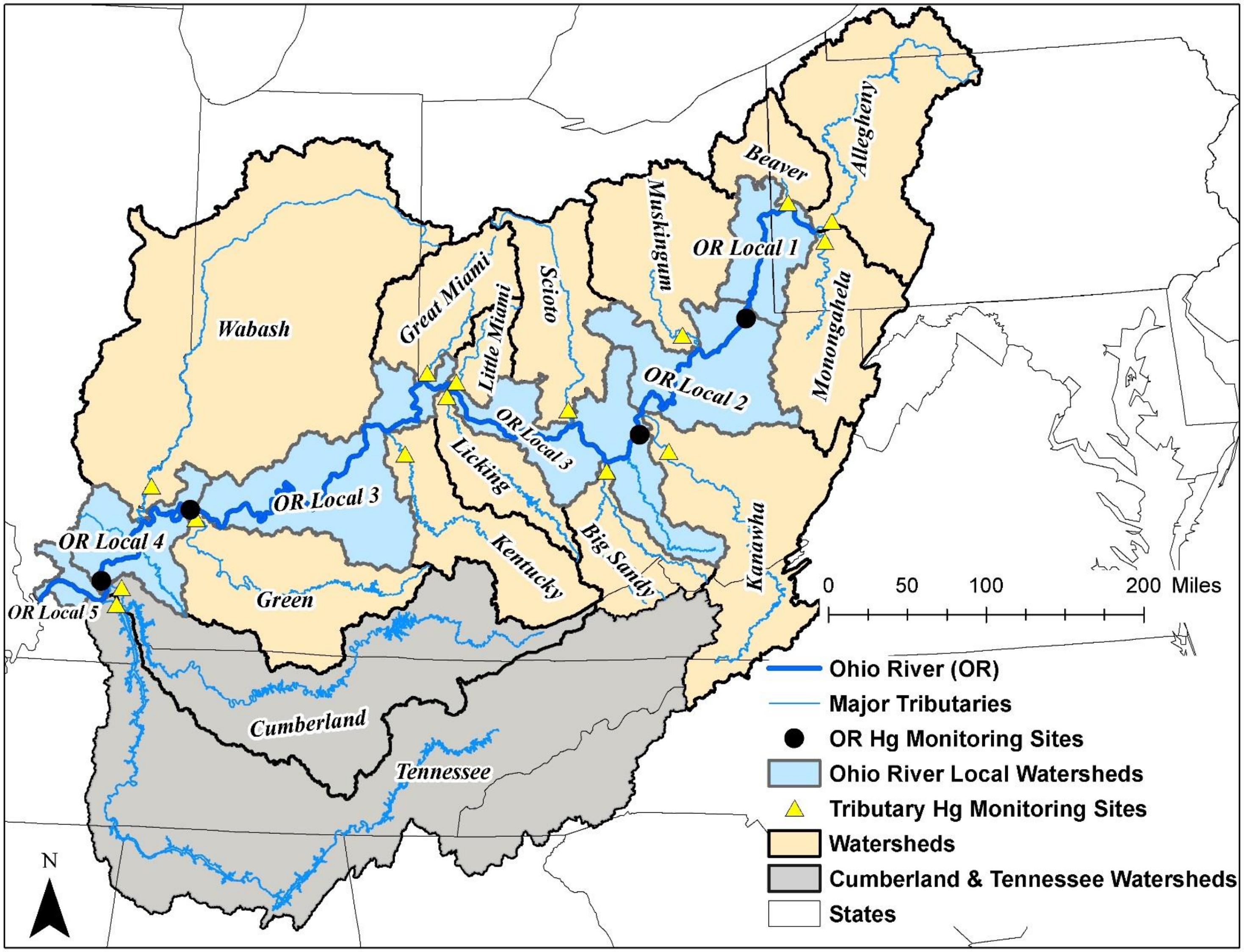


Figure 4. The 15 tributary mercury (Hg) monitoring sites and four Ohio River Local mercury monitoring sites.

Table 4. ORSANCO monitoring water sample mile point locations and method; daily flow data source and mile point location.

[ORM, Ohio River mile; Sample Mile Point, sites correspond to distance from the Ohio River; Asterisk *, sample dates that required adjusting]

River	Ohio River Confluence Mile Point	Primary Sampling Platform	Sample Mile Point	Sample Dates	Sample Location	Sample Collection Method	Daily Flow Data From	Daily Flow Mile point
Allegheny	0.0	Boat	12.0	November 2015-October 2016	Cheswick, PA	USGS flow-weighted cross-sectional composite	USGS	17.5
Monongahela	0.0	Boat	15.0	November 2015-October 2016	McKeesport, PA	USGS flow-weighted cross-sectional composite	USGS	11.2
Beaver	25.4	Boat	2.0	November 2015-October 2016	Bridgewater, PA	USGS flow-weighted cross-sectional composite	USGS	5.5
ORM 126*	126.0	Boat	0.0	July 2012-June 2013	Hannibal, OH	USGS flow-weighted cross-sectional composite	USGS	126.2
Muskingum	172.2	Boat	20.5	November 2015-October 2016	Beverly, OH	USGS flow-weighted cross-sectional composite	USGS	20.5
Kanawha	265.7	Boat	38.5	November 2015-October 2016	Poca, WV	USGS flow-weighted cross-sectional composite	USGS	54.5
ORM 282*	282.0	Boat	0.0	June 2015-May 2016	Mercers Bottom, WV	USGS flow-weighted cross-sectional composite	Cascade	282.5
Big Sandy	317.1	Boat	7.9	November 2015-October 2016	Kenova, WV	USGS flow-weighted cross-sectional composite	Cascade	9.9
Scioto	356.5	Bridge	15.0	November 2015-October 2016	Lucasville, OH	mid-stream, mid-depth grab	USGS	34
Little Miami	464.1	Bridge	7.5	November 2015-October 2016	Newtown, OH	mid-stream, mid-depth grab	USGS	12.9
Licking	470.2	Boat	7.5	November 2015-October 2016	Wilder, KY	USGS flow-weighted cross-sectional composite	USGS	18
Great Miami	491.1	Bridge	15.0	November 2015-October 2016	Elizabethtown, OH	mid-stream, mid-depth grab	USGS	35
Kentucky	545.8	Boat	28.5	November 2015-October 2016	Gratz, KY	USGS flow-weighted cross-sectional composite	USGS	31
ORM 782*	782.0	Boat	0.0	July 2015-June 2016	Newburgh, IN	USGS flow-weighted cross-sectional composite	Cascade	782.6
Green	784.2	Boat	10.3	November 2015-October 2016	Spottsville, KY	USGS flow-weighted cross-sectional composite	USGS	9
Wabash	848.0	Boat	42.0	November 2015-October 2016	New Harmony, IN	USGS flow-weighted cross-sectional composite	USGS	42
ORM 912*	912.0	Boat	0.0	November 2016-October 2017	Bay City, IL	USGS flow-weighted cross-sectional composite	Cascade	908.9
Cumberland	920.4	Boat	16.0	November 2015-October 2016	Pinkneyville, KY	USGS flow-weighted cross-sectional composite	Cascade	18.4
Tennessee	934.5	Boat	20.5	November 2015-October 2016	Gilbertsville, KY	USGS flow-weighted cross-sectional composite	Cascade	21.5

2.2.2 Daily Mean Flow

The daily mean flows during the monitoring period were a key part of the regression model to estimate the one year mercury loads for the project period. Three flow data sources were considered: The USGS stream gaging network, USACE Cascade model data, and National Weather Service modeled data (NWS) (Table 5). The USGS stream gaging network is comprised of more than 10,000 stream gages throughout the U.S. The data generated is quality assured and made available online [48]. The USACE Cascade model has various flow stations along each tributary and the Ohio River. USACE utilizes a dynamic, one-dimensional unsteady flow model called Cascade [2]. NWS data were considered but not utilized since the NWS flow data were derived from USGS, Cascade flow data, and other sources.

USGS flow stations were preferred to USACE and NWS because the USGS data is measured, as opposed the modeled data from the USACE and NWS, but all sites were evaluated based on proximity to the location of ORSANCO's mercury monitoring site. It was important that there were no tributary confluences between the mercury monitoring location and the flow station used in order to maintain a reasonable representation of stream flow. The flow data used in the calculations had no significant tributary confluences between the mercury monitoring station and the flow gage. Cascade flow data were used when there were no USGS gages suitable to represent flow at the mercury monitoring station (Big Sandy, Cumberland, and Tennessee Rivers). Additionally, no suitable USGS flow stations were available for use with mercury monitoring stations on the main stem at ORM 282, 782, and 912. Cascade model flow data were used in the regression model to estimate the mercury load for ORM 126, ORM 282, ORM 782, ORM 912, Big Sandy, Cumberland, and Tennessee Rivers (Figure 5). Overall, only USGS and Cascade flow data were used in regression model and missing daily flow values were replaced with the average of the daily mean flows before and after the missing data point (Table 6).

Table 5. Daily Flow station mile point locations accessed to use for estimating mercury loads during study period

[ORM, Ohio River mile point; USGS, United States Geological Survey; USACE, United States Army Corps of Engineers; NWS, National Weather Service; shaded cells indicate flow data used in final load calculation]

River	Mercury Sample Mile Point	USGS Flow Station Mile Point	USACE Cascade Flow Station Mile Point	NWS Flow Station Mile Point
Allegheny	12	17.5	None	15.8
Monongahela	15	11.2	None	11.2
Beaver	2	5.5	None	6.5
ORM 126	126	130.5	126.2	161.8
Muskingum	20.5	20.5	20	45.5
Kanawha	38.5	54.5	37	94.5
ORM 282	282	325.5	282.5	279.2
Big Sandy	7.9	None	9.9	20.9
Scioto	15	34	15	34
Little Miami	28.5	12.9	None	12.9
Licking	7.5	18	8.3	50
Great Miami	15	35	16.1	None
Kentucky	28.5	31	27.05	67
ORM 782	782	724	782.6	776
Green	10.3	9	11.9	11.9
Wabash	42	42	41.74	42
ORM 912	912	966	908.9	918.5
Cumberland	16	None	18.4	30.6
Tennessee	21.6	None	21.5	22.4

Table 6. Source of the USGS & Cascade streamflow data during the monitoring period (11/01/2015-10/31/2016) used in regression model to estimate mercury loads during study period.

[ORM, Ohio River mile point; ID, identification; URL, web address; USGS, United States Geological Society; USACE, U.S. Army Corps of Engineers; %, percentage]

River	% Missing Flow Data	Streamgage ID	URL
Allegheny	0%	USGS 03049500 at Natrona, PA	https://waterdata.usgs.gov/nwis/dv/?referred_module=sw&site_no=0304950
Monongahela	0.3%	USGS 03085000 at Braddock, PA	00
Beaver	0%	USGS 03107500 at Beaver Falls, PA	https://waterdata.usgs.gov/nwis/dv?referred_module=sw&cb_00060=on&format=gif_default&site_no=03107500
ORM 126	0%	USGS 03114306 above Sardis, OH	https://waterdata.usgs.gov/nwis/dv/?referred_module=sw&site_no=031143
Muskingum	0%	USGS 03150500 at Beverly OH	00
Kanawha	0%	USGS 03198000 at Charleston, WV	https://waterdata.usgs.gov/nwis/uv?03198000
ORM 282	0.5%	Ohio River mile point 282.5	USACE Cascade model data
Big Sandy	0%	Big Sandy River mile point 9.85	USACE Cascade model data
Scioto	0%	USGS 03237020 at Piketon OH	20
Little Miami	0%	USGS 03245500 at Milford OH	00
Licking	0%	USGS 03254520 at Hwy 536 near Alexandria, KY	20
Great Miami	0%	USGS 03274000 at Hamilton OH	00
Kentucky	5.7%	USGS 03290500 at Lock 2 at Lockport, KY	00
ORM 782	1.1%	Ohio River mile point 782.57	USACE Cascade model data
Green	0%	USGS 03321500 at Lock 1 at Spottsville, KY	00
Wabash	2.5%	USGS 03378500 at New Harmony, IN	00
ORM 912	0.8%	Ohio River mile point 908.89	USACE Cascade model data
Cumberland	0%	Cumberland River mile point 19.39	USACE Cascade model data
Tennessee	0%	Tennessee River mile point 21.5	USACE Cascade model data

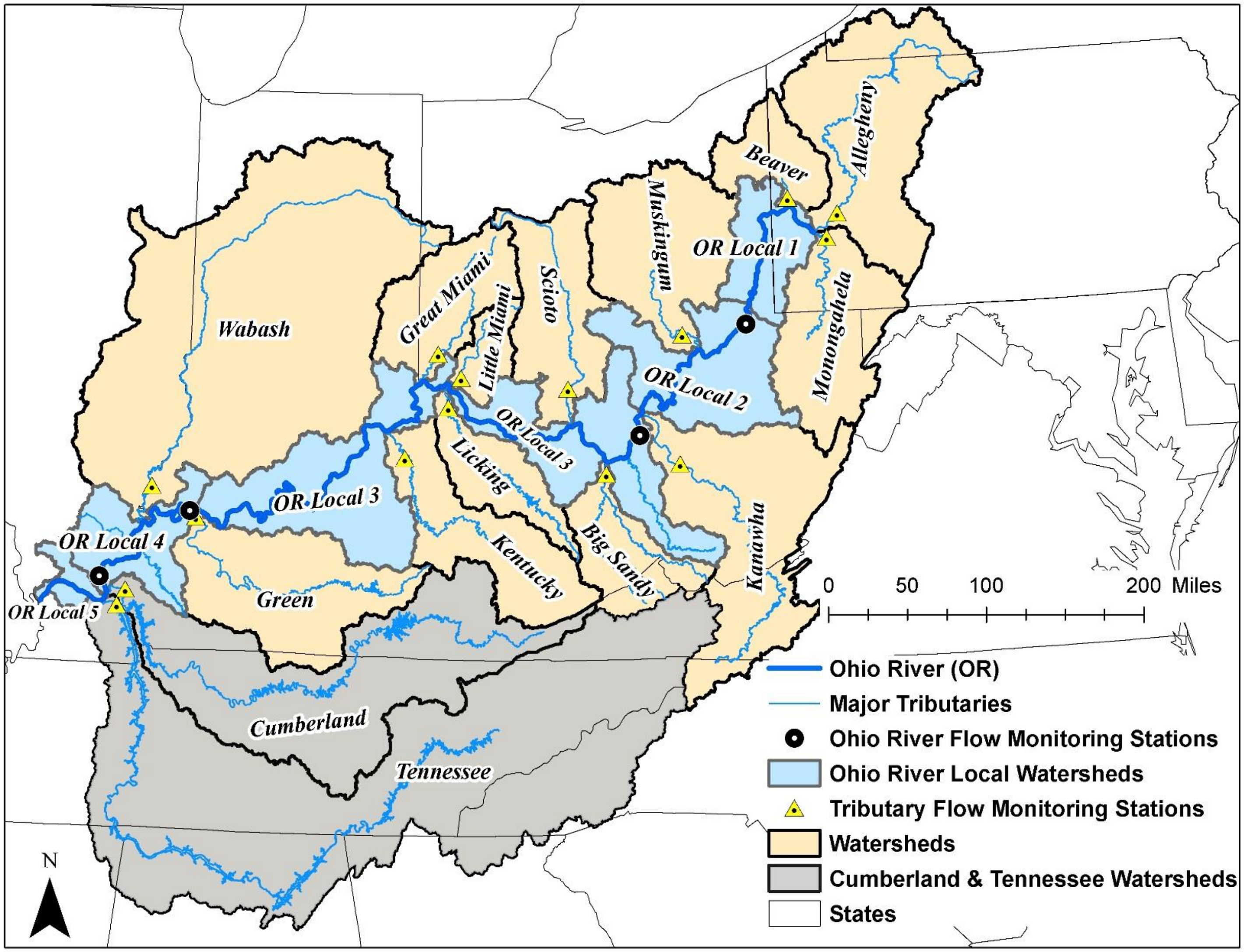


Figure 5. Flow monitoring station locations used in the final mercury load calculations.

2.2.3 Daily Mercury Load Estimation Model

Two statistical methods were used to calculate the instream mercury loads. For both methods, the 12 monthly mercury concentrations and instantaneous flow samples collected for each site were used to create a regression model (Appendix Figures A1-A19). The three sample sites collected from bridges used the 12 monthly mercury concentrations and USGS daily mean flow from the day collected to create a regression model. Daily mercury loads were then interpolated for the study period. The daily flow values during the study period were entered into the models to estimate the daily mercury load. These daily loads were summed to calculate one year loads for the project period.

The first method employed was a second order polynomial regression equation. A scatter graph of the natural log of the mercury concentration samples and the natural log of the flow discharge for each tributary and the four main stem stations was made and then a polynomial line was drawn to calculate the equation and R^2 value (Table 7). The daily mercury loads were calculated as a function of flow by plugging the natural log daily mean flow values for each of the 15 tributaries and four Ohio River Local sites into the respective regression equation. Finally, the 366 daily mercury loads were then summed to get the total point source mercury loads for the study period.

Model Equation

Table 7. Regression models made with 12 daily flow samples (one per month) and mercury concentration samples during 11/1/2015-10/31/2016 collected for each river; except Scioto, Little Miami, and Great Miami used USGS flow data since no flow was recorded

[lbs, pound; %, percentage; shaded cells indicate model used in final load calculation; x = natural log of daily flow; y = natural log of daily

River	Polynomial Equation	R Squared Polynomial Equation	Polynomial Equation Load (lbs)	LOADEST Equation	R Squared LOADEST	LOADEST Load (lbs)	Percent Load Difference
Allegheny	$0.0944x^2-1.3224x+4.3651$	0.64	69	model 9	0.99	81	18%
Monongahela	$0.3786x^2-6.0716x+24.558$	0.83	68	model 2	0.96	71	5%
Beaver	$0.5176x^2-7.6497x+28.657$	0.65	51	model 4	0.97	31	-39%
ORM 126	$0.2784x^2-5.1598x+24.248$	0.65	223	model 9	0.98	0.00	-100%
Muskingum	$-0.0237x^2+0.9784x-5.4448$	0.66	73	model 1	0.94	81	10%
Kanawha	$0.1838x^2-2.9791x+12.405$	0.60	144	model 4	0.98	168	17%
ORM 282	$0.1733x^2-2.8627x+11.455$	0.82	618	model 1	0.95	593	-4%
Big Sandy	$0.3384x^2-4.7063x+16.563$	0.82	82	model 6	0.99	71	-13%
Scioto	$0.1868x^2-2.4651x+8.6265$	0.65	98	model 3	0.95	83	-15%
Little Miami	$0.0361x^2-0.151x+0.0773$	0.31	9	model 7	0.95	11	15%
Licking	$0.1416x^2-1.8186x+6.4723$	0.75	74	model 6	1.00	102	37%
Great Miami	$-0.1181x^2+1.903x-6.7592$	0.12	16	model 7	0.98	17	10%
Kentucky	$0.1984x^2-2.7334x+9.335$	0.60	115	model 1	0.90	71	-38%
ORM 782	$0.4274x^2-873x+44.952$	0.87	2,604	model 5	0.97	2,153	-17%
Green	$0.1383x^2-1.7155x+5.2247$	0.86	327	model 1	0.96	285	-13%
Wabash	$-1.8767x^2+38.777x-197.93$	0.32	380	model 2	0.68	389	2%
ORM 912	$-0.4226x^2+11.608x-76.951$	0.86	2,451	model 1	0.94	2,961	21%
Cumberland	$-0.475x^2+10.033x-51.794$	0.35	156	model 1	0.76	211	35%
Tennessee	$0.1836x^2-3.4774x+16.357$	0.77	285	model 5	0.98	278	-2%

Table 8. LOADEST regression model numbers (Specified value) used to calculate mercury loads [37].
[I, Integer; lnQ, ln(streamflow) - center of ln(streamflow); *dtime*, decimal time - center of decimal time; per, period, 1 or 0 depending on defined period (record type 8)]

Specified value	Regression model
0	automatically select best model from models 1-9.
1	$a_0 + a_1 \ln Q$
2	$a_0 + a_1 \ln Q + a_2 \ln Q^2$
3	$a_0 + a_1 \ln Q + a_2 dtime$
4	$a_0 + a_1 \ln Q + a_2 \sin(2\pi dtime) + a_3 \cos(2\pi dtime)$
5	$a_0 + a_1 \ln Q + a_2 \ln Q^2 + a_3 dtime$
6	$a_0 + a_1 \ln Q + a_2 \ln Q^2 + a_3 \sin(2\pi dtime) + a_4 \cos(2\pi dtime)$
7	$a_0 + a_1 \ln Q + a_2 \sin(2\pi dtime) + a_3 \cos(2\pi dtime) + a_4 dtime$
8	$a_0 + a_1 \ln Q + a_2 \ln Q^2 + a_3 \sin(2\pi dtime) + a_4 \cos(2\pi dtime) + a_5 dtime$
9	$a_0 + a_1 \ln Q + a_2 \ln Q^2 + a_3 \sin(2\pi dtime) + a_4 \cos(2\pi dtime) + a_5 dtime + a_6 dtime^2$

$$\hat{L}_{AMLE} = \exp\left(a_0 + \sum_{j=1}^{M} a_j X_j\right) H(a, b, s^2, \alpha, \kappa) \qquad [1]$$

The second method determined mercury loads with Load estimator (LOADEST), a FORTRAN program created by USGS for estimating loads in rivers [36]. LOADEST is best suited for large, non-urban watersheds. The watersheds in the Ohio River Basin fit this requirement with the watershed areas ranging from 2,395 km^2 (Ohio River Local 5) to 105, 947 km^2 (Tennessee River) averaging 10% urban land use. LOADEST determines a regression model that best fits the inputted data for the estimation of constituent load based on nine models (Table 8) [37]. LOADEST then selects a method for estimating model coefficients based on retransformation bias, data censoring, and non-normality. Adjusted Maximum Likelihood Estimation (AMLE) is one of three load estimation methods used within LOADEST and the estimation method that were used for all the load calculations. AMLE was preferred as first order bias in the model coefficients was eliminated using the calculations given in Shenton and Bowman (1977) [equation 1] to achieve "nearly unbiased" estimates [6, 41]. Where ˆLAME is the AMLE estimate of instantaneous load, a and b are functions of the explanatory variables, α and κ are parameters of the gamma distribution, and s^2 is the residual variance.

The R^2 values for the polynomial equation used in the first method range from 12% to 87% (Table 7). The second method using LOADEST produced R^2 values varying from 68% to 100% for each station (Table 7 & Table 8). Because the second method resulted in higher R^2 values overall, it was chosen as the preferred method to complete the load calculations.

Computational difficulties arose in LOADEST when the estimation time period (November 2015-October 2016) included time periods outside the time frame associated with the calibration dataset (monitoring data). The monitoring data from the 15 tributaries aligned with the estimation time period, so there were no issues using LOADEST data for the tributary sites. The four Ohio River Local monitoring data (ORM 126, 282, 782, and 912) did not align with the estimation time period. In the LOADEST regression models, models 3 through 9 contain *dtime*, which is the estimation day in decimal time minus the center calibration day in decimal time (Table 7). If the estimation days and calibration days were too far apart, then LOADEST will fail to calculate an appropriate load estimation when *dtime* is in the model. LOADEST selected model 1 for ORM 282 monitoring data (June 2015-May 2016) and ORM 912 monitoring data (November 2016-October 2017). Model 1 did not include *dtime* and represents a linear regression line in time that is present in the calibration data set [37]. Even though the estimation time and calibration time for ORM 282 and ORM 912 did not overlap consistently, LOADEST still produced reasonable results. LOADEST selected model 5 for ORM 782 monitoring data (July 2015-June 2016), which has *dtime* in the model. ORM 782 monitoring data overlaps five months with the study period estimation time, June 2016-October 2016. ORM 782 monitoring data overlaps seven months with the study period making the estimation days and calibration days similar enough for the model 5 regression line to estimate loads reasonably. LOADEST selected model 9 for ORM 126 monitoring data (July 2012-June 2013), which has *dtime* in the model. It was unreasonable to expect the linear regression line for ORM 126 to extend from 2012-2013 to the study period estimation time 2015-2016 since they were too far apart in time. The LOADEST ORM 126 load resulted in being unreasonable (~0 lbs). The polynomial regression equation was chosen as the preferred method over LOADEST for ORM 126.

Using LOADEST, the residual variance for the tributaries and the Ohio River vary from 0.04 to 0.47 kg/day (Appendix Table A6). The residual variance was less than 0.5 kg/day meaning there was a low variance between the discharge measured when the sample was taken and the nearby stream gage. These results suggest a good fit for each other.

2.3 Results

The instream mercury loads for the study period in Ohio River tributaries ranged from 11 (Little Miami River) to 389 pounds (lbs) (Wabash River) (Table 9, Fig. 6; same as Fig. 22 in Chapter 5). The instream mercury yield for the study period in the Ohio River tributaries ranged from 0.6 μg/m²/yr (Great Miami River) to 5.4 μg/m²/yr (Green River). The instream mercury load increases on the main stem with river mile, ranging from 223 lbs at ORM 126 to 2,961 lbs downstream at ORM 912. The instream mercury yield for the study period in the Ohio River main stem ranges from 1.5 μg/m²/yr (ORM 126) to 3.9 μg/m²/yr (ORM 782) indicating accumulation downstream (Table 9, Fig. 6). Tributary watersheds contribution to the Ohio River instream loading at ORM 912, the most downstream Ohio River station, ranges from 0.4% (Little Miami) to 13.1%

(Wabash). All tributaries combined account for 49.4% of the total load at ORM912 (Table 10). The total mercury loads of the Cumberland and Tennessee Rivers are downstream from the most downstream main stem station at ORM 912, so they were not included in any comparison to main stem loads at ORM 912.

Table 9. Instream mercury loads and yield during the study period

[Hg, mercury; ORM, Ohio River Mile; lbs, pound; µg/m²/yr, microgram per square meter per year]

River	Instream Hg Load (lbs)	Instream Hg Yield
Allegheny	81	1.2
Monongahela	71	1.7
Beaver	31	1.7
ORM 126	223	1.5
Muskingum	81	1.8
Kanawha	168	2.4
ORM 282	593	2.0
Big Sandy	71	2.9
Scioto	83	2.2
Little Miami	11	1.1
Licking	102	4.8
Great Miami	17	0.6
Kentucky	71	1.8
ORM 782	2,153	3.9
Green	285	5.4
Wabash	389	2.1
ORM 912	2,961	3.6
Cumberland	211	2.1
Tennessee	278	1.2

Table 10. Tributary instream mercury load contribution to the total instream mercury load at Ohio River mile point 912 during study period

[Hg, mercury; %, percentage]

Tributary	% Tributary Instream Hg Load Contribution
Allegheny	2.7%
Monongahela	2.4%
Beaver	1.1%
Muskingum	2.7%
Kanawha	5.7%
Big Sandy	2.4%
Scioto	2.8%
Little Miami	0.4%
Licking	3.5%
Great Miami	0.6%
Kentucky	2.4%
Green	9.6%
Wabash	13.1%
Total at ORM 912	**49.4%**

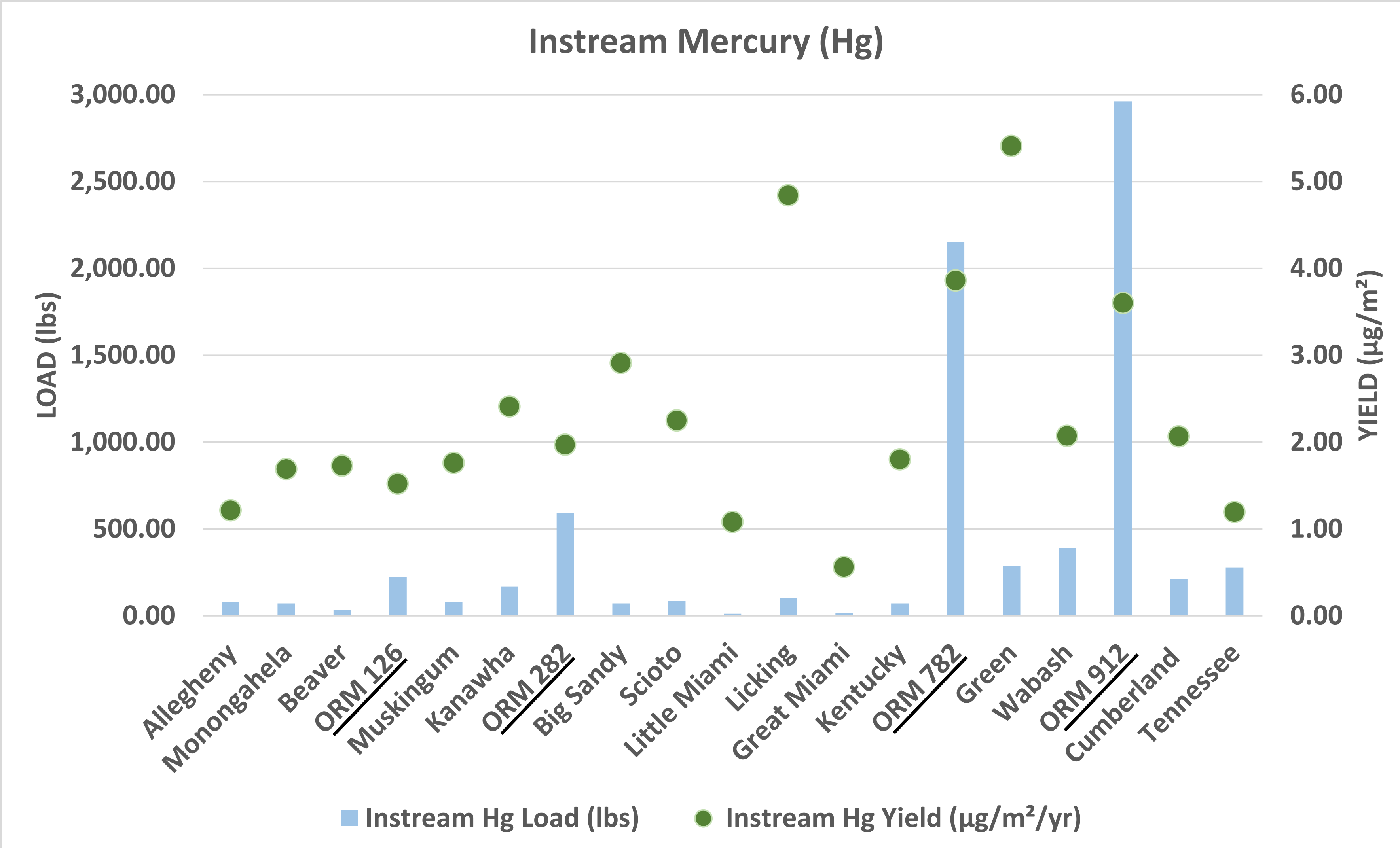


Figure 6. Instream mercury (Hg) loads and yields normalized to the watershed area during the one year study period November 1, 2015 through October 31, 2016.

2.4 Discussion

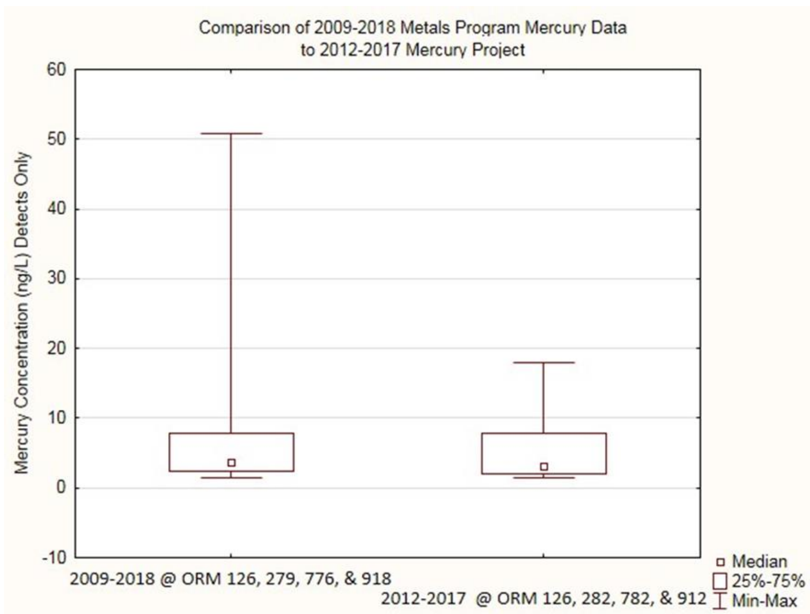
The Licking and the Green Rivers had the highest mercury yields of all tributaries at 4.8 µg/m²/yr and 5.4 µg/m²/yr (Table 9, Fig. 6). The Green River mercury load (285 lbs) was high compared with other sites, while the Licking River mercury load (102 lbs) was lower. While the Licking and Green Rivers have similar mercury yields, they have vastly different drainage areas (and loads). Mercury yields in the Little Miami River (1.1 µg/m²/yr) and the Great Miami River (0.6 µg/m²/yr) had the lowest yields. The Ohio River Local watersheds mercury yields generally increase with river mile, from 1.5 µg/m²/yr at ORM 126, to 3.6 µg/m²/yr at ORM 912 (Table 9, Fig. 6).

Descriptive statistics (e.g. mean, median, standard deviation, and variance) for the 12 monthly monitored mercury concentration samples were calculated (Appendix Table A7). The monthly mercury concentrations during the study period reveals that the Big Sandy River had the highest variance at 78.42 ng/L followed by the Wabash River (34.39 ng/L) and the ORM 912 (34.02 ng/L). The highest mean mercury concentrations were also the Big Sandy River, Wabash River, and the ORM 912 ranging from 6.05 ng/L to 9.41 ng/L for the mean.

Twelve mercury concentration samples for the calibration is the minimum amount necessary for the LOADEST to calculate estimated loads. The regression equations used by the LOADEST model are fairly complex. Since only 12 mercury concentration samples were used, there might be an element of overfitting going on in LOADEST due to the limited number of data points. The percent difference of estimated loads between LOADEST and polynomial regression ranges from 2% to 39%, excluding ORM 126 (Table 7). The mercury estimated loads from the two sources were similar enough to suggest overfitting was not a major issue.

LOADEST was used to evaluate the representativeness of the estimated loads with summary statistics: Load Bias in Percent (Bp), Partial Load Ratio (PLR), and Nash Sutcliffe Efficiency Index (E). When Bp values were positive or negative exceeding ±25% bias, this suggests that the load estimation was over or under. PLR is the sum of estimated loads divided by sum of observed loads. Values greater than or less than 1 suggest an overestimation or underestimation, and best fit equals 1. Lastly, when E equals 1, then the model was a perfect fit to observed data. When E equals 0, then model estimates were as accurate as the mean of observed data. These statistics show the estimation to be good fits, except for the Kentucky River. The Kentucky River has a Bp of -28.23, meaning the load of 71 lbs was an under estimate (Appendix Table A6.). Using the polynomial equation, the load for Kentucky River was 115 lbs, which was greater than the LOADEST estimate. The R^2 for the Kentucky River polynomial equation was 60% and the R^2 for the Kentucky River LOADEST equation was 90%. The LOADEST model was likely an under estimation, but was still a better fit than the polynomial equation. Aside from the Kentucky River, Bp's ranged from -9.52 % to 9.2 %, which was in the acceptable range (±25% bias according to LOADEST). The PLR for the tributaries and Ohio River during the study period ranged from 0.72 for the Kentucky River and 0.92 for the Scioto and Kanawha rivers, to 1.09 at ORM 912 (Appendix Table A6). E values range from 0.22 (Cumberland River) to 0.99 (Big Sandy and Licking Rivers), indicating the model estimates were good fits to the observed data. Overall, given the observed statistics fell within their respective constraints, the LOADEST estimations were deemed to be reasonable.

Instream mercury concentrations from the four main stem stations (2012-2017) were combined and compared against ten years (2009-2018) of mercury concentration data combined from four long-term monitoring stations located nearest these project monitoring stations (Fig. 7; same as Fig. 25 in Chapter 5). One would conclude based on this comparison that the project period data were similar to conditions over a longer time period. This suggests that, relative to Ohio River mercury concentrations, the project period was similar to a longer time period. In other words, the project monitoring data were not collected under unusual conditions relative to longer term mercury concentrations.



*Non-detections were set to 0.

Figure 7. Comparison of this project's main stem mercury data (right box plot) with 10 years of ORSANCO's bimonthly metals program mercury data (left box plot), where data below the detection level was set to zero).

2.5 Summary and Conclusions

Methods described above were used to combine ORSANCO mercury monitoring data with USGS and Cascade flow data to calculate instream mercury loads from the 15 major tributaries and the Ohio River. The total mercury loading from the 13 major tributaries to the Ohio River main stem upstream of ORM 912 was 1,461 lbs (excluding Cumberland and Tennessee rivers which are downstream of ORM 912), or about 49 % of the total mercury loading in the Ohio River at ORM 912 (2,961 lbs). This loading estimate does not include the instream loads from the Cumberland and Tennessee Rivers since their confluences are downstream of the most downstream Ohio River station at ORM 912.

Mercury loads in the Ohio River increase in a downstream direction indicating the cumulative effects of sources upstream in the watershed. The Green and Wabash Rivers had the highest mercury loads of all tributaries, while the Licking and Green Rivers had the highest tributary yields. ORM 912 had the highest mercury load of all project sites.

A comparison of project mercury concentrations for the main stem to historical concentrations suggests that the project period mercury concentrations represent typical conditions.

Chapter 3: Point Source Mercury Loads

3.1 Approach

Point source mercury loads for the one year project period were calculated using discharge monitoring report data from the U.S. EPA's Enforcement and Compliance History Online (EPA-ECHO) database, or directly from the states. Point source data used in the project was checked by the states. There were 752 monitored outfalls discharging mercury from 653 facilities throughout the Ohio River Basin (ORB) (Table 3). The method for calculating the mercury loads is presented, and the results are discussed in the following sections. Intermittent storm water discharges and non-contact cooling water discharges were excluded from the results as discussed below. It should be noted that NPDES discharges without mercury monitoring requirements may contain mercury in their discharge.

The great majority of NPDES permits in the basin do not include mercury monitoring and reporting requirements because for many of these permits, such as general storm water permits, mercury is not a primary contaminant of concern. Otherwise, mercury was not identified as having reasonable potential to cause or contribute to an excursion above the water quality standard via the permitting agency's EPA-approved reasonable potential analysis. Reasonable Potential Analysis (RPA) is a process used by permit writers to determine whether a Water Quality-Based Effluent Limit (WQBEL), or monitoring, is required for a pollutant in a NPDES permit. This process is used to determine whether a discharge(s) has the potential to cause or contribute to an excursion above an applicable water quality standard. Reasonable potential calculations and procedures are outline in EPA's "Technical Support Document for Water Quality-based Toxics Control" (EPA 505/2-90-001). The reasonable potential methodology and statistical approach implement the water quality-based effluent limit and reasonable potential requirements of 40 CFR 122.44(d) (1) in a manner that is scientifically, statistically, and regulatory defensible.

3.2 Methods

Mercury point source discharge data used to calculate mercury loads in the Ohio River Basin was either retrieved from the U.S. EPA's EPA-ECHO national database or sent directly by each state. Final datasets were reviewed and approved by the relative state agencies. The ECHO system incorporated data from the Integrated Compliance Information System National Pollutant Discharge Elimination System (ICIS-NPDES) [11]. ICIS-NPDES, and thus ECHO, is an information management system maintained by the Office of Compliance to track monitoring and compliance of facilities regulated by the NPDES under the Clean Water Act (CWA). ECHO database contains discharge monitoring data for facilities required to monitor through their NPDES permit. Permitted facilities self-monitor and report total mercury concentrations and daily flow discharge at a frequency specified in their permit, and for many facilities, that would include twice annually or quarterly sampling. For the most part, there was not an abundance of discharge data.

A minimum loading was calculated by setting all values below the detection level to zero, then averaging mercury concentrations and flows for the year, and then multiplying those averages by 365 days with appropriate conversion factors to obtain a mercury loading in lbs. A maximum loading was calculated in the same way, except values below the detection level were set at the detection level. There were 752 monitored outfalls and 653 monitored facilities discharging mercury varying across 11 states throughout ORB (Table 3). The data set has 250 outfalls (33.24%) with non-detect mercury concentration values (out of 752 outfalls). The mercury load (lbs) for each outfall was calculated by multiplying the average daily concentration (mg/L) and the average daily flow (MGD) by 365 days and appropriate conversion factors (Appendix Table A8-A36). The mercury loads (lbs) from each outfall were summed for each watershed (using GIS). This was done for two scenarios (1) when the non-detects were equal to zero (minimum) and (2) when the non-detects were equal to the detection limit (maximum).

By definition intermittent storm water discharges do not consistently discharge and rarely is the duration of the discharge documented. These discharges were therefore excluded from the data set due to a lack of accurate flow data to calculate an accurate estimate of a load. Pure non-contact cooling water discharges were also excluded from the data set, since such discharges return mercury to the same waterbody from which it was withdrawn, thereby not adding any additional mercury to the system.

3.3 Results

The minimum point source mercury load for the study period in the Ohio River Basin varies by watershed from 0.04 lbs (Licking River) to 9 lbs (OR Local 3, Table 11, Fig. 8, Fig. 10). The maximum point source mercury load for the study period in the Ohio River Basin ranged from 0.04 lbs (Licking River) to 18.9 lbs (Cumberland River, Fig. 9). The largest differences between the minimum and the maximum occurred in the Cumberland River watershed (11.6 lbs) and the OR Local 5 watershed (7.1 lbs, Table 11, Fig. 10). These differences were due to the facilities' detection levels and values below the detection level in their discharge. A method with a high detection level will increase the maximum loading result.

At ORM 912, the cumulative minimum point source mercury load for the Ohio River Basin was 43.6 lbs (non-detections set equal to zero) and the maximum was 63.0 lbs (non-detections set at the detection level) (Table 11). For outfalls discharging to the Ohio River, the cumulative mercury load at ORM 912 was 19 lbs (minimum, below detection level values set to zero) and 25 lbs (maximum, below detection level values set to the detection level) (Table 12, Fig. 11; same as Fig. 24 in Chapter 5). At ORM 912, there were a total of 685 monitored outfalls upstream in the watershed, of which 135 discharge directly to the Ohio River.

Table 11. Minimum and maximum point source mercury loading during study period November 2015 thru October 2016.

[Hg, mercury; ORM, Ohio River Mile point; min, minimum (Hg concentration non-detects are calculated as 0); max, maximum (Hg concentration non-detects are calculated as detection limit); Shaded cells are accumulative values upstream of the mile point shown]

Watershed	Number of Hg Monitored Outfalls	Min Point Source Hg Load (lbs)	Max Point Source Hg Load (lbs)	Load (lbs) Difference
Allegheny	7	0.2	2.6	2.4
Monongahela	15	1.3	1.5	0.1
Beaver	29	1.0	1.0	0
OR Local 1	55	1.7	4.1	2.4
ORM 126	106	4.2	9.1	4.9
Muskingum	97	1.8	1.8	0.01
Kanawha	37	5.6	8.9	3.3
OR Local 2	49	8.6	9.1	0.5
ORM 282	289	20.2	28.9	8.7
Big Sandy	33	0.3	0.7	0.4
Scioto	63	0.4	3.0	2.6
Little Miami	27	0.3	0.6	0.3
Licking	3	0.04	0.04	0
Great Miami	60	1.3	2.5	1.2
Kentucky	9	0.4	1.0	0.6
OR Local 3	91	9.0	11.8	2.9
ORM 782	575	31.9	48.5	16.6
Green	21	2.2	4.8	2.6
Wabash	74	8.8	9.0	0.2
OR Local 4	15	0.7	0.7	0.03
ORM 912	685	43.6	63.0	19.4
Cumberland	34	7.3	18.9	11.6
Tennessee	27	9.8	9.8	0
OR Local 5	6	0.3	7.4	7.1
Ohio River Basin	**752**	**61.0**	**99.1**	**38.2**

Table 12. Point source mercury loads discharging directly into the Ohio River accumulating at each mile point during the study period November 2015 thru October 2016

[Hg, mercury; lbs, pounds; min, minimum (Hg concentration non-detects are calculated as 0), max, maximum (Hg concentration non-detects are calculated as detection limit)]

Watershed	Number of Hg Monitored Outfalls	Min Point Source direct discharges load (lbs) to Ohio River accumulative	Max Point Source direct discharges load (lbs) to Ohio River accumulative
ORM 126	32	1	4
ORM 282	69	10	13
ORM 782	126	19	24
ORM 912	135	19	25

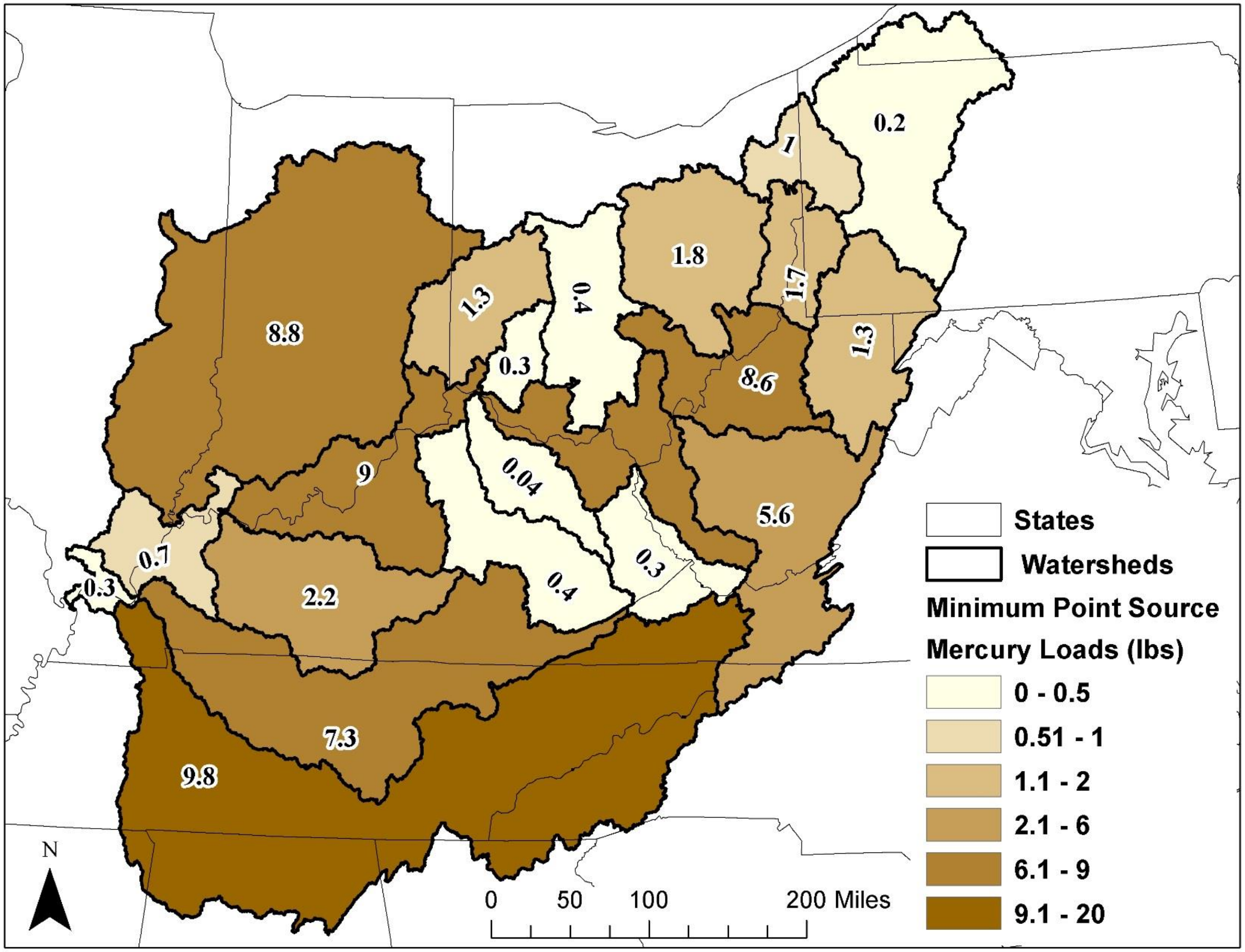


Figure 8. Minimum (Non-detects=0) point source mercury loading (pounds; lbs) per watershed in the Ohio River Basin during the study period.

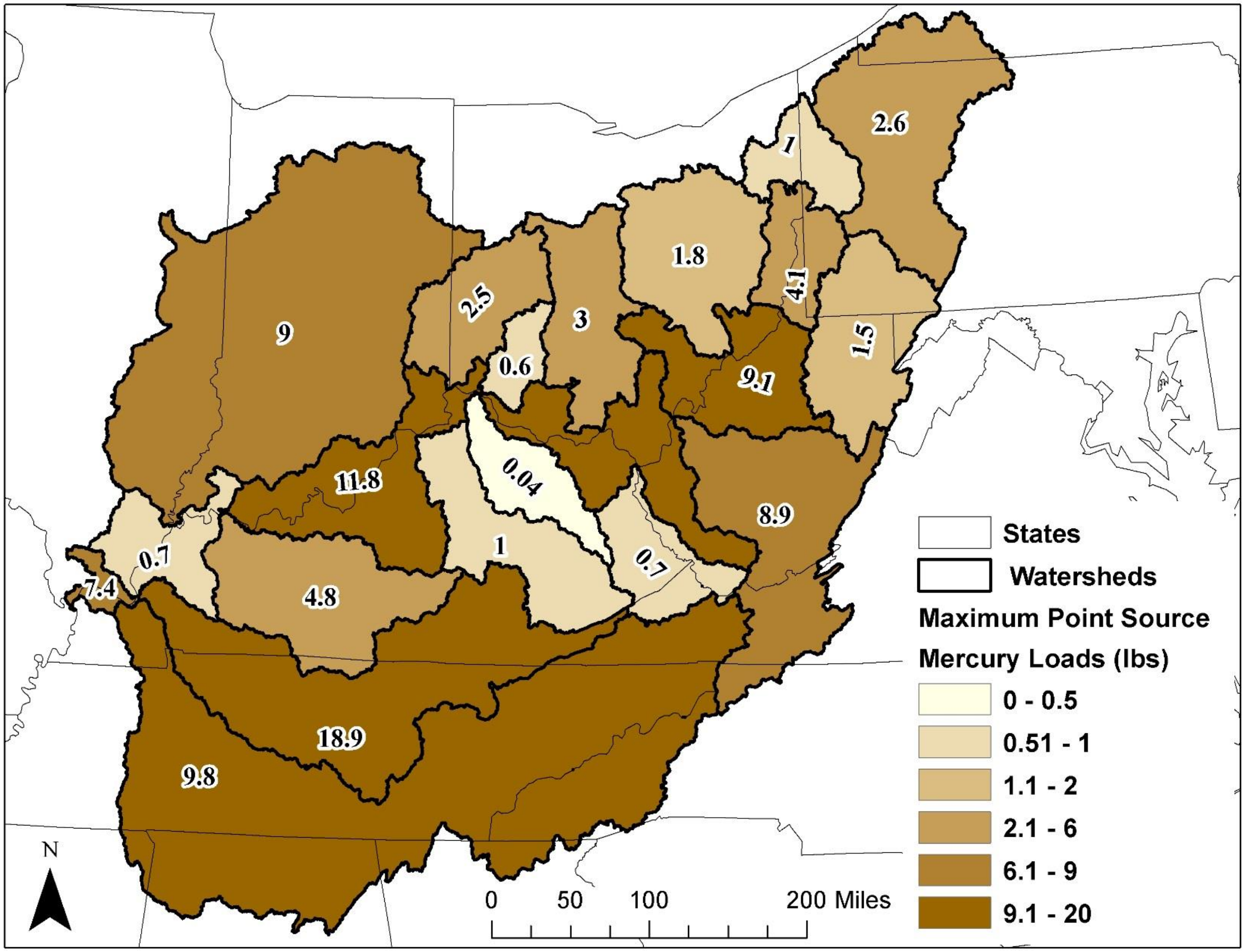


Figure 9. Maximum (Non-detects=detection limit) point source mercury loading (pounds; lbs) per watershed in the Ohio River Basin during the study period.

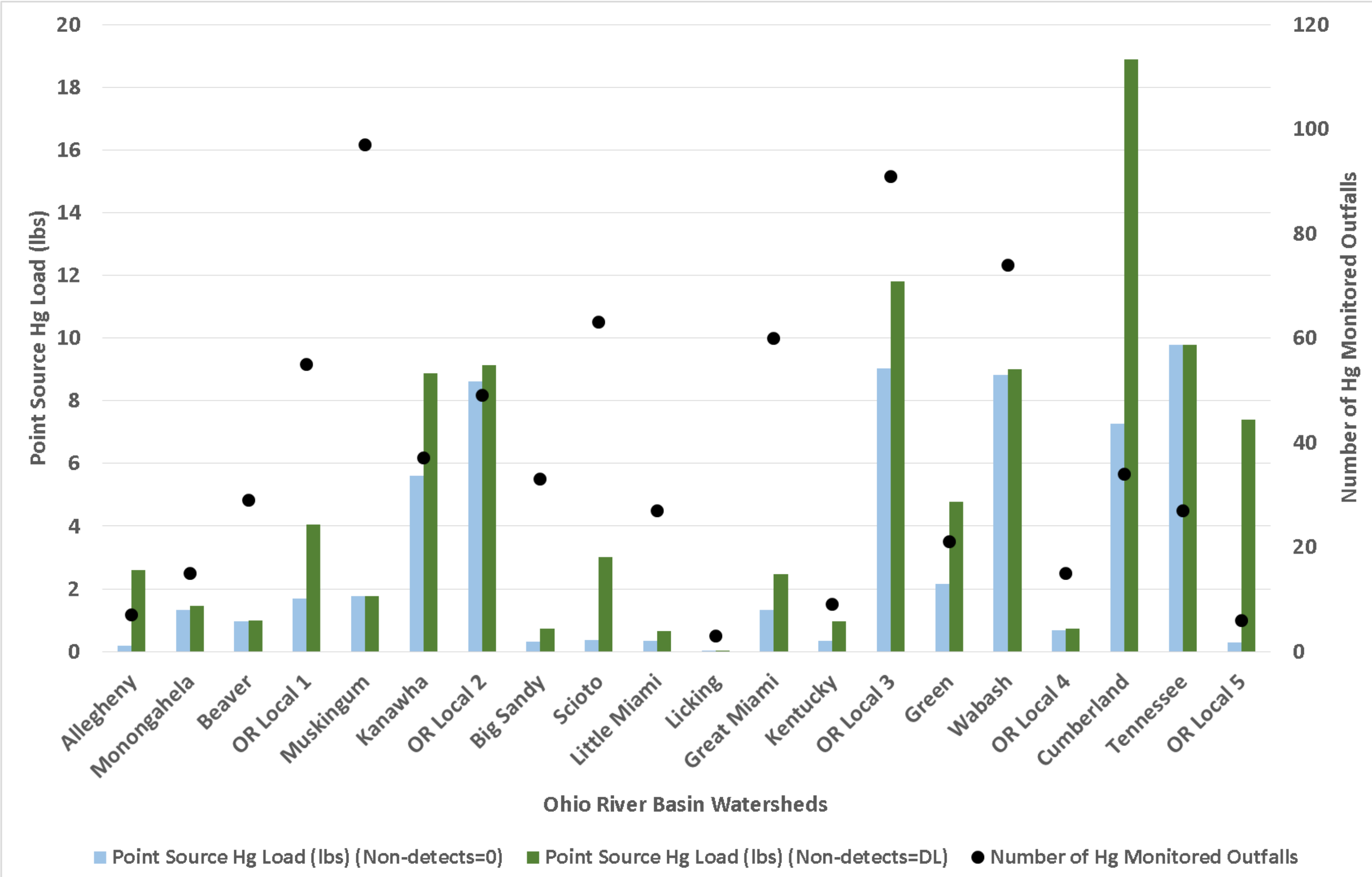


Figure 10. Total point source mercury (Hg) loadings per Ohio River Basin watershed compared to number of discharging mercury monitoring outfalls in each watershed.

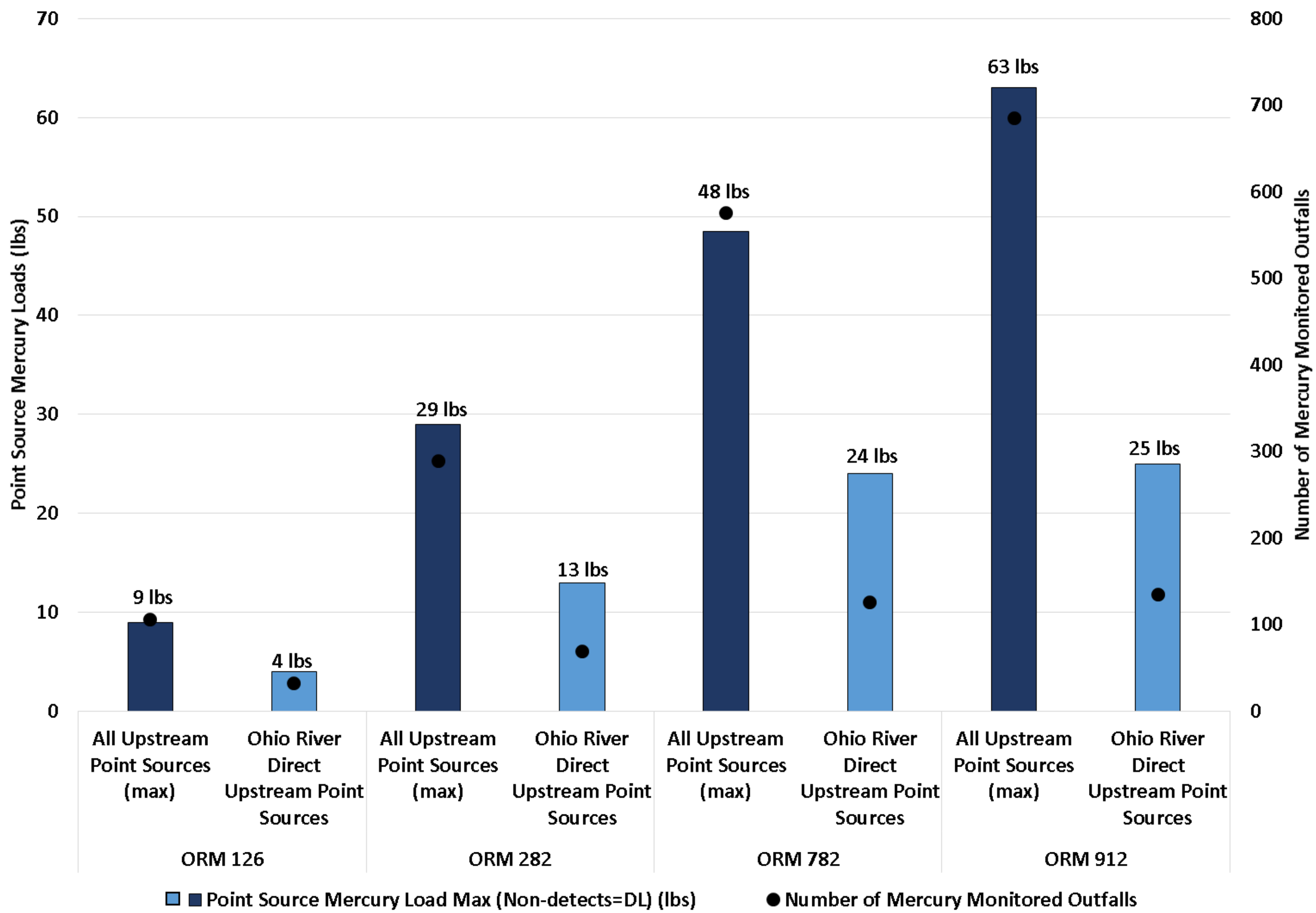


Figure 11. All mercury (Hg) outfall loads (pounds; lbs) accumulating throughout Ohio River Basin compared to the mercury outfall loads (lbs) only directly on the Ohio River accumulating to Ohio River mile points 126, 282, 782, and 912.

3.4 Discussion

Differences in the point source loadings throughout the Ohio River Basin watersheds were due to differences in the number and types of discharges, discharge flow volumes, mercury concentrations, and variable monitoring requirements by state. The Excel CORREL function was used to assess the correlation between the number of outfalls and the point source mercury loadings for each watershed (N=20). The correlation coefficient between numbers of outfalls and minimum (and maximum) point source mercury loading was 0.47 (0.29). There was a low correlation between the number of outfalls and the mercury loads meaning more permitted point source outfalls does not necessarily mean there were more mercury loads per watershed.

Overall, these calculations were an estimate of point source mercury loading within Ohio River Basin as they were highly dependent on the data provided. Point source discharge data was available when a discharge has a monitoring requirement and/or an effluent limitation for mercury in their permit. These mercury loading estimates only represent monitored discharge sources, and exclude loadings from intermittent storm water and non-contact cooling water. Given the pervasive nature of trace mercury levels throughout the atmosphere and soils, there were probably sporadic trace levels of mercury transported in storm water virtually everywhere. This may be the prime mechanism by which atmospheric deposition upon the watershed is transported to the Ohio River and tributaries. Storm water sources in contact with industrial areas that have potential exposure to elevated mercury concentrations are regulated and required to monitor. Otherwise, intermittent storm water was not a point source used for this study, and their exclusion does not materially affect the point source loadings for this study. It is noted that point sources not monitored for mercury may contain de minimis amounts of mercury in their discharge.

3.5 Summary and Conclusions

Discharge monitoring data were utilized to calculate a point source mercury load to the 15 major tributary watersheds and the five Ohio River Local watersheds. The minimum and maximum point source mercury loadings at ORM 912 were 43.6 lbs and 63 lbs, respectively. The methods and data were deemed to be the most reasonable given the limited availability of data. These findings were appropriate to use in the broader ORSANCO goal of comparing mercury point source loads to instream loads. At ORM 912, there were a total of 685 mercury outfalls upstream in the basin discharging 63 lbs of mercury. Of those, 135 outfalls discharge directly to the Ohio River totaled 19 lbs (minimum, non-detections set to zero), and 25 lbs (maximum, non-detections set to the detection level) of mercury.

Chapter 4: Atmospheric Mercury Deposition

4.1 Approach

Atmospheric mercury deposition was calculated with monitoring data from three National Atmospheric Deposition Program (NADP) networks by use of geographic information system (GIS) software. Three types of mercury deposition are described separately for the 20 watersheds: wet-mercury deposition, dry-mercury deposition to forest land cover, and dry-mercury deposition to non-forest land cover. The method for calculating each mercury deposition is presented and the results discussed in the following sections. Finally, the three mercury deposition types were summed for each watershed and the Ohio River Basin. The total mercury mass deposition was calculated for each watershed and the entire basin (in pounds). A normalized deposition (in micrograms per square meter) was also calculated by dividing the watershed deposition (in milligrams) by the watershed area [equation 2]. Normalized mercury deposition were uniformly comparable by type and among different sized watersheds. The atmospheric mercury deposition calculations do not account for retention of mercury in the landscape as that was beyond the scope of this study. Chapter 4 is an abridged version of "Atmospheric Mercury Loads to Watersheds in the Ohio River Basin" by Martin Risch, Bridget Taylor, and Jason Heath; for more information please consult this report [36].

$$\left(\frac{\text{mg/year}}{\text{km}^2}\right) \times\ 0.001\ = \mu\text{g/m}^2\text{/yr} \qquad [2]$$

4.2 Methods

4.2.1 Wet Atmospheric Mercury Deposition

Weekly precipitation monitoring data from 20 NADP Mercury Deposition Network (MDN) sites in the Ohio River Basin or within 110 km of the Basin boundary were used to calculate wet-mercury deposition for this study (Fig. 12) [23]. The data records from these sites were complete for 2014 through 2016 fitting the study period November, 2015 through October, 2016. Weekly observations with precipitation less than 0.25 mm and no reported mercury concentrations were not included. Missing weekly mercury values were interpolated with data from valid samples using established research methods [28, 33-34]. For valid samples, weekly mercury concentration and precipitation depths were used to calculate precipitation-weighted mercury concentration for each site during the study period [equation 3] (Table 13). As used by the NADP and previous research, the precipitation-weighted mercury concentration accounts for variability of weekly precipitation mercury concentrations during the year that include high mercury concentrations in low volume (low mercury mass) samples that would bias a mean concentration. The precipitation-weighted mean concentration was a good measure to calculate weekly mercury deposition because it will reduce the bias imparted by low-volume-high concentration samples.

$$WC = C \times (S/T) \qquad [3]$$

Where WC is weekly volume-weighted concentration (ng/L), C is weekly concentration (ng/L), S is weekly sample volume (mL), and T is sum of weekly sample volume (during study period) (mL).

GIS software was used to apply an inverse-distance-weighted algorithm to a 5-km by 5-km grid overlain on the study area [13]. Weights are proportional to the inverse of the distance (d) between the data sites raised to the power value (^{p}), where a higher power value will decrease the weights for distant points [equation 4]. The algorithm interpolated precipitation-weighted mercury concentration to grid cells between the 20 NADP sites based on the five nearest sites to each grid cell, applying a power of three for the nearest points.

$$w(d)= 1/d^p \qquad [4]$$

Precipitation depths for the study period were obtained from the spatial climate dataset PRISM, and GIS was used to prepare a raster formatted dataset for the 5-km by 5-km grid overlain on the study area [25]. The raster-formatted mercury concentration dataset (ng/L) was multiplied by the precipitation depth dataset (millimeters) to calculate a wet-mercury deposition (micrograms per square meter) for each 25 km^2 grid cell.

GIS was used to overlay the boundaries of the 20 watersheds and to sum the wet-mercury deposition from the grid cells in each watershed (in pounds). Isopleth maps were constructed using GIS with color-coded ranges of the mercury concentration, precipitation depths, wet-mercury deposition, and normalized wet-mercury deposition in the study area.

Table 13 National Atmospheric Deposition Program Mercury Deposition Network sites and precipitation-Weighted mercury concentrations for Ohio River Basin, November 1, 2015 through October 31, 2016.

(No., number; ID, identification; km, kilometer; Hg, mercury; ng/L, nanogram per liter)

No.	Site ID	Site Name	Location	Precipitation-weighted Hg concentration (ng/L)
1	AL19	Birmingham	70.6 km outside basin boundary	9.4
2	GA40	Yorkville	84.4 km outside basin boundary	8.5
3	IL11	Bondville	8.5 km outside basin boundary	10.4
4	IN21	Clifty Falls State Park	in Ohio River Basin	7.6
5	IN22	Southwest Purdue Agriculture Center	in Ohio River Basin	9.3
6	IN34	Indiana Dunes National Lakeshore	52 km outside basin boundary	7.7
7	KY10	Mammoth Cave National Park	in Ohio River Basin	7.5
8	MO46	Mingo National Wildlife Refuge	78.6 km outside basin boundary	8.4
9	NY43	Rochester	107.3 km outside basin boundary	7.5
10	OH02	Athens Super Site	in Ohio River Basin	7.3
11	OH52	South Bass Island	78.9 km outside basin boundary	7.4
12	PA13	Allegheny Portage National Historic Site	in Ohio River Basin	8.1
13	PA21	Goddard State Park	in Ohio River Basin	9.1
14	PA29	Kane Experimental Forest	in Ohio River Basin	7.3
15	PA30	Erie	14.2 km outside basin boundary	8.1
16	PA37	Waynesburg	in Ohio River Basin	9.9
17	PA42	Leading Ridge	56.7 km outside basin boundary	6.7
18	PA90	Hills Creek State Park	53.9 km outside basin boundary	7.2
19	TN11	Great Smoky Mountains National Park	in Ohio River Basin	10.4
20	VA28	Shenandoah National Park	97.2 km outside basin boundary	5.1

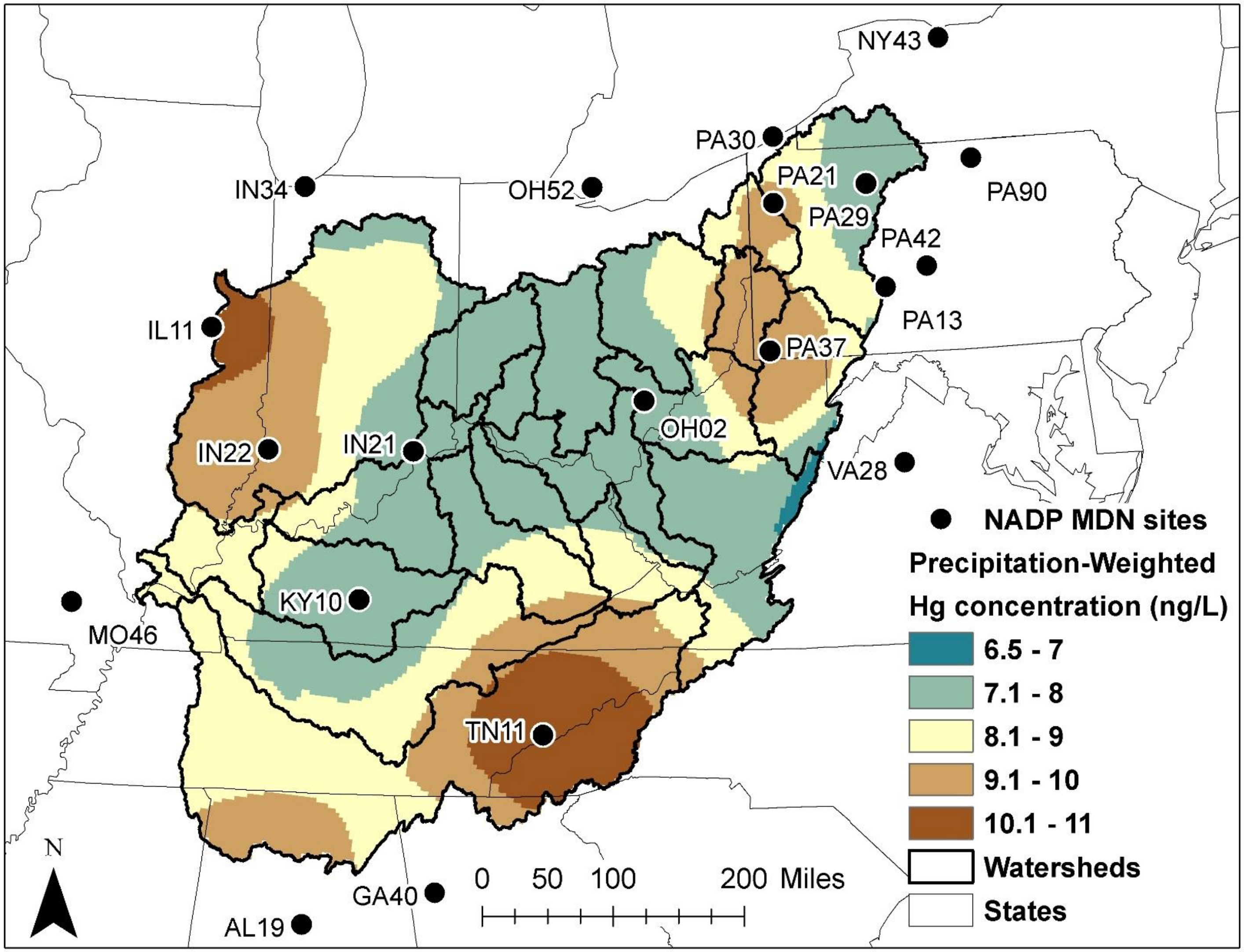


Figure 12. Locations of National Atmospheric Deposition Program (NADP) Mercury (Hg) Deposition Network (MDN) sites for calculating wet-mercury deposition to the study area overlaying precipitation-weighted mercury concentration isopleth map for study period.

4.2.2 Dry Forested Atmospheric Mercury Deposition

Forest land cover in the study area was delineated with GIS and was further delineated according to 12 forest types in a U.S. Forest Service classification (Fig. 13) [19, 46]. This spatial dataset contained five forest types, which comprised more than 0.1% of the forest land cover in the study area. Dry-mercury deposition was calculated for the spatial dataset of each forest type. The NADP Litterfall Mercury Monitoring Network 2016 data methods were consulted to obtain dry-mercury deposition rates for 13 sites within, and near, the study area (Fig. 13, Table 14) [30, 35]. Passive sample collectors were deployed during the entire autumn leaf drop season, and the litterfall was retrieved from the collectors on a monthly schedule to be analyzed for mercury. GIS software was used to apply an inverse-distance-weighted algorithm to a 2.5-km by 2.5-km grid overlain on the study area to interpolate dry-mercury deposition rates between sites in the predominant oak-hickory forest type, based on the five nearest sites to each grid cell, applying a power of three for the nearest points [13]. GIS was used to assign dry-mercury litterfall deposition rates from the isopleth map to grid cells in the oak-hickory forest type (Fig. 14). The NADP data and methods were used to derive dry-mercury deposition index rates for the four other forest types (Table 15) [30, 35]. Allegheny and Tennessee watersheds were outside the oak-hickory isopleth map, so dry-mercury deposition index rates were derived for these two watersheds with the same NADP data and methods as the other four forest types. The deposition rates were assigned to forest types that comprised the majority of forest land cover in each watershed until dry-mercury deposition was calculated for approximately 99% of the forest cover in each watershed.

The oak-hickory forest type comprised 84.5% of the forest land cover and contributed 85% of the dry-mercury deposition from forest land cover in the study area. The inverse-distance-weighting method for interpolation of dry-mercury deposition to the oak-hickory forest type was selected because it was objective and consistent with the wet-mercury interpolation. The selected method was compared with two other methods—use of the value for the closest NADP monitoring site and the average value for the three closest NADP monitoring points. The comparison indicated dry-mercury deposition was within 1% to 3% of those for the inverse-distance-weighting method, meaning the results were not highly sensitive to the method criteria.

Table 14. National Atmospheric Deposition Network Litterfall Mercury Monitoring Network sites in vicinity of study area

[Hg, mercury; μg/m²/yr, microgram per square meter per year; ID, identification]

Site ID	Forest type	2016 dry-Hg litterfall load rate (μg/m²/yr)[a]
IN21	oak-hickory	12.4
IN22	oak-hickory	14.9
IN34	oak-hickory	15.1
MO46	oak-hickory	15.2
PA13	maple-beech-birch	15.4
PA18	maple-beech-birch	8.4
PA21	maple-beech-birch	11.0
PA29	maple-beech-birch	14.9
PA30	hardwood	13.9
PA42	hardwood	9.7
PA52	oak-hickory	9.5
PA90	maple-beech-birch	5.7
TN11	oak-hickory	12.8

[a] Calculated with data from reference [34] using methods in [30]

Table 15. Dry-mercury deposition index rates for forest cover types in study area during study period

[μg/m²/yr, microgram per square meter per year; IDW, inverse-distance-weighting algorithm; NADP, National Atmospheric Deposition Program; Hg, mercury]

Forest type	Dry-Hg deposition index rate (μg/m²/yr)	Reference for Dry-Hg deposition index rate[a]
Oak-hickory	variable	IDW interpolationof 2016 data from 6 NADP Litterfall Hg Network sites [34]
Maple-beech-birch	13.8	mean of 2016 data from NADP Litterfall Hg Network sites PA13, PA21, PA29 [34]
Elm-ash-cottonwood	9.1	median litterfall Hg load for hardwood forest type in [30]
Oak-gum-cypress	7.1	median litterfall Hg load for mixed forest type in [30]
Oak-pine	14.7	2015-2016 average litterfall Hg load at MD99; mixed forest type in [30]

[a] References [34], [30]

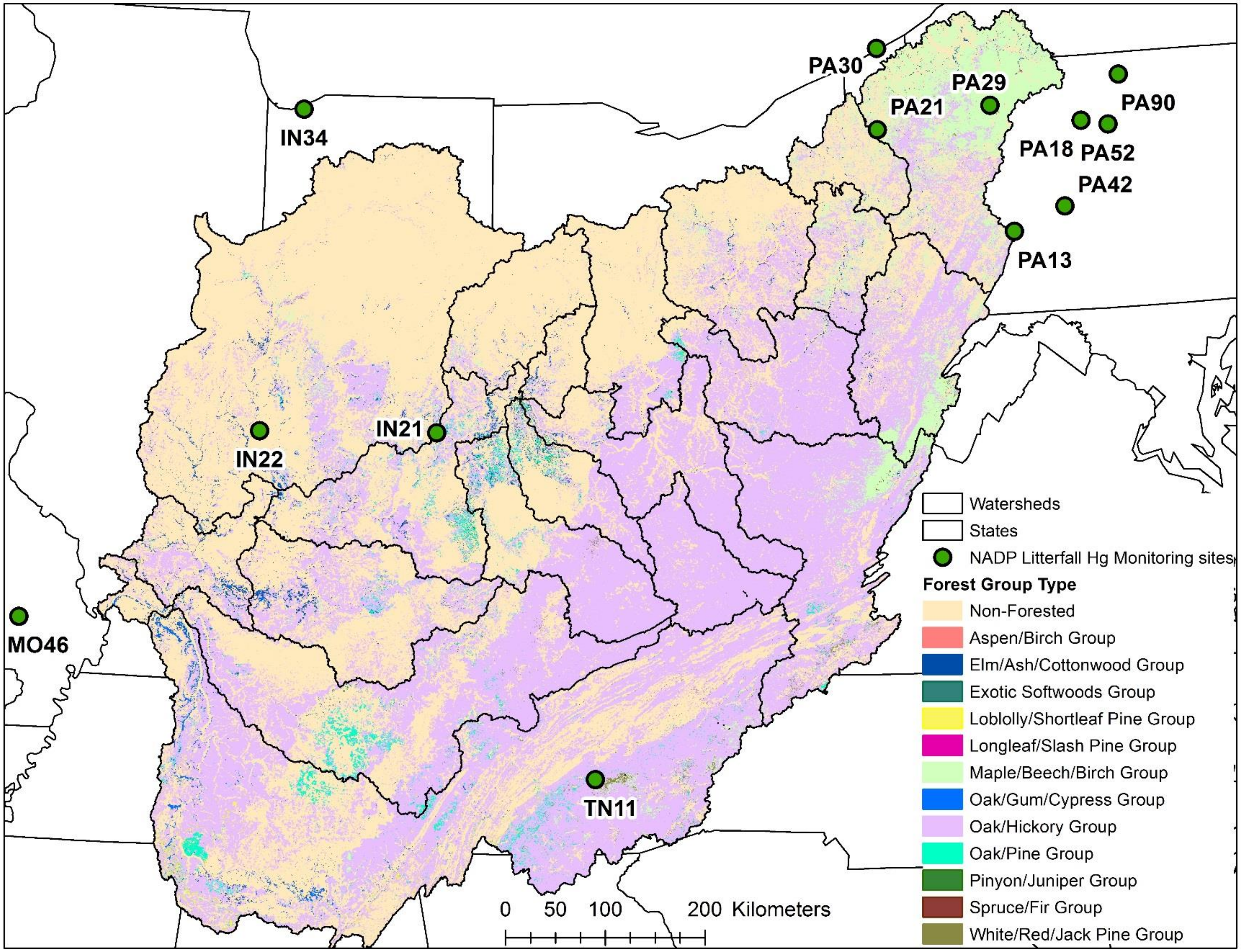


Figure 13. Forest types throughout Ohio River Basin and National Atmospheric Deposition Program (NADP) Litterfall Mercury (Hg) Monitoring Network sites in 2016 in and near the study area.

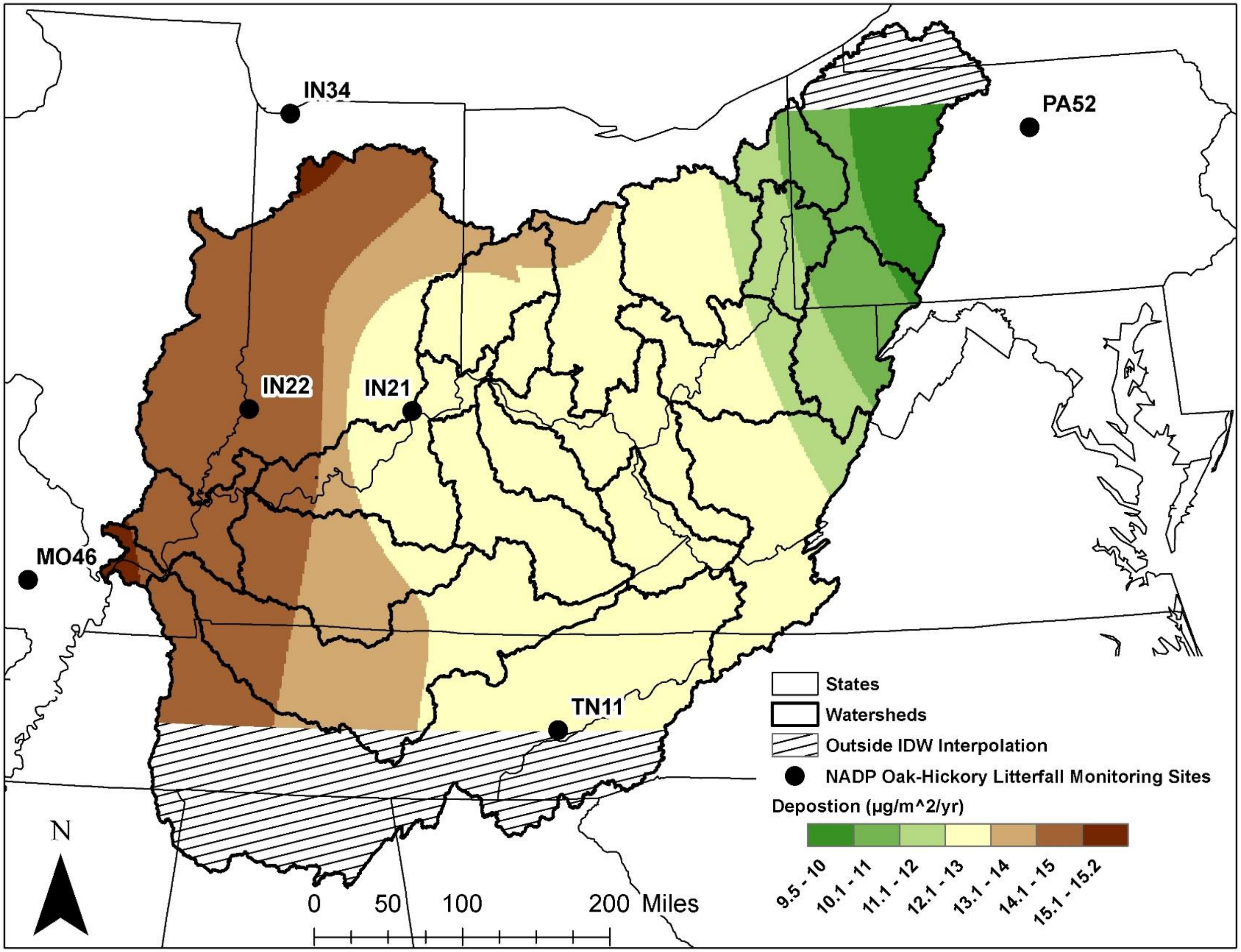


Figure 14. Isopleth map of dry mercury (Hg) litter fall deposition rates in 2016 for the oak-hickory forest type in the study area.

4.2.3 Dry Non-Forested Atmospheric Mercury Deposition

Non-forest land cover in the study area (Fig. 15) was delineated with the GIS and was further delineated as four land cover types based on single or combined classes from the National Land Cover Dataset [6]. From this, a spatial dataset was prepared that contained the four land cover types that comprised more than 0.8 % of the total non-forest land cover. The NADP Atmospheric Mercury Network (AMNet) data for five sites active during the study period, in or near the study area, were consulted to calculate dry-mercury deposition for each land cover type (Fig. 15) [23]. AMNet site OH02 was selected as the site with appropriate data for dry-mercury deposition index rates for the cropland, urban, and grassland land cover types as it comparably most represents these land covers. AMNet site OH52 was selected as the site with appropriate data for a dry-mercury deposition index rate for the open water land cover type since it is on the coast of Lake Erie. AMNet sites continuously collect and analyze air samples for three operationally defined fractions of mercury (GEM, GOM, and PBM; defined in the introduction section of this report). The method developed for AMNet data and used by NADP to calculate dry-mercury deposition rates was referenced for the dry-mercury deposition index rates for the four land cover types (Table 16) [56]. GIS software was used to apply the index rates to the spatial dataset of the four land cover types [13].

Table 16. Non-forest land cover types, dry-mercury deposition index rates, and dry-mercury deposition for study area during study period

[km^2, square kilometer; $\mu g/m^2/yr$, microgram per square meter per year; Hg, mercury; total, sum of 3 Hg fractions; GEM, gaseous elemental Hg; GOM, gaseous oxidized Hg; PBM, particulate bound Hg]

Non-Forest Land Cover		Dry-Hg deposition in $\mu g/m^2/yr$ [a]				
		Index rate [a]				Hg Deposition (kg)
Type	Area (km^2)	Total	GEM	GOM	PBM	
Cropland	180,221	11.7	9.7	0.9	1.1	2,109
Urban	49,827	7.3	4.4	1.4	1.5	364
Grassland	13,223	9.0	7.0	0.9	1.1	119
Water	7,771	1.4	0.0	0.8	0.6	11

[a] from reference [54]

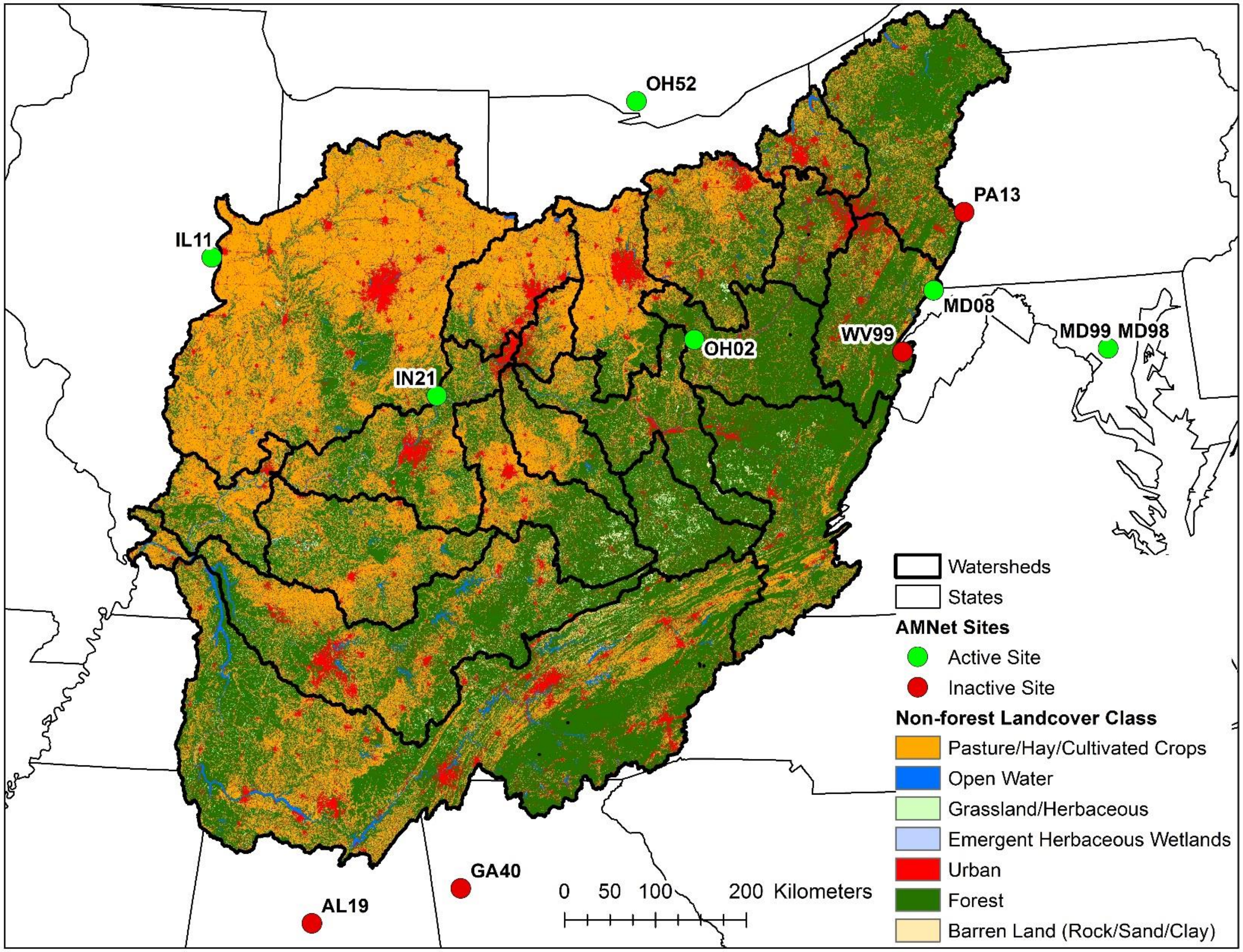


Figure 15. Non-forest land and forest land cover types corresponding with National Atmospheric Mercury Network (AMNet) 2016 sites in and near the study area.

4.3 Results

4.3.1 Wet Atmospheric Mercury Deposition

The precipitation-weighted mercury concentration for the study period ranged from 5.1 to 10.4 nanogram per liter (ng/L) (Fig. 12, Table 13). The precipitation depths for the study period ranged from 780 to 2,124 millimeter (mm) (Fig. 16). Wet-mercury deposition by watershed ranged from 60 to 2,815 pounds (lbs) (Table 17). Normalized (to watershed area) wet-mercury deposition to the 20 watersheds for the study period ranged from 7.9 µg/m^2/yr in the Scioto River and Muskingum River watersheds to 13.3 µg/m^2/yr in the Ohio River Local four watershed near the Green River (Table 17); the median was 9.7 µg/m^2/yr. Normalized wet-mercury deposition to the Ohio River Basin during the study period was 10.6 µg/m^2/yr.

Table 17. Wet-mercury deposition and normalized deposition for watersheds during the study period.

[Hg, mercury; lbs, pounds; µg/m^2/yr, microgram per square meter per year]

Watershed	Wet-Hg deposition (lbs)	Normalized wet-Hg deposition (µg/m^2/yr)
Allegheny	590	8.8
Monongahela	460	10.9
Beaver	159	8.8
OR Local 1	200	10.0
Muskingum	365	7.9
Kanawha	663	9.5
OR Local 2	356	9.3
Big Sandy	229	9.4
Scioto	295	7.9
Little Miami	90	9.0
Licking	195	9.2
Great Miami	256	8.4
Kentucky	416	10.5
OR Local 3	929	10.0
Green	632	12.0
Wabash	2,099	11.2
OR Local 4	319	13.3
Cumberland	1,159	11.3
Tennessee	2,815	12.1
OR Local 5	60	11.4
Ohio River Basin	**12,287**	**10.6**

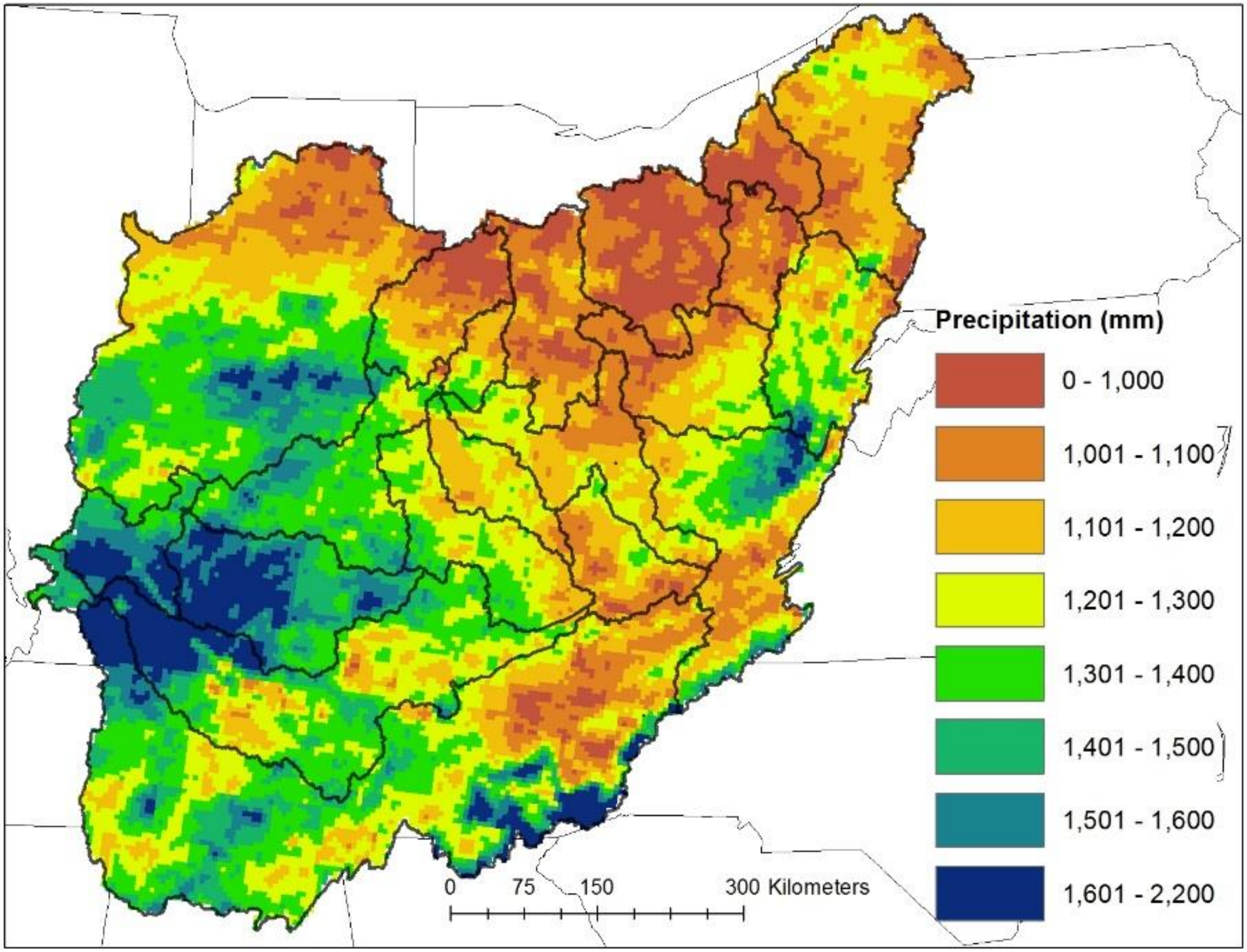


Figure 16. Precipitation depth isopleth map for study period.

4.3.2 Dry Forested Atmospheric Deposition

The Ohio River Basin has 51.9% forest land cover, which varies by watershed from 7.8% (Great Miami River) to 93.8% (Big Sandy River); the median was 48.4% (Fig. 13). The dominant forest type is oak-hickory, comprising 84.5 % of forest cover, followed by 10.4% maple-beech-birch, and 3.9% for the remaining three forest types. Normalized (to watershed area) dry-mercury deposition to forest land cover total watershed area ranged from 1.0 µg/m^2/yr (Great Miami River) to 11.8 µg/m^2/yr (Big Sandy River, Table 18). Normalized dry-mercury deposition to forest land cover in the total Ohio River Basin area during the study period was 12.5 µg/m^2/yr. Watersheds vary in their dry-mercury deposition by number, predominance, and percentages of forest types (Appendix Table A40). By forest type, the dry-mercury deposition contributions to the Ohio River Basin was 85% from oak-hickory, 11.4% from maple-beech-birch, 2.4% from oak-pine, 0.8% from elm-ash-cottonwood, and 0.2% from oak-gum-cypress forest types.

Table 18. Dry-mercury deposition and normalized dry-mercury deposition to forest land cover in total watershed area during study period

[Hg, mercury; lbs, pounds; µg/m^2/yr, microgram per square meter per year]

Watershed	Dry-Hg deposition (lbs)	Normalized dry-Hg deposition (µg/m^2/yr)
Allegheny	582	8.7
Monongahela	333	7.9
Beaver	67	3.7
OR Local 1	116	5.8
Muskingum	186	4.1
Kanawha	713	10.2
OR Local 2	369	9.6
Big Sandy	289	11.8
Scioto	99	2.7
Little Miami	20	2.0
Licking	115	5.4
Great Miami	29	1.0
Kentucky	311	7.8
OR Local 3	625	6.7
Green	264	5.0
Wabash	339	1.8
OR Local 4	103	4.3
Cumberland	726	7.1
Tennessee	1,809	7.7
OR Local 5	13	2.5
Ohio River Basin	**7,111**	**12.5**

4.3.3 Dry Non-Forested Atmospheric Deposition

The study area contains 253,508 km^2 of non-forest land cover: 71.1% cropland, 19.7% urban, 5.2% grassland, and 3.1% open water. The total dry-mercury deposition to the non-forest land cover was 5,736 lbs: 81% to cropland, 14% to urban, 4.6% to grassland and 0.4% to open water. The normalized dry-mercury deposition to non-forest land cover per total watershed area was 10.3 µg/m^2/yr and ranged by watershed from 1.6 µg/m^2/yr (Big Sandy River) to 8.9 µg/m^2/yr (Great Miami River); the median was 4.8 µg/m^2/yr (Table 19).

Table 19. Dry-mercury deposition and normalized deposition to the total study area during the study period.

lbs, pounds; Hg, mercury; µg/m^2/yr, microgram per square meter per year; km^2, square kilometer]

Watershed	Dry-Hg deposition (lbs)	Normalized dry-Hg deposition (µg/m^2/yr)	Non-forest area (km^2)	Drainage Area (km^2)
Allegheny	185	2.8	8,611	30,368
Monongahela	108	2.6	5,312	19,102
Beaver	96	5.3	4,591	8,177
OR Local 1	77	3.9	3,742	9,059
Muskingum	262	5.7	11,500	20,848
Kanawha	153	2.2	7,345	31,720
OR Local 2	87	2.3	4,063	17,450
Big Sandy	39	1.6	2,258	11,119
Scioto	293	7.9	12,440	16,866
Little Miami	80	8.0	3,473	4,553
Licking	113	5.4	4,789	9,597
Great Miami	274	8.9	11,613	13,900
Kentucky	167	4.2	7,508	18,040
OR Local 3	391	4.2	17,775	42,209
Green	301	5.7	12,732	23,916
Wabash	1,649	8.8	68,218	85,350
OR Local 4	151	6.3	6,523	10,884
Cumberland	414	4.1	19,079	46,389
Tennessee	859	3.7	40,301	105,947
OR Local 5	36	6.9	1,632	2,392

4.3.4 Total Atmospheric Mercury Deposition

Atmospheric-mercury deposition to the Ohio River Basin during the study period, computed as the sum of wet-mercury and combined dry-mercury deposition, was 25,135 lbs (Table 20, Fig. 17). Normalized to the watershed area, the atmospheric-mercury deposition was 21.6 µg/m^2/yr. Watershed mercury deposition varied by watershed from 17.7 µg/m^2/yr (Muskingum River) to 23.9 µg/m^2/yr (OR Local 4). The 12,287 lbs wet-mercury deposition for the basin was 49% of the total atmospheric deposition, compared with the 12,847 lbs combined dry-mercury deposition (51% of the total). Wet-mercury and dry-mercury portions of the total atmospheric deposition for each watershed had a median 48% and 52% respectively.

Atmospheric mercury deposition for the Ohio River Basin study area appear to be reasonable when compared with wet-mercury and dry-mercury deposition to Midwestern states and with national wet-mercury deposition gradient maps in a similar time period [20, 22, 31]. The relative proportions of wet mercury and dry mercury in the atmospheric deposition for the study area were consistent with other research [9, 31, 56].

As one might expect, larger watersheds by land area tend to have larger amounts of deposition (Fig. 18). Yields are a good way to compare watersheds that differ in area. None of the watersheds stand out as being particularly high or low, indicating that atmospheric deposition rates were fairly similar throughout the basin (Fig. 19). Figure 20 displays cumulative atmospheric deposition at the four main stem project stations. Mercury deposition from all watersheds upstream of the station were added together for each main stem location. Mercury mass from air deposition increases in a downstream direction as would be expected.

Table 20. Combined wet-mercury and dry-mercury deposition and normalized deposition to watersheds in the study area during study period

[lbs, pounds; Hg, mercury; μg/m²/yr, microgram per square meter per year]

Watershed	Wet-Hg deposition (lbs)	Normalized wet-Hg deposition (μg/m²/yr)	Total dry-Hg deposition (lbs)	Normalized total dry-Hg deposition (μg/m²/yr)	Total atmospheric Hg deposition (lbs)	Normalized atmospheric Hg deposition (μg/m²/yr)
Allegheny	590	8.8	767	11.5	1,357	20.3
Monongahela	460	10.9	441	10.5	901	21.4
Beaver	159	8.8	163	9.1	322	17.8
OR Local 1	200	10.0	194	9.7	394	19.7
Muskingum	365	7.9	449	9.8	814	17.7
Kanawha	663	9.5	867	12.4	1,530	21.9
OR Local 2	356	9.3	456	11.9	812	21.1
Big Sandy	229	9.4	328	13.4	557	22.7
Scioto	295	7.9	393	10.6	687	18.5
Little Miami	90	9.0	100	10.0	190	18.9
Licking	195	9.2	228	10.8	423	20.0
Great Miami	256	8.4	303	9.9	560	18.3
Kentucky	416	10.5	478	12.0	894	22.5
OR Local 3	929	10.0	1,017	10.9	1,946	20.9
Green	632	12.0	565	10.7	1,197	22.7
Wabash	2,099	11.2	1,989	10.6	4,088	21.7
OR Local 4	319	13.3	254	10.6	573	23.9
Cumberland	1,159	11.3	1,140	11.2	2,299	22.5
Tennessee	2,815	12.1	2,668	11.4	5,482	23.5
OR Local 5	60	11.4	50	9.4	110	20.8
Ohio River Basin	**12,287**	**10.6**	**12,847**	**11.0**	**25,135**	**21.6**

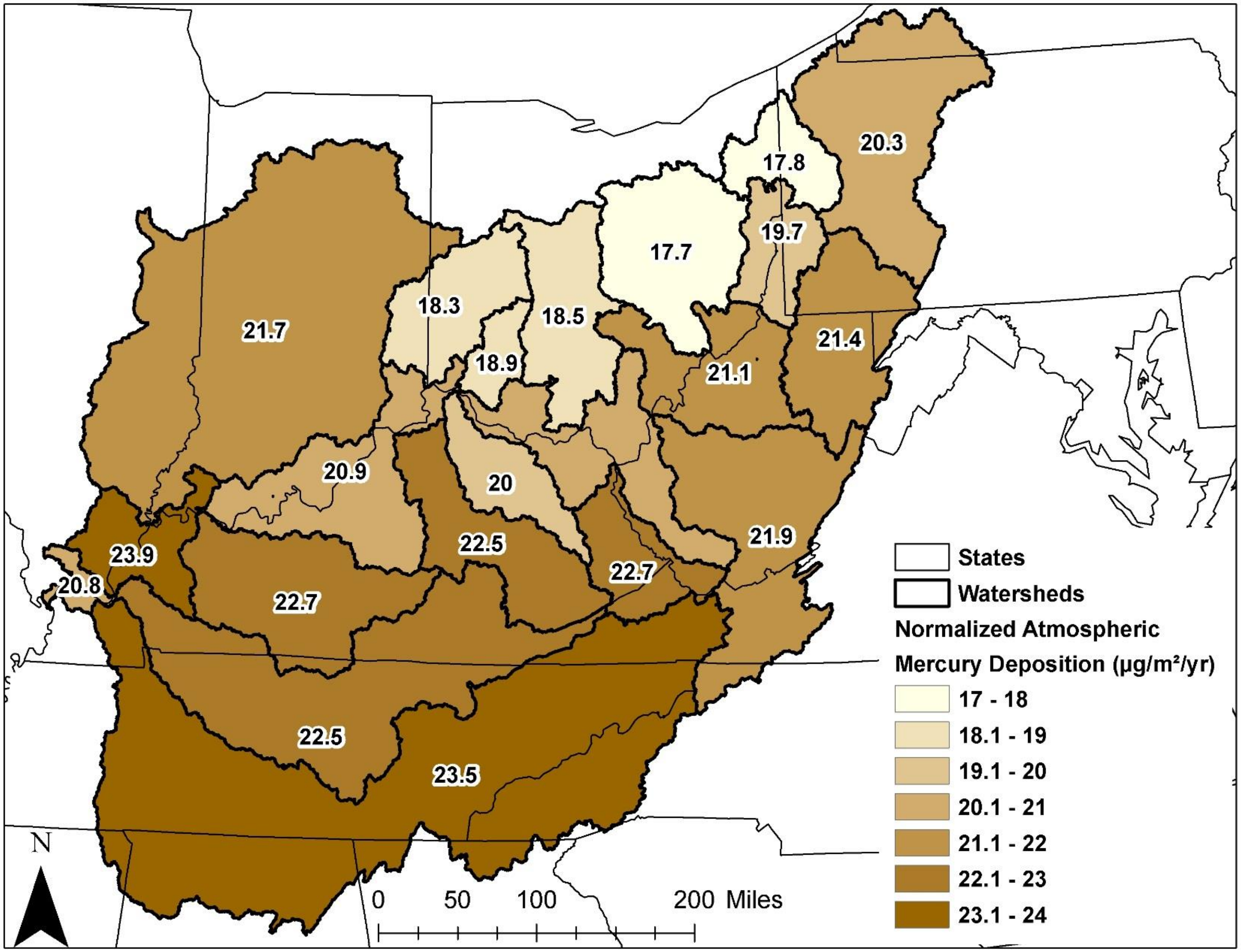


Figure 17. Normalized atmospheric mercury deposition to watersheds in the study area.

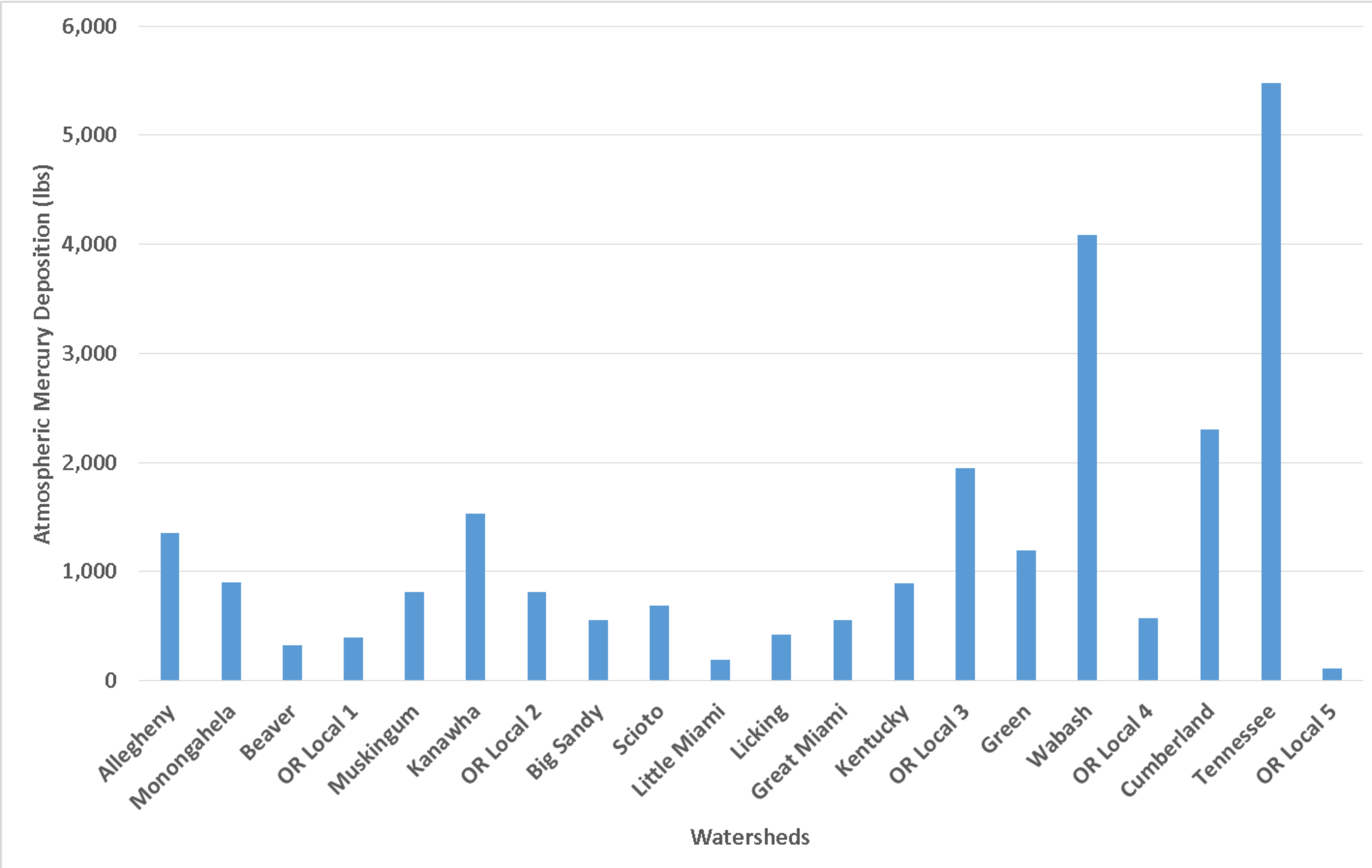


Figure 18. Total atmospheric mercury deposition (pounds; lbs) per Ohio River Basin watershed.

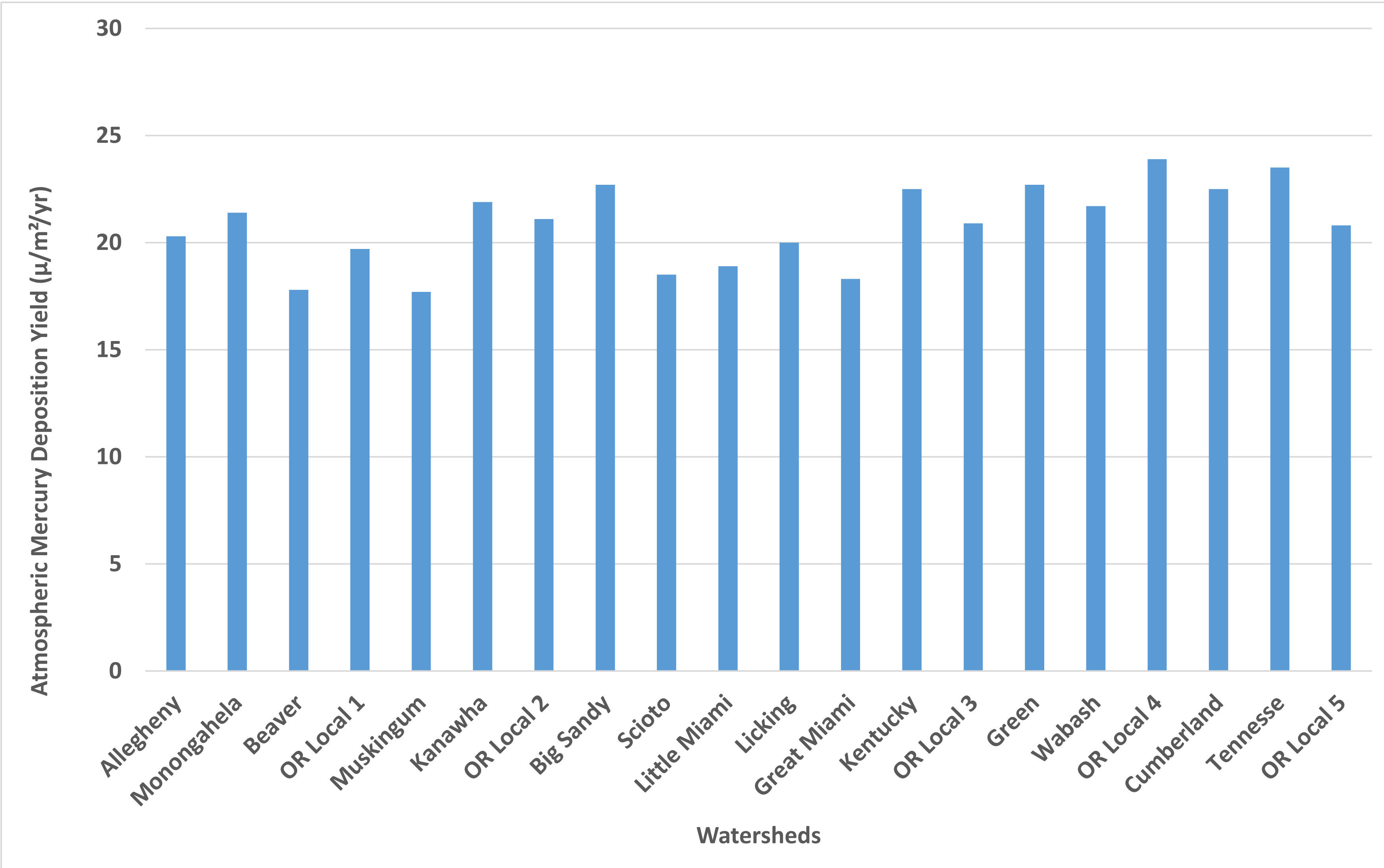


Figure 19. Total atmospheric mercury deposition yield (microgram per square meter; µ/m²/yr) per Ohio River Basin watershed.

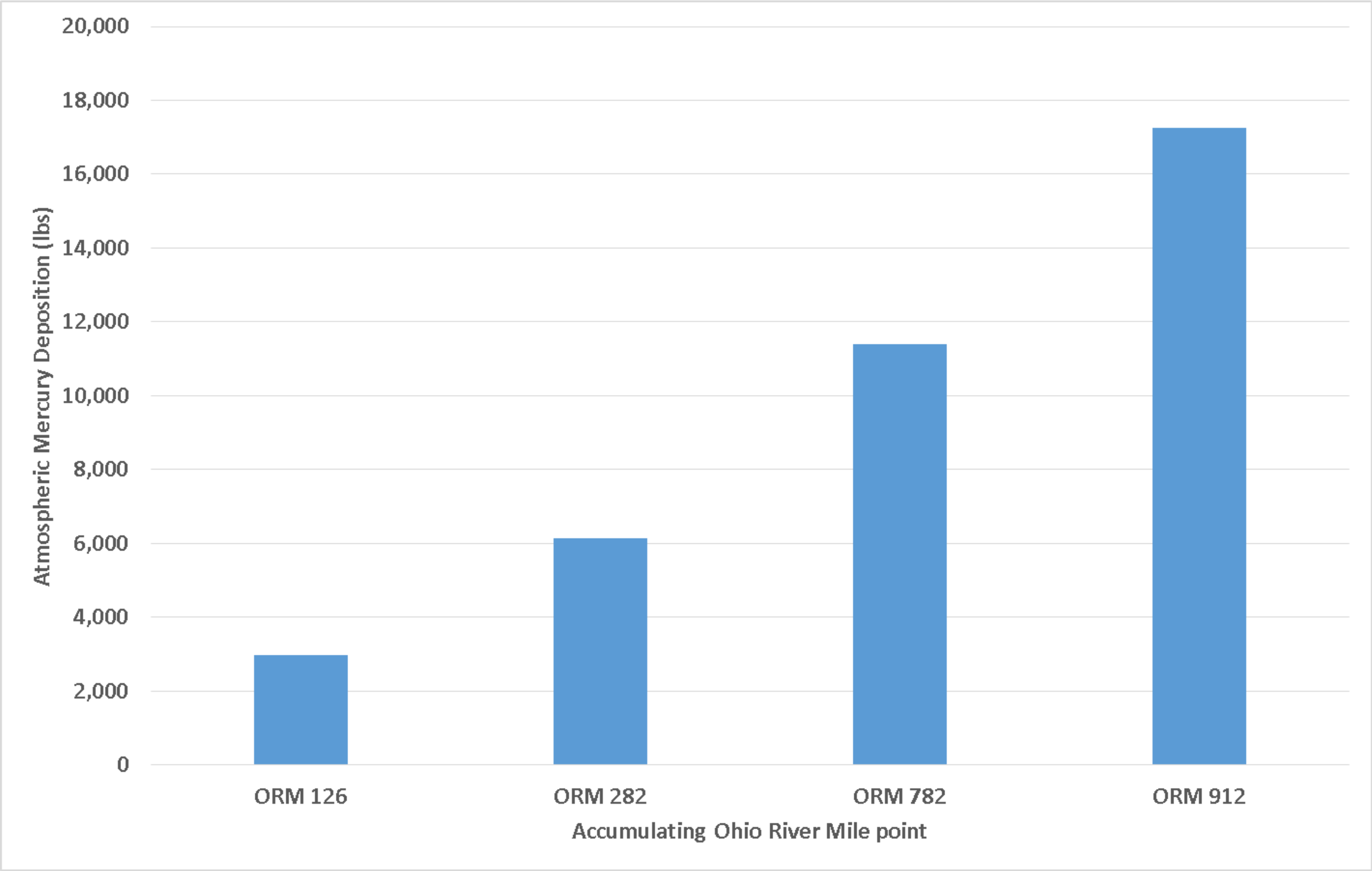


Figure 20. Total atmospheric mercury deposition (pounds; lbs) at accumulating Ohio River mile points (126, 282, 782, 912).

4.4 Summary and Conclusions

Documented methods were used to combine national mercury monitoring data with widely accepted spatial data to calculate atmospheric mercury deposition to 20 watersheds in the Ohio River Basin. The combined total deposition to the basin (of wet mercury from precipitation, and dry mercury, to forest and non-forest land cover) was 25,135 lbs for the study period. The methods and data were evaluated with several techniques and found to be reasonable and representative measures of atmospheric mercury deposition during the prescribed study period. The objectives of this analysis was achieved, and are presented in figures, tables, and supporting material in this report.

It should be recognized that these findings were somewhat limited in accuracy by the density of mercury monitoring network data sites. It is important to note that atmospheric deposition values represent deposition to land and water, and the quantity deposited to land or to water was not determined individually. One might reasonably expect that the amount of atmospheric mercury in the water was much smaller than what was deposited on land, including the amount that may runoff from land to water. Only a fraction of the mercury from the total atmospheric deposition ends up in the water, as much is sequestered on the landscape.

Chapter 5: Mercury Loading Analysis Conclusions and Discussion

5.1 Approach

This study was an analysis of mercury loadings 1) instream in the Ohio River and 15 major tributaries, 2) to the Ohio River Basin from point source discharges, and 3) from atmospheric deposition, for the project period which was November 1, 2015 through October 31, 2016. Instream mercury loads were developed from monthly instream mercury monitoring at four Ohio River monitoring stations. Point source mercury loads for the entire basin were developed using discharge monitoring data from the state or the EPA-ECHO data base. Atmospheric mercury deposition was developed using atmospheric monitoring data from the National Atmospheric Deposition Program and modeled within a GIS framework. Methods used to estimate instream and point source loads, and atmospheric deposition, are detailed in the full report. The following are the main conclusions from the report based on data contained in Table 21.

Table 21. Comparison of instream mercury loads, atmospheric mercury deposition, and point source mercury loads in pounds and percentage of instream loads throughout the Ohio River Basin for the study period: November 1, 2015 thru October 31, 2016

[Hg, mercury; lbs, pounds; OR, Ohio River; ORM, Ohio River mile]

Watershed	Instream Hg Load (lbs)	Point Source Hg Load Min (lbs)	Upstream Point Source % Instream Hg Load Min	Point Source Hg Load Max (lbs)	Upstream Point Source % Instream Hg Load Max	Atmospheric Hg Deposition (lbs)	Ratio Atmospheric Deposition to Instream Load
Allegheny	81	0.2	0.2%	2.6	3%	1,357	16.7:1
Monongahela	71	1.3	2%	1.5	2%	901	12.7:1
Beaver	31	1.0	3%	1.0	3%	322	10.3:1
OR Local 1		1.7		4.1		394	
ORM 126	223	4.2	2%	9.1	4%	2,973	13.3:1
Muskingum	81	1.8	2%	1.8	2%	814	10.1:1
Kanawha	168	5.6	3%	8.9	5%	1,530	9.1:1
OR Local 2		8.6		9.1		812	
ORM 282	593	20.2	3%	28.9	5%	6,129	10.3:1
Big Sandy	71	0.3	0.4%	0.7	1%	557	7.8:1
Scioto	83	0.4	0.4%	3.0	4%	687	8.2:1
Little Miami	11	0.3	3%	0.6	6%	190	17.6:1
Licking	102	0.04	0.04%	0.04	0.0%	423	4.1:1
Great Miami	17	1.3	8%	2.5	15%	560	32.8:1
Kentucky	71	0.4	0.5%	1.0	1%	894	12.5:1
OR Local 3		9.0		11.8		1,946	
ORM 782	2,153	31.9	1%	48.5	2%	11,386	5.3:1
Green	285	2.2	0.8%	4.8	2%	1,197	4.2:1
Wabash	389	8.8	2%	9.0	2%	4,088	10.5:1
OR Local 4		0.7		0.7		573	
ORM 912	2,961	43.6	1%	63.0	2%	17,244	5.8:1
Cumberland	211	7.3	3%	18.9	9%	2,299	10.9:1
Tennessee	278	9.8	4%	9.8	4%	5,482	19.7:1
OR Local 5		0.3		7.4		110	

5.2 Conclusions

Conclusion: Cumulative, monitored, upstream point source loads were estimated to be 2% of the instream load; Cumulative upstream atmospheric deposition was estimated to be approximately 6 times the instream load at ORM 912.

Figure 21 shows instream mercury loads at each of the main stem stations along with the cumulative, upstream mercury loading for monitored point sources and atmospheric deposition. A total Ohio River instream mercury loading of 2,961 pounds (lbs) was estimated at the most downstream main stem monitoring station (ORM 912). Cumulative point source loads upstream of ORM 912 total 63 lbs, which was 2% of the instream load (based on the maximum point source loading which was calculated by setting non-detection values at the detection level) (Table 21). Cumulative, atmospheric deposition upstream of ORM 912 total 17,244 lbs, which was approximately six times the instream Ohio River load at ORM 912. However, the atmospheric deposition estimates account for deposition to the entire watershed, which includes both land and water. It can be seen that atmospheric deposition to the watershed, which does not exclude mercury sequestered on the landscape, were much larger than both point source loads and instream loads.

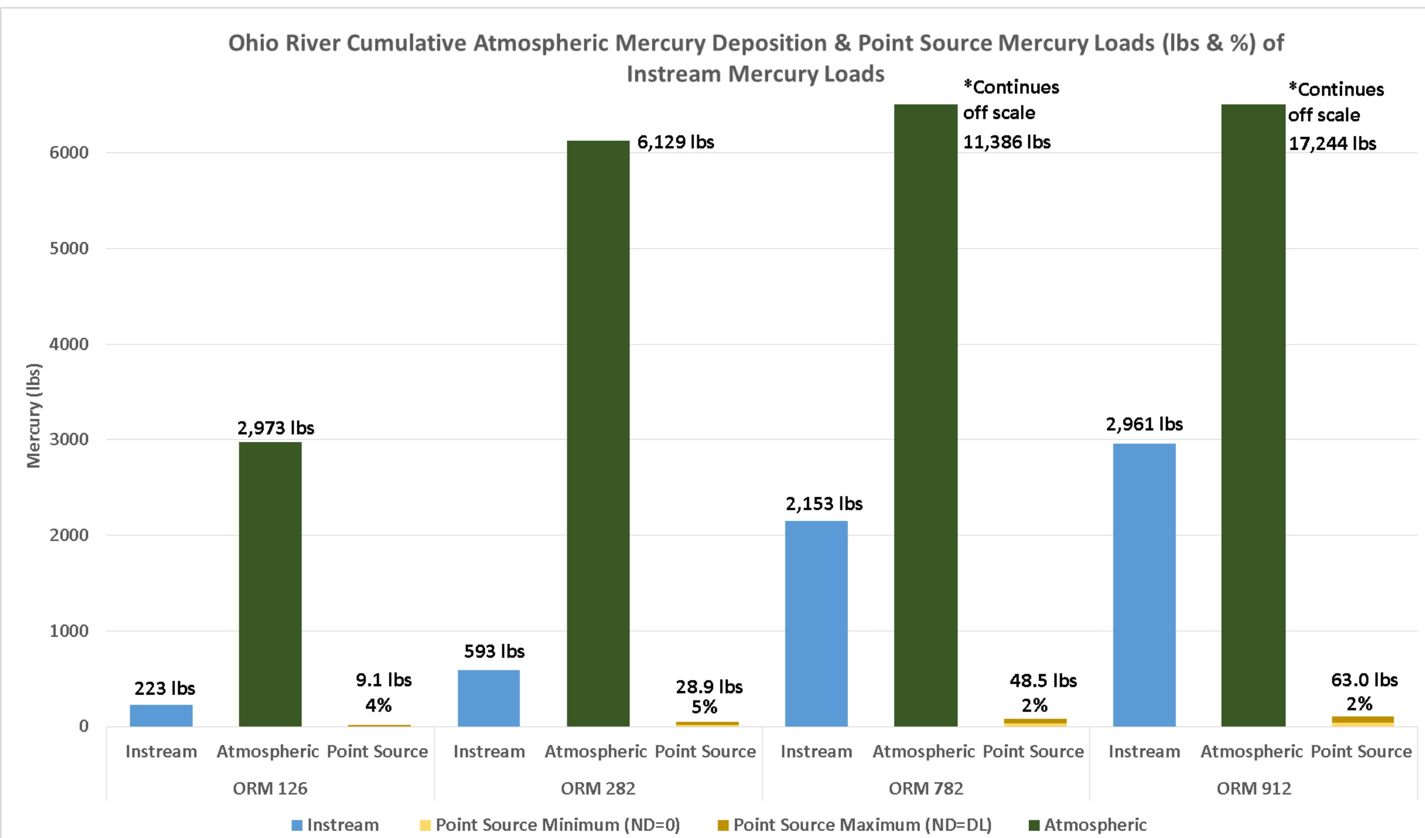


Figure 21. Comparing instream mercury loads at four Ohio River stations to monitored point source cumulative mercury loads and cumulative atmospheric deposition.

Conclusion: Instream mercury loads and yields from 15 major tributaries to the Ohio River

Figure 22 (same as Fig. 6 in Chapter 2) represents mercury loads and yields for each watershed based on loads calculated from instream monitoring data. Loads are the total number of mercury pounds (lbs) that were discharged by the tributaries into the Ohio River during the one year study period. Yields represent loads relative to (divided by) watershed area, thereby normalizing loads to watershed area making watershed loads comparable. It is evident from the graph that Ohio River loads were generally higher than tributary loads, and that some tributaries contribute significantly more mercury to the Ohio River than others.

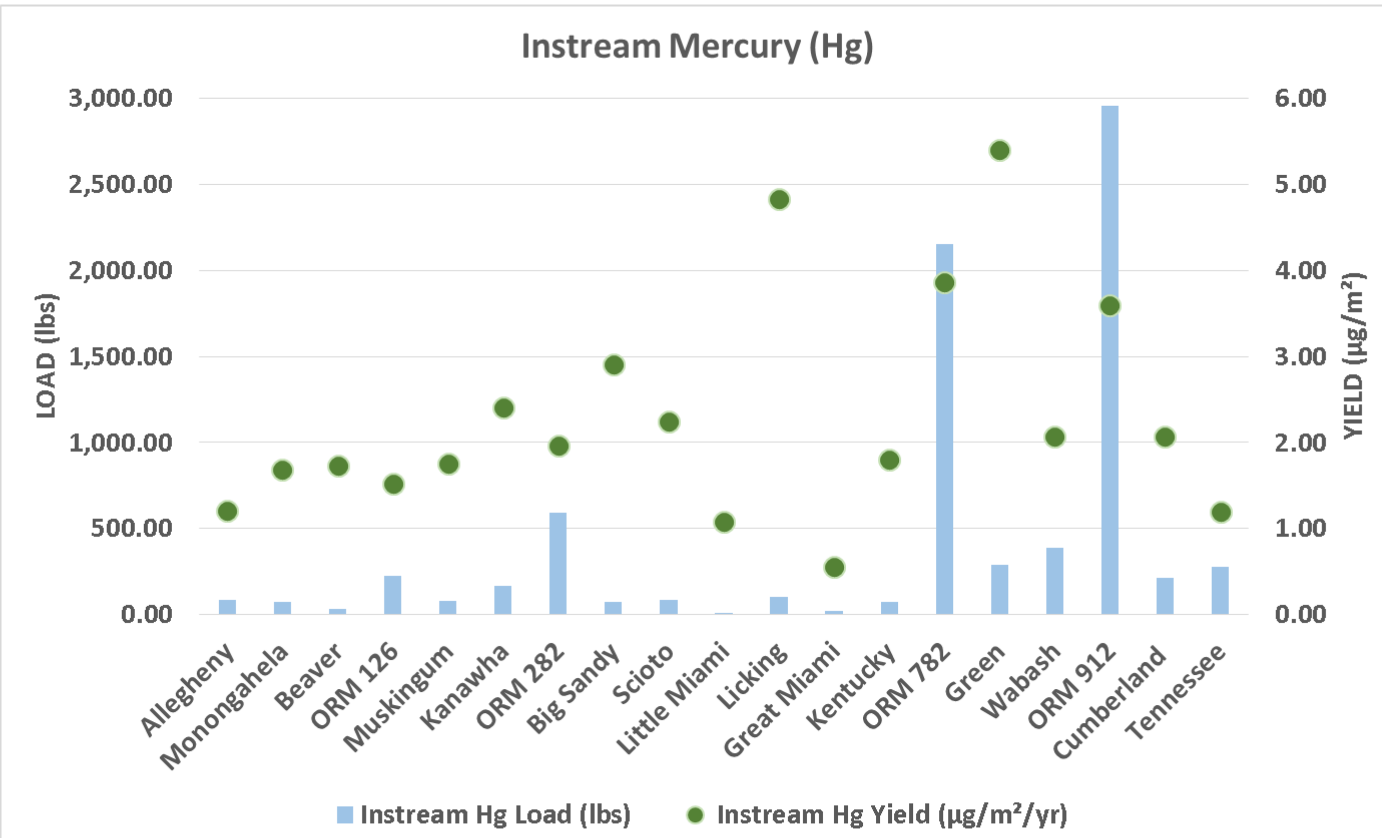


Figure 22. Instream mercury loads and yields normalized to the watershed area for one year study period November 1, 2015 through October 31, 2016.

Conclusion: Upstream cumulative tributary loads were estimated to be half of the Ohio River instream load at ORM 912

The comparison between mercury instream loads at the four Ohio River mile points to the cumulative mercury loadings from upstream tributaries show that cumulative tributary loadings to the Ohio River account for 49% of the instream load at ORM 912 (Fig. 23). The remaining amount would be from other sources in the watershed.

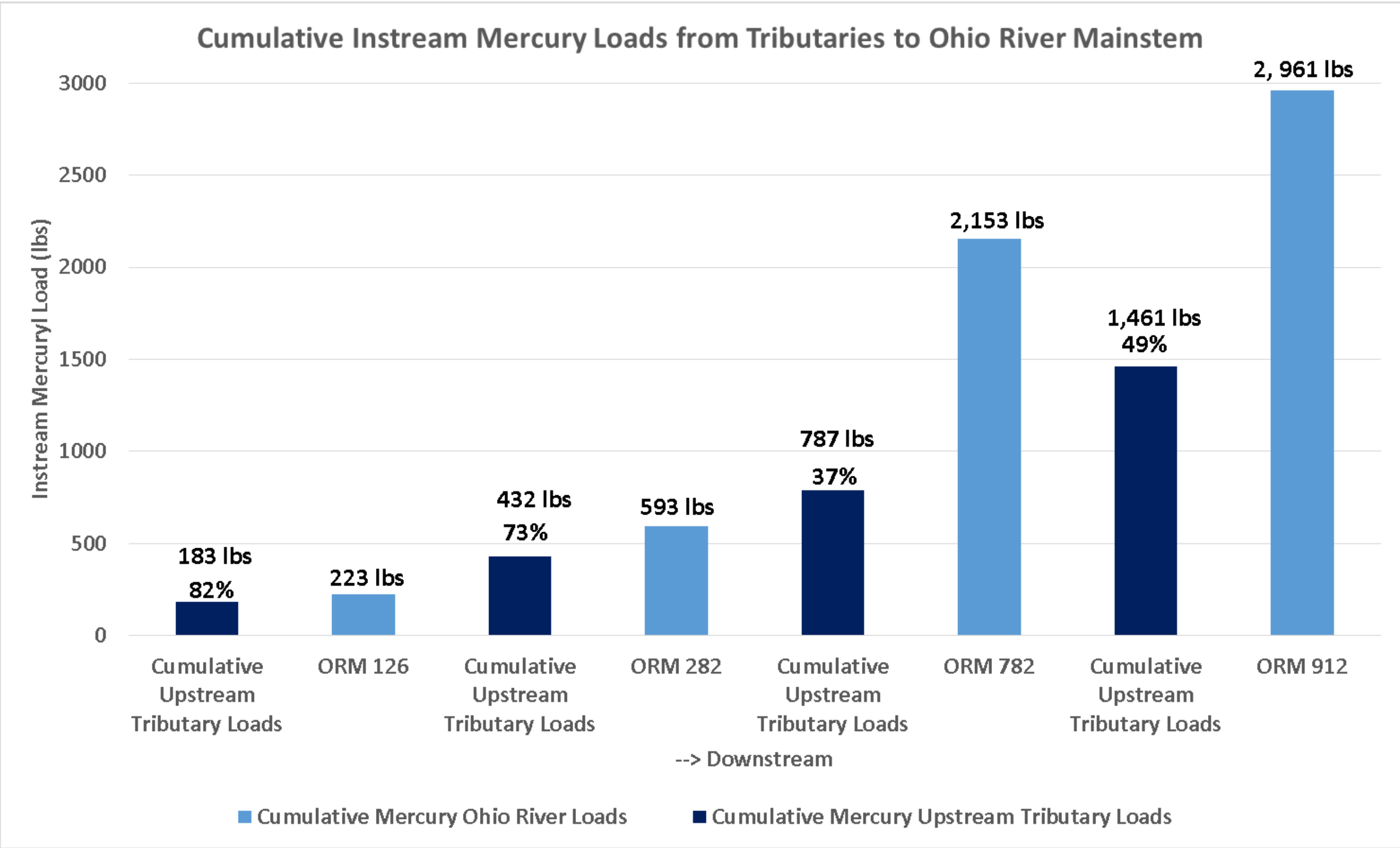


Figure 23. Instream mercury loads at the four Ohio River stations compared to the cumulative mercury loadings from the major tributaries upstream of each station.

Conclusion: Monitored Ohio River direct discharges were estimated to be less than half the cumulative point source loading at ORM 912

Cumulative, monitored point sources discharging directly to the Ohio River upstream of ORM 912, account for a mercury loading of 25 lbs; all cumulative point sources upstream of ORM 912 account for 63 lbs. (Table 11, 12, Fig. 24; same as Fig. 11 in Chapter 3). There were 135 direct discharge outfalls to the Ohio River where mercury was monitored upstream of ORM 912, while there were 685 outfalls throughout the basin where mercury was monitored upstream of ORM 912. The mercury loading from outfalls discharging directly to the Ohio River totaled 40% of all discharges monitored for mercury in the basin upstream of mercury loading at ORM 912.

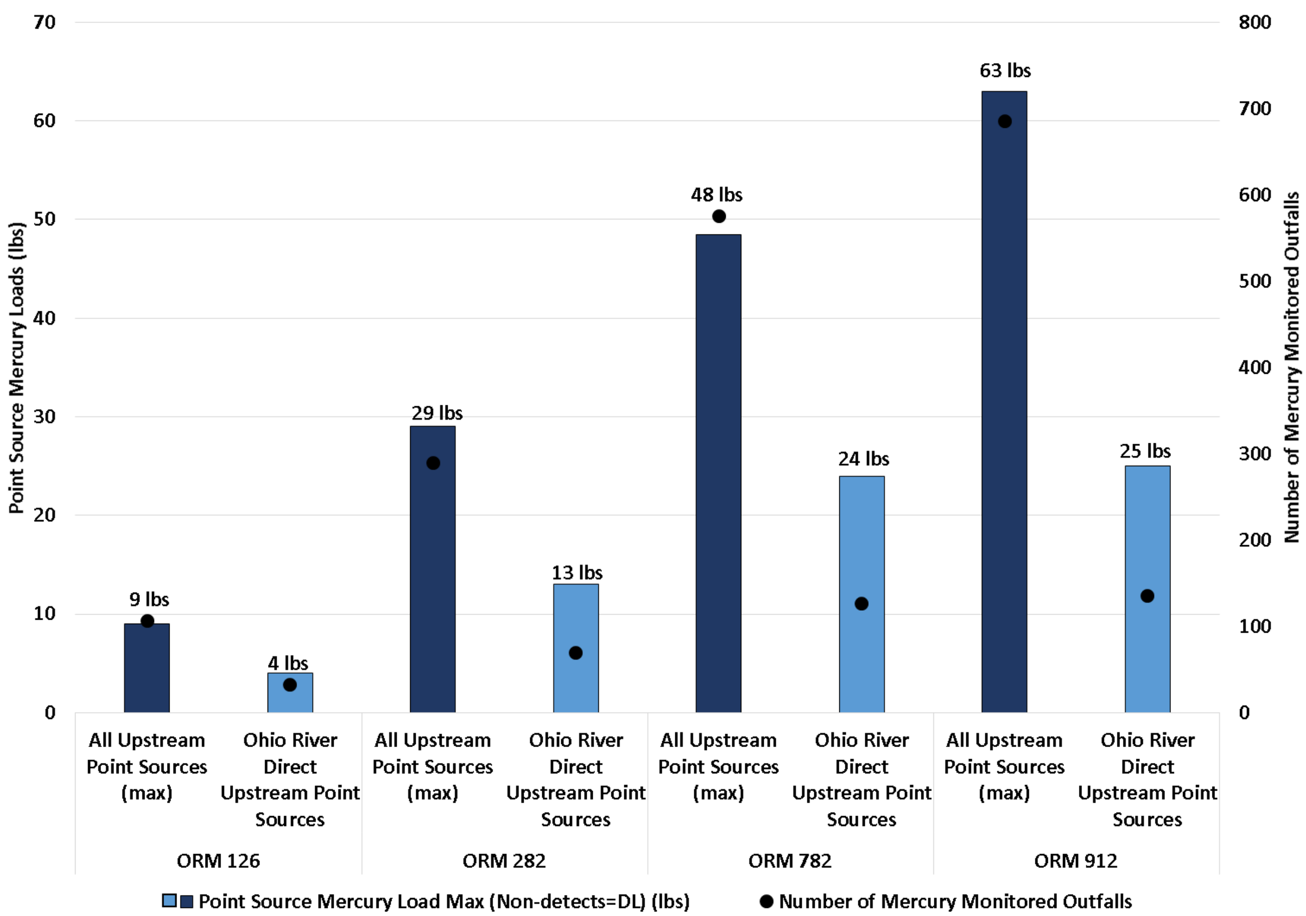
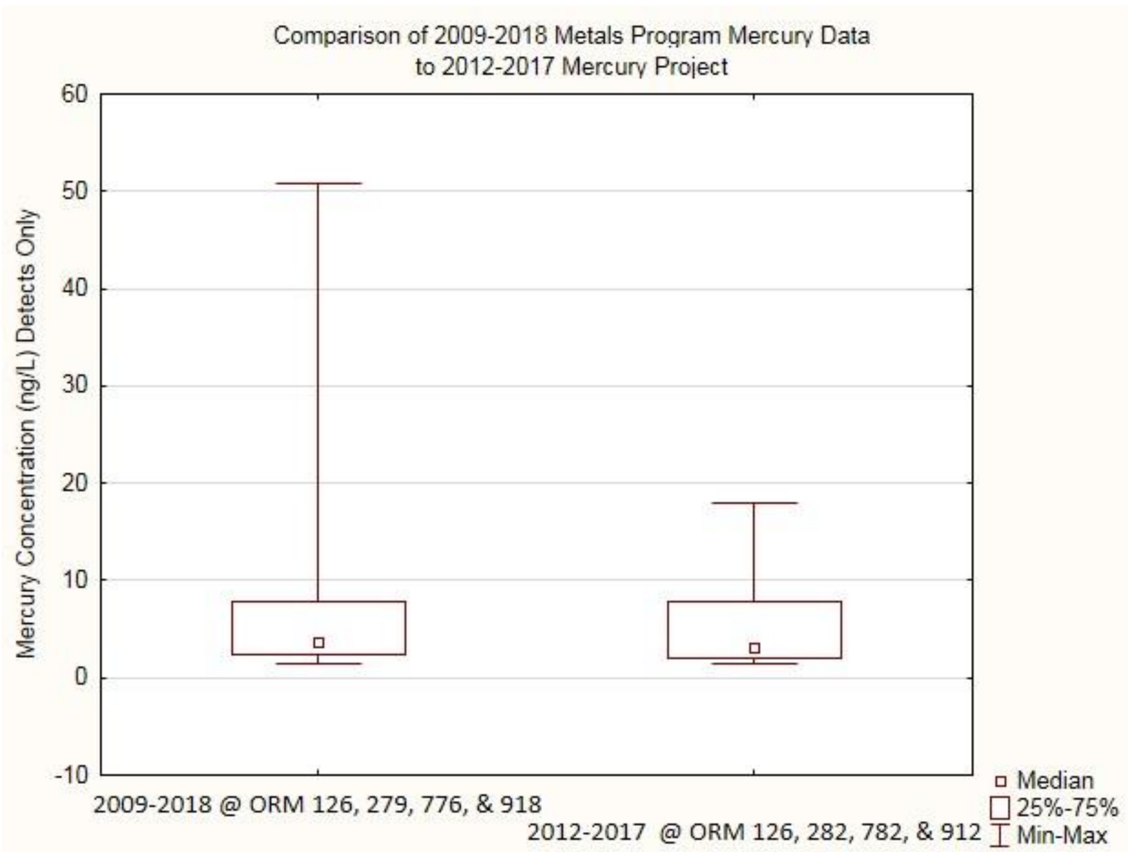


Figure 24. Comparison of cumulative upstream mercury loads for the entire basin to cumulative upstream loads from discharges direct to the Ohio River.

Conclusion: Ohio River mercury project instream data related well to ten years of Ohio River instream data collected by ORSANCO's clean metals monitoring program

The four main stem project sites were all located near routine monitoring sites so that a comparison could be made between the instream mercury project monitoring data and historical mercury data collected through the clean metals monitoring program. Historical mercury concentration data for the ten years 2009-2018 (clean metals program data) from the four routine monitoring sites near the project monitoring sites were all grouped together and compared against mercury concentration data from the four main stem project sites which were collected between 2012 through 2017 (mercury project data). For this analysis, data below the detection level were set equal to zero. It can be seen that the project data falls well within the historical range of mercury concentrations (Fig. 25; same as Fig. 7 in Chapter 2). Therefore, the project data was comparable to longer term conditions in the Ohio River.



*Non-Detections set to 0.

Figure 25. Comparison of mercury project data (box plot on the right) to ten years of ORSANCO's clean metals program data (box plot on the left) (data below detection levels were set equal to zero).

5.3 Discussion

The USEPA, ORSANCO and its member states will continue to be vigilant about mercury levels in the biota and water of the Ohio River. Water quality and fish tissue monitoring will continue. As commercial and industrial uses of mercury decline, we expect downward trends in both of these indicator parameters in the future. While concern about mercury will continue, the Ohio River water quality and its fish should not be perceived as in a "crisis state". With respect to mercury, the Ohio River is safe to swim in, safe to consume potable water from after treatment, and safe to consume fish from in accordance with state issued advisories. ORSANCO recommends discharger effluent limitations for mercury not be relaxed. Further, all member states continue to issue fish consumption advisories based on mercury. Any revision of discharger mercury effluent limitations, monitoring, or NPDES implementation guidance would be done so through USEPA delegated NPDES programs administered by our member state agencies.

5.3.1 Study Limitations

Instream Mercury Loads

There were several limitations associated with estimates of the instream loads. Instream mercury loads were calculated based on only twelve monthly mercury samples, resulting in a unknown level of uncertainty. All tributaries were sampled during the project period of Nov., 2015 through Oct., 2016. Most sites were sampled using a cross-sectional method, however some were grab-sampled where not possible to utilize the cross-sectional method. The effect of this inconsistent sampling method was unknown. Additionally, Ohio River main stem sites were sampled monthly for mercury for a twelve month period, but during different time frames spanning different years. It was decided to use existing data and model the results to the existing project period using the LOADEST program. This would also introduce some unknown uncertainty.

Finally, there was no consideration of instream transport and fate. There was no accounting for instream gains, losses, or transformation of mercury in the stream. For the purposes of this project, mercury was considered conservative. The uncertainty associated with this approach was unknown.

Point Source Loadings

Data used to estimate point source loadings of mercury was limited in terms of calculating a one year loading for the project period. Generally, there was no more than quarterly mercury data with which to calculate a load. As a result, all available data was averaged to calculate the load, and four samples provides a limited data set with which to calculate an estimated total mercury loading for a point source discharge.

In addition, there were point sources that discharge some level of mercury, but for which there was no mercury monitoring data to calculate a load. There were thousands of permitted point sources in the Ohio Basin, but only hundreds have mercury monitoring requirements. Therefore, it was reasonable to assume that many mercury discharges in the basin have no data to calculate loads. This study did not evaluate estimated loadings from unmonitored discharges.

Atmospheric Deposition

A significant limitation of this study were the estimates of atmospheric mercury deposition. These were estimates of total deposition to both the water and land. There were no additional estimates of how much deposition from the land was delivered to the surface waters. Since we wish to compare instream loads to atmospheric deposition, ideally there would have been an estimate of how much of the atmospheric deposition was delivered to the streams. Modeling the delivery of atmospheric deposition loads to the receiving streams was considered, but it was beyond the scope of the study, and results were expected to have a very high level of uncertainty and were therefore not pursued.

The other significant limitation with atmospheric deposition estimates was the amount of mercury atmospheric data available from the National Atmospheric Deposition Program in which to model mercury deposition.

5.3.2 Areas for Further Study

Through this analysis the understanding of mercury influence on the Ohio river has been advanced in two important ways: a) point sources known to be potential sources of mercury were under monitoring and reporting requirements that allowed estimation of their contribution to the mass loading burden of the river to be approximately 2% of total river load; and b) atmospheric deposition of airborne mercury delivers proportionally an overwhelming amount of mercury to the river's watershed each year. While the study results were indeed significant, they also highlight the importance of critical issues still in need of further understanding. Key outstanding questions remain within each of the three study areas, the River itself, the point source arena and the fate and impact of mercury loading upon the watershed from air transport and deposition. Priorities warranting future study and resource allocations include:

Ohio River Considerations:

- Trend analysis to determine if and to what extent ambient river concentrations and fish tissue are stable or trending higher or lower.
- Further research and monitoring to understand interaction and dynamics of mercury species within the natural environment, including methylation processes and sediment/water column interaction.

Point Source Mercury

- Continued diligence of state and federal regulatory agencies to identify, quantify and apply management requirements for mercury discharges.

Air Deposition/Watershed Considerations

- Continued monitoring and analysis to track progress of atmospheric mercury reductions through the various air emission reduction efforts within the watershed, nationally and even internationally.
- Perhaps among the most intriguing unanswered question is the fate and impact of the mercury deposition that continues to fall upon the watershed year after year. To what extent is it captured and contained within the soils and to what extent does it migrate offsite and into the various waterways that drain to the Ohio River? Physical, chemical and biological processes could all affect ultimate significance of mercury air deposition.
- Additionally, how does the significantly large global atmospheric reservoir of legacy mercury (estimated at 5,500-6,600 tons) impact the continual deposition of mercury over time to watersheds and in turn its continuous contributions to aquatic ecosystems [9, 16]?

Some of these continued needs clearly fall within the wheelhouse of ORSANCO, particularly river monitoring activities. However other needs are beyond the scope of ORSANCO core expertise and to that extent ORSANCO partners and fellow scientists in government, academia and the private sector are encouraged to consider these issues as top candidates for further study. While mercury does not appear to be a critical threat to the Ohio River, a better understanding of how it behaves in the environment and tracking to assure conditions are stable or trending downwards is prudent.

References

(1) Abma, R. A., Paterson, G., McLeod, A., & Hafner, G. D. (2015). Cross-basin comparison of mercury bioaccumulation in Lake Huron trout emphasizes ecological characteristics. Environmental Toxicology and Chemistry, 34, pp.355-359.

(2) Adams, T., Chen, S., Davis, R., Schade, T., & Lee, D. (2010). The Ohio river community HEC-RAS model. In *World Environmental and Water Resources Congress 2010: Challenges of Change* (pp. 1512-1523).

(3) Brigham, M. E., Wentz, D. A., Aiken, G. R., & Krabbenhoft, D. P. (2009). Mercury cycling in stream ecosystems. 1. Water column chemistry and transport. Environmental Science and Technology, 43(8), pp.2720-2725.

(4) Chalmers, A. T., Argue, D. M., Gay, D. A., Brigham, M. E., Schmitt, C. J., & Lorenz, D. L. (2011). Mercury trends in fish from rivers and lakes in the United States, 1969-2005. *Environmental Monitoring and Assessment, 175*, pp.175-191.

(5) Chetelat, J., Amyot, M., Cloutier, L., & Poulain, A. (2008). Metamorphosis in chironomids, more than mercury supply, controls methylmercury transfer to fish in high Arctic lakes. Environmental Science and Technology, 42(24), pp.9110-9115.

(6) Cohn, T. A. (1988). *Adjusted maximum likelihood estimation of the moments of lognormal populations from type 1 censored samples* (No. 88-350). US Geological Survey.

(7) Donovan, P. M., Blum, J. D., Demers, J. D., Gu, B., Brooks, S. C., & Peryam, J. (2014). Identification of multiple mercury sources to stream sediments near Oak Ridge, TN, USA. *Environmental science & technology*, 48(7), 3666-3674.

(8) Downs, S. G., Macleod, C. L., & Lester, J. N. (2003). Mercury in precipitation and its relation to bioaccumulation in fish: A literature review. Water, Air, and Soil Pollution, 108, pp.149-187.

(9) Driscoll, C. T., Mason, R. P., Chan, H. M., Jacob, D. J., & Pirrone, N. (2013). Mercury as a global pollutant: sources, pathways, and effects. *Environmental science & technology*, *47*(10), 4967-4983.

(10) Driscoll, C. T., Han, Y., Chen, C. Y., Evers, D. C., Lambert, K. F., Holsen, T. M., et al. (2007). Mercury contamination in forest and freshwater ecosystems in the northeastern United States. BioScience, 57(1), pp.17-28.

(11) Environmental Protection Agency (2019). *ICIS-NPDES Download Summary and Data Element Dictionary* |ECHO| US EPA. [online] Echo.epa.gov. Available at https://echo.epa.gov/tools/data-downloads/icis-npdes-download-summary

(12) EPRI (2013). Application of the dynamic mercury cycling model (D-MCM) to the Robert C. Byrd navigation pool of the Ohio River. EPRI 3002001216 pp.1-96 Palo Alto, CA.

(13) ESRI, ArcGIS. 2018, www.esri.com

(14) Fitzgerald, W. F., Engstrom, D. R., Mason, R. P., & Nater, E. A. (1998). The case for atmospheric mercury contamination in remote areas. *Environmental science & technology*, *32*(1), 1-7.

(15) Harris, R. C., & Bodaly, R. A. (1998). Temperature, growth and dietary effects on fish mercury dynamics in two Ontario lakes. Biogeochemistry, 40(2/3), p.175.

(16) Horowitz, H. M., Jacob, D. J., Amos, H. M., Streets, D. G., & Sunderland, E. M. (2014). Historical mercury releases from commercial products: Global environmental implications. Environmental Science and Technology, 48, p.9.

(17) Lindberg, S., Bullock, R., Ebinghaus, R., Engstrom, D., Feng, X., Fitzgerald, W., ... & Seigneur, C. (2007). A synthesis of progress and uncertainties in attributing the sources of mercury in deposition. *AMBIO: a Journal of the Human Environment*, *36*(1), 19-34.

(18) Mergler, D., Anderson, H. A., Chan, L. H. M., Mahaffey, K. R., Murray, M., Sakamoto, M., & Stern, A. H. (2007). Methylmercury exposure and health effects in humans: a worldwide concern. *AMBIO: A Journal of the Human Environment*, *36*(1), 3-12.

(19) Multi-Resolution Land Characteristics Consortium, National Land Cover Database. 2018, https://www.mrlc.gov/nlcd2011.php

(20) National Atmospheric Deposition Program annual report for 2016. 2018, http://nadp.slh.wisc.edu/lib/data/2016as.pdf

(21) National Atmospheric Deposition Program Mercury Deposition Network. 2018, http://nadp.slh.wisc.edu/mdn/

(22) National Atmospheric Deposition Program Atmospheric Mercury Deposition Network gradient maps for 2015. 2018, http://nadp.slh.wisc.edu/maplib/pdf/mdn/hg_dep_2015.pdf

(23) National Atmospheric Deposition Program Atmospheric Mercury Network. 2018, http://nadp.slh.wisc.edu/amnet/default.aspx

(24) National Research Council. Toxicological effects of methylmercury. National Academy Press, Washington, D.C., 2000.

(25) Northwest Alliance for Computational Science & Engineering, PRISM spatial climate datasets. 2018, http://prism.oregonstate.edu/

(26) ORSANCO (2015). Development of an Ohio River site-specific methylmercury bioaccumulation factor. ORSANCO pp.1-27 Cincinnati, OH.

(27) Pickhardt, P. C., Folt, C. L., Chen, C. Y., Klaue, B., & Blum, J. D. (2002). Algal blooms reduce the uptake of toxic methylmercury in freshwater food webs. Proceedings of the National Academy of Sciences, 99(7), p.5.

(28) Prestbo, E. M., & Gay, D. A. (2009). Wet deposition of mercury in the US and Canada, 1996–2005: Results and analysis of the NADP mercury deposition network (MDN). *Atmospheric Environment*, *43*(27), 4223-4233.

(29) Reash, R. J., Brown, L., & Merritt, K. (2015). Mercury and other trace elements in Ohio River fish collected near coal-fired power plants: Interspecific patterns and consideration of consumption risks. Integrated Environmental Assessment and Management, 11, pp.474-480.

(30) Risch, M. R., Baker, N. T., Fowler, K. K., Egler, A. L., & Lampe, D. C. (2010). Mercury in Indiana watersheds: Retrospective for 2001-2006. USGS 1780 p.92 Reston, VA.

(31) Risch, M. R., DeWild, J. F., Gay, D. A., Zhang, L., Boyer,E. W., & Krabbenhoft, D. P. (2017). Atmospheric mercury deposition to forests in the eastern USA. *Environmental pollution, 228*, 8-18.

(32) Risch, M. R., DeWild, J. F., Krabbenhoft, D. P., Kolka, R. K., & Zhang, L. (2012). Litterfall mercury dry deposition in the eastern USA. Environmental Pollution, 161(2012), p.7.

(33) Risch, M.R.; Fowler, K.K. Mercury in Precipitation in Indiana, January 2004-December 2005; U.S. Geological Survey Scientific Investigations Report 2008–5148; USGS: Reston, VA, USA, 2008.

(34) Risch, M. R., Gay, D. A., Fowler, K. K., Keeler, G. J., Backus, S. M., Blanchard, P., ... & Dvonch, J. T. (2012). Spatial patterns and temporal trends in mercury concentrations,

precipitation depths, and mercury wet deposition in the North American Great Lakes region, 2002–2008. *Environmental pollution*, *161*, 261-271.

(35) Risch, M. R. (2017). Mercury and methylmercury concentrations and litterfall mass in autumn litterfall samples collected at selected National Atmospheric Deposition Program sites in 2007-2009 and 2012-2015.

(36) Risch, M. R., Taylor, B. M., & Heath, J. (2019). Atmospheric Mercury Loads to Watersheds in the Ohio River Basin [Adobe Digital Editions version]. Retrieved from http://www.orsanco.org.

(37) Runkel, R. L., Crawford, C. G., & Cohn, T. A. (2004). *Load Estimator (LOADEST): A FORTRAN program for estimating constituent loads in streams and rivers* (No. 4-A5).

(38) Rypel, A. L. (2010). Mercury concentrations in lentic fish populations related to ecosystem and watershed characteristics. Ambio, 39, pp.14-19.

(39) Scheuhammer, A. M., Meyer, M. W., Sandheinrich, M. B., & Murray, M. W. (2007). Effects of environmental methylmercury on the health of wild birds, mammals, and fish. *AMBIO: a Journal of the Human Environment*, *36*(1), 12-20.

(40) Scudder, B. C., Chasar, L. C., Wentz, D. A., Bauch, N. J., Brigham, M. E., Moran, P. W., et al. (2009). Mercury in fish, bed sediment, and water from streams across the United States, 1998-2005. USGS 2009-5109, 74pp.

(41) Shenton, L.R., and Bowman, K.O., 1977, Maximum likelihood estimation in small samples: London, Charles Griffin and Co., 186 p

(42) USEPA (2013a). 2011 National Listing of Fish Advisories Fact Sheet. USEPA EPA-820-F-13-058, p.8 Washington, D.C.

(43) USEPA (1997). Mercury study report to Congress - Volume VI: An ecological assessment for anthropogenic mercury emissions in the United States. USEPA EPA-452/R-97-008, 158pp.

(44) USEPA (2001). Water quality criterion for the protection of human health: methylmercury. EPA-823-R-01-001, pp.1-303

(45) U.S. Geological Survey. Mercury in the environment. Fact Sheet 146-00, 2000, https://www.epa.gov/mercury/basic-information-about-mercury

(46) U.S. Geological Survey, National watershed boundary dataset. 2018, https://nhd.usgs.gov/wbd.htmll

(47) U.S. Forest Service, National Forest type dataset. 2018, https://data.fs.usda.gov/geodata/rastergateway/forest_type/

(48) "USGS Streamgaging Network." USGS, www.usgs.gov/mission-areas/water-resources/science/usgs-streamgaging-network?qt-science_center_objects=0#qt-science_center_objects.

(49) Walters, D. M., Blocksom, K. A., Lazorchak, J., Jicha, T. A., Angradi, T. R., & Bolgrien, D. W. (2010). Mercury contamination in fish in mid-continent great rivers of the United States: Importance of species traits and environmental factors. *Environmental Science and Technology, 44,* pp.2947-2953.

(50) Washburn, S. J., Blum, J. D., Kurz, A. Y., & Pizzuto, J. E. (2018). Spatial and temporal variation in the isotopic composition of mercury in the South River, VA. *Chemical Geology*, 494, 96-108.

(51) Wentz, D. A., Brigham, M. E., Chasar, L. C., Lutz, M. A., & Krabbenhoft, D. P. (2014). *Mercury in the nation's streams-Levels, trends, and implications* (No. 1395). US Geological Survey.

(52) Wiener, J. G., Knights, B. C., Sandheinrich, M. B., Jeremiason, J. D., Brigham, M. E., Engstrom, D. R., et al. (2006). Mercury in soils, lakes, and fish in Voyageurs National Park (Minnesota): Importance of atmospheric deposition and ecosystem factors. Environmental Science and Technology, 40, pp.6261-6268.

(53) Wiener, J. G., Krabbenhoft, D. P., Heinz, G. H., & Scheuhammer, A. M. (2003). Ecotoxicology of mercury. In D. J. Hoffman, B. A. Rattner, J. Burton, G.A., & J. Cairns, J. (Eds.), *Handbook of Ecotoxicology* (2nd ed., pp. 409-463). Boca Raton, FL: CRC Press.

(54) Zananski, T. J., Holsen, T. M., Hopke, P. K., & Crimmins, B. S. (2011). Mercury temporal trends in top predator fish of the Laurentian Great Lakes. *Ecotoxicology*, *20*(7), 1568-1576.

(55) Zhang, L., Wright, L. P., & Blanchard, P. (2009). A review of current knowledge concerning dry deposition of atmospheric mercury. *Atmospheric Environment*, *43*(37), 5853-5864.

(56) Zhang, L., Wu, Z., Cheng, I., Wright, L. P., Olson, M. L., Gay, D. A., ... & Edgerton, E. S. (2016). The estimated six-year mercury dry deposition across North America. *Environmental science & technology*, *50*(23), 12864-12873.

Appendix

Table A1. Monthly mercury and flow samples collected by ORSANCO used in the calculation to estimate mercury loads during study period.

[cfs, cubic feet per second; ng/L, nanograms per liter; Hg, mercury; shaded cells indicate the flow value is from USGS]

Confluence Mile Point	Date	River	Sample Mile Point	Flow (cfs)	Total Hg (ng/L)
0	11/3/2015	Allegheny	12	26,388	3.62
0	12/2/2015	Allegheny	12	13,831	0.89
0	1/5/2016	Allegheny	12	32,853	2.09
0	2/3/2016	Allegheny	12	31,049	1.81
0	3/1/2016	Allegheny	12	42,659	2.68
0	4/5/2016	Allegheny	12	17,610	1.66
0	5/3/2016	Allegheny	12	24,455	1.79
0	6/1/2016	Allegheny	12	9,954	1
0	7/5/2016	Allegheny	12	4,691	0.97
0	8/2/2016	Allegheny	12	4,282	0.75
0	9/6/2016	Allegheny	12	3,246	0.86
0	10/4/2016	Allegheny	12	7,156	1.85
0	11/3/2015	Monongahela	15	2,220	2.5
0	12/1/2015	Monongahela	15	4,016	1
0	1/6/2016	Monongahela	15	5,766	1.88
0	2/3/2016	Monongahela	15	33,313	12
0	3/2/2016	Monongahela	15	11,995	2.45
0	4/6/2016	Monongahela	15	5,536	0.96
0	5/4/2016	Monongahela	15	18,523	4.66
0	6/2/2016	Monongahela	15	3,142	1.32
0	7/6/2016	Monongahela	15	14,837	2.53
0	8/3/2016	Monongahela	15	3,727	1.61
0	9/7/2016	Monongahela	15	1,396	1.04
0	10/11/2016	Monongahela	15	3,295	1.09
25.4	12/2/2015	Beaver	2	1,790	1
25.4	1/6/2016	Beaver	2	4,709	3.18
25.4	2/2/2016	Beaver	2	2,610	1.2
25.4	3/1/2016	Beaver	2	8,213	4.96
25.4	4/5/2016	Beaver	2	3,967	1.93
25.4	5/3/2016	Beaver	2	4,749	3.93
25.4	6/1/2016	Beaver	2	1,265	1.66
25.4	7/5/2016	Beaver	2	938	1.54
25.4	8/2/2016	Beaver	2	1,186	1.64
25.4	9/6/2016	Beaver	2	885	1.61
25.4	10/4/2016	Beaver	2	1,367	2.91
25.4	11/7/2016	Beaver	2	1,561	1.31
172.2	11/4/2015	Muskingum	20.5	2,387	1.97
172.2	12/2/2015	Muskingum	20.5	4,734	3.51
172.2	1/7/2016	Muskingum	20.5	6,330	2.71
172.2	2/3/2016	Muskingum	20.5	8,400	12.3
172.2	3/2/2016	Muskingum	20.5	17,419	6.88
172.2	4/6/2016	Muskingum	20.5	11,985	3.96
172.2	5/4/2016	Muskingum	20.5	15,836	4.94
172.2	6/2/2016	Muskingum	20.5	4,589	1.63
172.2	7/6/2016	Muskingum	20.5	1,955	2.57
172.2	8/3/2016	Muskingum	20.5	1,645	1.46
172.2	9/7/2016	Muskingum	20.5	1,027	1.12
172.2	10/11/2016	Muskingum	20.5	1,210	1.5

Table A2. Monthly mercury and flow samples collected by ORSANCO used in the calculation to estimate load during study period.

[cfs, cubic feet per second; ng/L, nanograms per liter; Hg, mercury; shaded cells indicate the flow value is from USGS]

Confluence Mile Point	Date	River	Sample Mile Point	Flow (cfs)	Total Hg (ng/L)
266	11/4/2015	Kanawha	38.5	8,504	1.27
266	12/3/2015	Kanawha	38.5	74,508	13.50
266	1/7/2016	Kanawha	38.5	18,801	1.28
266	2/4/2016	Kanawha	38.5	75,230	5.61
266	3/3/2016	Kanawha	38.5	33,091	1.87
266	4/7/2016	Kanawha	38.5	7,842	1.09
266	5/5/2016	Kanawha	38.5	50,313	4.67
266	6/3/2016	Kanawha	38.5	6,855	1.58
266	7/7/2016	Kanawha	38.5	30,320	8.66
266	8/4/2016	Kanawha	38.5	4,688	1.45
266	9/8/2016	Kanawha	38.5	4,095	1.60
266	10/11/2016	Kanawha	38.5	13,457	5.12
317	11/19/2015	Big Sandy	7.9	1,531	1.37
317	12/3/2015	Big Sandy	7.9	18,111	29.20
317	1/11/2016	Big Sandy	7.9	2,482	0.95
317	2/4/2016	Big Sandy	7.9	19,935	18.60
317	3/17/2016	Big Sandy	7.9	5,395	1.53
317	4/18/2016	Big Sandy	7.9	1,482	0.72
317	5/23/2016	Big Sandy	7.9	10,474	5.68
317	6/6/2016	Big Sandy	7.9	6,521	6.98
317	7/20/2016	Big Sandy	7.9	1,847	1.39
317	8/17/2016	Big Sandy	7.9	1,456	2.97
317	9/21/2016	Big Sandy	7.9	1,167	2.24
317	10/17/2016	Big Sandy	7.9	542	0.98
357	11/19/2015	Scioto	15	2,260	1.72
357	12/10/2015	Scioto	15	2,070	0.96
357	1/11/2016	Scioto	15	7,770	3.78
357	2/18/2016	Scioto	15	5,380	3.68
357	3/17/2016	Scioto	15	24,900	15.90
357	4/18/2016	Scioto	15	6,310	3.96
357	5/23/2016	Scioto	15	5,570	3.19
357	6/6/2016	Scioto	15	3,700	3.38
357	7/20/2016	Scioto	15	2,180	1.17
357	8/17/2016	Scioto	15	3,620	8.02
357	9/23/2016	Scioto	15	921	2.20
357	10/17/2016	Scioto	15	1,040	1.88
464	11/30/2015	Little Miami	7.5	1,760	4.39
464	12/22/2015	Little Miami	7.5	3,360	8.53
464	1/21/2016	Little Miami	7.5	1,150	1.40
464	2/11/2016	Little Miami	7.5	1,520	2.08
464	3/8/2016	Little Miami	7.5	1,260	1.78
464	4/11/2016	Little Miami	7.5	3,750	1.63
464	5/19/2016	Little Miami	7.5	920	1.32
464	6/8/2016	Little Miami	7.5	844	2.99
464	7/13/2016	Little Miami	7.5	239	1.67
464	8/8/2016	Little Miami	7.5	196	1.15
464	9/15/2016	Little Miami	7.5	464	2.55
464	10/13/2016	Little Miami	7.5	232	1.19

Table A3. Monthly mercury and flow samples collected by boat by ORSANCO used in the calculation to estimate load during study period.

[cfs, cubic feet per second; ng/L, nanograms per liter; Hg, mercury; shaded cells indicate the flow value is from USGS]

Confluence Mile Point	Date	River	Sample Mile Point	Flow (cfs)	Total Hg (ng/L)
470.2	11/9/2015	Licking	7.5	1,507	2.12
470.2	12/21/2015	Licking	7.5	3,091	2.24
470.2	1/28/2016	Licking	7.5	5,900	2.29
470.2	2/22/2016	Licking	7.5	16,560	9.84
470.2	3/9/2016	Licking	7.5	9,583	4.41
470.2	4/20/2016	Licking	7.5	928	1.55
470.2	5/24/2016	Licking	7.5	7,375	7.73
470.2	6/23/2016	Licking	7.5	1,103	2.47
470.2	7/14/2016	Licking	7.5	663	1.86
470.2	8/10/2016	Licking	7.5	1,524	2.9
470.2	9/22/2016	Licking	7.5	354	2.37
470.2	10/18/2016	Licking	7.5	298	1.64
491.1	11/30/2015	Great Miami	15.0	4,970	4.07
491.1	12/22/2015	Great Miami	15.0	4,060	4.68
491.1	1/21/2016	Great Miami	15.0	3,450	2.54
491.1	2/11/2016	Great Miami	15.0	3,190	1.98
491.1	3/8/2016	Great Miami	15.0	4,970	2.14
491.1	4/11/2016	Great Miami	15.0	7,040	1.44
491.1	5/19/2016	Great Miami	15.0	2,500	1.7
491.1	6/8/2016	Great Miami	15.0	1,760	2.4
491.1	7/13/2016	Great Miami	15.0	870	2.08
491.1	8/8/2016	Great Miami	15.0	547	2.31
491.1	9/15/2016	Great Miami	15.0	951	2.02
491.1	10/13/2016	Great Miami	15.0	680	1.4
545.8	11/9/2015	Kentucky	28.5	1,914	1.8
545.8	12/21/2015	Kentucky	28.5	5,792	1.96
545.8	1/28/2016	Kentucky	28.5	9,570	0.94
545.8	2/22/2016	Kentucky	28.5	23,600	9.94
545.8	3/29/2016	Kentucky	28.5	6,627	3.42
545.8	4/20/2016	Kentucky	28.5	2,323	0.81
545.8	5/31/2016	Kentucky	28.5	5,190	1.89
545.8	6/23/2016	Kentucky	28.5	1,683	0.91
545.8	7/14/2016	Kentucky	28.5	6,415	1.72
545.8	8/10/2016	Kentucky	28.5	7,336	1.47
545.8	9/22/2016	Kentucky	28.5	1,689	1.43
545.8	10/18/2016	Kentucky	28.5	948	0.6
784.2	11/24/2015	Green	10.3	17,820	6.97
784.2	12/7/2015	Green	10.3	30,904	10.6
784.2	1/19/2016	Green	10.3	12,163	4.34
784.2	2/24/2016	Green	10.3	41,231	8.46
784.2	3/30/2016	Green	10.3	9,162	4.17
784.2	4/26/2016	Green	10.3	4,143	1.23
784.2	5/25/2016	Green	10.3	21,861	7.2
784.2	6/28/2016	Green	10.3	7,095	2.25
784.2	7/26/2016	Green	10.3	12,526	3.54
784.2	8/24/2016	Green	10.3	26,138	10.7
784.2	9/27/2016	Green	10.3	1,738	1.54
784.2	10/25/2016	Green	10.3	5,195	1.16

Table A4. Monthly mercury and flow samples collected by boat by ORSANCO used in the calculation to estimate load during study

[cfs, cubic feet per second; ng/L, nanograms per liter; Hg, mercury; shaded cells indicate the flow value is from USGS]

Confluence Mile Point	Date	River	Sample Mile Point	Flow (cfs)	Total Hg (ng/L)
848	11/24/2015	Wabash	42	17,073	4.61
848	12/7/2015	Wabash	42	20,482	5.32
848	1/19/2016	Wabash	42	56,000	5.93
848	2/24/2016	Wabash	42	31,409	25.4
848	3/30/2016	Wabash	42	42,253	6.87
848	4/26/2016	Wabash	42	42,425	7.32
848	5/25/2016	Wabash	42	28,727	5.05
848	6/28/2016	Wabash	42	29,409	12.1
848	7/26/2016	Wabash	42	22,561	9.42
848	8/24/2016	Wabash	42	33,472	11.4
848	9/27/2016	Wabash	42	16,053	5.93
848	10/25/2016	Wabash	42	30,469	13.6
920.4	11/23/2015	Cumberland	16	47,230	1.54
920.4	12/8/2015	Cumberland	16	48,211	1.85
920.4	1/26/2016	Cumberland	16	56,531	2.14
920.4	2/25/2016	Cumberland	16	85,616	3.68
920.4	3/31/2016	Cumberland	16	33,245	14.8
920.4	4/27/2016	Cumberland	16	17,435	1.31
920.4	5/26/2016	Cumberland	16	15,855	2.65
920.4	6/29/2016	Cumberland	16	9,723	1.62
920.4	7/27/2016	Cumberland	16	10,930	1.34
920.4	8/25/2016	Cumberland	16	31,178	4.26
920.4	9/28/2016	Cumberland	16	12,831	1.58
920.4	10/26/2016	Cumberland	16	6,793	0.82
934.5	11/23/2015	Tennessee	21.6	60,197	1.64
934.5	12/8/2015	Tennessee	21.6	161,821	2.44
934.5	1/26/2016	Tennessee	21.6	123,718	2.81
934.5	2/25/2016	Tennessee	21.6	155,549	2.9
934.5	3/31/2016	Tennessee	21.6	27,653	1.66
934.5	4/27/2016	Tennessee	21.6	25,647	0.81
934.5	5/26/2016	Tennessee	21.6	6,603	0.89
934.5	6/29/2016	Tennessee	21.6	10,778	1.09
934.5	7/27/2016	Tennessee	21.6	20,856	1.02
934.5	8/25/2016	Tennessee	21.6	58,443	0.97
934.5	9/28/2016	Tennessee	21.6	21,794	0.75
934.5	10/26/2016	Tennessee	21.6	25,607	0.77

Table A5. Monthly mercury and flow samples collected by ORSANCO used in the calculation

[cfs, cubic feet per second; ng/L, nanograms per liter; Hg, mercury]

Location ID	Date	Flow (cfs)	Total Hg (ng/L)
ORM 126	7/24/2012	7,144	1.04
ORM 126	8/30/2012	9,800	2.15
ORM 126	9/27/2012	14,591	1.95
ORM 126	10/25/2012	9,731	1.31
ORM 126	11/19/2012	20,689	1.06
ORM 126	12/17/2012	47,995	2.53
ORM 126	1/14/2013	102,310	7.7
ORM 126	2/14/2013	70,051	1.91
ORM 126	3/19/2013	72,268	2.62
ORM 126	4/15/2013	85,246	8.03
ORM 126	5/21/2013	21,906	1.97
ORM 126	6/17/2013	42,450	3.3
ORM 282	6/9/2015	28,150	0.97
ORM 282	7/21/2015	58,994	2.61
ORM 282	8/19/2015	29,841	1.42
ORM 282	9/17/2015	21,534	1.78
ORM 282	10/13/2015	23,691	1.3
ORM 282	11/16/2015	43,365	1.67
ORM 282	12/15/2015	21,036	0.9
ORM 282	1/14/2016	69,504	4.62
ORM 282	2/16/2016	96,264	4.96
ORM 282	3/15/2016	164,319	4.43
ORM 282	4/14/2016	177,798	13.8
ORM 282	5/16/2016	83,746	2.56
ORM 782	7/22/2015	264,430	14.6
ORM 782	8/15/2015	21,948	1.71
ORM 782	9/15/2015	31,036	1.66
ORM 782	10/14/2015	45,125	1.2
ORM 782	11/18/2015	66,444	2.62
ORM 782	12/14/2015	62,895	1.97
ORM 782	1/13/2016	134,256	7.86
ORM 782	2/17/2016	107,025	3.83
ORM 782	3/14/2016	241,667	8.24
ORM 782	4/13/2016	189,091	5.25
ORM 782	5/17/2016	196,159	8.93
ORM 782	6/20/2016	57,757	1.05
ORM 912	11/15/2016	59,063	0.51
ORM 912	12/12/2016	116,153	1.54
ORM 912	1/17/2017	350,368	18
ORM 912	2/15/2017	263,093	5.26
ORM 912	3/15/2017	281,227	14.5
ORM 912	4/12/2017	359,501	12.3
ORM 912	5/17/2017	474,877	8.14
ORM 912	6/21/2017	114,539	1.83
ORM 912	7/12/2017	156,335	4.92
ORM 912	8/15/2017	70,817	1.76
ORM 912	9/6/2017	88,700	1.87
ORM 912	10/10/2017	129,163	2.88

Table A6. Statistical evaluation of representativeness of the estimated loads using LOADEST

[Bp, Load Bias in Percent positive (negative) values indicate over (under) estimation; PLR, Partial Load Ratio (sum of estimated loads divided by sum of observed loads); Efficiency Index, Nash Sutcliffe Efficiency Index (E=1; a perfect fit to observed data)]

River	Flow Data	R squared %	Residual Variance	Bp [%]	PLR	Efficiency Index
Allegheny	USGS	99	0.04	-0.03	1.00	0.94
Monongahela	USGS	96	0.12	-1.02	0.99	0.96
Beaver	USGS	97	0.06	-1.81	0.98	0.98
ORM 126	USGS	98	0.08	-3.39	0.97	0.97
Muskingum	USGS	94	0.19	-0.22	1.00	0.74
Kanawha	USGS	98	0.09	-7.65	0.92	0.92
ORM 282	Cascade	95	0.13	-9.52	0.91	0.75
Big Sandy	Cascade	99	0.10	-2.14	0.98	0.99
Scioto	USGS	95	0.17	-8.10	0.92	0.98
Little Miami	USGS	95	0.14	-5.88	0.94	0.84
Licking	USGS	100	0.02	2.00	0.98	0.99
Great Miami	USGS	98	0.03	0.64	1.01	0.93
Kentucky	USGS	90	0.28	-28.225	0.72	0.70
ORM 782	Cascade	97	0.11	7.97	1.08	0.90
Green	USGS	96	0.12	1.78	1.02	0.87
Wabash	USGS	68	0.19	-1.54	0.99	0.42
ORM 912	Cascade	94	0.21	9.20	1.09	0.42
Cumberland	Cascade	76	0.47	-0.64	0.99	0.22
Tennessee	Cascade	98	0.05	0.24	1.00	0.95

Table A7. Summary statistics of 12 monthly monitored mercury concentration samples ORSANCO collected November 2015 thru October 2016.

[ng/L, nanograms per liter]

River	Mean (ng/L)	Median (ng/L)	Standard Deviation (ng/L)	Variance (ng/L)
Allegheny	1.66	1.73	0.86	0.74
Monongahela	2.75	1.75	3.10	9.59
Beaver	2.24	1.65	1.23	1.52
ORM 126	2.96	2.06	2.38	5.67
Muskingum	3.71	2.64	3.19	10.16
Kanawha	3.98	1.74	3.84	14.75
ORM 282	2.96	2.17	3.57	12.78
Big Sandy	6.05	1.89	8.86	78.42
Scioto	4.15	3.29	4.14	17.17
Little Miami	2.56	1.73	2.10	4.40
Licking	3.45	2.33	2.64	6.95
Great Miami	2.40	2.11	1.00	0.99
Kentucky	2.24	1.60	2.54	6.44
ORM 782	4.91	3.23	4.20	17.68
Green	5.18	4.26	3.51	12.35
Wabash	9.41	7.10	5.86	34.39
ORM 912	6.13	3.90	5.83	34.02
Cumberland	3.13	1.74	3.81	14.52
Tennessee	1.48	1.06	0.81	0.66

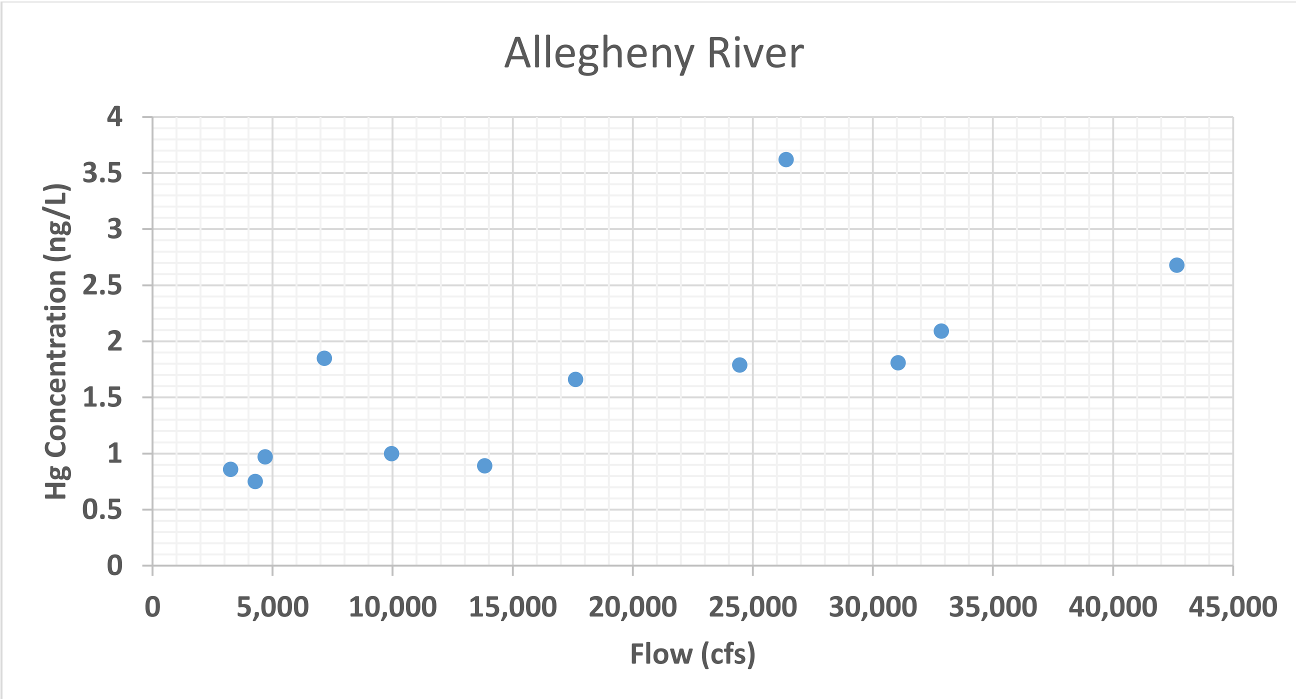


Figure A1. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Allegheny River.

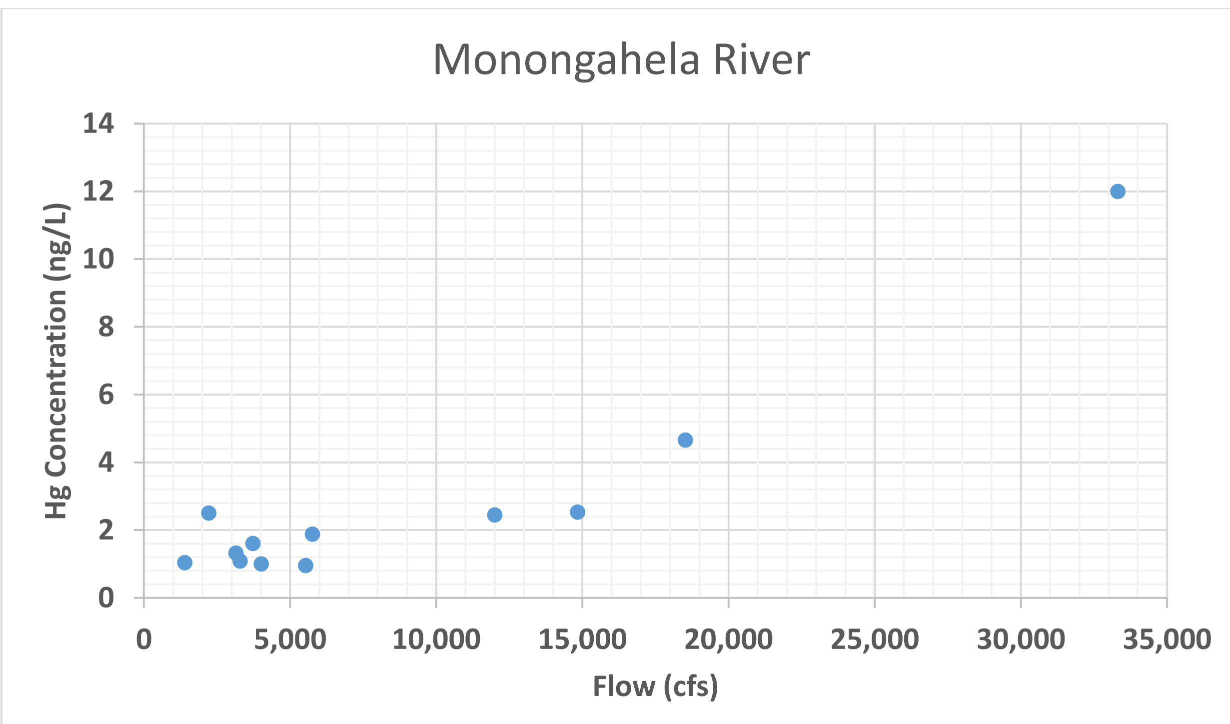


Figure A2. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Monongahela River.

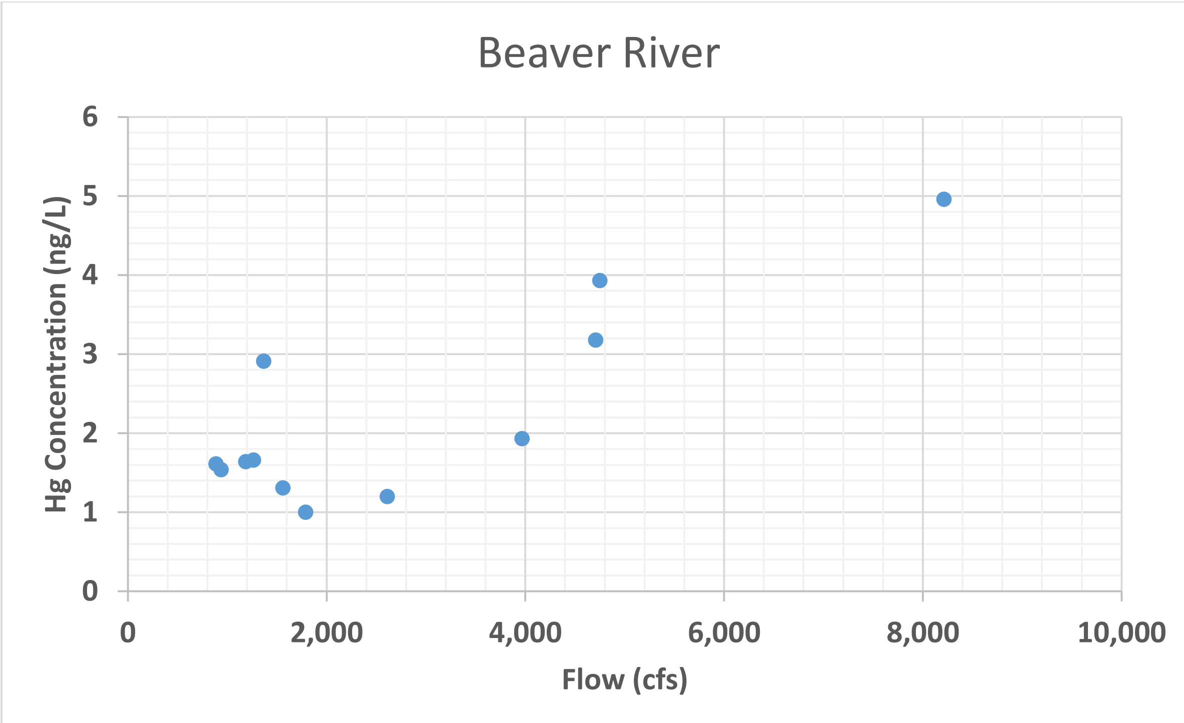


Figure A3. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Beaver River.

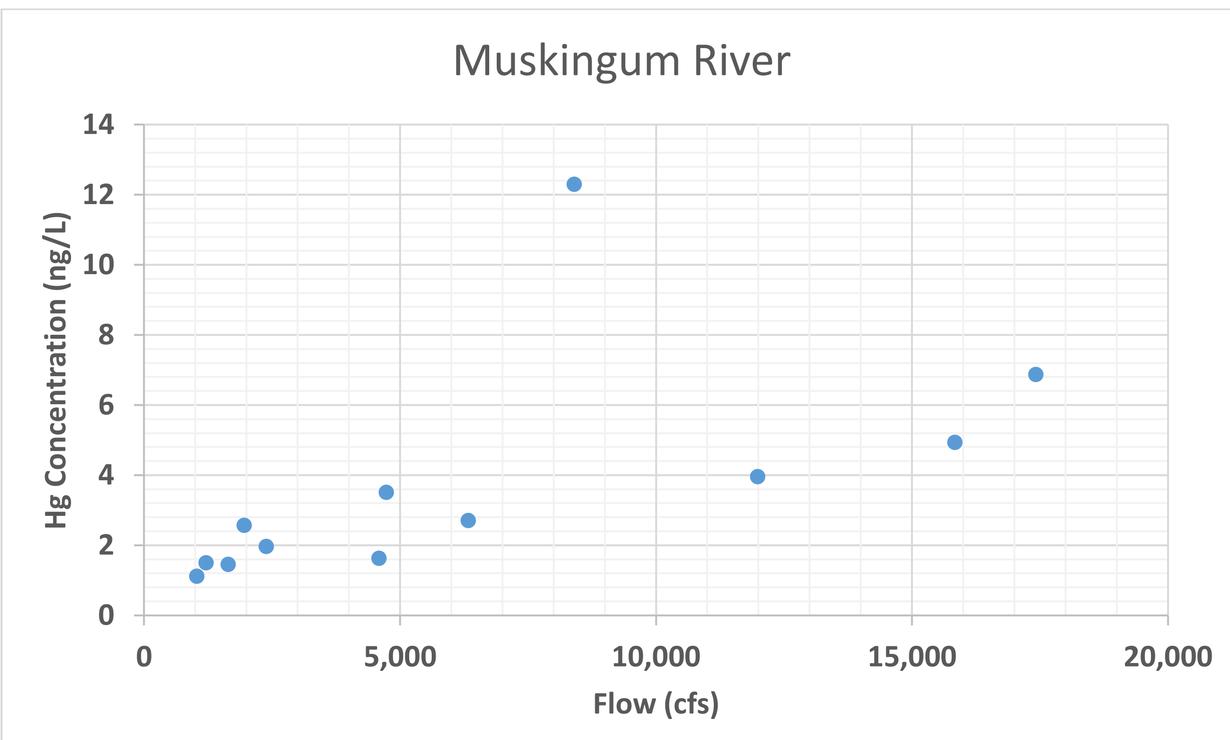


Figure A4. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Muskingum River.

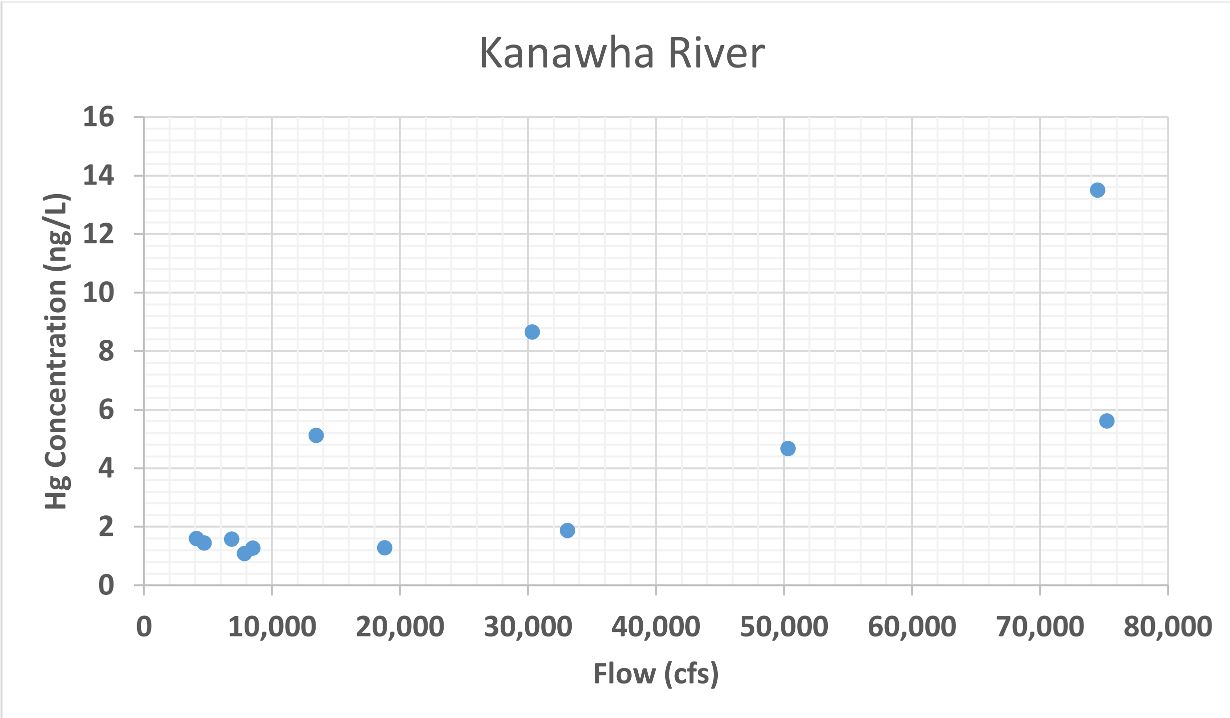


Figure A5. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Kanawha River.

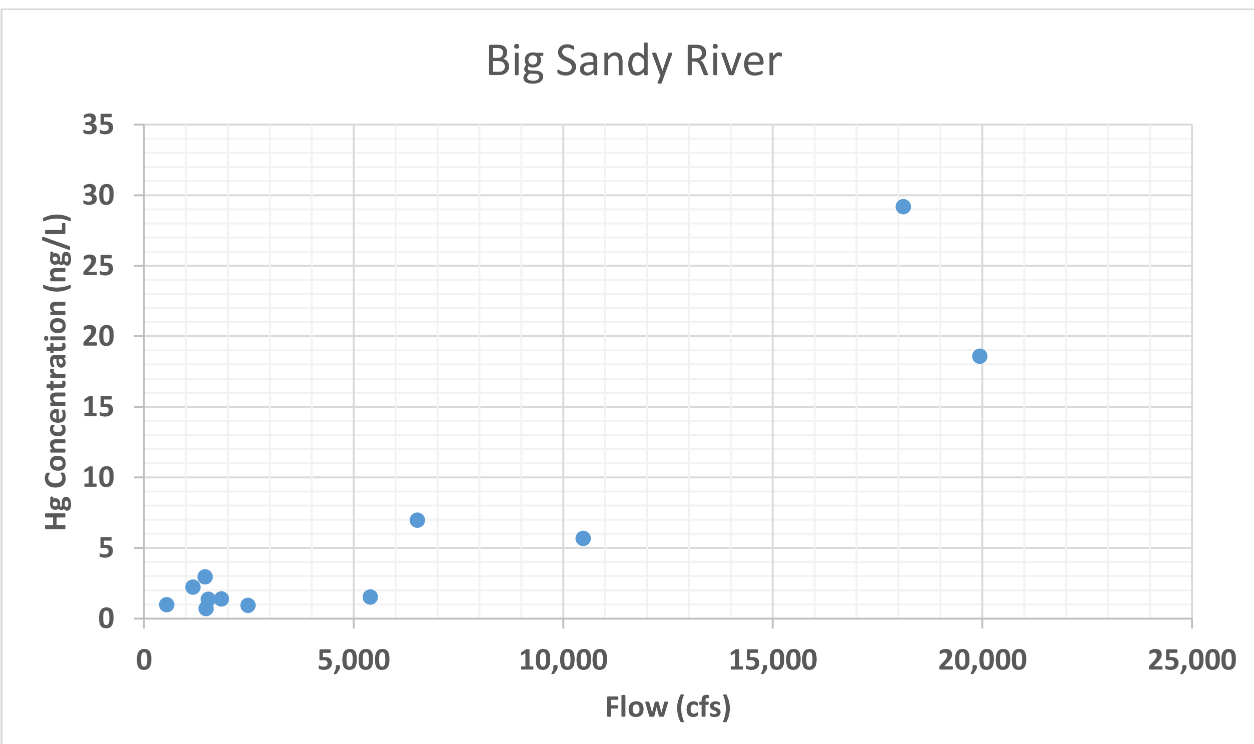


Figure A6. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Big Sandy River.

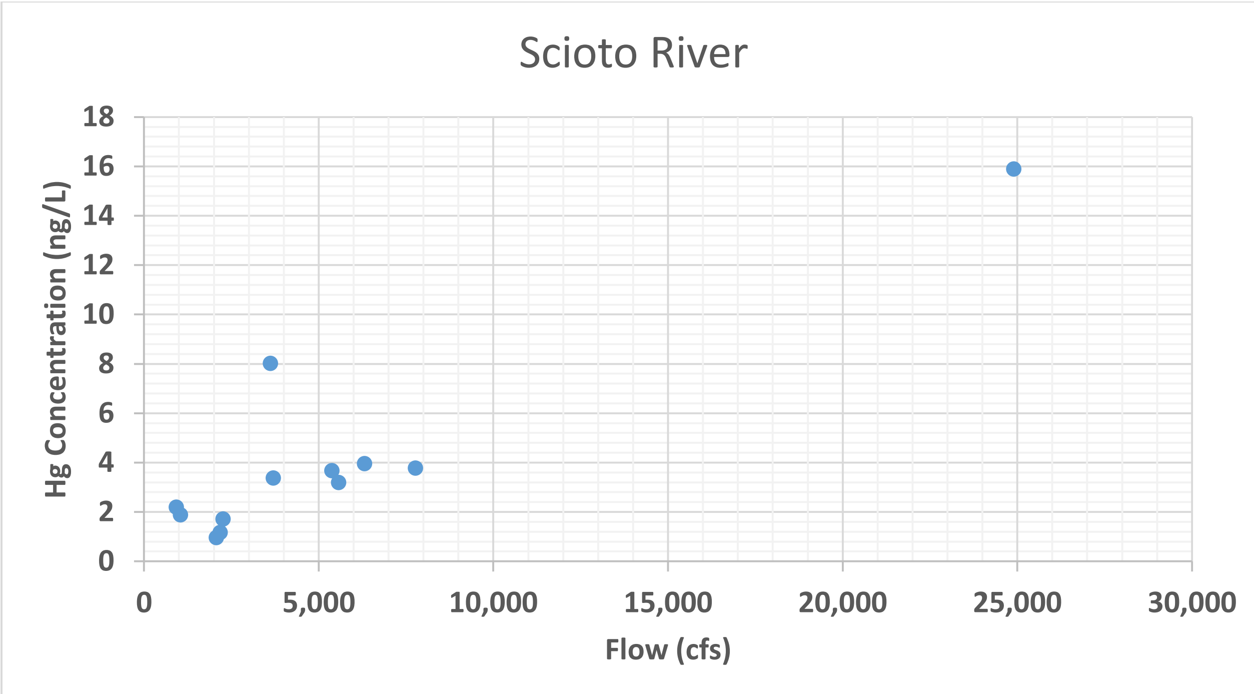


Figure A7. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Scioto River.

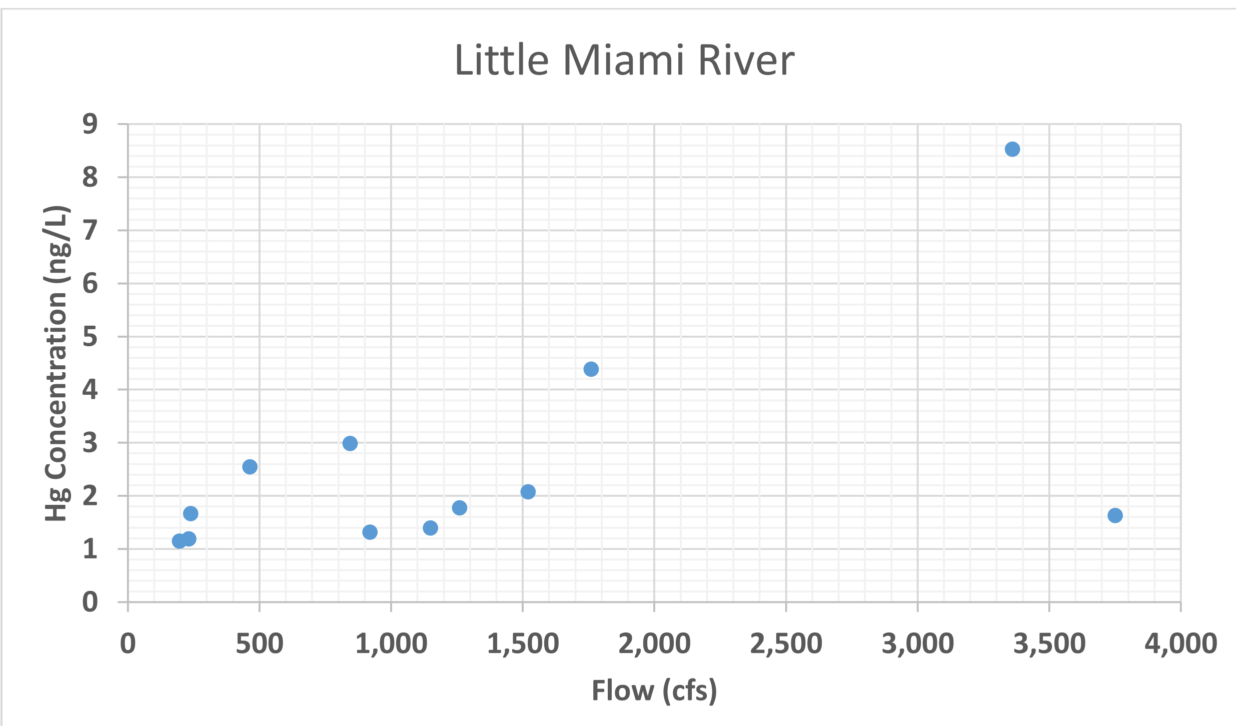


Figure A8. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Little Miami River.

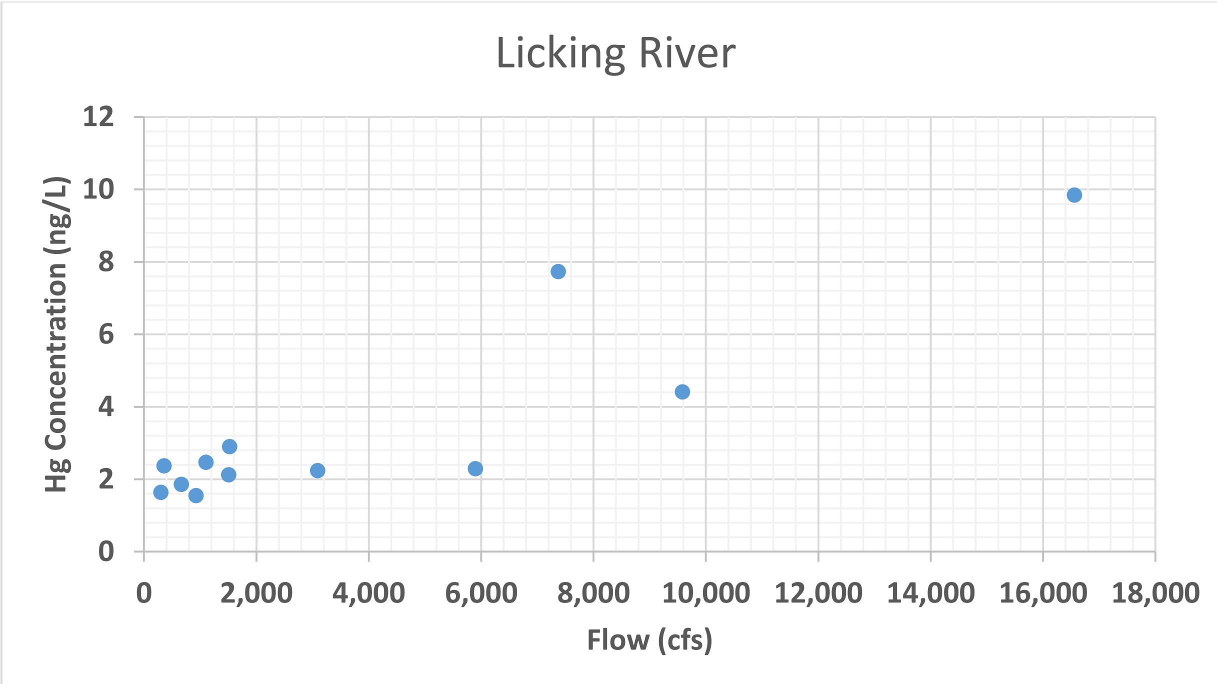


Figure A9. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Licking River.

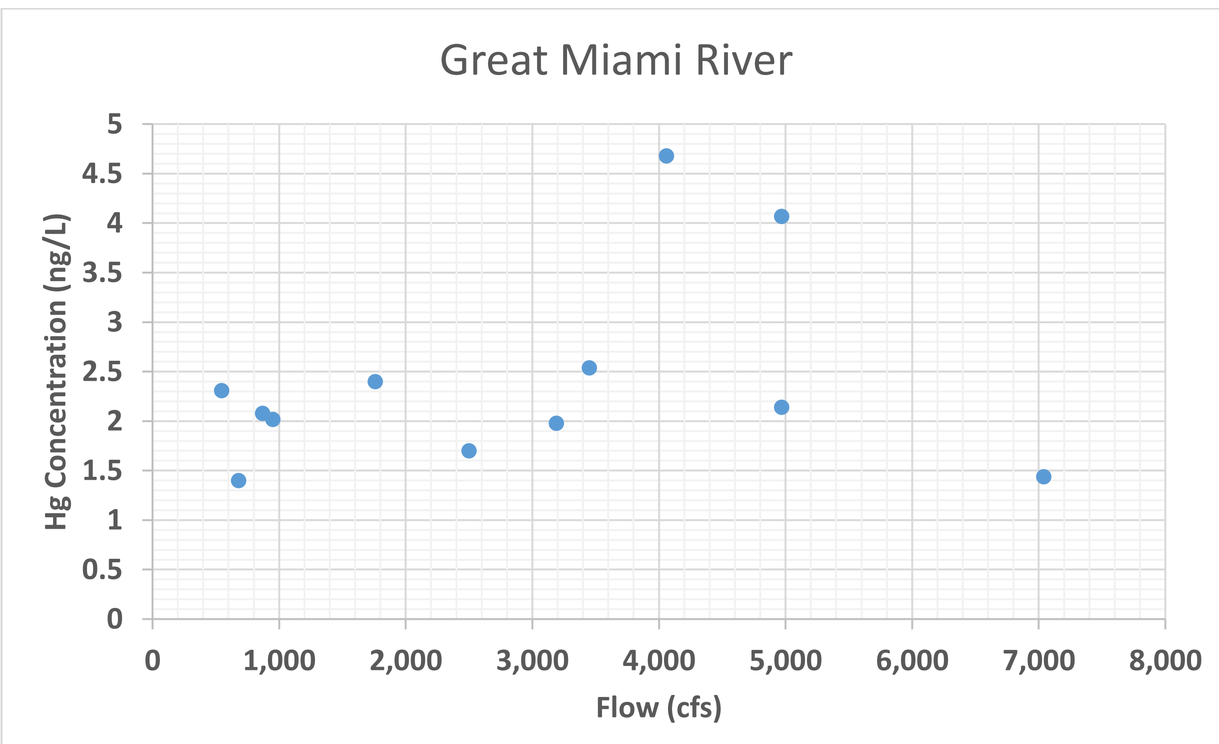


Figure A10. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Great Miami River

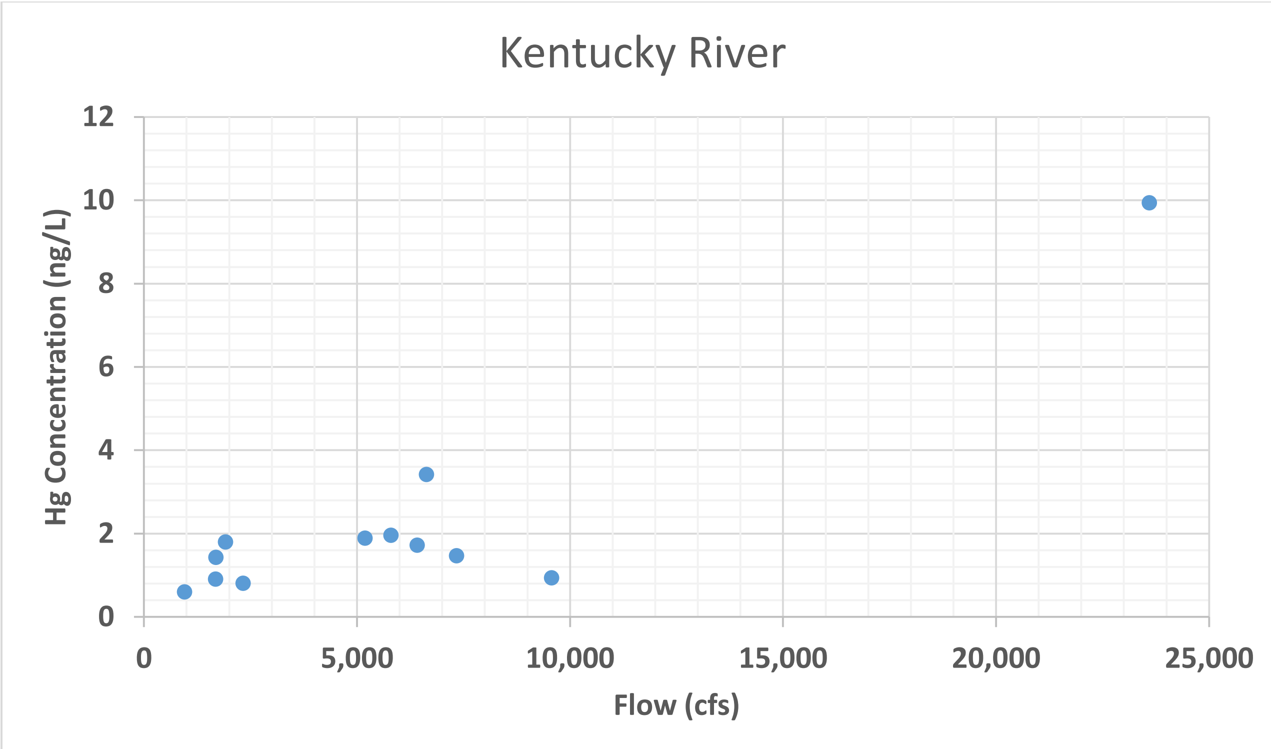


Figure A11. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Kentucky River.

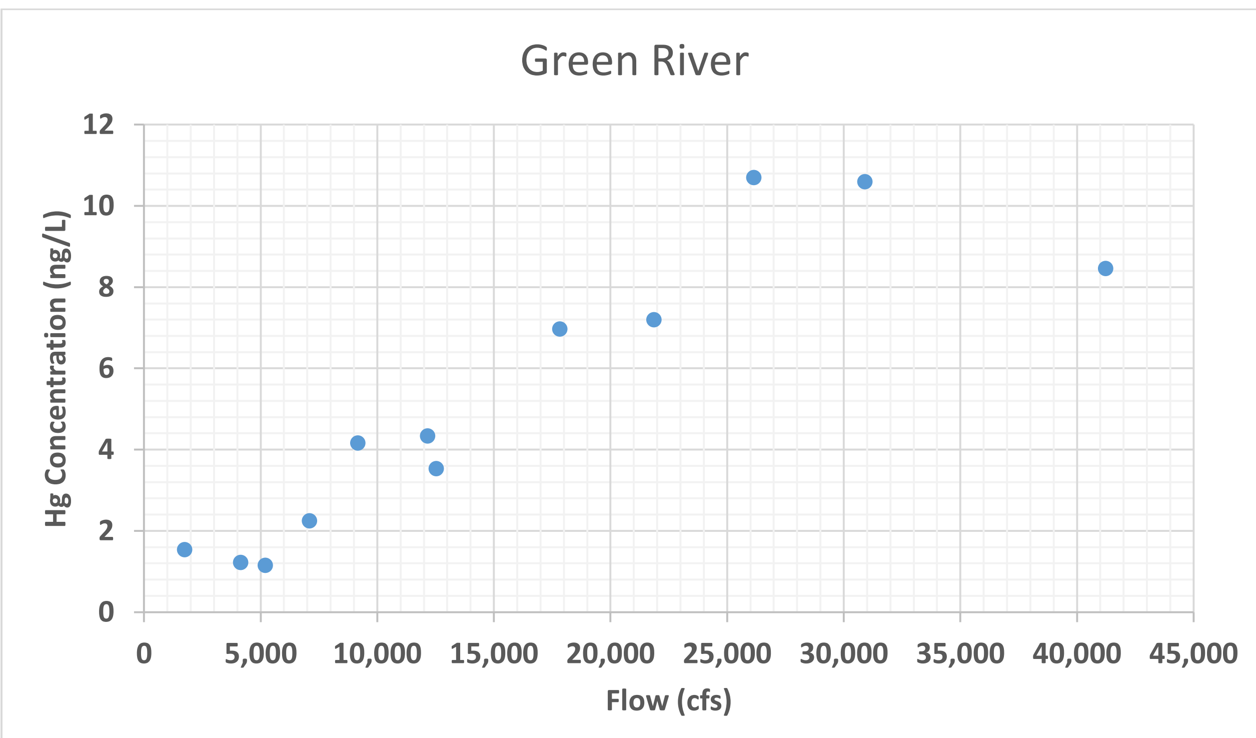


Figure A12. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Green River.

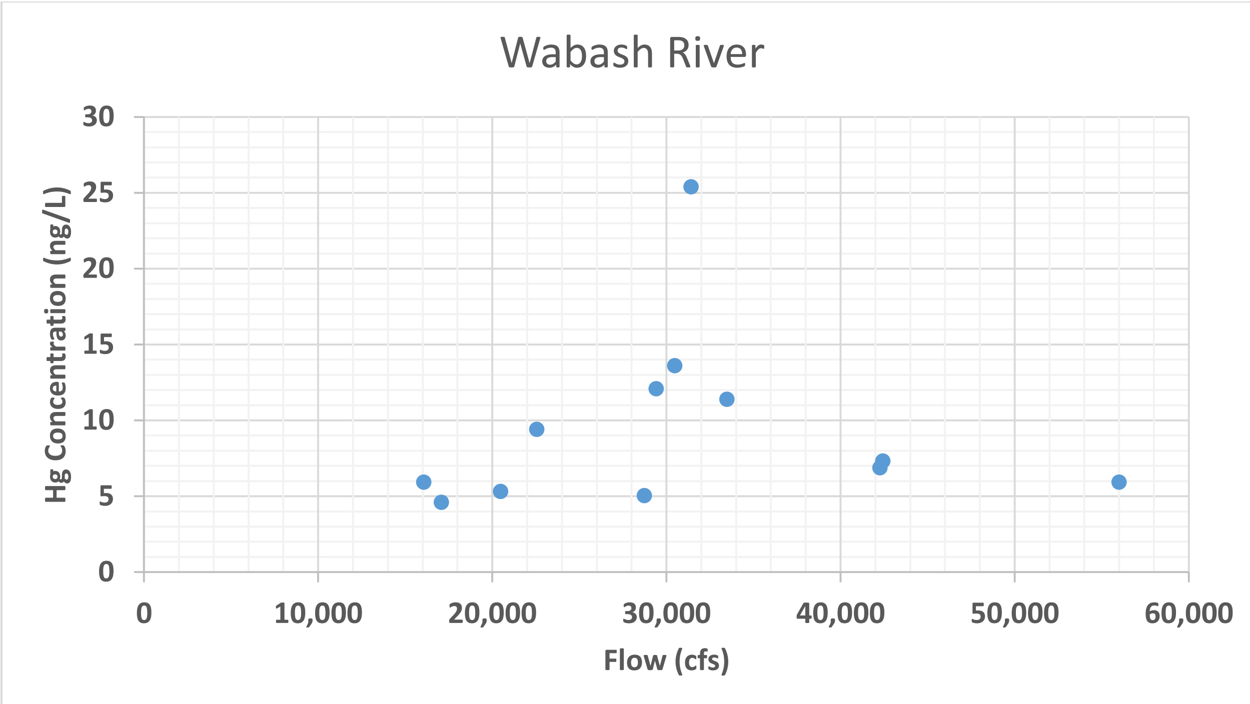


Figure A13. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Wabash River.

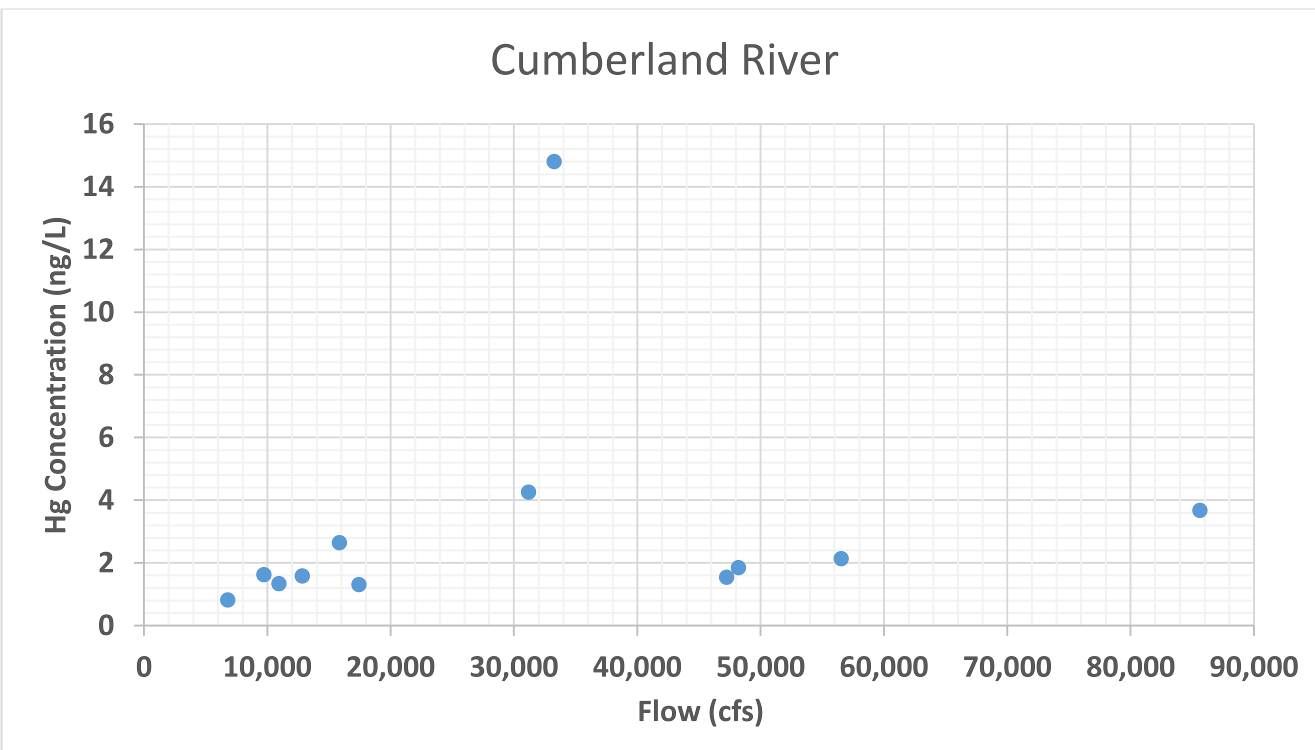


Figure A14. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Cumberland River.

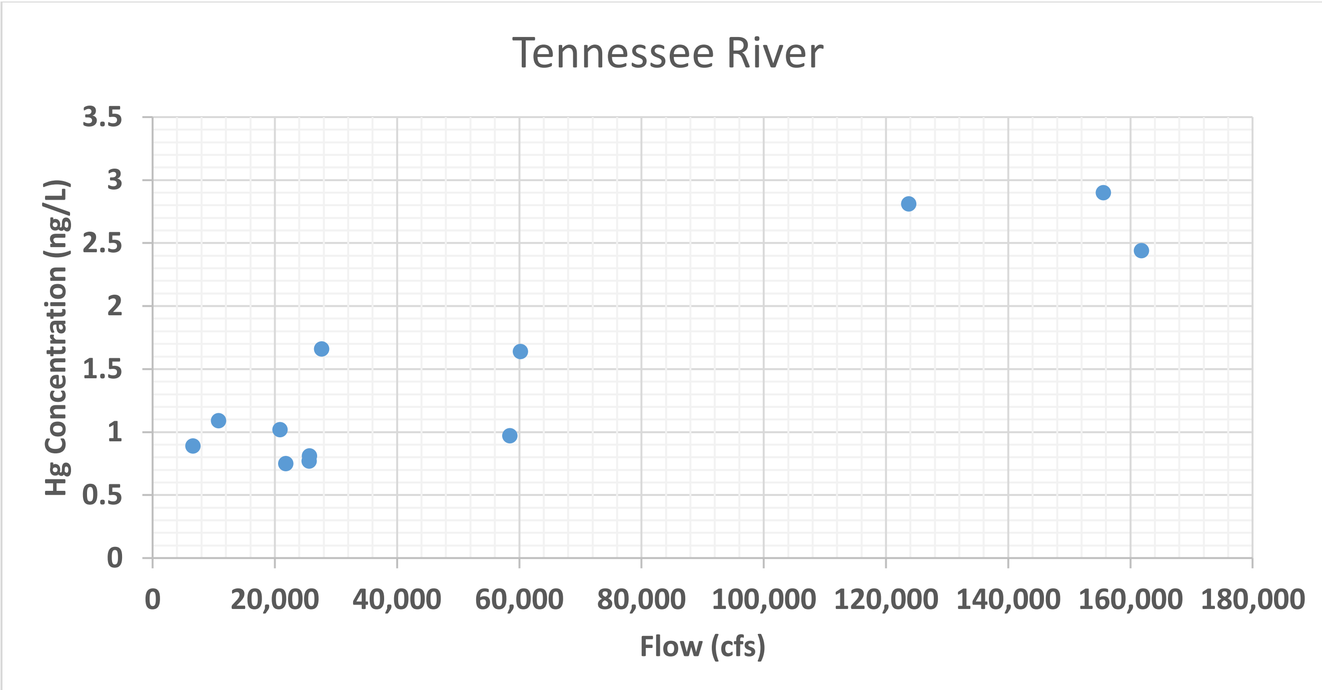


Figure A15. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Tennessee River.

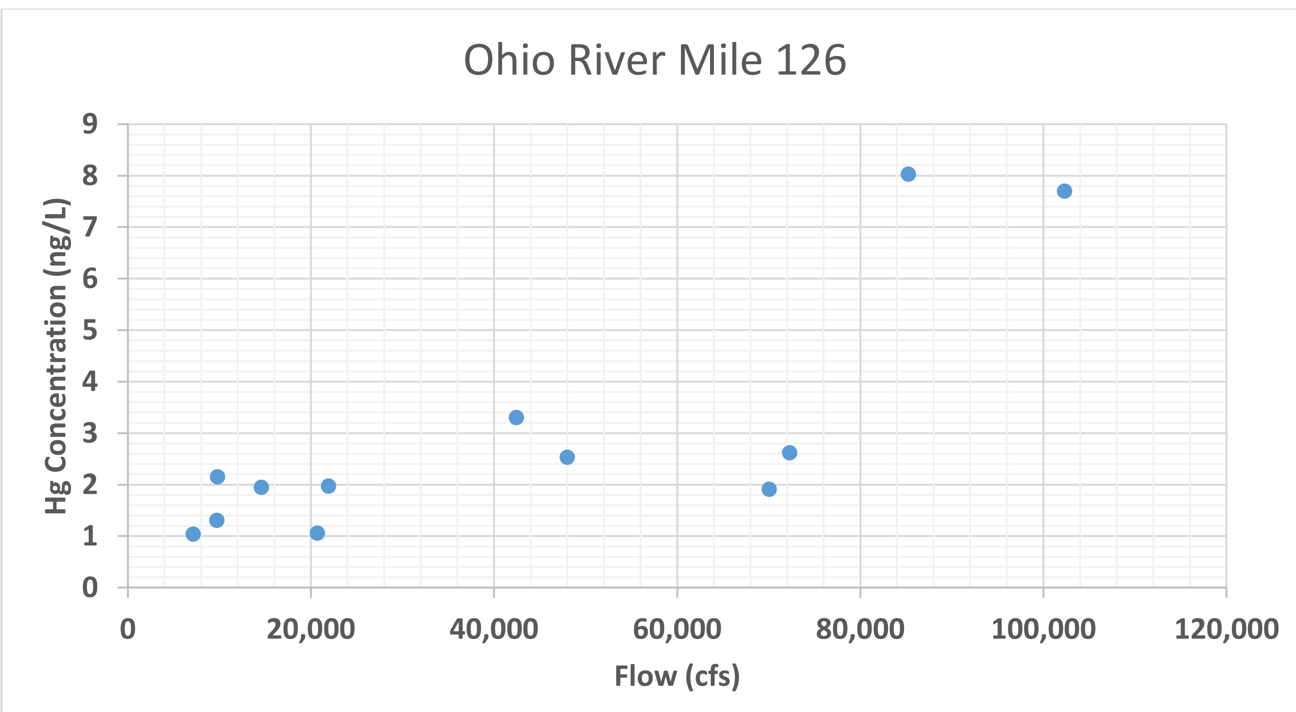


Figure A16. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Ohio River at mile point 126.

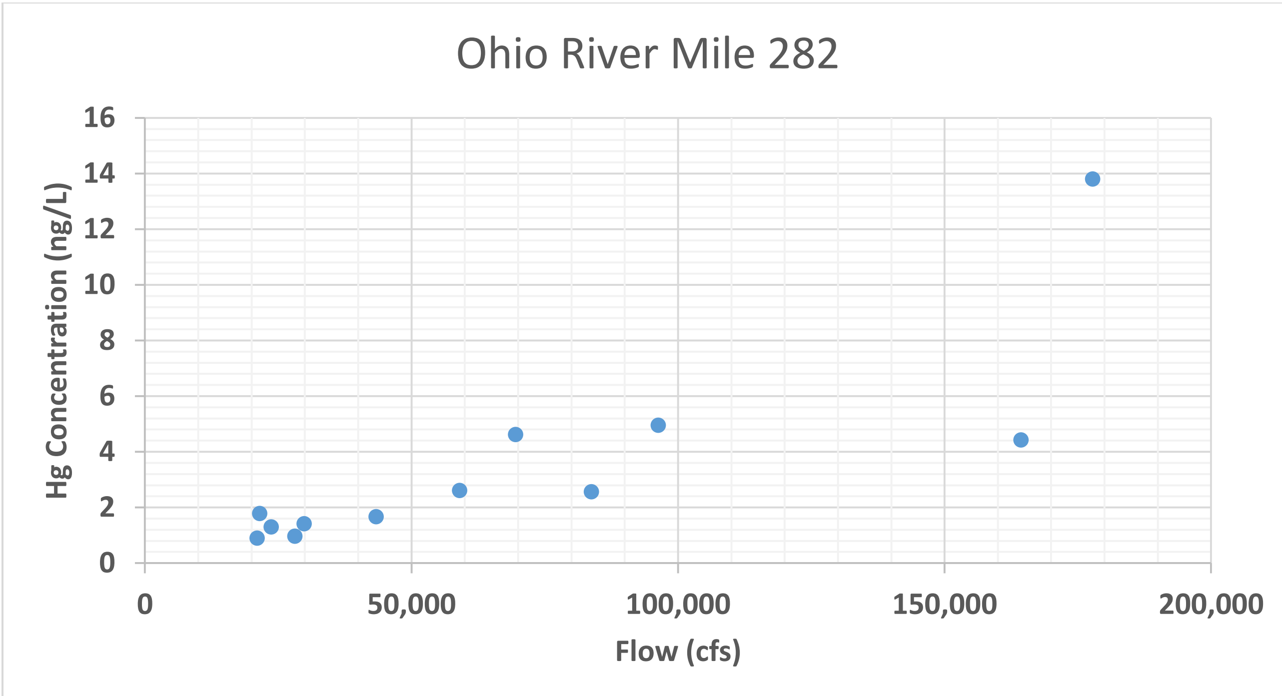


Figure A17. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Ohio River at mile point 282.

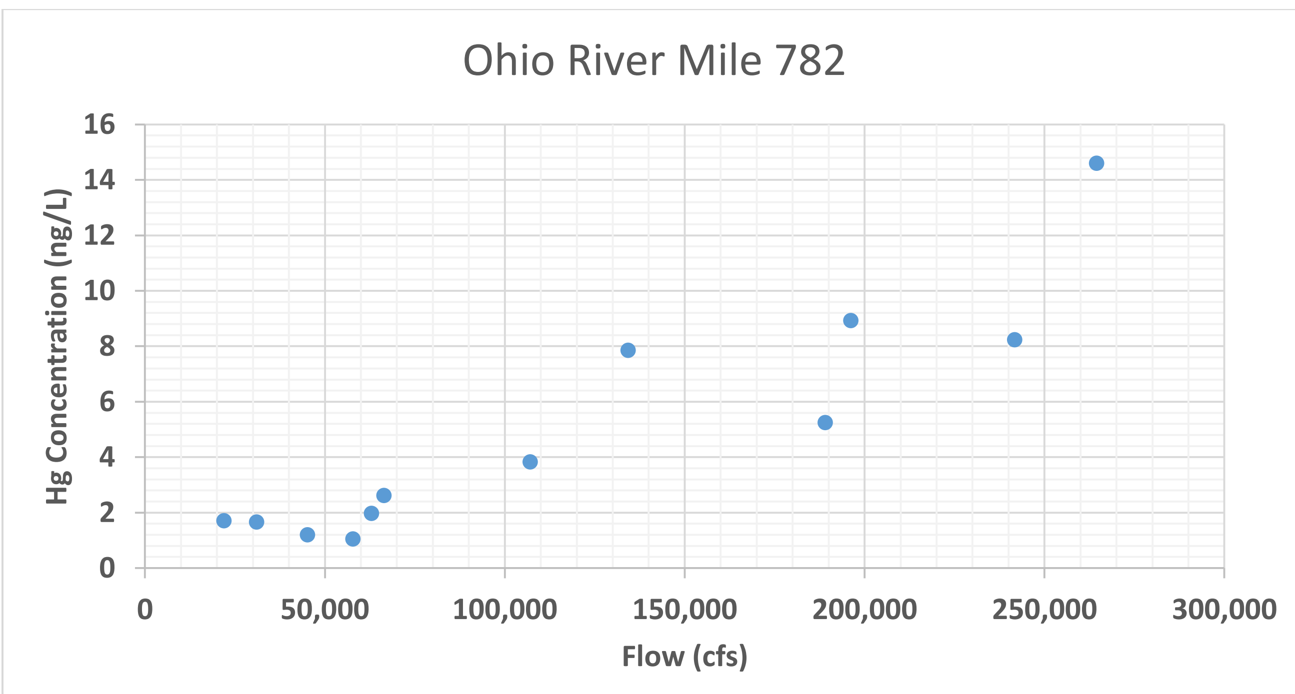


Figure A18. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Ohio River at mile point 782.

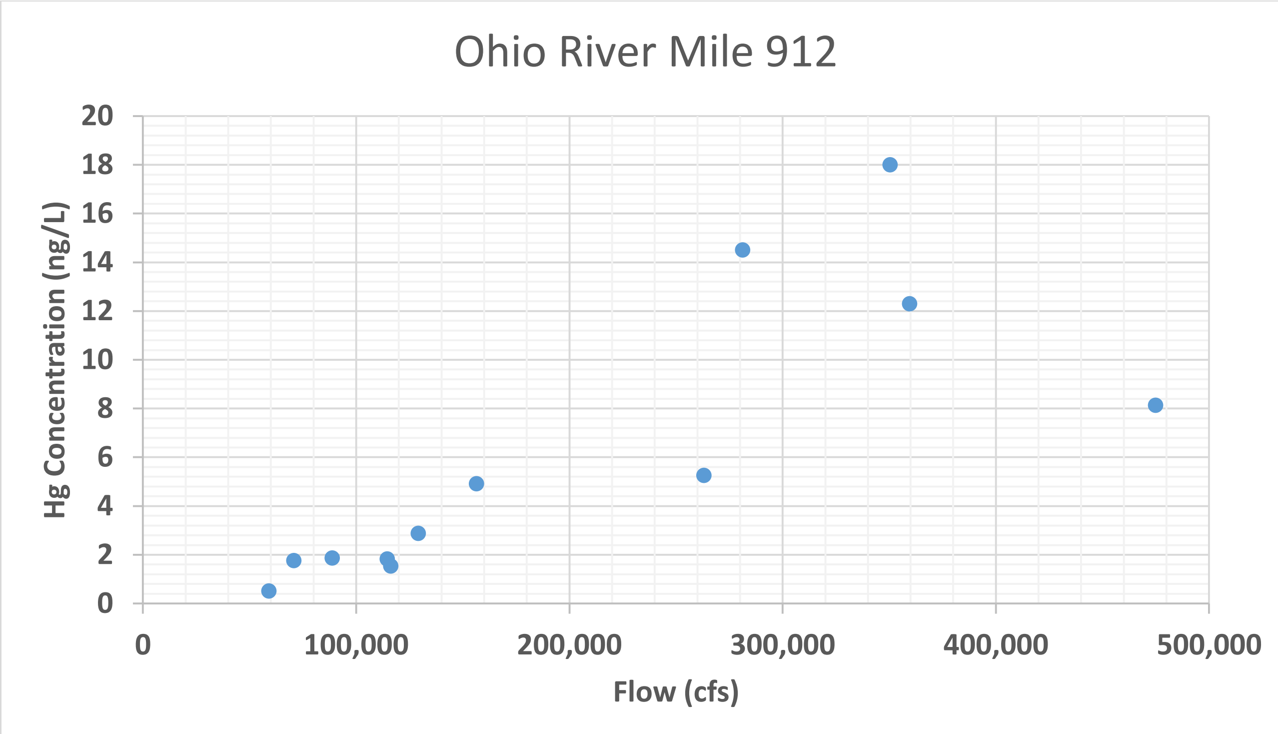


Figure A19. The monthly Hg concentration and the monthly flow discharge ORSANCO collected and monitored on the Ohio River at mile point 912.

Table A8. Point Source Hg pipe discharge per monitored facility's outfall in the Allegheny watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
NY0003395	VALEO INC ENGINE COOLING TRUCK DIVISION	001	4.0E-04	4.0E-04	3714
PA0001627	CHESWICK GENERATING STA	003	0	2.39	4911
PA0001627	CHESWICK GENERATING STA	503	0.02	0.02	4911
PA0002062	KEYSTONE POWER PLANT	003	0.06	0.06	4911
PA0005011	CONEMAUGH POWER PLANT	207	0.02	0.02	4911
PA0005011	CONEMAUGH POWER PLANT	007	0.08	0.08	4911
PA0005037	HOMER CITY POWER GENERATION SITE	001	0.01	0.01	2051
		Total	**0.19**	**2.59**	

Table A9. Point Source Hg pipe discharge per monitored facility's outfalls in the Monongahela watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
MD0070629	CASSELMAN MINE	001	0.02	0.08	1222
PA0002941	HATFIELDS FERRY POWER STA	206	0	1.5E-03	4911
PA0002941	HATFIELDS FERRY POWER STA	006	0	1.5E-03	4911
WV0004731	FORT MARTIN POWER STATION	002	0.46	0.46	4911
WV0005339	HARRISON POWER STATION	001	0.06	0.06	4911
WV0005339	HARRISON POWER STATION	002	0.37	0.37	4911
WV0023124	MORGANTOWN, CITY OF	001	0.03	0.09	4952
WV0023302	CLARKSBURG SANITARY BD	001	0.04	0.05	4952
WV0023353	FAIRMONT CITY OF	001	0.23	0.23	4952
WV0025461	BRIDGEPORT WASTEWATER TREATMENT PLANT	001	0.05	0.05	4952
WV0028088	WESTON CITY OF	001	0	4.2E-04	4952
WV0028088	WESTON CITY OF	007	0.06	0.06	4952
WV0079235	AMERICAN BITUMINOUS POWER PARTNERS LP	101	2.7E-04	9.6E-04	4911
WV0084301	GREATER HARRISON CO. PSD	001	1.8E-03	3.1E-03	4952
WV0114341	HORNBECK FACILITY	001	3.3E-05	3.3E-05	3273
		Total	**1.33**	**1.46**	

Table A10. Point Source Hg pipe discharge per monitored facility's outfalls in the Beaver watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
OH0010863	RMI Titanium Company LLC	001	2.0E-03	2.0E-03	3356
OH0011207	Warren Steel Holdings LLC	005	0.01	0.01	3312
OH0011207	Warren Steel Holdings LLC	008	0.03	0.03	3312
OH0011274	ArcelorMittal Warren	014	0.02	0.02	3312
OH0011274	ArcelorMittal Warren	213	0.01	0.02	3312
OH0011363	Thomas Steel Strip Corporation - TATA Steel Plating	001	2.3E-03	2.3E-03	3471
OH0020443	Sebring WWTP	001	3.0E-03	3.0E-03	4952
OH0021776	Columbiana WWTP	001	0.01	0.01	4952
OH0022110	Newton Falls WPC	001	0.01	0.01	4952
OH0023868	Alliance WWTP	001	0.09	0.09	4952
OH0023876	Andover WPCF	001	1.9E-03	1.9E-03	4952
OH0024091	Beloit WWTP	001	7.9E-04	7.9E-04	4952
OH0024325	Campbell WWTP	001	0.01	0.01	4952
OH0025330	Garrettsville WWTP	001	6.0E-04	6.0E-04	4952
OH0025364	Girard WWTP	001	0.05	0.05	4952
OH0025801	Hiram WWTP	001	5.4E-04	5.4E-04	4952
OH0025810	Hubbard WPCF	001	0.01	0.01	4952
OH0026204	Lowellville WWTP	001	0.01	0.01	4952
OH0026743	Niles WWTP	001	0.07	0.08	4952
OH0027600	Struthers WWTP	001	0.13	0.13	4952
OH0027987	Warren WPCF	001	0.12	0.12	4952
OH0028223	Youngstown WWTP	001	0.26	0.26	4952
OH0037249	Boardman WWTP	001	0.03	0.03	4952
OH0043401	Trumbull Mosquito Creek WWTP	001	0.03	0.03	4952
OH0043851	Craig Beach WWTP	001	3.5E-03	3.5E-03	4952
OH0045462	Windham WWTP	001	2.3E-03	2.3E-03	4952
OH0045721	Meander WPCF	001	0.03	0.03	4952
OH0101079	BDM Warren Steel Operations	023	3.5E-05	3.5E-05	3312
OH0140350	Kinsman WWTP	001	2.9E-04	2.9E-04	4952
		Total	**0.97**	**0.98**	

Table A11. Point Source Hg pipe discharge per monitored facility's outfalls in the OR Local 1 watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
OH0010910	Titanium Metals Corp Toronto Plant	006	0.01	0.01	3356
OH0011525	FirstEnergy W.H. Sammis Plant	009	0.15	0.15	4911
OH0011738	Valley Converting Co Inc	001	4.2E-03	4.2E-03	2631
OH0011827	Hopedale Mining Preparation Plant	009	1.9E-03	1.9E-03	1222
OH0011835	Hopedale Mining - Cadiz Portal	001	1.6E-03	1.6E-03	1222
OH0011835	Hopedale Mining - Cadiz Portal	002	3.7E-04	3.7E-04	1222
OH0011835	Hopedale Mining - Cadiz Portal	006	1.5E-04	1.5E-04	1222
OH0011835	Hopedale Mining - Cadiz Portal	007	3.0E-04	3.0E-04	1222
OH0012581	Cardinal Operating Co 1 & 2 *	019	0.15	0.15	4911
OH0012581	Cardinal Operating Co 1 & 2 *	601	0.39	0.39	4911
OH0020214	Toronto WWTP	001	0.04	0.04	4952
OH0021121	Bethesda WWTP	001	3.8E-04	3.8E-04	4952
OH0021652	Leetonia WWTP	001	1.9E-03	1.9E-03	4952
OH0021661	Adena WWTP	001	1.1E-03	1.1E-03	4952
OH0021784	East Palestine WWTP	001	2.7E-03	2.7E-03	4952
OH0022144	Wintersville A WWTP	001	0.01	0.01	4952
OH0022543	Yorkville STP *	001	3.0E-03	3.0E-03	4952
OH0024015	Barnesville WWTP	001	2.0E-03	2.0E-03	4952
OH0024295	Cadiz WWTP	001	0.15	0.15	4952
OH0024970	East Liverpool WWTP	001	0.08	0.08	4952
OH0025143	Flushing WWTP	001	8.4E-04	8.4E-04	4952
OH0025895	Jefferson Co - M WWTP	001	1.8E-03	1.8E-03	4952
OH0026565	Mingo Junction STP	001	0.01	0.01	4952
OH0026735	New Waterford WWTP	001	2.9E-04	3.8E-04	4952
OH0027219	Powhatan Point WWTP	001	2.3E-03	2.3E-03	4952
OH0027294	St Clairsville WWTP	001	0.01	0.01	4952
OH0027383	Shadyside WWTP	001	0.01	0.01	4952
OH0027511	Steubenville WWTP	001	0.06	0.06	4952
OH0037273	New Middletown - Springfield Twp WWTP	001	2.1E-03	2.1E-03	4952
OH0041131	Hopedale WWTP	001	3.0E-04	3.0E-04	4952
OH0049999	Eastern Ohio Regional WW Authority	001	0.01	0.02	4952
OH0050148	Smithfield WWTP	001	1.5E-03	1.5E-03	4952
OH0059307	Pennwood Estates Subdiv	001	3.9E-04	3.9E-04	4952
OH0063681	Gilford Lake STP	001	1.7E-03	1.7E-03	4952
OH0063746	Salineville WWTP	001	2.1E-03	2.1E-03	4952
OH0076546	Dillonvale-Mt Pleasant	001	7.2E-04	7.2E-04	4952
OH0076864	Marietta Coal Co Bellaire Refuse Disposal Site	001	6.7E-09	6.7E-09	1221
OH0090891	Tiltonsville WWTP	001	2.2E-03	2.2E-03	4952
OH0135411	Riddles Run Refuse Disposl/Coal Processing Plant	001	6.6E-05	6.6E-05	1222
PA0002208	SHELL CHEMICAL APPALACHIA PETROCHEMICALS COMPLEX	101	0	0.02	2869
PA0092223	BASF MONACA PLT	002	0.01	0.01	2822
PA0092223	BASF MONACA PLT	004	0.02	0.02	2822
WV0004499	AK STEEL CORP	004	0.16	0.16	3312
WV0004499	AK STEEL CORP	006	0.06	0.06	3312

Table A12. Continued, Point Source Hg pipe discharge per monitored facility's outfalls in the OR Local 1 watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
WV0004588	KOPPERS, INC. - FOLLANSBEE	001	0.03	0.03	2865
WV0005291	AEP KAMMER POWER PLANT	004	1.7E-03	1.7E-03	4911
WV0005304	AEP MITCHELL POWER PLANT	001	0.08	0.08	4911
WV0020273	FOLLANSBEE CITY OF	001	4.7E-03	4.7E-03	4952
WV0023108	WEIRTON, CITY OF	001	0.14	0.14	4952
WV0023230	WHEELING CITY OF	001	0.02	0.05	4952
WV0023264	MOUNDSVILLE CITY OF	001	0.03	2.35	4952
WV0026832	WELLSBURG WASTE WATER TREATMEN	001	4.4E-03	4.4E-03	4952
WV0116939	OHIO POWER COMPANY - CONNER RUN IMPOUNDMENT, D/B/A AEP	001	0.01	0.01	4911
WV0116939	OHIO POWER COMPANY - CONNER RUN IMPOUNDMENT, D/B/A AEP	002	3.2E-05	3.2E-05	4911
WV0117366	HARSCO CORPORATION, MOUNDSVILLE	002	1.5E-04	1.6E-04	3291
		Total	**1.68**	**4.06**	

Table A13. Point Source Hg pipe discharge per monitored facility's outfalls in the Muskingum watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
OH0128180	Rosebud Mining Co - Tusky Mine	001	7.6E-04	7.6E-04	1221
OH0140040	Rosebud Mining Co - Vail Mine	001	1.2E-04	1.2E-04	1222
OH0004235	Spirit Funding LLC	003	0.15	0.15	2631
OH0005657	Marathon Petroleum Co LP	001	5.2E-04	2.4E-03	2911
OH0005657	Marathon Petroleum Co LP	003	4.1E-03	4.1E-03	2911
OH0006840	AK Steel Corporation - Mansfield Works	001	7.0E-04	2.7E-03	3312
OH0006840	AK Steel Corporation - Mansfield Works	006	1.1E-04	1.1E-04	3312
OH0006912	Republic Steel	010	0.10	0.10	3312
OH0007498	Globe Metallurgical Inc *	001	5.7E-04	5.7E-04	3313
OH0004260	AK Steel - Coshocton Works	001	2.1E-03	3.5E-03	3316
OH0004901	Casting Solutions LLC	005	5.2E-04	5.2E-04	3321
OH0048372	Miba Bearings US LLC	601	0	9.7E-05	3714
OH0005371	AEP Conesville Plant	001	0.44	0.44	4911
OH0006149	Muskingum River Development LLC	002	3.2E-03	3.2E-03	4911
OH0076627	Conesville Residual Waste Disposal Facility	001	0.01	0.01	4911
OH0076627	Conesville Residual Waste Disposal Facility	002	4.4E-03	4.4E-03	4911
OH0127892	AEP- Appalachian Power - Dresden Generating Plant	001	0.01	0.01	4911
OH0020036	Navarre WWTP	001	0.01	0.01	4952
OH0020079	Twin City WWTP	001	0.01	0.01	4952
OH0020168	Millersburg WWTP	001	2.0E-03	2.2E-03	4952
OH0020257	Lexington WWTP	001	0.01	0.01	4952
OH0020273	Pataskala WWTP	001	9.0E-04	1.4E-03	4952
OH0020371	Orrville WWTP	001	0.02	0.02	4952
OH0020508	Johnstown WWTP	001	2.7E-03	2.7E-03	4952
OH0020516	Massillon WWTP	001	0.10	0.10	4952
OH0020567	Brewster WWTP	001	0.01	0.01	4952
OH0020648	Beverly WWTP	001	3.7E-03	3.7E-03	4952
OH0020869	Gnadenhutten WWTP	001	0.04	0.04	4952
OH0020915	Centerburg Wastewater Works	001	1.2E-03	1.2E-03	4952
OH0020923	Hartville WWTP	001	5.1E-04	7.8E-04	4952
OH0020931	Carrollton WWTP	001	0.03	0.03	4952
OH0021024	New Concord WWTP	001	3.1E-04	5.4E-04	4952
OH0021270	Brilliant Water & Sewer District WWTP	001	3.2E-03	3.2E-03	4952
OH0021342	Doylestown WPCF	001	0.02	0.02	4952
OH0021377	West Salem WWTP	001	3.1E-04	3.1E-04	4952
OH0021466	McConnelsville WWTP	001	0.01	0.01	4952
OH0021504	Mineral City WWTP	001	1.3E-03	1.3E-03	4952
OH0021539	Hebron Village WRF	001	2.7E-03	2.8E-03	4952
OH0021687	Dalton WWTP	001	1.1E-03	1.2E-03	4952
OH0021849	Minerva STP	001	0.01	0.01	4952
OH0021971	Smithville WWTP	001	1.2E-03	1.2E-03	4952
OH0022047	Canal Fulton Regional WWTP	001	3.3E-03	3.3E-03	4952
OH0022284	West Lafayette WWTP	001	5.8E-04	5.8E-04	4952
OH0023345	Granville WWTP	001	0.01	0.01	4952

Table A14. Continued, Point Source Hg pipe discharge per monitored facility's outfalls in the Muskingum watershed during study period November 2015 through October 2016					
[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]					
NPDES Permit	**Facility**	**Outfall ID Number**	**Minimum Hg Load (lbs)**	**Maximum Hg Load (lbs)**	**SIC**
OH0023540	Shelby WWTP	001	0.01	0.01	4952
OH0023892	Apple Creek WWTP	001	0	5.3E-04	4952
OH0023906	Ashland WWTP	001	0.04	0.04	4952
OH0024007	Barberton WPCF	001	0.04	0.04	4952
OH0024309	Cambridge WPCC	001	0.03	0.03	4952
OH0024350	City of Canton Water Reclamation Facility	001	0.11	0.11	4952
OH0024775	Coshocton WWTP	001	0.15	0.15	4952
OH0024872	Danville WWTP	001	2.9E-03	3.0E-03	4952
OH0024945	Dover WWTP	001	0.02	0.02	4952
OH0024953	Dresden WWTP	001	2.3E-03	2.3E-03	4952
OH0025321	Gambier WWTP	001	1.7E-04	2.4E-04	4952
OH0025763	Heath WWTP	001	0.02	0.02	4952
OH0026182	Louisville WWTP	001	0.01	0.01	4952
OH0026328	Mansfield WWTP	001	0.06	0.06	4952
OH0026395	Chippewa Lake SD No 700	001	7.1E-04	7.7E-04	4952
OH0026531	Millersport STP	001	3.9E-04	3.9E-04	4952
OH0026662	Mount Vernon WWTP	001	0.05	0.05	4952
OH0026689	Newcomerstown WWTP	001	0.01	0.01	4952
OH0026727	New Philadelphia WWTP	001	0.04	0.04	4952
OH0027375	Seville WWTP	001	1.7E-03	1.7E-03	4952
OH0027553	Strasburg WWTP	001	0.06	0.06	4952
OH0027618	Sugarcreek WWTP	001	4.4E-03	4.4E-03	4952
OH0027723	Thornville WWTP	001	2.9E-04	4.6E-04	4952
OH0027855	Tuscarawas WWTP	001	7.4E-04	7.4E-04	4952
OH0027898	Utica WWTP *	001	0	2.8E-04	4952
OH0028011	Washingtonville WWTP	001	9.3E-04	9.3E-04	4952
OH0028045	Wellsville WWTP	001	0.02	0.02	4952
OH0028185	Wooster WPCP	001	0.02	0.02	4952
OH0036561	Wayne Co Eastwood Subdiv STP	001	9.8E-05	9.8E-05	4952
OH0037117	Little Jelloway Creek WWTP	001	9.5E-04	1.2E-03	4952
OH0039098	Buckeye Lake WWTP	001	1.0E-03	1.3E-03	4952
OH0039217	Eastview WWTP	001	2.0E-03	2.0E-03	4952
OH0045373	Shreve WWTP	001	0.01	0.01	4952
OH0045390	Westfield Center WWTP	001	7.3E-04	8.1E-04	4952
OH0045489	Beach City WWTP	001	1.0E-04	1.9E-04	4952
OH0045497	Zelray Park WWTP No 48	001	2.1E-04	2.1E-04	4952
OH0045853	Norton Acres WWTP No 13	001	1.2E-03	1.2E-03	4952
OH0047783	Baltic WWTP	001	5.2E-04	5.2E-04	4952
OH0048615	Sandyville-East Sparta WWTP	001	3.4E-03	3.4E-03	4952
OH0050750	Warsaw WWTP	001	4.4E-05	4.4E-05	4952

Table A15. Continued, Point Source Hg pipe discharge per monitored facility's outfalls in the Muskingum watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
OH0064017	Upper Tuscarawas WWTP No 36	001	0.01	0.01	4952
OH0075809	Rolling Hills Subdiv WWTP	001	4.5E-04	4.5E-04	4952
OH0076261	Wilkshire Hills WWTP	001	3.4E-03	3.4E-03	4952
OH0091847	Magnolia Village WWTP	001	3.5E-03	3.5E-03	4952
OH0102857	Rittman WWTP	001	0.01	0.01	4952
OH0102903	Walnut Creek WWTP	001	4.2E-05	1.6E-04	4952
OH0112127	Berlin Village WWTP	001	2.9E-03	2.9E-03	4952
OH0113964	Southwest Licking W & SD Gale Rd Envir Control Facility	001	0	2.7E-03	4952
OH0114049	Kirkersville WWTP	001	2.8E-04	2.8E-04	4952
OH0128023	Pleasant City WWTP	001	1.3E-04	1.3E-04	4952
OH0133451	Kidron WWTP	001	1.3E-04	1.3E-04	4952
OH0136425	Hanover WWTP	001	4.2E-04	4.2E-04	4952
OH0139700	Byesville WWTP	001	1.8E-03	1.8E-03	4952
		Total	**1.77**	**1.78**	

Table A16. Point Source Hg pipe discharge per monitored facility's outfalls in the Kanawha watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
WV0000167	ELKEM METALS COMPANY, LP, ALLOY, WV FACILITY	002	2.3E-03	0.14	3313
WV0000167	ELKEM METALS COMPANY, LP, ALLOY, WV FACILITY	004	7.7E-04	0.09	3313
WV0000167	ELKEM METALS COMPANY, LP, ALLOY, WV FACILITY	001	0	6.1E-06	3313
WV0001058	PHILIP SPORN PLANT C/O AMERICAN ELECTRIC POWER	001	2.8E-03	2.8E-03	4911
WV0001074	AEP - JOHN E AMOS POWER PLANT	003	1.47	1.47	4911
WV0001074	AEP - JOHN E AMOS POWER PLANT	004	0.03	0.03	4911
WV0001074	AEP - JOHN E AMOS POWER PLANT	005	1.5E-03	1.5E-03	4911
WV0001074	AEP - JOHN E AMOS POWER PLANT	006	0.02	0.02	4911
WV0001074	AEP - JOHN E AMOS POWER PLANT	011	2.6E-03	2.6E-03	4911
WV0001074	AEP - JOHN E AMOS POWER PLANT	025	7.7E-04	7.7E-04	4911
WV0001074	AEP - JOHN E AMOS POWER PLANT	203	0.84	0.84	4911
WV0020630	CITY OF SUMMERSVILLE	001	0.01	0.01	4952
WV0023094	PRINCETON WASTEWATER TREATMENT PLANT	001	0.02	0.03	4952
WV0023116	SOUTH CHARLESTON WWTW	001	0.10	0.10	4952
WV0023141	BLUEFIELD, SANITARY BOARD OF	001	2.9E-03	3.1E-03	4952
WV0023175	CITY OF ST. ALBANS	001	3.5E-03	3.5E-03	4952
WV0023183	BECKLEY CITY OF	001	0.04	0.05	4952
WV0023205	CITY OF CHARLESTON WASTEWATER TREATMENT PLANT	001	0.05	0.08	4952
WV0023299	NITRO WWTP	001	0.02	0.02	4952
WV0024236	RONCEVERTE CITY OF	001	4.3E-04	4.3E-04	4952
WV0025925	BRADLEY PSD	001	3.3E-03	3.3E-03	4952
WV0027740	NORTH BECKLEY PSD	001	4.6E-03	0.01	4952
WV0028118	CITY OF DUNBAR SANITARY BOARD	001	0.01	0.01	4952
WV0028151	HURRICANE CITY OF	001	0.02	0.02	4952
WV0034991	KANAWHA FALLS PSD	001	2.31	2.31	4952
WV0037486	ROCKY FORK WASTEWATER PLANT	001	0.01	0.01	4952
WV0038776	KANAWHA PUBLIC SERVICE DISTRICT	001	1.3E-03	1.3E-03	4952
WV0040525	GREENBRIER COUNTY PUBLIC SERVICE DISTRICT NO 2	001	1.7E-03	4.0E-03	4952
WV0050610	MALDEN PUBLIC SERVICE DISTRICT	001	0.01	2.97	4952
WV0075621	AC & S INC	001	8.2E-05	8.7E-05	3743
WV0077348	BECKLEY ASPHALT & AGGREGATE LLC, MABSCOTT	002	6.9E-06	7.2E-06	3273
WV0080403	SHADY SPRING PSD	001	0.01	0.01	4952
WV0080900	ELK-PINCH PUBLIC SERVIC DISTRI	001	0.01	0.01	4952
WV0082309	CRAB ORCHARD/MACARTHUR PSD	001	0.61	0.61	4952
WV0082627	GREEN VALLEY-GLENWOOD PSD	001	0	0.01	4952
WV0084000	CITY-WHITE SULPHUR SPRINGS	001	0	0.01	4952
WV0115339	ESSROC READY MIX	001	5.7E-06	0.00	3273
		Total	**5.61**	**8.86**	

Table A17. Point Source Hg pipe discharge per monitored facility's outfalls in the OR Local 2 watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
OH0005282	Ohio Valley Electric Corp Kyger Creek Station	001	4.7E-03	4.7E-03	4911
OH0005282	Ohio Valley Electric Corp Kyger Creek Station	028	1.5E-04	1.5E-04	4911
OH0005282	Ohio Valley Electric Corp Kyger Creek Station	031	2.0E-03	2.0E-03	4911
OH0005282	Ohio Valley Electric Corp Kyger Creek Station	005	0.10	0.10	4911
OH0007030	Kraton Polymers US LLC	002	0	1.9E-03	2822
OH0011550	Hannibal Development Partners	001	2.3E-03	2.3E-03	3334
OH0011550	Hannibal Development Partners	017	4.0E-05	4.0E-05	3334
OH0011550	Hannibal Development Partners	002	0.02	0.02	3334
OH0011550	Hannibal Development Partners	003	5.1E-04	5.5E-04	3334
OH0011550	Hannibal Development Partners	004	2.9E-03	2.9E-03	3334
OH0020541	Nelsonville WWTP	001	1.7E-03	1.7E-03	4952
OH0020559	Caldwell WWTP	001	1.9E-03	1.9E-03	4952
OH0020621	Belpre WWTP	001	0.0E+00	4.2E-03	4952
OH0021725	Pomeroy WWTP	001	4.6E-03	4.6E-03	4952
OH0022331	New Matamoras WWTP	001	6.2E-04	6.2E-04	4952
OH0023388	Logan WWTP	001	3.9E-03	3.9E-03	4952
OH0023566	Somerset WWTP	001	0.02	0.02	4952
OH0023931	Athens WWTP	001	0.01	0.01	4952
OH0026026	Lancaster WPCF	001	0.02	0.02	4952
OH0026344	Marietta WWTP *	001	0.03	0.03	4952
OH0026514	Middleport WWTP	001	1.4E-03	1.4E-03	4952
OH0028177	Woodsfield STP	001	1.8E-03	1.8E-03	4952
OH0028762	General James M Gavin Power Plt	006	0.21	0.21	4911
OH0028762	General James M Gavin Power Plt	007	2.6E-03	2.6E-03	4911
OH0028762	General James M Gavin Power Plt	008	0.01	0.01	4911
OH0028762	General James M Gavin Power Plt	009	0.03	0.03	4911
OH0048194	Amanda WWTP	001	0	2.4E-04	4952
OH0050580	The Plains SD No 1 Buchtel	001	3.9E-03	3.9E-03	4952
OH0050661	Syracuse-Racine Regional SD WWTP	001	1.6E-03	1.6E-03	4952
OH0099619	Trimble Township WWTP	001	4.6E-04	4.6E-04	4952
OH0101630	Southeastern Correctional Institute	001	2.6E-03	2.7E-03	4952
OH0127809	Albany WWTP	001	3.1E-04	3.1E-04	4952
OH0136603	Upper Hocking WPCF	001	0	1.9E-03	4952
WV0000094	MPM SILICONES LLC	001	0.05	0.06	2869
WV0000787	CYTEC INDUSTRIES INC.	001	0.01	0.02	2869
WV0001058	PHILIP SPORN PLANT C/O AMERICAN ELECTRIC POWER	014	2.6E-03	2.6E-03	4911
WV0004359	NATRIUM PLANT	004	0.01	0.01	2812
WV0004359	NATRIUM PLANT	009	6.52	6.52	2812
WV0004359	NATRIUM PLANT	012	0.02	0.02	2812
WV0004359	NATRIUM PLANT	016	7.7E-05	7.9E-05	2812

Table A18. Continued, Point Source Hg pipe discharge per monitored facility's outfalls in the OR Local 2 watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
WV0005169	BAYER MATERIAL SCIENCE	001	0	0.49	2869
WV0023213	PARKERSBURG UTILITY BOARD	001	0.04	0.04	4952
WV0023248	ALLEGHENY ENERGY PLEASANTS POWER STATION	001	0.03	0.03	4911
WV0023248	ALLEGHENY ENERGY PLEASANTS POWER STATION	003	1.37	1.37	4911
WV0027472	NEW MARTINSVILLE	001	0	0.02	4952
WV0032590	LUBECK PSD - PARKERSBURG CS	001	4.8E-04	3.1E-03	4952
WV0048500	MOUNTAINEER PLANT	001	0.07	0.07	4911
WV0115932	CONSTELLIUM ROLLED PRODUCTS, RAVENSWOOD, LLC	001	0	5.9E-04	3353
WV0115932	CONSTELLIUM ROLLED PRODUCTS, RAVENSWOOD, LLC	002	0	1.1E-03	3353
		Total	**8.61**	**9.14**	

Table A19. Point Source Hg pipe discharge per monitored facility's outfalls in the Big Sandy watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
KY0000396	LONG FORK COAL CO (898-9159)	2	7.3E-04	7.3E-04	1221
KY0000396	LONG FORK COAL CO (898-9159)	9	5.6E-04	5.6E-04	1221
KY0022276	Calgon Carbon Corp	4	0.04	0.06	2819
KY0025950	SIDNEY COAL CO INC (898-5168)	1	3.8E-03	3.8E-03	1221
KY0025950	SIDNEY COAL CO INC (898-5168)	3	4.8E-04	4.8E-04	1221
KY0025950	SIDNEY COAL CO INC (898-5168)	5	0	1.3E-05	1221
KY0025950	SIDNEY COAL CO INC (898-5168)	6	1.8E-04	1.8E-04	1221
KY0040495	Czar Coal Corp - Pevler Prep Plant (880-8002)	16	0	0.05	1221
KY0051551	MCCOY ELKHORN COAL CORP (898-8180)	31	0	1.9E-03	1221
KY0053546	Liberty Management LLC (836-8083)	1	2.4E-03	2.4E-03	1221
KY0053546	Liberty Management LLC (836-8083)	3	0.23	0.23	1221
KY0078271	Liberty Management LLC (836-8081)	2	0	0.03	1221
KY0078271	Liberty Management LLC (836-8081)	202	0	0.03	1221
KY0090123	Beech Fork Processing Inc - Lackey Branch Plant (858-9000)	4	1.0E-03	0.01	1221
KY0094510	Kentucky Fuel Corp (860-8020)	3	0	0.01	1221
KY0094510	Kentucky Fuel Corp (860-8020)	5	0	0.24	1221
KY0097934	PREMIER ELKHORN COAL CO INC (898-8076)	3	2.3E-03	2.3E-03	1221
KY0097934	PREMIER ELKHORN COAL CO INC (898-8076)	8	0	2.0E-04	1221
KY0102008	Clintwood Elkhorn Mining Co (898-8097)	22	2.9E-05	2.9E-05	1221
KY0102008	Clintwood Elkhorn Mining Co (898-8097)	39	8.4E-05	1.2E-04	1221
KY0102008	Clintwood Elkhorn Mining Co (898-8097)	40	7.8E-06	1.4E-05	1221
KY0105783	Matt Co Inc (836-0307)	1	3.0E-05	1.0E-04	1221
KY0105783	Matt Co Inc (836-0307)	12	8.3E-05	1.0E-04	1221
KY0105783	Matt Co Inc (836-0307)	13	4.5E-05	7.6E-05	1221
KY0108049	CZAR COAL CORP (880-5139)	1	0	0.02	1221
KY0108049	CZAR COAL CORP (880-5139)	6	2.2E-03	2.2E-03	1221
KY0108049	CZAR COAL CORP (880-5139)	80	0	0.01	1221
KY0108065	CZAR COAL CORP (880-0124)	22	0	2.5E-04	1221
KY0108065	CZAR COAL CORP (880-0124)	27	0	8.3E-04	1221
KY0108588	Kentucky Fuel Corp (860-5350)	1	0	0.01	1221
KY0108669	LANDFALL MINING INC (836-9028)	1	3.5E-04	3.5E-04	1221
WV0024589	WELCH CITY OF	1	0.02	0.02	4952
WV0026271	WILLIAMSON CITY OF	1	4.2E-03	4.2E-03	4952
WV0026271	WILLIAMSON CITY OF	1	4.2E-03	4.2E-03	4952
		Total	**0.31**	**0.74**	

Table A20. Point Source Hg pipe discharge per monitored facility's outfalls in the Scioto watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
OH0004251	PPG Industries Ohio Inc	001	0.09	0.09	2821
OH0006769	Durez Corporation	001	3.9E-05	1.7E-04	2821
OH0020389	Hillsboro WWTP	001	0.04	0.04	4952
OH0020834	Jackson WWTP	001	0.02	0.02	4952
OH0020877	Ashville WWTP	001	1.6E-03	1.6E-03	4952
OH0021083	Greenfield WWTP	001	4.2E-03	4.2E-03	4952
OH0021482	Frankfort WWTP	001	4.7E-03	4.7E-03	4952
OH0022128	Sabina WWTP	001	1.7E-04	6.1E-04	4952
OH0022209	Mechanicsburg WWTP	001	5.0E-04	5.0E-04	4952
OH0022519	Williamsport WWTP	001	4.0E-04	4.0E-04	4952
OH0023361	Cardington WWTP	001	1.3E-03	1.3E-03	4952
OH0023582	North Lewisburg WWTP	001	8.1E-05	1.8E-04	4952
OH0023779	London WWTP	001	0.01	0.01	4952
OH0023990	Baltimore WWTP	001	4.4E-04	8.0E-04	4952
OH0024333	Canal Winchester WWTP	001	0.01	0.01	4952
OH0024406	Chillicothe WWTP - Easterly	001	0.02	0.02	4952
OH0024465	Circleville WWTP	001	0.01	0.01	4952
OH0024732	Jackson Pike Wastewater Treatment Plt	001	0	1.17	4952
OH0024741	Columbus Southerly WWTP	001	0	1.43	4952
OH0024911	Upper Olentangy Water Reclamation Center	001	1.2E-03	0.01	4952
OH0025313	Galion WWTP	001	0.01	0.01	4952
OH0025925	Kenton WWTP	001	0.02	0.02	4952
OH0026271	McGuffey STP	001	3.4E-05	1.2E-03	4952
OH0026352	Marion WPC	001	0.01	0.02	4952
OH0026654	Mount Sterling WWTP	001	8.2E-04	9.9E-04	4952
OH0027031	Piketon WWTP	001	0.01	0.01	4952
OH0027057	Plain City WWTP	001	1.1E-03	1.5E-03	4952
OH0028002	Washington Court House WWTP	001	0.03	0.03	4952
OH0031119	Pickerington WWTP	001	0.01	0.01	4952
OH0036005	Aqua Ohio Water Co Inc - Lake Darby WWTP	001	1.2E-03	1.2E-03	4952
OH0036013	Aqua Ohio Water Co Inc - Huber Ridge WWTP	001	0.02	0.02	4952
OH0036021	Aqua Ohio Water Co Inc - Blacklick WWTP	001	4.8E-03	4.8E-03	4952
OH0036196	Rattlesnake SD #1 WWTP	001	7.7E-04	7.7E-04	4952
OH0036692	Oakhurst Knolls WWTP	001	0.0E+00	6.3E-05	4952
OH0039284	Lucasville WWTP	001	1.4E-03	1.4E-03	4952
OH0047953	Flat Branch WWTP	001	1.7E-05	6.1E-05	4952
OH0050491	Pleasant Valley Regional SD	001	1.7E-03	1.7E-03	4952
OH0050784	Laurelville WWTP *	001	2.1E-04	2.1E-04	4952
OH0050881	Leesburg WWTP	001	0.01	0.01	4952
OH0054224	Pickaway Correctional Institution	001	2.4E-03	2.5E-03	4952
OH0054305	Tussing Rd Water Reclaimation Facility	001	3.7E-04	2.9E-03	4952

Table A21. Continued, Point Source Hg pipe discharge per monitored facility's outfalls in the Scioto watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
OH0054321	West Jefferson WWTP	001	1.2E-03	1.7E-03	4952
OH0054364	Bloomingburg WWTP	001	2.6E-04	2.6E-04	4952
OH0054399	Olentangy Environmental Control Center	001	0	0.01	4952
OH0054917	Walnut Creek SD	001	2.9E-04	3.7E-04	4952
OH0055093	Sunbury WWTP	001	3.5E-03	3.6E-03	4952
OH0058157	SD No 7 Water Reclamation Plant	001	5.6E-04	1.8E-03	4952
OH0058327	Alger WWTP	001	0.0E+00	2.3E-04	4952
OH0070467	Earnhart Hill Regional W & SD *	001	6.9E-04	7.3E-04	4952
OH0076490	Chillicothe Correctional Institution	001	3.5E-03	4.0E-03	4952
OH0081370	Candlewood Lake WWTP	001	0	8.0E-05	4952
OH0102041	Madison Co Sewer Dist No 1	001	1.5E-04	1.5E-04	4952
OH0119075	Rocky Fork Lake WWTP	001	1.1E-03	1.1E-03	4952
OH0121088	Little Walnut Sycamore WRF	001	1.5E-03	1.6E-03	4952
OH0121371	Earnhart Hill Regional W & SD WWTP #2	001	0	2.4E-05	4952
OH0121380	Alum Creek WWTP *	001	2.1E-03	0.01	4952
OH0124001	Commercial Point WWTP	001	8.1E-04	8.1E-04	4952
OH0130915	Madison County Sewer District #2 WWTP	001	2.2E-04	3.6E-04	4952
OH0130923	Darbydale WWTP	001	5.1E-04	5.8E-04	4952
OH0130991	South Bloomfield WWTP No 2	001	3.5E-04	3.5E-04	4952
OH0136191	Jeffersonville WWTP No 2	001	8.4E-04	9.4E-04	4952
OH0136271	Marysville WRF	001	0.02	0.03	4952
OH0142344	Liberty Twp Regional Treatment Facility	001	0	1.3E-05	4952
		Total	**0.36**	**3.00**	

Table A22. Point Source Hg pipe discharge per monitored facility's outfalls in the Little Miami watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
OH0020010	Cedarville WWTP	001	0	1.5E-03	4952
OH0020052	South Charleston WWTP	001	8.4E-03	0.01	4952
OH0020419	Polk Run WWTP	001	0	0.05	4952
OH0020451	Milford City WWTP	001	0.01	0.01	4952
OH0020494	Mason WWTP No 2	001	0.03	0.03	4952
OH0020753	Waynesville Regional WWTP	001	1.8E-03	1.8E-03	4952
OH0021059	Lebanon WWTP	001	0.02	0.02	4952
OH0021571	Williamsburg WWTP	001	2.1E-03	2.1E-03	4952
OH0021733	Blanchester WWTP	001	1.4E-03	1.6E-03	4952
OH0022667	Lynchburg WWTP	001	8.5E-04	8.5E-04	4952
OH0025381	Beavercreek WRRF	001	4.4E-03	0.03	4952
OH0025488	Sycamore Creek WWTP	003	0.03	0.10	4952
OH0025879	Jamestown WWTP	001	3.3E-04	6.2E-04	4952
OH0026590	Eastern Regional Water Reclamation Facility	001	0	0.13	4952
OH0028134	Wilmington WWTP	001	0.01	0.02	4952
OH0028193	Xenia Ford Road WWTP	001	0.03	0.03	4952
OH0028207	Glady Run WWTP	001	0.01	0.01	4952
OH0028215	Yellow Springs WWTP	001	1.3E-03	1.3E-03	4952
OH0040592	Sugarcreek WRF	001	2.1E-03	0.02	4952
OH0048089	O'Bannon Creek Regional WWTP	001	0.01	0.01	4952
OH0049379	Lower East Fork Regional WWTP	001	0.02	0.02	4952
OH0049387	Middle East Fork Regional WWTP	001	0.06	0.06	4952
OH0071692	Lower Little Miami WWTP	001	0.08	0.08	4952
OH0096504	Miami Trails WWTP	001	7.1E-04	8.1E-04	4952
OH0119041	Fayetteville Perry Twp WWTP	001	0.01	0.01	4952
OH0133914	Wards Corner Regional WWTP	001	3.1E-04	4.1E-04	4952
OH0134171	Martinsville-Midland WWTP	001	0	5.9E-04	4952
		Total	**0.33**	**0.64**	

Table A23. Point Source Hg pipe discharge per monitored facility's outfalls in the Licking watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
KY0021229	Flemingsburg STP	001	0.01	0.01	4952
KY0105856	Cynthiana STP (New)	001	0.03	0.03	4952
KY0106887	Bath County Industrial Park	001	6.1E-04	6.1E-04	4952
		Total	**0.04**	**0.04**	

Table A24. Point Source Hg pipe discharge per monitored facility's outfalls in the Great Miami watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
OH0009717	Wausau Paper Towel & Tissue	002	0.02	0.02	2621
OH0105228	Wausau Paper Towel & Tissue LLC	001	0.34	0.34	2621
OH0009997	AK Steel Corp	011	0.05	0.05	3312
OH0009997	AK Steel Corp	003	0.03	0.03	3312
OH0009954	Navistar Inc	001	1.9E-03	1.9E-03	3711
OH0009954	Navistar Inc	021	5.5E-04	5.5E-04	3711
IN0022535	CENTERVILLE WWTP	001	0.01	0.01	4952
OH0009580	USDOE Fernald Closure Project	001	2.6E-03	0.01	4952
OH0020044	New Carlisle WWTP	001	4.8E-03	4.8E-03	4952
OH0020133	West Carrollton WWTP	001	0.01	0.01	4952
OH0020192	Bradford WWTP	001	2.1E-03	2.1E-03	4952
OH0020605	Brookville WWTP	001	3.8E-03	3.8E-03	4952
OH0020656	Versailles WWTP	001	0.01	0.01	4952
OH0020907	Eaton WWTP	001	2.0E-03	2.6E-03	4952
OH0020940	Arcanum WWTP	001	1.1E-03	1.1E-03	4952
OH0021113	New Paris WWTP	001	4.8E-04	4.8E-04	4952
OH0021440	Harrison WWTP	001	3.5E-03	3.5E-03	4952
OH0021644	Union WWTP	001	0	0.55	4952
OH0021806	Saint Paris WWTP	001	1.7E-04	3.4E-04	4952
OH0021857	West Milton WWTP	001	0.01	0.01	4952
OH0022098	West Liberty STP	001	9.7E-04	1.0E-03	4952
OH0022217	Botkins WWTP	001	0.03	0.03	4952
OH0023370	Anna STP	001	1.3E-03	1.3E-03	4952
OH0024066	Bellefontaine WWTP	001	1.9E-03	4.9E-03	4952
OH0024261	Queen Acres Water Reclamation Facility	001	0	5.1E-04	4952
OH0024317	Camden WWTP	001	9.8E-05	2.5E-04	4952
OH0024881	Dayton WWTP	001	0.15	0.15	4952
OH0025011	Englewood WWTP	001	0.03	0.03	4952
OH0025062	Fairborn Water Reclamation Center	001	0.01	0.01	4952
OH0025071	Fairfield WWTP	001	0	0.08	4952
OH0025275	Franklin Regional WWTP	001	0.02	0.02	4952
OH0025429	Greenville WWTP	001	0.02	0.02	4952
OH0025445	Hamilton Water Reclamation Facility	001	0.05	0.05	4952
OH0025861	Jackson Center WWTP	001	3.2E-04	5.5E-04	4952
OH0026051	Lewisburg WWTP	001	1.2E-03	1.2E-03	4952
OH0026492	Miamisburg Water Reclamation Facility	001	0.02	0.02	4952
OH0026522	Middletown WWTP	001	0.24	0.43	4952
OH0026573	Minster WWTP	002	1.3E-03	2.7E-03	4952
OH0026638	Western Regional WRF	001	0	0.29	4952

Table A25. Continued, Point Source Hg pipe discharge per monitored facility's outfalls in the Great Miami watershed during study period November 2015 through October 20126					
[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]					
NPDES Permit	**Facility**	**Outfall ID Number**	**Minimum Hg Load (lbs)**	**Maximum Hg Load (lbs)**	**SIC**
OH0026719	New Miami WWTP	001	4.7E-04	4.7E-04	4952
OH0026930	Oxford WWTP	001	0.01	0.01	4952
OH0027049	Piqua WWTP	001	0.02	0.02	4952
OH0027421	Sidney WWTP	001	0.01	0.01	4952
OH0027472	Springboro WWTP	001	0	3.1E-03	4952
OH0027758	Troy WWTP	001	0.02	0.02	4952
OH0027880	Urbana WPCF *	001	1.5E-03	2.8E-03	4952
OH0028029	Waynesfield WWTP	001	9.1E-04	9.1E-04	4952
OH0029475	Pleasant Hill WWTP	001	1.2E-03	1.2E-03	4952
OH0035882	Quincy-DeGraff STP	001	1.1E-03	1.1E-03	4952
OH0036641	Indian Lake WPCF	001	0.01	0.01	4952
OH0040584	New Madison STP	001	3.0E-04	3.0E-04	4952
OH0040983	Taylor Creek WWTP	001	6.2E-04	0.03	4952
OH0047571	Gratis WWTP	001	1.4E-03	1.4E-03	4952
OH0049417	Lesourdsville Water Reclamation Facility	001	0.06	0.06	4952
OH0049476	Lakengren Water Authority	001	2.2E-03	2.2E-03	4952
OH0049492	Eldorado WWTP	001	4.9E-04	4.9E-04	4952
OH0049646	Tri-Cities North Regional WW Authority	001	0.12	0.12	4952
OH0049794	Southwest Regional WWTP	001	4.6E-03	4.6E-03	4952
OH0096733	Lake Loramie Special Sanitary SD	001	2.4E-03	2.6E-03	4952
OH0123145	Wade Mill Water Reclamation Facility	001	5.5E-04	5.5E-04	4952
		Total	**1.32**	**2.48**	

Table A26. Point Source Hg pipe discharge per monitored facility's outfalls in the Kentucky watershed during study period November 2015 through October 2016					
[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]					
NPDES Permit	**Facility**	**Outfall ID Number**	**Minimum Hg Load (lbs)**	**Maximum Hg Load (lbs)**	**SIC**
KY0020150	Georgetown STP #1	001	0.01	0.01	4952
KY0021491	Lexington Town Branch STP	001	0.03	0.03	4952
KY0021504	Lexington West Hickman STP	001	0.08	0.08	4952
KY0024619	Stanford STP	001	0	0.52	4952
KY0057193	Danville STP	001	0	0.08	4952
KY0082007	Georgetown STP #2	001	0.01	0.01	4952
KY0100404	Jessamine Creek Environmental Control #1	001	0.03	0.03	4952
KY0022861	Frankfort Municipal STP	001	0.19	0.19	4952
KY0020699	KY DMA Bluegrass Station Division	004	4.3E-05	2.5E-04	9711
		Total	**0.35**	**0.96**	

Table A27. Point Source Hg pipe discharge per monitored facility's outfalls in the OR Local 3 watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
IN0001155	ALCOA WARRICK LLC	001	0.01	0.01	3334
IN0001155	ALCOA WARRICK LLC	003	0.38	0.40	3334
IN0001155	ALCOA WARRICK LLC	004	3.5E-03	3.5E-03	3334
IN0001155	ALCOA WARRICK LLC	005	3.1E-03	3.1E-03	3334
IN0001759	IN-KY ELECTRIC CORP. CLIFTY CREEK STATION	001	0	4.2E-04	4911
IN0001759	IN-KY ELECTRIC CORP. CLIFTY CREEK STATION	002	0.02	0.05	4911
IN0002071	LEHIGH CEMENT COMPANY LLC - SPEED	005	0	2.7E-04	3241
IN0002160	TANNERS CREEK DEVELOPMENT LLC	003	4.3E-05	1.6E-04	4911
IN0002259	VECTREN CORP - SIGECO F. B. CULLEY STATION	001	1.27	2.56	4911
IN0020893	CORYDON WWTP	001	0.01	0.01	4952
IN0021016	TELL CITY MUNICIPAL WWTP	001	0.00	0.03	4952
IN0023302	JEFFERSONVILLE DOWNTOWN WWTP	022	0.06	0.06	4952
IN0023884	NEW ALBANY WWTP	100	0	0.02	4952
IN0024538	SOUTH DEARBORN R.S.D.	001	0.04	0.04	4952
IN0025666	MADISON WWTP	001	2.2E-03	4.2E-03	4952
IN0039268	BATESVILLE WWTP, CITY OF	001	0.02	0.02	4952
IN0047058	CLARKSVILLE WWTP	010	0.02	0.02	4952
IN0051845	AMERICAN ELECTRIC POWER, ROCKPORT PLANT	001	0.04	0.04	4911
IN0051845	AMERICAN ELECTRIC POWER, ROCKPORT PLANT	002	8.9E-04	9.5E-04	4911
IN0060950	LAWRENCEBURG POWER	001	0.03	0.03	4911
IN0062863	CORYDON #2 SATELLITE	002	1.2E-03	1.2E-03	4959
IN0063673	JEFFERSONVILLE NORTH WATER RECLAMATION FACILITY	004	0.01	0.01	4952
KY0020257	Maysville STP	001	0.01	0.01	4952
KY0021237	Bardstown STP	001	2.9E-03	2.9E-03	4952
KY0021466	Northern KY Sanitation District 1- Dry Creek	001	0.02	0.02	4952
KY0022373	ASHLAND STP	001	0.03	0.03	4952
KY0022411	Morris Forman WQTC MSD	001	0.60	0.60	4952
KY0022420	Hite Creek WQTC MSD	001	0.01	0.01	4952
KY0025194	JEFFERSONTOWN WQTC MSD	001	0.01	0.01	4952
KY0026549	Lebanon STP	001	0.01	0.01	4952
KY0027359	Shepherdsville STP	001	0.06	0.06	4952
KY0033979	SWVA Kentucky LLC	003	0.05	0.05	3312
KY0078956	Derek R Guthrie WQTC MSD	001	2.89	2.89	4952
KY0104027	Jerry L Riley STP	001	0.03	0.03	4952
OH0060046	AES Ohio Generation LLC - Killen	001	0.36	0.36	4911
OH0060097	McGinnis Inc	001	0	3.05E-05	4491
OH0137570	Tate Monroe Water Association STU 2	001	0.02	0.02	4941
OHD000002	Pristine Inc	001	4.54E-04	4.54E-04	1629

Table A28. Continued, Point Source Hg pipe discharge per monitored facility's outfalls in the OR Local 3 watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
OH0004316	AES Ohio Generation-JM Stuart	012	0.89	0.89	4911
OH0004316	AES Ohio Generation-JM Stuart	013	0.15	0.15	4911
OH0004316	AES Ohio Generation-JM Stuart	020	0.01	0.01	4911
OH0007391	ALTIVIA Petrochemicals LLC	001	0.01	0.01	2865
OH0009865	New Richmond Development Corp	002	9.7E-06	1.9E-05	4911
OH0009865	New Richmond Development Corp	025	6.9E-05	7.4E-05	4911
OH0009873	Dynegy Miami Fort LLC	02	0.16	0.16	4911
OH0009873	Dynegy Miami Fort LLC	006	4.0E-05	4.0E-05	4911
OH0020478	Gallipolis WPCF	001	0.02	0.02	4952
OH0020842	Manchester WWTP	001	4.5E-04	4.5E-04	4952
OH0020966	Ripley WWTP	001	3.6E-04	4.5E-04	4952
OH0021156	New Richmond WWTP	001	1.2E-03	1.3E-03	4952
OH0021300	Georgetown WWTP	001	3.0E-03	3.4E-03	4952
OH0021814	South Point WWTP	001	0.02	0.02	4952
OH0023507	Wellston WWTP North	001	3.1E-03	3.1E-03	4952
OH0023825	Aberdeen WWTP	001	9.6E-04	9.6E-04	4952
OH0024597	Felicity WWTP	001	8.1E-04	8.1E-04	4952
OH0024678	Indian Creek WWTP	001	2.8E-03	0.01	4952
OH0025453	Little Miami WWTP	003	0.16	0.43	4952
OH0025461	Mill Creek WWTP	604	0.84	1.76	4952
OH0025470	Muddy Creek WWTP *	001	0.01	0.16	4952
OH0025852	Ironton WWTP	001	0.05	0.05	4952
OH0026646	Mt Orab WWTP	001	2.5E-03	2.5E-03	4952
OH0026859	Oak Hill WWTP	001	6.2E-04	6.2E-04	4952
OH0026964	Peebles WWTP	001	4.9E-03	4.9E-03	4952
OH0027197	Portsmouth Lawson Run WWTP	001	0.09	0.09	4952
OH0027201	Sciotoville WWTP	001	1.5E-03	1.5E-03	4952
OH0027278	Rio Grande WWTP	001	7.0E-04	9.3E-04	4952
OH0027341	Seaman WWTP	001	7.7E-04	7.7E-04	4952
OH0028088	West Union WWTP	001	3.8E-03	3.8E-03	4952
OH0028142	Winchester WWTP	002	6.4E-04	6.4E-04	4952
OH0029432	Coal Grove WWTP	001	7.4E-04	7.4E-04	4952
OH0048241	McArthur WWTP	001	2.7E-04	2.7E-04	4952
OH0048836	William H Zimmer Station	005	0.08	0.08	4911
OH0048836	William H Zimmer Station	601	3.5E-04	3.5E-04	4911
OH0048836	William H Zimmer Station	602	4.0E-05	4.0E-05	4911
OH0048836	William H Zimmer Station	099	0.26	0.26	4911
OH0049361	Nine Mile Creek WWTP	001	4.7E-03	0.01	4952
OH0050016	Wheelersburg WWTP SD No 2	001	0.04	0.04	4952
OH0072087	Upper Mill Creek Water Reclamation Facility *	001	0.02	0.02	4952
OH0076309	West Portsmouth WWTP	001	1.5E-03	1.5E-03	4952
OH0076465	West Virginia Resources Inc - Dundas Prep Plant	001	1.0E-04	1.0E-04	1221
OH0094684	Union Rome Twps Sub-SD WWTP	001	0.05	0.05	4952
OH0099309	Americas Styrenics LLC - Hanging Rock	001	0	9.9E-04	3086

Table A29. Continued, Point Source Hg pipe discharge per monitored facility's outfalls in the OR Local 3 watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
OH0115771	Waynoka Regional W & SD	001	2.1E-03	0.01	4952
OH0124664	Bidwell Porter WWTP	001	3.6E-07	3.6E-07	4952
OH0134945	Hamden WWTP	001	3.2E-04	3.2E-04	4952
OH0137499	Highland Co Southwest WWTP	001	0.02	0.02	4952
WV0023159	HUNTINGTON WWTP	001	0.07	0.10	4952
WV0023159	HUNTINGTON WWTP	002	0.04	0.05	4952
WV0027138	CENTER PSD	001	3.6E-05	3.6E-05	4952
WV0084450	SALT ROCK SEWER PSD	002	1.4E-03	1.4E-03	4952
WV0105171	LOGAN COUNTY PUBLIC SERVICE DISTRICT WASTEWATER DIVISION	001	7.4E-04	7.4E-04	4952
		Total	**9.03**	**11.81**	

Table A30. Point Source Hg pipe discharge per monitored facility's outfalls in the Green watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
KY0020613	LIVERMORE STP	001	0	0.21	4952
KY0020877	Russellville STP	001	0	0.81	4952
KY0021024	Cmuc STP	001	0.04	0.04	4952
KY0021164	Glasgow STP	001	0.01	0.01	4952
KY0022403	Bowling Green Municipal Utilities	001	0.02	0.02	4952
KY0024783	Scottsville STP	001	0.01	0.01	4952
KY0026352	Liberty STP	001	1.5E-03	1.5E-03	4952
KY0027456	Franklin STP	001	0.06	0.06	4952
KY0054836	Big Rivers Electric - Wilson	015	1.50	1.50	4911
KY0054836	Big Rivers Electric - Wilson	002	0.47	0.47	4911
KY0081566	Southern Waste Service Landfill	004	0.01	0.04	4953
KY0090913	ERP ENVIRONMENTAL FUND INC (851-8006)	002	2.6E-03	2.6E-03	1221
KY0100293	Henderson South STP #2	001	0	0.01	4952
KY0105660	Sebree Mining LLC (917-5026)	001	0	3.9E-03	1221
KY0105660	Sebree Mining LLC (917-5026)	010	0.01	0.02	1221
KY0105660	Sebree Mining LLC (917-5026)	002	0	2.4E-03	1221
KY0105660	Sebree Mining LLC (917-5026)	005	0.02	0.02	1221
KY0105660	Sebree Mining LLC (917-5026)	006	0.00	0.01	1221
KY0105660	Sebree Mining LLC (917-5026)	007	3.3E-03	0.01	1221
KY0105660	Sebree Mining LLC (917-5026)	009	1.8E-03	3.0E-03	1221
KY0105791	Ohio County Regional STP	001	0	1.53	4952
		Total	**2.16**	**4.78**	

Table A31. Point Source Hg pipe discharge per monitored facility's outfalls in the Wabash watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Min Annual Hg Load (lbs)	Max Annual Hg Load (lbs)	SIC
IL0004065	RAIN CII CARBON LLC	001	1.7E-04	1.7E-04	3624
IL0004073	MARATHON PETROLEUM COMPANY, LP	001	0.03	0.03	2911
IL0004120	AMERENENERGY MEDINA COGEN LLC	002	1.9E-04	2.4E-04	4911
IL0021377	PARIS, CITY OF	001	0.01	0.01	4952
IL0024830	HOOPESTON, CITY OF	B01	2.7E-04	2.7E-04	4952
IL0030023	MOUNT CARMEL, CITY OF	B01	0.17	0.17	4952
IL0030732	ROBINSON, CITY OF	001	0.02	0.02	4952
IL0031500	URBANA & CHAMPAIGN SANITARY DISTRICT	001	0.18	0.18	4952
IL0036960	WABASH MINE HOLDING COMPANY	001	2.6E-05	2.6E-05	1222
IL0036960	WABASH MINE HOLDING COMPANY	011	4.4E-05	4.4E-05	1222
IL0036960	WABASH MINE HOLDING COMPANY	008	1.0E-05	1.0E-05	1222
IL0048755	OLNEY STP, CITY OF	001	0	2.9E-03	4952
IL0049191	ILLINOIS POWER GENERATING COMPANY	001	0.32	0.32	4911
IL0074802	PEABODY MIDWEST MINING, LLC	003	1.4E-03	1.9E-03	1222
IL0078921	HAMILTON COUNTY COAL LLC	002	0	3.2E-03	1222
IN0001601	TAGHLEEF INDUSTRIES	001	1.1E-04	1.1E-04	3081
IN0001775	LEHIGH CEMENT COMPANY LLC	001	0	0.12	1422
IN0001775	LEHIGH CEMENT COMPANY LLC	007	0	9.7E-04	1422
IN0001813	ROLLS-ROYCE CORPORATION	001	0.01	0.01	3724
IN0001813	ROLLS-ROYCE CORPORATION	002	0.01	0.01	3724
IN0002763	DUKE ENERGY INDIANA CAYUGA GENERATING STATION	001	3.98	3.98	4911
IN0002763	DUKE ENERGY INDIANA CAYUGA GENERATING STATION	002	0.03	0.03	4911
IN0002780	DUKE ENERGY INDIANA EDWARDSPORT IGCC STATION	002	0.39	0.39	4911
IN0002810	DUKE ENERGY INDIANA WABASH RIVER GEN. STATION	002	0.01	0.01	4911
IN0002852	ELANCO US INC., CLINTON LABS	001	0.05	0.05	2834
IN0002861	EVONIK CORPORATION TIPPECANOE LAB	001	0.06	0.06	2833
IN0002887	IPALCO - PETERSBURG GEN STATION	001	0.78	0.78	4911
IN0002887	IPALCO - PETERSBURG GEN STATION	007	0.01	0.01	4911
IN0003573	GENERAL MOTORS LLC - CET BEDFORD	002	2.9E-04	4.2E-04	3365
IN0004391	HOOSIER ENERGY - FRANK E RATTS GEN STATION	003	7.4E-05	7.4E-05	4911
IN0004391	HOOSIER ENERGY - FRANK E RATTS GEN STATION	004	2.4E-04	2.4E-04	4911
IN0004685	IPL - HARDING ST GENERATING STATION	005	1.21	1.21	4911
IN0004685	IPL - HARDING ST GENERATING STATION	006	1.07	1.07	4911
IN0020150	YORKTOWN WWTP, TOWN OF	001	1.3E-03	1.9E-03	4952
IN0020176	MONTICELLO WWTP	005	0.01	0.01	4952
IN0020362	NORTH MANCHESTER WWTP	001	4.2E-03	4.4E-03	4952
IN0020575	LINTON WWTP, CITY OF	001	4.2E-03	4.2E-03	4952
IN0036447	INTERNATIONAL PAPER COMPANY - NEWPORT MILL	001	3.2E-03	3.2E-03	2631
IN0063134	WABASH VALLEY RESOURCES LLC	001	4.4E-03	4.5E-03	4911

Table A32. Continued, Point Source Hg pipe discharge per monitored facility's outfalls in the Wabash watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Min Annual Hg Load (lbs)	Max Annual Hg Load (lbs)	SIC
IN0003859	PURDUE U. WADE PHYSICAL PLANT	001	2.6E-03	2.7E-03	8221
IN0020834	JASPER MUNICIPAL WWTP	001	0.01	0.01	4952
IN0021211	BRAZIL WWTP, CITY OF	001	4.1E-03	4.1E-03	4952
IN0021300	CUMBERLAND WWTP	002	6.8E-04	1.5E-03	4952
IN0021377	DELPHI WWTP	001	2.9E-04	1.6E-03	4952
IN0021474	TIPTON WWTP	001	2.9E-03	2.9E-03	4952
IN0021539	CRANE DIVISION, NAVAL SURFACE WARFARE CENTER	001	3.1E-03	3.1E-03	9711
IN0021628	HARTFORD CITY WWTP	001	0.01	0.01	4952
IN0021661	ROCHESTER WASTEWATER TREATMENT PLANT	001	4.7E-03	4.7E-03	4952
IN0022314	BARGERSVILLE WWTP	001	6.6E-04	1.5E-03	4952
IN0022608	CLINTON MUNICIPAL WWTP	001	1.2E-03	1.2E-03	4952
IN0022624	COLUMBIA CITY WWTP	001	0.01	0.01	4952
IN0022951	FRENCH LICK MUNICIPAL WWTP	001	0.01	0.01	4952
IN0023124	HUNTINGBURG WWTP	001	1.6E-03	1.6E-03	4952
IN0023825	MOORESVILLE WWTP, TOWN OF	001	4.3E-03	4.3E-03	4952
IN0023825	MOORESVILLE WWTP, TOWN OF	002	7.8E-04	7.8E-04	4952
IN0024392	PRINCETON WASTEWATER TREATMENT PLANT	001	4.6E-03	4.6E-03	4952
IN0024449	ROCKVILLE MUNICIPAL WWTP	001	0.01	0.01	4952
IN0024554	SULLIVAN MUNICIPAL WWTP	025	2.9E-03	2.9E-03	4952
IN0024741	WABASH WWTP	004	0.02	0.02	4952
IN0024821	WEST LAFAYETTE WWTP	001	0.13	0.13	4952
IN0025607	TERRE HAUTE WWTP, CITY OF	001	0.08	0.08	4952
IN0025623	BEDFORD WASTEWATER TREATMENT PLANT	001	4.8E-03	4.8E-03	4952
IN0032476	ANDERSON WWTP	001	0	0.03	4952
IN0032867	SHELBYVILLE WATER RESOURCE RECOVERY FACILITY	001	0.01	0.01	4952
IN0032875	KOKOMO WWTP, CITY OF	025	0.05	0.05	4952
IN0032964	CRAWFORDSVILLE WWTP, CITY OF	005	0.03	0.03	4952
IN0035378	AQUA INDIANA MAIN ABOITE	001	0.01	0.01	4952
IN0035718	BLOOMINGTON S (DILLMAN ROAD)	001	0.03	0.03	4952
IN0038334	COUNTY HOME WWTP	002	1.5E-03	1.5E-03	8361
IN0042391	AQUA INDIANA INC MIDWEST WWTP	001	0.01	0.01	4952
IN0063983	CHESTERFIELD WWTP	001	4.0E-03	4.0E-03	4952
IN0064211	WHITESTOWN SOUTH WWTP	001	1.4E-03	1.4E-03	4952
OH0020028	Saint Henry WWTP	001	4.2E-03	4.4E-03	4952
OH0020320	Celina WWTP	001	3.1E-03	4.4E-03	4952
		Total	**8.84**	**9.00**	

Table A33. Point Source Hg pipe discharge per monitored facility's outfalls in the OR Local 4 watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
IL0004316	SOUTHERN ILLINOIS POWER COOPER ATIVE	005	1.7E-04	6.1E-04	4911
IL0029149	HARRISBURG, CITY OF	001	0.03	0.03	4952
IL0073636	VIGO COAL OPERATING CO INC FRIENDSVILLE MINE	007	1.8E-04	1.8E-04	1221
IL0079626	KD CRAIN AND SONS INC	015	0.02	0.02	1241
IN0002101	SABIC INNOVATIVE PLASTICS MT VERNON LLC	002	0.01	0.01	2821
IN0002470	COUNTRYMARK REFINING & LOGISTICS LLC.	001	5.8E-04	3.1E-03	2911
IN0032956	EVANSVILLE WEST WWTP	023	0.12	0.12	4952
IN0033073	EVANSVILLE EAST WWTP	003	0.10	0.10	4952
IN0035696	MOUNT VERNON MUNICIPAL WWTP	001	0.05	0.05	4952
IN0043117	EVANSVILLE WATERWORKS DEPT	002	0.07	0.07	4941
IN0043117	EVANSVILLE WATERWORKS DEPT	004	0.02	0.03	4941
IN0043117	EVANSVILLE WATERWORKS DEPT	005	0.16	0.16	4941
IN0052191	VECTREN CORP - SIGECO A. B. BROWN GEN. STATION	001	0	0.02	4911
KY0021440	Morganfield WWTP	001	0.07	0.07	4952
KY0098043	Madisonville STP West Side	001	0.04	0.04	4952
		Total	**0.69**	**0.72**	

Table A34. Point Source Hg pipe discharge per monitored facility's outfalls in the Cumberland watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
KY0003492	JRL Coal INC (Multiple)	001	8.9E-04	1.3E-03	1221
KY0020133	Corbin STP	001	0.19	0.22	4952
KY0021270	London STP	001	0	5.6E-09	4952
KY0021539	Harlan Cumberland Coal Co LLC (848-8071)	007	0	0.01	1221
KY0028401	Princeton STP	001	0.01	0.01	4952
KY0043133	Harlan Cumberland Coal Co LLC (848-8059)	011	0	3.0E-03	1221
KY0043133	Harlan Cumberland Coal Co LLC (848-8059)	002	1.9E-04	0.05	1221
KY0043133	Harlan Cumberland Coal Co LLC (848-8059)	004	3.5E-04	0.05	1221
KY0043133	Harlan Cumberland Coal Co LLC (848-8059)	006	2.5E-04	0.04	1221
KY0043133	Harlan Cumberland Coal Co LLC (848-8059)	008	9.9E-05	0.03	1221
KY0043851	Revelation Energy LLC (807-8075)	021	4.3E-05	4.6E-05	1221
KY0043851	Revelation Energy LLC (807-8075)	022	0	1.7E-05	1221
KY0049158	Double Mountain Mining LLC (807-8082)	001	0.12	0.12	1221
KY0062995	Russell County Regional STP	001	0.02	0.02	4952
KY0066532	Hopkinsville Hammond Wood STP	001	0.01	0.01	4952
KY0072885	Middlesboro STP	001	0	4.67	4952
KY0079154	ALDEN RESOURCES LLC (918-8015)	009	3.3E-04	3.3E-04	1221
KY0087327	Revelation Energy LLC (848-5571)	001	1.1E-04	1.1E-04	1221
KY0087327	Revelation Energy LLC (848-5571)	002	1.5E-03	1.9E-03	1221
KY0087327	Revelation Energy LLC (848-5571)	003	0	1.6E-04	1221
KY0087327	Revelation Energy LLC (848-5571)	004	0.01	0.01	1221
KY0087327	Revelation Energy LLC (848-5571)	006	8.3E-05	8.3E-05	1221
KY0097608	Sequoia Energy LLC (848-8076)	001	0	0.01	1221
KY0097608	Sequoia Energy LLC (848-8076)	002	0	1.2E-03	1221
KY0097608	Sequoia Energy LLC (848-8076)	003	0	1.6E-04	1221
KY0101729	Harlan Cumberland Coal Co LLC (848-5395)	022	7.8E-05	2.1E-04	1221
KY0103021	Revelation Energy LLC (Multiple)	002	4.9E-03	4.9E-03	1221
KY0104183	Middlesboro Mining Operations Inc (807-5246)	003	0	1.5E-04	1221
KY0107689	Revelation Energy LLC (848-5575)	008	0	4.5E-05	1221
KY0108073	Revelation Energy LLC (848-5569)	004	3.3E-05	3.3E-05	1221
TN0005428	TVA-GALLATIN STEAM	001	0.18	0.18	4911
TN0005789	TVA - CUMBERLAND FOSSIL PLANT	001	6.71	13.42	4911
TN0025488	WATERTOWN STP	001	0	4.1E-04	4952
TN0062332	WATER AUTHORITY OF DICKSON COUNTY - FAIRVIEW STP	001	0.02	0.02	4952
		Total	**7.27**	**18.89**	

Table A35. Point Source Hg pipe discharge per monitored facility's outfalls in the Tennessee watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
AL0000213	OCCIDENTAL CHEMICAL CORPORATION - MUSCLE SHOALS PLANT	01N	0.23	0.23	2813
AL0020206	ATHENS WWTP	001	0.07	0.07	4952
AL0024180	MUSCLE SHOALS WATER TRMT PLANT	002	0.02	0.02	4952
AL0027987	RUSSELLVILLE WWTP	001	0.03	0.03	4952
AL0042765	RAINSVILLE WASTEWATER TREATMENT PLANT	001	0.01	0.01	4952
AL0055042	HUNTSVILLE BIG COVE WWTP	001	4.7E-03	4.7E-03	4952
AL0056057	HENAGAR WWTP	001	7.6E-04	7.6E-04	4952
AL0057428	CHASE AREA WASTEWATER TREATMENT PLANT	001	0.01	0.01	4952
GA0037583	BLUE RIDGE (CITY OF) WPCP	001	0.20	0.20	4952
KY0003603	Arkema Inc	001	3.04	3.04	2819
KY0003484	Westlake Vinyls Inc	001	2.58	2.58	2812
KY0021130	CALVERT CITY STP	001	0.02	0.02	4952
NC0000396	ASHEVILLE STEAM ELECTRIC POWER PLANT	001	0.06	0.06	4911
TN0002461	OLIN CHLOR-ALKALI, CHARLESTON PLANT	001	2.49	2.49	2812
TN0002968	USDOE-OAK RIDGE Y12 PLT	502	2.5E-03	4.8E-03	9611
TN0002968	USDOE-OAK RIDGE Y12 PLT	551	2.9E-03	2.9E-03	9611
TN0005410	TVA BULL RUN FOSSIL PLANT	001	0.20	0.20	4911
TN0005436	JOHN SEVIER COMBUSTION TURBINE COMBINED CYCLE PLANT	003	0.46	0.46	4911
TN0005436	JOHN SEVIER COMBUSTION TURBINE COMBINED CYCLE PLANT	006	2.1E-03	2.1E-03	4911
TN0005444	TENNESSEE VALLEY AUTHORITY - JOHNSONVILLE FOSSIL PLANT	001	0.22	0.22	4911
TN0021261	SPRING CITY NEW LAKE RD PLT	001	0.01	0.01	4952
TN0023515	ELIZABETHTON WWTP	001	0.01	0.01	4952
TN0024155	OAK RIDGE STP	001	0.02	0.02	4952
TN0024945	MOUNTAIN CITY WWTP	001	0.01	0.01	4952
TN0058238	TASS- NILES FERRY STP	001	8.5E-08	1.7E-07	4952
TN0078905	HALLSDALE POWELL UTILITY	001	0.07	0.07	4952
TN0080870	US TVA KINGSTON FOSSIL PLANT	01A	0.01	0.01	4911
		Total	**9.79**	**9.79**	

Table A36. Point Source Hg pipe discharge per monitored facility's outfalls in the OR Local 5 watershed during study period November 2015 through October 2016

[NPDES, National Pollutant Discharge Elimination System; SIC, Standard Industrial Classification; Hg, mercury; lbs, pounds; minimum, Non-detects = 0; maximum, Non-detects = detection limit]

NPDES Permit	Facility	Outfall ID Number	Minimum Hg Load (lbs)	Maximum Hg Load (lbs)	SIC
IL0004081	HOLCIM US INC.	013	4.4E-03	4.4E-03	3241
IL0004421	HONEYWELL INTERNATIONAL INC	002	0.26	0.26	2819
IL0029874	METROPOLIS, CITY OF	001	0.02	0.02	4952
IL0070033	CHOATE MENTAL HEALTH & DEVELOPMENTAL CENTER	001	2.5E-05	2.5E-05	8063
IL0078751	MET-SOUTH INC	001	0.01	0.01	4953
KY0022799	Paducah/McCracken County JSA - Paducah	001	0	7.10	4952
		Total	**0.48**	**7.59**	

Table A37. Comparison of wet-mercury deposition by watershed from two sets of parameters for the inverse-distance-weighting algorithm used for calculating precipitation-weighted mercury concentrations during study period

[Hg, mercury; µg/m^2/yr, microgram per square meter per year; IDW, inverse-distance-weighting algorithm]

Watershed	Normalized wet-Hg deposition (µg/m^2/yr) IDW: 5 sites power 3	IDW: 12 sites power 2	Percent difference
Allegheny	8.8	8.8	-0.7%
Monongahela	10.4	10.9	-4.8%
Beaver	8.4	8.8	-4.3%
OR Local 1	9.4	10.0	-6.7%
Muskingum	7.8	8.0	-1.7%
Kanawha	9.6	9.5	0.9%
OR Local 2	9.1	9.3	-1.4%
Big Sandy	9.2	9.3	-1.8%
Scioto	8.2	7.9	3.4%
Little Miami	9.5	9.0	5.2%
Licking	9.5	9.2	3.0%
Great Miami	8.8	8.3	5.0%
Kentucky	10.5	10.5	0.7%
OR Local 3	10.2	10.0	2.5%
Green	12.3	12.0	2.7%
Wabash	11.1	11.2	-0.7%
OR Local 4	13.3	13.3	-0.1%
Cumberland	11.5	11.3	1.5%
Tennessee	11.8	12.1	-2.4%
OR Local 5	11.5	11.4	0.9%

Table A38. Rank order of study area watershed drainage areas and normalized wet-mercury deposition during study period.

[km^2, square kilometer; Hg, mercury; $\mu g/m^2/yr$, microgram per square meter per year]

Watershed Name	Rank order drainage area (km^2)		Watershed Name	Rank order normalized wet-Hg deposition ($\mu g/m^2/yr$)
OR Local 5	2,393		Muskingum	7.8
Little Miami	4,553		Scioto	8.2
Beaver	8,178		Beaver	8.4
OR Local 1	9,059		Allegheny	8.8
Licking	9,598		Great Miami	8.8
OR Local 4	10,885		OR Local 2	9.1
Big Sandy	11,119		Big Sandy	9.2
Great Miami	13,900		OR Local 1	9.4
Scioto	16,867		Little Miami	9.5
OR Local 2	17,450		Licking	9.5
Kentucky	18,041		Kanawha	9.6
Monongahela	19,104		OR Local 3	10.2
Muskingum	20,849		Monongahela	10.4
Green	23,917		Kentucky	10.5
Allegheny	30,371		Wabash	11.1
Kanawha	31,724		Cumberland	11.5
OR Local 3	42,210		OR Local 5	11.5
Cumberland	46,390		Tennessee	11.8
Wabash	85,353		Green	12.3
Tennessee	105,950		OR Local 4	13.3

Table A39. Statistical evaluation of precipitation-weighted mercury concentrations and precipitation depths at 20 NADP MDN sites in 2014, 2015, and 2016

[NADP, National Atmospheric Deposition Program; MDN, Mercury Deposition Network; Hg, mercury; conc., precipitation-weighted Hg concentration; precip., precipitation depth; statistical significance indicated by shading]

Statistical test[a]	Group 1	Group 2	Test significance
Wilcoxon SR	2014 Hg conc.	2015 Hg conc.	$p < 0.001$
Wilcoxon RS	2014 Hg conc.	2015 Hg conc.	$p = 0.037$
Wilcoxon SR	2014 Hg conc.	2016 Hg conc.	$p = 0.003$
Wilcoxon RS	2014 Hg conc.	2016 Hg conc.	$p = 0.027$
Wilcoxon SR	2015 Hg conc.	2016 Hg conc.	$p = 0.456$
Wilcoxon RS	2015 Hg conc.	2016 Hg conc.	$p = 1.00$
Wilcoxon SR	2014 Hg precip.	2015 Hg precip.	$p = 0.019$
Wilcoxon RS	2014 Hg precip.	2015 Hg precip.	$p = 0.320$
Wilcoxon SR	2014 Hg precip.	2016 Hg precip.	$p = 0.131$
Wilcoxon RS	2014 Hg precip.	2016 Hg precip.	$p = 0.359$
Wilcoxon SR	2015 Hg precip.	2016 Hg precip.	$p = 0.002$
Wilcoxon RS	2015 Hg precip.	2016 Hg precip.	$p = 0.102$

[a] Wilcoxon SR, signed rank; Wilcoxon RS, rank sum; both are 2-sided tests

Table A40. Forest types area and dry-mercury loads for the study period by watershed

[Hg, mercury; km^2, square kilometer; kg, kilogram; shaded cells indicate forest type was less than 1% of forest land cover]

Watershed	Oak-hickory		Maple-beech-birch		Elm-ash-cottonwood		Oak-pine		Oak-gum-cypress	
	Area (km^2)	Dry-Hg deposition (kg)	Area (km^2)	Dry-Hg deposition (kg)	Area (km^2)	Dry-Hg deposition (kg)	Area (km^2)	Dry-Hg deposition (kg)	Area (km^2)	Dry-Hg deposition (kg)
Allegheny	6,657	63	14,582	201						
Monongahela	9,879	105	3,348	46						
Beaver	1,232	13	1,173	16	32	311				
OR Local 1	2,912	33	1,388	19	74	1				
Muskingum	5,844	73	739	10	145	1.0				
Kanawha	23,635	292	2,321	32						
OR Local 2	13,377	163	280	4						
Big Sandy	10,412	131								
Scioto	3,278	42	118	2	48	0.5	87	1		
Little Miami	506	7	62	1	82	0.8	18	0.3		
Licking	3,625	46			133	1.2	299	4		
Great Miami	781	10	205	3	81	0.8				
Kentucky	10,448	133	31	0.4	139	1.3	470	7		
OR Local 3	20,499	263	438	6	406	3.9	711	10		
Green	8,194	113			355	3.4	234	3		
Wabash	8,617	126	1,288	18	814	7.9	161	2		
OR Local 4	2,786	42	24	0.3	363	3.5	29	0.4	48	0.3
Cumberland	24,897	313					1,144	17		
Tennessee	60,281	772	730	10			2,060	30	766	5
OR Local 5	341	5	6	0.1	63	0.6			42	0.3

Table A41. Rank order of study area watersheds by forest area and normalized dry-mercury deposition during study period

[km^2, square kilometer; Hg, mercury; $\mu g/m^2/yr$, microgram per square meter per year]

Watershed Name	Rank forest area (km^2)		Watershed Name	Rank order normalized dry-Hg deposition ($\mu g/m^2/yr$)
OR Local 5	469		Great Miami	1.0
Little Miami	671		Wabash	1.8
Great Miami	1,085		Little Miami	2.0
Beaver	2,451		OR Local 5	2.5
OR Local 4	3,275		Scioto	2.7
Scioto	3,554		Beaver	3.7
Licking	4,206		Muskingum	4.1
OR Local 1	4,382		OR Local 4	4.3
Muskingum	6,768		Green	5.0
Green	8,898		Licking	5.4
Big Sandy	10,430		OR Local 1	5.8
Wabash	10,922		OR Local 3	6.7
Kentucky	11,185		Cumberland	7.1
Monongahela	13,332		Tennessee	7.7
OR Local 2	13,801		Kentucky	7.8
Allegheny	21,523		Monongahela	7.9
OR Local 3	22,218		Allegheny	8.7
Cumberland	26,375		OR Local 2	9.6
Kanawha	26,423		Kanawha	10.2
Tennessee	66,116		Big Sandy	11.8

Table A42. Rank order of normalized dry-mercury deposition to non-forest land cover and area of non-forest land cover per watershed during study period.

[kg, kilogram; Hg, mercury; µg/m²/yr, microgram per square meter per year; km², square kilometer]

Watershed	Dry-Hg Deposition (kg)	Normalized dry-Hg deposition (µg/m²/yr)	Non-forest area (km²)		Watershed	Dry-Hg deposition (kg)	Normalized dry-Hg deposition (µg/m²/yr)	Non-forest area (km²)
Big Sandy	18	1.6	2,258		OR Local 5	16	6.9	1,632
Kanawha	70	2.2	7,345		Big Sandy	18	1.6	2,258
OR Local 2	40	2.3	4,063		Little Miami	36	8.0	3,473
Monongahela	49	2.6	5,312		OR Local 1	35	3.9	3,742
Allegheny	84	2.8	8,611		OR Local 2	40	2.3	4,063
Tennessee	390	3.7	40,301		Beaver	44	5.3	4,591
OR Local 1	35	3.9	3,742		Licking	51	5.4	4,789
Cumberland	188	4.1	19,079		Monongahela	49	2.6	5,312
Kentucky	76	4.2	7,508		OR Local 4	68	6.3	6,523
OR Local 3	178	4.2	17,775		Kanawha	70	2.2	7,345
Beaver	44	5.3	4,591		Kentucky	76	4.2	7,508
Licking	51	5.4	4,789		Allegheny	84	2.8	8,611
Muskingum	119	5.7	11,500		Muskingum	119	5.7	11,500
Green	137	5.7	12,732		Great Miami	124	8.9	11,613
OR Local 4	68	6.3	6,523		Scioto	133	7.9	12,440
OR Local 5	16	6.9	1,632		Green	137	5.7	12,732
Scioto	133	7.9	12,440		OR Local 3	178	4.2	17,775
Little Miami	36	8.0	3,473		Cumberland	188	4.1	19,079
Wabash	748	8.8	68,218		Tennessee	390	3.7	40,301
Great Miami	124	8.9	11,613		Wabash	748	8.8	68,218