Sources of Mercury Deposition in the Northeast United States

Prepared by
NESCAUM

March 2008

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SOURCES OF MERCURY DEPOSITION IN THE NORTHEAST UNITED STATES

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Executive Summary

In December 2007, the U.S. EPA approved a regional total maximum daily load (TMDL) for mercury that was submitted by NEIWPCC and its member states. For the NEIWPCC states to meet this regional TMDL, atmospheric mercury deposition in the region must be reduced by at least 98 percent relative to 1998 levels.

In order to help achieve the regional mercury TMDL, there is a need to identify and summarize available information on the sources of anthropogenic mercury being deposited in the NEIWPCC states and the NEIWPCC region. In this report, NESCAUM draws upon modeling studies using the Regional Modeling System for Aerosols and Deposition (REMSAD) to help identify sources and source regions in the U.S. contributing to atmospheric mercury deposition in the Northeast.

With respect to mercury deposition attributable to emissions from continental U.S. sources, the REMSAD modeling information indicates that nearly half of the mercury deposited across the NEIWPCC region comes from sources within the seven NEIWPCC states. Another forty percent of the deposition in the region attributable to U.S. sources derives from sources in states immediately upwind, including Pennsylvania, New Jersey, Ohio, West Virginia and Maryland. Contributions from other states and individual sources are also important, as tabulated in this report.

1. INTRODUCTION

On October 24, 2007, the six New England states along with New York submitted a request to the United States Environmental Protection Agency (U.S. EPA) to establish a regional total maximum daily load (TMDL) for mercury under the Clean Water Act (NEIWPCC, 2007). The U.S. EPA approved the TMDL request on December 20, 2007 (US EPA, 2007).

In developing their TMDL request, the states considered sources of mercury to regional waters that included atmospheric deposition, municipal wastewater treatment plants, non-municipal wastewater discharges, and stormwater. Among these sources, the states identified 97.9 percent of the total mercury load as coming from atmospheric deposition. The states also determined that achieving target fish mercury concentrations ranging from 0.1 to 0.3 ppm will require an at least 98 percent reduction in atmospheric mercury deposition arising from anthropogenic sources relative to 1998 levels.

In order to help achieve the states' TMDL goals, there is a need to identify and summarize available information on the sources of anthropogenic mercury being deposited in the NEIWPCC states and the NEIWPCC region. In this report, NESCAUM draws upon modeling studies using the Regional Modeling System for Aerosols and Deposition (REMSAD) to help identify sources and source regions in the U.S. contributing to atmospheric mercury deposition in the Northeast. The REMSAD information comes from a report prepared by ICF International for the U.S. EPA Office of Water (ICF, 2006) as well as REMSAD studies previously performed by NESCAUM.

With respect to mercury deposition attributable to emissions from continental U.S. sources, the REMSAD modeling information indicates that nearly half of the mercury deposited across the NEIWPCC region comes from sources within the seven NEIWPCC states. Only New York State receives less than half of its mercury deposition from within the region. Another forty percent of the deposition in the region attributable to U.S. sources derives from sources in states immediately upwind, including Pennsylvania, New Jersey, Ohio, West Virginia and Maryland. Those same five states account for over half of the modeled deposition to New York State. Contributions from other states and individual sources are also important, as tabulated in this report.

2. MERCURY IN THE ENVIRONMENT

Mercury (elemental symbol Hg) exists naturally in the earth's crust at trace levels. This metal can enter the environment through natural (e.g., volcanic eruptions, diffusion from water and land) and man-made processes (e.g., combustion of mercury-containing fuels), after which it may cycle through land, air, and water while undergoing chemical and physical transformations. From the perspective of public health, the concern rests primarily with a toxic organic form, methylmercury, which bioaccumulates in fish, thus exposing people who eat the fish to mercury's toxic effects.

An early step to address mercury in the environment was taken in 1998 by the northeast states (through air, water, and waste interstate agencies), along with U.S. federal and Canadian partners, by documenting the state of knowledge of mercury in the environment (NESCAUM et al., 1998). The report covered a wide range of topics, including: background information on mercury; how it cycles in the environment; what were the primary emission sources in the Northeast in 1996 and in what quantity; and how local, regional and global sources affected the Northeast. Following this publication, the New England Governors and Eastern Canadian Premiers (NEG-ECP) released their Mercury Action Plan. This plan, and revisions thereof, outlined the region's goal for virtual elimination of regional mercury emissions, with interim emission reduction goals of 50 percent by 2003 and 75 percent by 2010 (Conference of New England Governors-Eastern Canadian Premiers, 1998; 2001). As a result of this and efforts in other Northeast states, the region has achieved significant reductions in mercury releases to the environment through a combination of pollution controls and waste management practices (NEIWPCC et al., 2007). These measures appear to have their intended effect. A recent study has found that a statistically significant decline in mercury wet deposition occurred in the Northeast between 1998 and 2005, based on wet deposition monitoring data from the Mercury Deposition Network (Butler et al., 2008). The authors of this study hypothesized that the downward trends are a result of changes in local and regional mercury emissions, rather than global.

Although this report focuses on anthropogenic emissions and their eventual deposition, this section provides a brief overview of the mercury cycle. The context here provides a basis for understanding the importance of tracking the human impact in the global cycling of this pollutant.

2.1. Mercury exposure and health effects

As a persistent, bioaccumulative, and neurotoxic pollutant, mercury is an important environmental concern in the northeastern United States. When released into the environment and deposited or carried into water bodies, mercury can be converted to methylmercury, a particularly toxic form of mercury. A number of factors influence the rate of methylation in the water, including the acidity of the surrounding water, dissolved sulfate, and dissolved organic carbon (DOC) levels (Wiener et al., 2006). Acidity and DOC appear to be particularly important parameters, with more acidified conditions and

higher levels of DOC frequently associated with higher levels of methylmercury (Kamman, 1998). Methylated mercury in the aquatic food chain can bioaccumulate in fish tissue to concentrations markedly higher than in the surrounding water. Birds, such as common loons, and mammals, such as otters, that eat the fish will also have high levels of mercury in their bodies.

A major route of exposure to mercury in humans is also through the eating of fish. Women of child bearing age are of special concern as methylmercury ingested by a mother can transport across the placenta into the brain of a developing fetus. In young children and fetuses, methylmercury inhibits the normal development of the nervous system, an effect that may occur even at low exposure levels. This damage frequently is not apparent until later in the developmental process, when motor and verbal skills are found to be delayed or abnormal. Developmental effects have been found in children exposed *in utero*, even though their mothers did not experience any symptoms of adult toxicity.

Given recent measurements showing elevated mercury levels in freshwater fish in the Northeast, eight northeast states (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont) have issued health advisories that recommended limiting the consumption of fish from state water bodies. This is the best immediate approach for limiting exposure to mercury that is already present in the environment. Over the longer term, because most mercury in the Northeast is believed to reach watersheds through atmospheric deposition, decreasing its introduction into the environment by limiting mercury emissions to the atmosphere should permit an eventual lifting of the fish consumption warnings.

2.2. Chemical properties

Mercury is present in several forms in the environment. In the gas phase, two forms dominate: elemental mercury (Hg^0) and its oxidized divalent form (Hg^{2+}). Divalent mercury often binds with other elements (sulfur, oxygen, halogens) as mercuric salts, and may exist in different phases (e.g., gas, particle, or aqueous). Atmospheric particulate mercury is a third species of mercury that is operationally defined as mercury collected in particulate measurement devices (e.g., filters) (Cohen et al., 2004).

Elemental mercury does not readily dissolve in water and has a relatively high volatility. As a result of these characteristics, it exists primarily in the gas phase as only small amounts will dissolve in atmospheric droplets or remain adsorbed onto the surfaces of aerosol particles. Therefore, elemental mercury is removed relatively slowly from the atmosphere, and has an atmospheric lifetime on the order of a year (Cohen et al., 2004, Seigneur et al., 2003; Poissant et al., 2005).

The divalent form of mercury (Hg^{2+}) in the gas phase is often termed reactive gaseous mercury (RGM). RGM is highly soluble, less volatile than Hg^0, and adheres readily to surfaces. The divalent form of mercury as well as other oxidized states can also exist in the atmosphere as particulate-bound mercury (Hg(p)). Particulate-bound

mercury is relatively insoluble and less volatile than elemental mercury. Oxidized mercury in either of these two phases is prone to removal from the atmosphere by wet and dry deposition, and has a considerably shorter atmospheric lifetime (days to weeks) than the elemental form (Cohen et al., 2004).

2.3. Atmospheric processes

Each of the mercury forms described above has a different fate in the atmosphere. Although mercury cycles between its elemental (reduced) and oxidized forms, most of the mercury in the atmosphere (the "global pool") exists in the elemental state (generally >95 percent). This is a direct result of the limited solubility and high volatility of Hg^0, such that it remains in the atmosphere with a lifetime on the order of one year, free from deposition processes associated with aqueous or particle bound states.

With its relatively long lifetime, gaseous elemental mercury can be transported over very long distances, even globally. Thus, emissions in any continent can contribute to deposition in other continents (UNEP, 2002). As noted above, the global pool of mercury is almost entirely elemental mercury. By contrast, reactive gaseous mercury and particle-bound mercury are more readily deposited, thus they have shorter lifetimes of days to weeks and typically deposit within 50 to 500 miles of their source. These forms of mercury tend to have a more local and regional impact.

3. REMSAD

3.1. General description

The Regional Modeling System for Aerosols and Deposition (REMSAD) is a three-dimensional Eulerian grid model developed by Systems Applications International, Inc. The U.S. EPA and others have used the model to simulate the physical and chemical atmospheric processes relevant to atmospheric pollutants, including fine particles and air toxics. The model relies on the continuity equation, which represents the mass balance of each species by mathematically tracking emissions, advection, diffusion, chemical reactions, and removal processes.

Model users specify grid spacing and dimensions. Input requirements for the model include meteorological parameters, emission fields, and boundary conditions. Using these inputs, the model solves the continuity equation in a stepwise fashion. For each time step, fresh emissions are added, followed by horizontal and then vertical transport by advection, diffusion and deposition. Chemical reactions are performed, and then transport processes are again performed.

After the model has been run, gridded output is available for analysis. The output is user-specified and generally includes concentration fields for the surface layer and deposition results. Post-processing programs are used to reformat the output for comparison to monitored results in assessing model performance, often summarizing results by relevant time intervals, such as daily or annual average values.

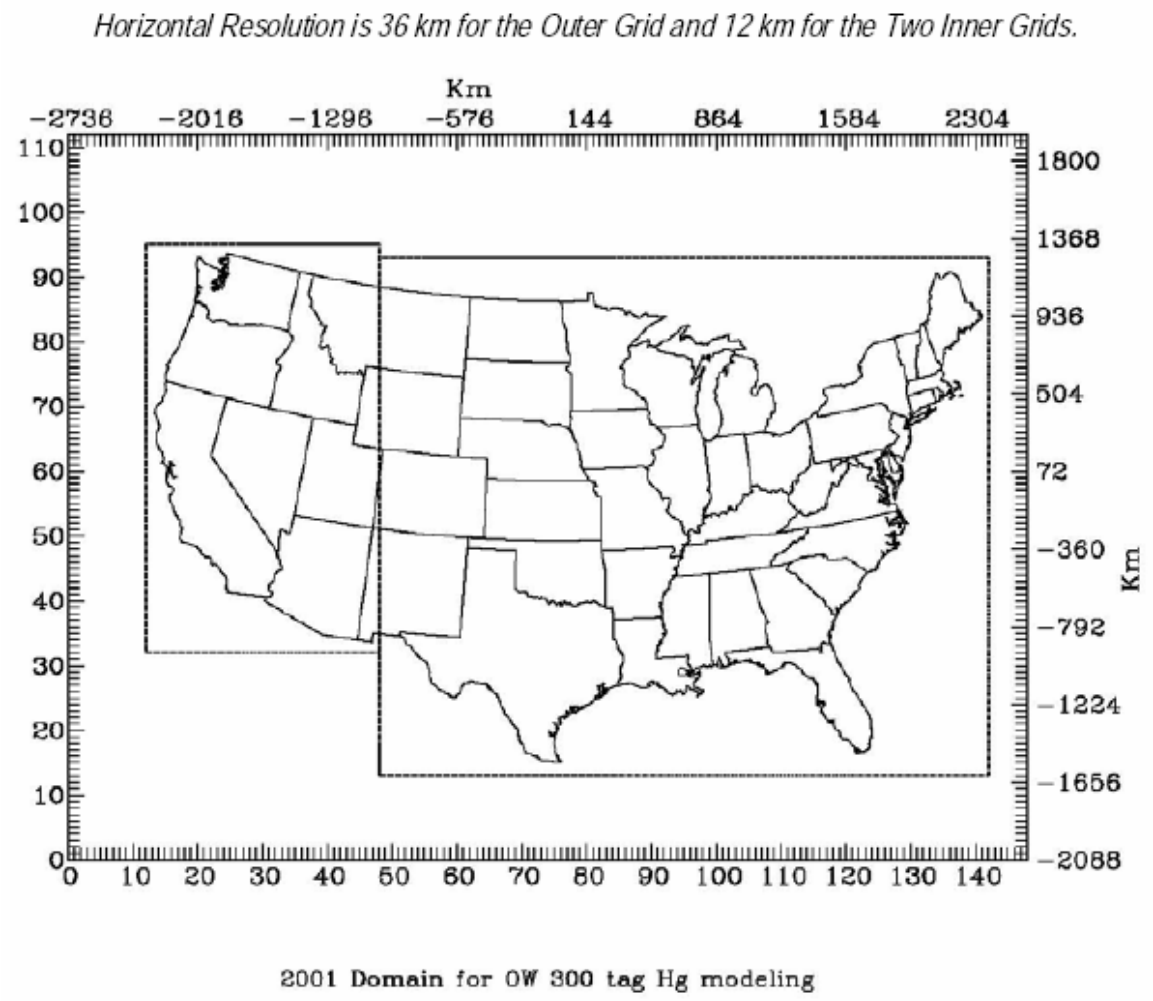
In this report, we summarize previous REMSAD results that have used a "tagging" feature in the model. In these modeling applications, mercury emissions from specific sources or regions have been "tagged" by REMSAD so that it can track mercury species (i.e., gaseous elemental mercury, reactive gaseous mercury, and particulate mercury) in space and time from the point of emission to the point of deposition (or exit out of the modeling domain) without disturbing the physical or chemical processes affecting that species. The REMSAD tagging feature provides the ability to compare the tagged contributions to mercury deposition in specific downwind locations from a range of local and upwind individual sources, source categories, and regions. In this summary report, we draw mainly from the reported results by ICF International in a REMSAD study done for the U.S. EPA Office of Water (ICF, 2006), and compare the ICF tagged results with previous REMSAD work done by NESCAUM for the Massachusetts Department of Environmental Protection (NESCAUM, 2007).

3.2. ICF model description

ICF has previously described its modeling framework and inputs in its report to the U.S. EPA Office of Water (ICF, 2006). Here, we only briefly present the model details before presenting the tagged contribution results relative to the NEIWPCC region

and individual NEIWPCC states. A more complete description is in the ICF report. Figure 3-1 displays the map of the model domain used in the ICF REMSAD (version 8) work. ICF used a 36-km outer grid modeling domain that covered the continental United States and adjacent portions of Canada and Mexico. Two higher resolution 12-km grids covered the entire continental United States, with one nested grid covering approximately the western quarter of the U.S. and the other nested grid covering the eastern three-quarters of the U.S. ICF modeled annual mercury deposition for the year 2001, with a total of 16 simulations performed for this deposition period.

Figure 3-1 Representation of continental 36-km gridded modeling domain with two nested 12-km inner grids



For mercury emissions used as inputs into the REMSAD simulations, ICF adapted a 2001 mercury emissions inventory for Canada and the U.S. developed by the U.S. EPA for the Clean Air Mercury Rule. ICF revised this inventory based on changes it received from U.S. EPA regional offices and states, which ICF documents in its report (ICF, 2006). For Mexico, ICF used a 1999 point source mercury inventory developed by the Commission for Environmental Cooperation (CEC, 2001). For criteria pollutants, ICF used an emissions inventory the U.S. EPA prepared for the Clean Air Interstate Rule.

ICF used a 2001 36-km scale resolution meteorological input from the NCAR/Penn State Mesoscale Model (MM5) prepared by the U.S. EPA for the Clean Air Interstate Rule and the Clean Air Mercury Rule. The REMSAD simulations used the carbon-bond V (five) photochemical mechanism (CB-V) (Gery et al., 1989) to represent chemical processing of mercury and other atmospheric pollutants. Additional parameters are included to account for re-emission to the atmosphere of previously deposited mercury, as well as other physical processes, such as dry and wet deposition.

3.3. ICF model performance

ICF performed a variety of graphical analyses and statistical measures of its REMSAD results, which are described in its report to the U.S. EPA (ICF, 2006). For mercury, ICF found the simulated spatial distribution of deposition to be consistent with the information on emissions, annual transport, and rainfall patterns. ICF found that wet deposition accounted for much of the deposition within the modeling domain, and compared the simulated wet deposition results to available monitoring data in 2001 from 53 sites in the Mercury Deposition Network (MDN), a network of the National Atmospheric Deposition Program (NADP, 2007). Overall, ICF noted that its modeled results tended to overestimate mercury wet deposition when compared to the MDN monitoring data. ICF noted that emerging research suggests that the MDN monitoring data may underestimate mercury wet deposition by 16 percent (Miller et al., 2005). ICF could not compare the simulated dry deposition results because an adequate dry deposition monitoring network does not exist.

4. MODELED CONTRIBUTIONS TO MERCURY DEPOSITION IN NEIWPCC STATES AND REGION

4.1. ICF REMSAD results

The U.S. EPA provided the ICF REMSAD results to NESCAUM with total (wet plus dry) annual deposition results for the Northeast covering the seven NEIWPCC states. Data tables in MS Access contained the deposition total and percent contribution from each tagged source. Using ArcGIS, NESCAUM assigned grid cells to states with an algorithm comparing the cell center location with state boundaries. Using these assignments, NESCAUM then calculated both overall total and tag-specific mercury deposition across each of the seven NEIWPCC states and the region as a whole. These calculations provide the basis for data tabulated in this report.

The tables display the ICF deposition results from continental U.S. sources to receptors in the NEIWPCC region in kilograms and their corresponding percent contributions. Deposition attributable to mercury sources outside the continental U.S. are not included in the tables, as well as contributions from sources in the U.S. whose emissions transport outside the country (and modeling domain) to become part of the "global" contribution that may later recirculate into the U.S. and deposit. In the ICF modeling results, the "global" mercury contribution is about 70 percent of total deposition in the NEIWPCC region as a whole, and varies by individual state (see Table 4–3).

As shown in Table 4-1a and b, nearly half of deposition within the NEIWPCC region attributable to U.S. sources comes from sources within the seven states. For most states (except Rhode Island and Vermont), internal sources represent the greatest contribution among U.S. sources to anthropogenic deposition within the state.

Table 4-1a Deposition from Anthropogenic Sources within the NEIWPCC Region (kg) (from U.S. sources only).

		Receiving Region							
		CT	*MA*	*ME*	*NH*	*NY*	*RI*	*VT*	*NEIWPCC*
Source Region	*CT*	48.8	9.7	3.0	2.8	10.1	4.8	1.7	**80.8**
	MA	12.1	80.1	10.9	11.1	15.2	3.8	11.9	**145.2**
	ME	0.1	0.6	34.7	1.3	0.3	0.1	0.3	**37.4**
	NH	0.5	3.3	6.6	22.8	1.5	0.2	4.9	**39.8**
	NY	17.4	10.0	8.3	5.9	212.3	1.6	13.5	**269.0**
	RI	1.4	17.1	1.6	0.8	1.0	3.8	0.4	**26.1**
	VT	<0.05	0.2	0.2	0.4	0.3	<0.05	2.2	**3.3**
	NEIWPCC	**80.5**	**120.8**	**65.1**	**45.1**	**240.7**	**14.3**	**35.0**	**601.6**

Table 4-1b Percent Anthropogenic Contribution to Deposition within the NEIWPCC Region (from U.S. sources only).

		Receiving Region							
		CT	MA	ME	NH	NY	RI	VT	NEIWPCC
Source Region	CT	42.0	6.2	2.6	4.0	1.4	25.1	2.4	**6.5**
	MA	10.5	51.1	9.6	16.1	2.2	19.7	17.3	**11.6**
	ME	0.1	0.4	30.3	1.8	<0.05	0.4	0.5	**3.0**
	NH	0.5	2.1	5.8	32.9	0.2	1.3	7.1	**3.2**
	NY	15.0	6.4	7.2	8.5	30.2	8.5	19.6	**21.6**
	RI	1.2	10.9	1.4	1.2	0.1	19.9	0.6	**2.1**
	VT	<0.05	0.1	0.2	0.6	<0.05	0.1	3.2	**0.3**
	NEIWPCC	**69.3**	**77.1**	**57.0**	**65.1**	**34.2**	**75.1**	**50.8**	**48.2**

Appendix A provides summary tables (Table 6–1) for each NEIWPCC state and the region that show the contribution to deposition from states in the continental U.S. relative to the total contribution attributable to continental U.S. sources. These results expand upon those in Table 4-1a and b. In addition to the contributions of NEIWPCC states to deposition in the Northeast, five other states rank in the top ten contributing states throughout the Northeast (Pennsylvania, New Jersey, Ohio, Maryland, and West Virginia). Virginia, Michigan, and Indiana also ranked in the top ten contributing states for some jurisdictions.

Additional tables in Appendix A (Table 6-2) show the contribution of individual source tags to deposition. In most cases the tags represent emissions from a specific source, although some tags include emissions from a discrete region or limited group of sources (e.g., StateName_Other_Utilities).

4.2. Comparison with NESCAUM REMSAD results

In preparing its regional mercury TMDL, NEIWPCC used NESCAUM's REMSAD deposition results from two modeling scenarios, a 1998 base-case and a 2002 control-case (NESCAUM, 2007). Although the NESCAUM results identified major source categories and source regions contributing to deposition in the Northeast, they did not track emissions from individual states. ICF, however, did follow a state-specific approach in its REMSAD modeling for the U.S. EPA. We compare the output from both models here to demonstrate reasonable consistency in the results, despite the number of differences that exist between the two modeling scenarios. Differences include meteorology, grid size, boundary conditions, emissions totals, and emissions speciation.

In this section, we compare the NESCAUM 2002 control-case REMSAD results with the ICF results, which used a 2001 year mercury emissions inventory. Differences in emissions totals and speciation of those emissions likely dominate the observed differences in deposition attribution, with differences in boundary conditions also likely having an important influence.

Table 4–2 summarizes the modeled emissions totals by source region (New England, New York/New Jersey, Rest of the US), model run (ICF and NESCAUM) and mercury speciation (Hg^0, Hg^{2+}, Hg(P)). Although similar total emissions (8 percent difference) were modeled in the NESCAUM region, emissions in the rest of the U.S. were substantially greater (25 percent) in NESCAUM's modeling. The overall speciation of the modeled emissions also differed, with ICF modeling a higher percentage of Hg^{2+} (21 percent) and Hg(P) (28 percent) in the NESCAUM region, but a lower percentage (by 35 and 38 percent, respectively) of these species in the rest of the U.S., relative to the NESCAUM emissions.

Although less important for this analysis, ICF and NESCAUM relied on different boundary conditions for their simulations. ICF used averaged model results based on three separate global models while the NESCAUM modeling used one global model to establish boundary conditions. ICF's global boundary conditions on average had somewhat higher Hg levels, which led to higher deposition attributable to the boundary.

Beyond emissions and boundary conditions, the modeled meteorological year was different, with ICF using 2001 and NESCAUM 1996. The major difference between these two years shows substantially increased rainfall in 1996 along the Eastern Seaboard and parts of the Midwest. This could lead to increased wet deposition in the Northeast. Unfortunately, ICF's results are available only for total deposition, so the influence of meteorology cannot be confirmed. The differences in total deposition due to meteorology when integrated over the entire NEIWPCC region may not be large, as increases in wet deposition may be offset by corresponding decreases in dry. Likewise, grid-size differences should not appreciably affect results when integrated over a wide region. Small states or areas with strong gradients in surface characteristics could see some differences.

Table 4-2 Emissions Summary for ICF and NESCAUM Modeling.

Comparison of Modeled Emission Data					
New England	ICF (kg/yr)	NESC (kg/yr)	ICF %	NESC %	% DIFFERENCE*
Hg^0	853	1,116	42.1	54.2	-23%
Hg^{2+}	862	680	42.5	33.0	27%
Hg(P)	318	263	15.4	12.8	19%
Hg Total	2,033	2,059			-1%
NY/NJ	ICF (kg/yr)	NESC (kg/yr)	ICF %	NESC %	% DIFFERENCE
Hg^0	2,087	2,830	55.0	66.8	-26%
Hg^{2+}	1,207	1,034	31.8	24.4	16%
Hg(P)	499	372	13.2	8.8	35%
Hg Total	3,793	4,236			-11%
Rest of US	ICF (kg/yr)	NESC (kg/yr)	ICF %	NESC %	% DIFFERENCE
Hg^0	50,340	59,239	59.3	52.5	-15%
Hg^{2+}	27,197	41,731	32.1	37.0	-35%
Hg(P)	7,285	11,884	8.6	10.5	-39%
Hg Total	84,822	112,854			-25%
US Total	ICF (kg/yr)	NESC (kg/yr)	ICF %	NESC %	% DIFFERENCE
Hg^0	53,279	63,140	58.8	53.0	-16%
Hg^{2+}	29,266	43,454	32.3	36.5	-33%
Hg(P)	8,101	12,519	8.9	10.5	-35%
Hg Total	90,646	119,113			-24%

* % DIFFERENCE calculated from (ICF – NESC)/NESC.

The NESCAUM modeling did not explicitly separate New Jersey's mercury emissions from New York's when tracking tagged emissions, so a direct comparison between the NESCAUM and ICF results of U.S. source contributions from inside and outside the NEIWPCC region is not possible. Therefore, the following comparison of modeling results refers to contributions from sources in the NESCAUM region (New England states plus New Jersey and New York) to deposition in the NEWIPCC region (New England states plus only New York). Contributions from sources in the rest of the U.S. refer to sources outside the NESCAUM region.

Despite the modeling differences, a comparison of the two results as shown in Table 4-3 reveals reasonable consistency, especially when focused on deposition to the NEIWPCC region as a whole (final table of Table 4–3). Overall, ICF modeled 71.6 percent of mercury deposition in the NEIWPCC region as coming from global sources (which would also include a portion of U.S. mercury emissions that form part of the global pool), while NESCAUM modeled a 61.2 percent contribution from global sources. ICF modeled NESCAUM sources contributing 15.3 percent to deposition in the NEIWPCC region with NESCAUM modeling a 16.7 percent contribution. ICF estimated

that U.S. sources outside the NESCAUM region contributed 13.1 percent to deposition in the NEIWPCC region with NESCAUM estimating a 22.1 percent contribution. As discussed previously, differences between the emissions inventories used by each model, differences in emitted mercury species profiles, different meteorological years, and different boundary conditions all contribute to differences in this comparison.

Differences in mercury speciation in the different inventories used by ICF and NESCAUM deserve special mention. The relative trends in deposition follow the relative contributions of reactive emissions, with the ICF results predicting 14-21 percent higher deposition in the NEIWPCC region due to NESCAUM sources as compared to NESCAUM results. ICF modeled 16-27 percent higher reactive emissions (RGM/Hg(P)) than did NESCAUM for NESCAUM source states. The opposite trend is observed for sources from the rest of the U.S. ICF predicted 76 percent of the deposition to the NEIWPCC region that NESCAUM modeling predicted. ICF's speciation in the rest of the U.S. had only two-thirds of the reactive emissions as NESCAUM modeling.

Generally speaking, the predicted contribution of New England states to deposition agrees well. In some instances, ICF results are greater, which is likely due to the higher levels of RGM emitted in the region relative to the NESCAUM emissions. Also, some variation in state-specific emissions totals explain differences (e.g., for Maine, ICF total emissions were more than twice those of the NESCAUM emissions for that state, which likely explains the much larger predicted deposition to Maine from ICF modeling).

In summary, based on this comparison, the results of the two model simulations are in reasonable agreement. ICF model inventories for states outside of the NESCAUM region better reflect current emissions for those states as they represent 2001 emissions. The NESCAUM emissions inventory for that region represents late 1990s emissions—the baseline period for the TMDL. This implies the ICF model apportionment results characterize near-current state-specific contributions to deposition in the Northeast. This apportionment provides a reasonable estimate of the relative importance of mercury emissions sources to deposition within the NEIWPCC region.

Table 4-3 Comparison of Hg Deposition from ICF and NESCAUM Modeling.

Total Modeled Deposition					
Connecticut	ICF kg	NESC kg	ICF %	NESC %	% DIFFERENCE*
New England	63.0	62.7	22.3	25.2	0.5%
NYNJ	25.9	33.1	9.1	13.3	-22%
ROUS	27.2	42.4	9.6	17.0	-36%
Global	166.7	110.4	59.0	44.4	51%
Total	282.8	248.6			14%
US Total	116.1	138.2			-16%

Maine	ICF kg	NESC kg	ICF %	NESC %	% DIFFERENCE*
New England	56.9	34.7	6.9	5.7	64%
NYNJ	11.6	10.1	1.4	1.7	15%
ROUS	45.8	58.0	5.5	9.5	-21%
Global	711.0	506.3	86.1	83.1	40%
Total	825.3	609.0			36%
US Total	114.3	102.7			11%

Massachusetts	ICF kg	NESC kg	ICF %	NESC %	% DIFFERENCE*
New England	110.9	92.4	28.1	27.4	20%
NYNJ	15.4	15.9	3.9	4.7	-3%
ROUS	30.4	50.1	7.7	14.8	-39%
Global	237.9	179.5	60.3	53.1	33%
Total	394.6	337.9			17%
US Total	156.7	158.4			-1%

New Hampshire	ICF kg	NESC kg	ICF %	NESC %	% DIFFERENCE*
New England	39.2	36.6	13.9	15.4	7%
NYNJ	8.4	8.6	3.0	3.6	-2%
ROUS	21.6	36.4	7.7	15.3	-41%
Global	212.3	156.6	75.4	65.7	36%
Total	281.5	238.1			18%
US Total	69.3	81.6			-15%

New York	ICF kg	NESC kg	ICF %	NESC %	% DIFFERENCE*
New England	28.4	27.1	1.3	1.5	5%
NYNJ	258.3	216.9	11.5	12.4	19%
ROUS	416.9	527.8	18.5	30.1	-21%
Global	1547.3	983.6	68.7	56.0	57%
Total	2250.9	1755.4			28%
US Total	703.6	771.8			-9%

Total Modeled Deposition					
Rhode Island	ICF kg	NESC kg	ICF %	NESC %	% DIFFERENCE*
New England	12.7	9.6	23.5	22.9	32%
NYNJ	2.6	1.9	4.8	4.6	37%
ROUS	3.8	6.5	7.1	15.5	-42%
Global	34.7	23.9	64.6	57.0	45%
Total	53.8	41.9			28%
US Total	19.0	18.0			6%

Vermont	ICF kg	NESC kg	ICF %	NESC %	% DIFFERENCE*
New England	21.5	11.7	7.0	5.6	84%
NYNJ	16.8	11.8	5.4	5.6	42%
ROUS	30.7	39.7	10.0	19.0	-23%
Global	239.0	145.5	77.6	69.7	64%
Total	308.0	208.7			48%
US Total	68.9	63.2			9%

NEIWPCC Region	ICF kg	NESC kg	ICF %	NESC %	% DIFFERENCE*
New England	332.5	274.7	7.6	8.0	21%
NYNJ	339.0	298.2	7.7	8.7	14%
ROUS	576.3	760.9	13.1	22.1	-24%
Global	3148.9	2105.8	71.6	61.2	50%
Total	4396.8	3439.6			28%
US Total	1247.9	1333.8			-6%

* % DIFFERENCE calculated from (ICF – NESC)/NESC.

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6. APPENDIX A: TABLES OF MERCURY CONTRIBUTIONS TO THE NEIWPCC REGION AND STATES

Data in this appendix summarize modeling results based on ICF's MS Access database from the U.S. EPA. Values are rounded to the nearest tenth of a kg and nearest tenth of a percent. Sources whose contribution would round to zero are listed with "<0.05." Listings of zero imply virtually no contribution (roughly below 10^{-7} percent contribution) was attributed to that source or source region.

The mass deposition and percent contributions in the tables are those attributable solely to continental U.S. mercury emission sources. Contributions from sources outside the U.S. (as well as from sources in the U.S. whose emissions transport out of the country and recirculate back in as part of the "global" background) are not included in the tables. In the ICF modeling results, the "global" mercury contribution is about 70 percent of total deposition in the NEIWPCC region as a whole, and varies by individual state (see Table 4–3).

Table 6-1. State Contributions to NEIWPCC Region and Individual States.

NEIWPCC Region		
State	kg	%
PA	270.8	21.7
NY	269.0	21.6
MA	145.2	11.6
CT	80.8	6.5
NJ	70.0	5.6
OH	68.8	5.5
WV	48.6	3.9
MD	46.2	3.7
NH	39.8	3.2
ME	37.4	3.0
RI	26.1	2.1
MI	25.1	2.0
VA	18.7	1.5
IN	16.4	1.3
KY	14.6	1.2
NC	14.2	1.1
IL	11.1	0.9
TN	6.8	0.5
AL	6.3	0.5
GA	5.7	0.5
DE	5.3	0.4
WI	3.4	0.3
VT	3.3	0.3
SC	2.5	0.2
TX	2.5	0.2
MO	2.5	0.2
FL	1.1	0.1
IA	1.0	0.1
AR	1.0	0.1
LA	0.7	0.1
MS	0.6	0.1
MN	0.6	<0.05
CA	0.5	<0.05
KS	0.5	<0.05
OK	0.3	<0.05
OR	0.1	<0.05
ND	0.1	<0.05
MT	<0.05	<0.05
ID	<0.05	<0.05
NM	<0.05	<0.05
UT	<0.05	<0.05
NE	<0.05	<0.05
SD	<0.05	<0.05
WY	<0.05	<0.05
CO	<0.05	<0.05
DC	<0.05	<0.05

Connecticut		
State	kg	%
CT	48.8	42.0
NY	17.4	15.0
PA	13.2	11.4
MA	12.1	10.5
NJ	8.4	7.3
MD	3.6	3.1
WV	1.9	1.6
OH	1.9	1.6
VA	1.7	1.5
RI	1.4	1.2
NC	1.0	0.8
DE	0.7	0.6
MI	0.6	0.5
NH	0.5	0.5
IN	0.4	0.4
KY	0.4	0.4
IL	0.3	0.3
GA	0.2	0.2
SC	0.2	0.2
AL	0.2	0.2
TN	0.2	0.2
ME	0.1	0.1
WI	0.1	0.1
FL	0.1	0.1
TX	0.1	0.1
MO	0.1	0.1
VT	<0.05	<0.05
IA	<0.05	<0.05
CA	<0.05	<0.05
LA	<0.05	<0.05
MN	<0.05	<0.05
AR	<0.05	<0.05
MS	<0.05	<0.05
KS	<0.05	<0.05
OK	<0.05	<0.05
OR	<0.05	<0.05
ID	<0.05	<0.05
MT	<0.05	<0.05
UT	<0.05	<0.05
SD	<0.05	<0.05
ND	<0.05	<0.05
CO	0.0	0.0
DC	0.0	0.0
NE	0.0	0.0
NM	0.0	0.0
WY	0.0	0.0

Maine		
State	kg	%
ME	34.7	30.3
PA	17.7	15.5
MA	10.9	9.6
NY	8.3	7.2
NH	6.6	5.8
OH	4.9	4.3
MD	3.8	3.3
WV	3.6	3.2
NJ	3.4	3.0
CT	3.0	2.6
MI	2.3	2.0
IN	1.8	1.6
VA	1.7	1.5
NC	1.7	1.5
KY	1.6	1.4
RI	1.6	1.4
IL	1.5	1.3
GA	0.9	0.8
TN	0.8	0.7
AL	0.8	0.7
DE	0.5	0.4
WI	0.4	0.4
TX	0.4	0.4
SC	0.4	0.3
MO	0.3	0.2
VT	0.2	0.2
AR	0.1	0.1
FL	0.1	0.1
CA	0.1	0.1
IA	0.1	0.1
MS	0.1	0.1
LA	0.1	<0.05
OK	<0.05	<0.05
MN	<0.05	<0.05
KS	<0.05	<0.05
OR	<0.05	<0.05
SD	<0.05	<0.05
MT	<0.05	<0.05
ID	<0.05	<0.05
CO	0.0	0.0
DC	0.0	0.0
ND	0.0	0.0
NE	0.0	0.0
NM	0.0	0.0
UT	0.0	0.0
WY	0.0	0.0

Massachusetts		
State	kg	%
MA	80.1	51.1
RI	17.1	10.9
PA	13.0	8.3
NY	10.0	6.4
CT	9.7	6.2
NJ	5.4	3.5
MD	4.3	2.8
NH	3.3	2.1
WV	2.4	1.5
OH	2.4	1.5
VA	1.9	1.2
NC	1.2	0.8
MI	0.9	0.6
IN	0.7	0.4
KY	0.7	0.4
DE	0.6	0.4
ME	0.6	0.4
IL	0.5	0.3
TN	0.3	0.2
GA	0.3	0.2
AL	0.3	0.2
SC	0.2	0.1
TX	0.2	0.1
VT	0.2	0.1
WI	0.1	0.1
MO	0.1	0.1
FL	0.1	<0.05
AR	<0.05	<0.05
CA	<0.05	<0.05
IA	<0.05	<0.05
MS	<0.05	<0.05
LA	<0.05	<0.05
MN	<0.05	<0.05
KS	<0.05	<0.05
OK	<0.05	<0.05
OR	<0.05	<0.05
SD	<0.05	<0.05
NM	<0.05	<0.05
UT	<0.05	<0.05
ID	<0.05	<0.05
MT	<0.05	<0.05
CO	<0.05	<0.05
ND	<0.05	<0.05
DC	0.0	0.0
NE	0.0	0.0
WY	0.0	0.0

New Hampshire		
State	kg	%
NH	22.8	32.9
MA	11.1	16.1
PA	8.9	12.9
NY	5.9	8.5
CT	2.8	4.0
NJ	2.5	3.7
MD	2.5	3.6
OH	2.1	3.0
WV	1.8	2.6
ME	1.3	1.8
VA	1.0	1.5
NC	0.9	1.3
RI	0.8	1.2
MI	0.8	1.2
IN	0.7	1.0
KY	0.6	0.9
IL	0.4	0.6
VT	0.4	0.6
DE	0.3	0.5
TN	0.3	0.4
GA	0.3	0.4
AL	0.2	0.3
SC	0.2	0.2
TX	0.1	0.2
WI	0.1	0.2
MO	0.1	0.1
AR	0.1	0.1
FL	<0.05	0.1
CA	<0.05	<0.05
IA	<0.05	<0.05
MS	<0.05	<0.05
MN	<0.05	<0.05
LA	<0.05	<0.05
OK	<0.05	<0.05
KS	<0.05	<0.05
OR	<0.05	<0.05
SD	<0.05	<0.05
CO	0.0	0.0
DC	0.0	0.0
ID	0.0	0.0
MT	0.0	0.0
ND	0.0	0.0
NE	0.0	0.0
NM	0.0	0.0
UT	0.0	0.0
WY	0.0	0.0

New York		
State	kg	%
NY	212.3	30.2
PA	203.2	28.9
OH	53.7	7.6
NJ	46.0	6.5
WV	36.2	5.1
MD	28.5	4.0
MI	19.1	2.7
MA	15.2	2.2
IN	11.7	1.7
VA	11.1	1.6
KY	10.3	1.5
CT	10.1	1.4
NC	8.3	1.2
IL	7.6	1.1
TN	4.7	0.7
AL	4.3	0.6
GA	3.5	0.5
DE	2.8	0.4
WI	2.4	0.3
MO	1.8	0.2
TX	1.5	0.2
NH	1.5	0.2
SC	1.3	0.2
RI	1.0	0.1
IA	0.8	0.1
FL	0.8	0.1
AR	0.7	0.1
LA	0.5	0.1
MS	0.5	0.1
MN	0.4	0.1
KS	0.4	0.1
ME	0.3	<0.05
CA	0.3	<0.05
VT	0.3	<0.05
OK	0.2	<0.05
ND	0.1	<0.05
OR	0.1	<0.05
MT	<0.05	<0.05
ID	<0.05	<0.05
NM	<0.05	<0.05
UT	<0.05	<0.05
NE	<0.05	<0.05
WY	<0.05	<0.05
SD	<0.05	<0.05
CO	<0.05	<0.05
DC	<0.05	<0.05

Rhode Island		
State	kg	%
CT	4.8	25.1
RI	3.8	19.9
MA	3.8	19.7
PA	1.7	9.0
NY	1.6	8.5
NJ	0.9	4.9
MD	0.5	2.8
OH	0.3	1.6
VA	0.3	1.4
WV	0.3	1.3
NH	0.2	1.3
NC	0.1	0.7
MI	0.1	0.7
DE	0.1	0.5
IN	0.1	0.5
ME	0.1	0.4
KY	0.1	0.4
IL	0.1	0.3
TN	<0.05	0.2
AL	<0.05	0.1
SC	<0.05	0.1
GA	<0.05	0.1
WI	<0.05	0.1
MO	<0.05	0.1
TX	<0.05	0.1
VT	<0.05	0.1
FL	<0.05	<0.05
IA	<0.05	<0.05
CA	<0.05	<0.05
MN	<0.05	<0.05
MS	<0.05	<0.05
AR	<0.05	<0.05
KS	<0.05	<0.05
LA	<0.05	<0.05
OR	<0.05	<0.05
OK	<0.05	<0.05
SD	<0.05	<0.05
CO	0.0	0.0
DC	0.0	0.0
ID	0.0	0.0
MT	0.0	0.0
ND	0.0	0.0
NE	0.0	0.0
NM	0.0	0.0
UT	0.0	0.0
WY	0.0	0.0

Vermont		
State	kg	%
NY	13.5	19.6
PA	13.0	18.9
MA	11.9	17.3
NH	4.9	7.1
OH	3.5	5.1
NJ	3.3	4.7
MD	3.1	4.5
WV	2.4	3.5
VT	2.2	3.2
CT	1.7	2.4
MI	1.3	1.9
NC	1.1	1.6
VA	1.0	1.5
IN	1.0	1.5
KY	0.9	1.3
IL	0.6	0.9
RI	0.4	0.6
TN	0.4	0.6
GA	0.4	0.5
AL	0.4	0.5
ME	0.3	0.5
DE	0.3	0.5
WI	0.2	0.3
TX	0.2	0.3
SC	0.2	0.3
MO	0.1	0.2
AR	0.1	0.1
FL	0.1	0.1
IA	<0.05	0.1
CA	<0.05	0.1
MN	<0.05	0.1
MS	<0.05	<0.05
LA	<0.05	<0.05
OK	<0.05	<0.05
KS	<0.05	<0.05
ND	<0.05	<0.05
OR	<0.05	<0.05
SD	<0.05	<0.05
UT	<0.05	<0.05
MT	<0.05	<0.05
ID	<0.05	<0.05
NM	<0.05	<0.05
WY	<0.05	<0.05
CO	0.0	0.0
DC	0.0	0.0
NE	0.0	0.0

Table 6-2 Source Contributions to NEIWPCC Region and Individual States.

Tagged Sources to NEIWPCC Region	kg	%
PA_Other_utilities	56.9	4.6
MA_Pittsfield_RRF	50.0	4.0
PA_Montour	43.7	3.5
PA_Keystone	37.7	3.0
PA_Homer_City	36.0	2.9
NJ_Essex_Co._RRF	28.4	2.3
MA_Springfield_RRF	27.2	2.2
PA_Shawville	25.4	2.0
NY_American_Ref-Fuel_Co_Niagara	24.2	1.9
NY_Counties_bordering _Lake_Ontario	21.5	1.7
OH_Other_utilities	21.4	1.7
NY_Counties_bordering _NY/NJ_Harbor	21.4	1.7
NY_Niagara_Falls	21.1	1.7
NY_Wheelabrator _Westchester	20.7	1.7
NY_Niagara_Mohawk _Pwr_Corp	20.7	1.7
NH_SES_Claremont_ RRF_(Wheelerbrator_ Claremont)	16.9	1.4
NJ_Counties_bordering _NY/NJ_Harbor	16.6	1.3
CT_Bridgeport_RES_CO _(Wheelabrator)	15.3	1.2
ME_Mid_Maine_Waste _Action_Corp.	14.9	1.2
MA_Brayton_Point	14.7	1.2
PA_Harrisburg_WTE	14.0	1.1
CT_Mid-Connecticut _Project_(CRRA)	13.2	1.1
WV_Other_utilities	11.5	0.9
WV_Mt._Storm_Power _Station	11.0	0.9
MA_SE_Mass_RRF	10.0	0.8
NH_Merrimack	9.7	0.8
CT_Mattabassett_ Regional_Sewage_ Authority	9.1	0.7
CT_Southeastern_ Connecticut_RRF_ (American)	8.6	0.7
OH_Eastlake	8.5	0.7

Tagged Sources to NEIWPCC Region	kg	%
OH_Cardinal	8.5	0.7
MI_Sources_in_Detroit_ Metro	8.2	0.7
OH_W._H._Sammis	8.2	0.7
PA_Bruce_Mansfield	8.0	0.6
PA_General_Electric_Co.	7.9	0.6
MD_Brandon_Shores	7.5	0.6
CT_Naugatuck_ Treatment_Company	7.4	0.6
KY_Ghent	7.1	0.6
OH_Conesville	7.1	0.6
WV_John_E_Amos	7.0	0.6
MI_Monroe_Power_Plant	6.6	0.5
MD_Other_utilities	6.6	0.5
WV_Fort_Martin	6.2	0.5
RI_Rhode_Island_ Hospital	5.9	0.5
WV_Mitchell_(WV)	5.9	0.5
RI_Zambarano_Memorial _Hospital	5.6	0.5
MD_Chalk_Point	5.6	0.4
NJ_Co_Steel_Sayreville	5.2	0.4
NJ_Hudson	5.1	0.4
MD_Morgantown	4.9	0.4
IN_Other_Utilities_outside _Gary,_IN_MSA	4.5	0.4
WV_Philip_Sporn	4.3	0.3
MD_Baltimore_Res_Co	4.0	0.3
NC_Roxboro	3.9	0.3
RI_Narragansett_Bay _Commission_Fields_Pt.	3.9	0.3
OH_Kyger_Creek	3.9	0.3
KY_Big_Sandy	3.3	0.3
RI_Woonsocket _WWTF/NET_Co	3.2	0.3
VA_Chesterfield_Power _Station	2.8	0.2
OH_ASHTA_Chemicals_ Inc.	2.7	0.2
VT_Residential_Fuel _Combustion	2.6	0.2
MI_Central_Wayne _Co._Sanitation_Authority	2.5	0.2

Tagged Sources to NEIWPCC Region	kg	%
IN_Rockport	2.5	0.2
NC_Belews_Creek	2.5	0.2
IL_Other_utilities_outside_Chicago_MSA	2.3	0.2
IL_Other_non-utility_source_inside_Chicago_MSA	2.3	0.2
NJ_Camden_RRF	2.2	0.2
MD_Phoenix_Services_Inc._(Formerly_Medical_Waste_Associates)	2.0	0.2
ME_Greater_Portland_Region_RRF	1.9	0.2
DE_Indian_River	1.8	0.1
TN_Kingston_Fossil_Plant	1.7	0.1
MI_J._H._Campbell	1.6	0.1
KY_Paradise_Fossil_Plant	1.6	0.1
DE_Occidental_Chemical_Corp.	1.6	0.1
NC_Marshall	1.6	0.1
GA_Bowen	1.5	0.1
NH_Wheelabrator_Concord	1.5	0.1
WV_PPG_Industries_-_Inc.	1.4	0.1
IN_Clifty_Creek	1.4	0.1
MI_St_Clair_Power_Plant	1.4	0.1
VA_NASA_Refuse-fired_Steam_Generator	1.3	0.1
AL_Gorgas	1.3	0.1
IL_Other_utilities_inside_Chicago_MSA	1.3	0.1
IL_Powerton	1.3	0.1
DE_Edge_Moor	1.3	0.1
AL_Gaston	1.2	0.1
GA_Scherer	1.2	0.1
MO_Labadie	1.2	0.1
IN_Gibson_Generating_Station	1.1	0.1
IN_Tanners_Creek	1.1	0.1
VA_Norfolk_Navy_Yard	1.1	0.1
KY_H._L._Spurlock	1.0	0.1
AL_Miller	1.0	0.1
WI_Pleasant_Prairie	1.0	0.1
VA_Chesapeake_Energy	0.9	0.1

Tagged Sources to NEIWPCC Region	kg	%
_Center		
IL_Joliet_29	0.8	0.1
ME_Penobscot_Energy_Recovery	0.8	0.1
GA_Wansley	0.7	0.1
IL_Waukegan	0.7	0.1
TN_Gallatin_Fossil_Plant	0.7	0.1
TN_Johnsonville_Fossil_Plant	0.7	0.1
NC_BMW_NC	0.6	0.1
TX_Monticello	0.6	0.1

Tagged Sources to Connecticut	kg	%
CT_Mid-Connecticut _Project_(CRRA)	8.8	7.6
CT_Bridgeport_RES_CO _(Wheelabrator)	8.5	7.3
CT_Mattabassett_Region al_Sewage_Authority	6.3	5.4
CT_Naugatuck_ Treatment_Co.	5.3	4.6
MA_Springfield_RRF	5.3	4.6
NY_Wheelabrator Westchester	4.3	3.7
MA_Pittsfield_RRF	3.6	3.1
NJ_Essex_Co._RRF	3.4	2.9
PA_Other_utilities	3.0	2.6
CT_Southeastern_CT_ RRF	2.7	2.4
PA_Montour	2.1	1.8
NJ Counties at NY/NJ Harbor	1.9	1.6
NY Counties at NY/NJ Harbor	1.8	1.5
PA_Keystone	1.6	1.4
PA_Homer_City	1.5	1.3
PA_Shawville	1.0	0.8
MA_Brayton_Point	0.8	0.7
PA_Harrisburg_WTE	0.7	0.6
NJ_Co_Steel_Sayreville	0.6	0.6
NJ_Hudson	0.6	0.5
MD_Brandon_Shores	0.6	0.5
OH_Other_utilities	0.6	0.5
WV_Mt._Storm_Power_ Stn.	0.6	0.5
MA_SE_Mass_RRF	0.5	0.4
MD_Chalk_Point	0.5	0.4
MD_Other_utilities	0.4	0.4
WV_Other_utilities	0.4	0.4
MD_Morgantown	0.4	0.3
RI_Zambarano_Mem._ Hpl.	0.3	0.3
MD_Baltimore_Res_Co	0.3	0.3
VA_Chesterfield_Power_ Stn.	0.3	0.3
PA_General_Electric_Co.	0.3	0.2
NC_Roxboro	0.3	0.2
OH_Cardinal	0.3	0.2
NJ_Camden_RRF	0.3	0.2

Tagged Sources to Connecticut	kg	%
DE_Indian_River	0.3	0.2
WV_John_E_Amos	0.3	0.2
OH_W._H._Sammis	0.2	0.2
PA_Bruce_Mansfield	0.2	0.2
NH_SES_Claremont_RR F_(Wheelerbrator_ Claremont)	0.2	0.2
WV_Fort_Martin	0.2	0.2
RI_Rhode_Island_ Hospital	0.2	0.2
OH_Conesville	0.2	0.2
WV_Mitchell_(WV)	0.2	0.2
NY_Counties at Lake Ontario	0.2	0.2
KY_Ghent	0.2	0.2
RI_Narragansett_Bay _Commission_Fields_Pt.	0.2	0.2
VA_NASA_Refuse-fired_Steam_Generator	0.2	0.2
MI_Monroe_Power_Plant	0.2	0.2
MI_Sources_in_Detroit_ Metro	0.2	0.2
DE_Occidental_Chemical _Co	0.2	0.1
VA_Norfolk_Navy_Yard	0.2	0.1
OH_Eastlake	0.2	0.1
NY_American_Ref-Fuel_Co_Niagara	0.2	0.1
NH_Merrimack	0.2	0.1
NY_Niagara_Falls	0.2	0.1
NY_Niagara_Mohawk_ Pwr_Co	0.2	0.1
MD_Phoenix_Services_ Inc._(Formerly_Medical_ Waste_Assn.)	0.1	0.1
DE_Edge_Moor	0.1	0.1
VA_Chesapeake_Energy _Ctr.	0.1	0.1
RI_Woonsocket_WWTF/ NET	0.1	0.1
WV_Philip_Sporn	0.1	0.1
NC_Belews_Creek	0.1	0.1
IN_Other_Utilities_outside _Gary,_IN_MSA	0.1	0.1
OH_Kyger_Creek	0.1	0.1
KY_Big_Sandy	0.1	0.1
NC Sources by Waccama Lake	0.1	0.1

Tagged Sources to Connecticut	kg	%
NC_Marshall	0.1	0.1
IL_Other_utilities_outside_Chicago_MSA	0.1	0.1
WV_PPG_Industries_-_Inc.	0.1	0.1
OH_ASHTA_Chemicals_Inc.	0.1	0.1
IN_Rockport	0.1	0.1
IL_Other_non-utility_sources_inside_Chicago_MSA	0.1	0.1
DE_Motiva_Enterprises_(formerly_Star)	0.1	0.1

Tagged Sources to Maine	kg	%
ME_Mid_Maine_Waste_ Action_Corp.	13.9	12.2
PA_Other_utilities	3.8	3.3
PA_Keystone	2.7	2.4
PA_Homer_City	2.7	2.3
PA_Montour	2.5	2.2
NH_Merrimack	2.5	2.1
MA_Pittsfield_RRF	2.0	1.8
ME_Greater_Portland_ Region_RRF	1.7	1.5
OH_Other_utilities	1.6	1.4
MA_Brayton_Point	1.6	1.4
MA_SE_Mass_RRF	1.5	1.3
PA_Shawville	1.5	1.3
MA_Springfield_RRF	1.3	1.2
NH_SES_Claremont_ RRF_(Wheelerbrator_ Claremont)	1.3	1.1
NJ_Essex_Co._RRF	1.1	1.0
PA_Harrisburg_WTE	0.9	0.8
WV_Other_utilities	0.8	0.7
KY_Ghent	0.8	0.7
WV_Mt._Storm_Power_ Station	0.8	0.7
ME_Penobscot_Energy_ Recovery	0.8	0.7
NJ_Counties_bordering_ NY/NJ_Harbor	0.7	0.6
NY_Wheelabrator_Westc hester	0.7	0.6
NY_American_Ref-Fuel_Co_Niagara	0.7	0.6
MI_Sources_in_Detroit_ Metro	0.7	0.6
CT_Bridgeport_RES_CO _(Wheelabrator)	0.6	0.6
MD_Brandon_Shores	0.6	0.6
NY_Niagara_Falls	0.6	0.5
NY_Niagara Mohawk Pwr Corp	0.6	0.5
WV_John_E_Amos	0.6	0.5
NY_Counties at Lake Ontario	0.6	0.5
OH_Cardinal	0.5	0.5
OH_W._H._Sammis	0.5	0.5
NY_Counties at NY/NJ Harbor	0.5	0.5

Tagged Sources to Maine	kg	%
IN_Other_Utilities_outside _Gary,_IN_MSA	0.5	0.5
PA_Bruce_Mansfield	0.5	0.5
CT_Southeastern_ Connecticut_RRF_ (American)	0.5	0.4
ME_Dragon_Products_Co	0.5	0.4
MD_Chalk_Point	0.5	0.4
OH_Eastlake	0.5	0.4
MD_Other_utilities	0.5	0.4
OH_Conesville	0.5	0.4
MI_Monroe_Power_Plant	0.5	0.4
PA_General_Electric_ Company	0.5	0.4
NC_Roxboro	0.5	0.4
MD_Morgantown	0.5	0.4
WV_Fort_Martin	0.4	0.4
CT_Mid-Connecticut_Project_ (CRRA)	0.4	0.3
WV_Mitchell_(WV)	0.4	0.3
NH_Schiller_	0.3	0.3
IL_Other_non-utility_sources_inside_Chi cago_MSA	0.3	0.3
WV_Philip_Sporn	0.3	0.3
OH_Kyger_Creek	0.3	0.3
RI_Rhode_Island_ Hospital	0.3	0.3
CT_Mattabassett_ Regional_Sewage_ Authority	0.3	0.3
GA_Other_Sources	0.3	0.3
RI_Zambarano_Memorial _Hpt.	0.3	0.3
MD_Baltimore_Res_Co	0.3	0.3
NH_Wheelabrator_ Concord	0.3	0.3
IL_Other_utilities_outside _Chicago_MSA	0.3	0.3
NJ_Co_Steel_Sayreville	0.3	0.3
KY_Big_Sandy	0.3	0.3
VA_Chesterfield_Power_ Station	0.3	0.3
IN_Rockport	0.3	0.2
RI_Narragansett_Bay_ Commission_Fields_Pt.	0.3	0.2

Tagged Sources to Maine	kg	%
NC_Belews_Creek	0.3	0.2
RI_Woonsocket WWTF/NET Co	0.3	0.2
GA_Scherer	0.2	0.2
OH_ASHTA_Chemicals_ Inc.	0.2	0.2
CT_Naugatuck_ Treatment_Co.	0.2	0.2
NJ_Hudson	0.2	0.2
MI_J._H._Campbell	0.2	0.2
MI_Central_Wayne_Co._ Sanitation_Authority	0.2	0.2
GA_Bowen	0.2	0.2
TN_Kingston_Fossil_ Plant	0.2	0.2
IL_Other_utilities_inside_ Chicago_MSA	0.2	0.2
DE_Occidental_Chemical _Corp	0.2	0.2
NJ_Camden_RRF	0.2	0.1
DE_Indian_River	0.2	0.1
NC_Marshall	0.2	0.1
MO_Labadie	0.2	0.1
AL_Gaston	0.2	0.1
AL_Gorgas	0.2	0.1
IL_Powerton	0.2	0.1
KY_Paradise_Fossil_Plan t	0.2	0.1
IN_Clifty_Creek	0.2	0.1
MD_Phoenix_Services_I nc._(Formerly_Medical_W aste_Associates)	0.2	0.1
AL_Miller	0.1	0.1
IN_Gibson_Generating_ Station	0.1	0.1
WI_Pleasant_Prairie	0.1	0.1
KY_H._L._Spurlock	0.1	0.1
VA_NASA_Refuse-fired_Steam_Generator	0.1	0.1
WV_PPG_INDUSTRIES_ -_INC.	0.1	0.1
IL_Joliet_29	0.1	0.1
TX_Monticello	0.1	0.1
VT_Residential_Fuel_Co mbust.	0.1	0.1
MI_St_Clair_Power_Plant	0.1	0.1
GA_Wansley	0.1	0.1

Tagged Sources to Maine	kg	%
DE_Edge_Moor	0.1	0.1
IN_Tanners_Creek	0.1	0.1
VA_Norfolk_Navy_Yard	0.1	0.1
IL_Waukegan	0.1	0.1
NC_BMW_NC	0.1	0.1
TN_Olin_Corp.	0.1	0.1
VA_Chesapeake_Energy _Ctr.	0.1	0.1
TN_Gallatin_Fossil_Plant	0.1	0.1
TN_Johnsonville_Fossil_ Plant	0.1	0.1
IA_Other_utilities	0.1	0.1
MO_Rush_Island	0.1	0.1
AL_Sources_in_the_ Mobile_Bay_area	0.1	0.1

Tagged Sources to Massachusetts	kg	%
MA_Pittsfield_RRF	22.2	14.1
MA_Springfield_RRF	14.6	9.3
MA_Brayton_Point	9.4	6.0
MA_SE_Mass_RRF	6.3	4.0
RI_Rhode_Island_ Hospital	4.6	3.0
RI_Zambarano_Memorial _Hpt.	3.3	2.1
PA_Other_utilities	3.1	2.0
RI_Narragansett_Bay_Co mmission_Fields_Pt.	2.8	1.8
RI_Woonsocket WWTF/NET Co	2.3	1.5
CT_Mid-CT_Project_(CRRA)	2.2	1.4
NJ_Essex_Co._RRF	2.0	1.3
PA_Montour	1.9	1.2
CT_Southeastern_CT_ RRF	1.6	1.0
CT_Bridgeport_RES_CO _(Wheelabrator)	1.5	1.0
PA_Keystone	1.5	0.9
PA_Homer_City	1.4	0.9
NY_Wheelabrator_ Westchester	1.4	0.9
NJ_Counties at NY/NJ Harbor	1.1	0.7
CT_Mattabassett_ Regional_Sewage_ Authority	1.1	0.7
NH_SES_Claremont_ RRF	1.0	0.6
PA_Shawville	0.9	0.6
NY_Counties at NY/NJ Harbor	0.9	0.6
PA_Harrisburg_WTE	0.8	0.5
NH_Merrimack	0.8	0.5
MD_Brandon_Shores	0.8	0.5
OH_Other_utilities	0.7	0.5
WV_Mt._Storm_Power_ Station	0.7	0.5
CT_Naugatuck_ Treatment_Co.	0.6	0.4
MD_Chalk_Point	0.6	0.4
MD_Other_utilities	0.6	0.4
WV_Other_utilities	0.5	0.3
MD_Morgantown	0.5	0.3

Tagged Sources to Massachusetts	kg	%
NJ_Co_Steel_Sayreville	0.5	0.3
WV_John_E_Amos	0.4	0.2
MD_Baltimore_Res_Co	0.4	0.2
NJ_Hudson	0.4	0.2
NC_Roxboro	0.3	0.2
KY_Ghent	0.3	0.2
OH_Cardinal	0.3	0.2
VA_Chesterfield_Power_ Station	0.3	0.2
PA_Bruce_Mansfield	0.3	0.2
OH_W._H._Sammis	0.3	0.2
PA_General_Electric_ Company	0.3	0.2
NY_Counties at Lake Ontario	0.3	0.2
NY American Ref-Fuel Co Niag.	0.3	0.2
MI_Sources_in_Detroit_ Metro	0.3	0.2
WV_Fort_Martin	0.3	0.2
OH_Conesville	0.3	0.2
DE_Indian_River	0.2	0.2
NJ_Camden_RRF	0.2	0.2
NY_Niagara_Falls	0.2	0.2
MI_Monroe_Power_Plant	0.2	0.1
WV_Mitchell_(WV)	0.2	0.1
OH_Eastlake	0.2	0.1
NY_Niagara_Mohawk_ Pwr_Co.	0.2	0.1
ME_Mid_Maine_Waste_ Action	0.2	0.1
WV_Philip_Sporn	0.2	0.1
IN_Other Util. outside Gary, IN	0.2	0.1
OH_Kyger_Creek	0.2	0.1
NC_Belews_Creek	0.2	0.1
VA NASA Refuse-fired_Steam_Generator	0.2	0.1
MD_Phoenix_Services_ Inc._(Formerly Medical Waste Asc.)	0.2	0.1
DE_Occidental_Chemical _Corp.	0.2	0.1
KY_Big_Sandy	0.2	0.1
VA_Norfolk_Navy_Yard	0.2	0.1
DE_Edge_Moor	0.1	0.1

Tagged Sources to Massachusetts	kg	%
VT_Residential FuelCombustion	0.1	0.1
VA_Chesapeake_Energy _Ctr.	0.1	0.1
NC_Marshall	0.1	0.1
IN_Rockport	0.1	0.1
IL_Other util.outside Chicago	0.1	0.1
OH_ASHTA_Chemicals_ Inc.	0.1	0.1
NH_Wheelabrator_ Concord	0.1	0.1
IL_Other non-utility sources inside Chicago MSA	0.1	0.1
TN_Kingston_Fossil_ Plant	0.1	0.1
MI_Central_Wayne_Co._ Sanitation_Authority	0.1	0.1
GA_Bowen	0.1	0.1

Tagged Sources to New Hampshire)	kg	%
NH_SES_Claremont_RRF_(Wheelerbrator_Claremont)	10.0	14.5
NH_Merrimack	5.3	7.6
MA_Pittsfield_RRF	3.4	4.9
MA_Springfield_RRF	2.0	2.9
PA_Other_utilities	2.0	2.9
PA_Montour	1.4	2.0
PA_Keystone	1.1	1.7
PA_Homer_City	1.1	1.7
NH_Wheelabrator_Concord	1.0	1.4
NJ_Essex_Co._RRF	0.9	1.3
PA_Shawville	0.7	1.0
OH_Other_utilities	0.7	1.0
CT_Bridgeport_RES_CO_(Wheelabrator)	0.6	0.9
MA_Brayton_Point	0.6	0.9
NY_Wheelabrator_Westchester	0.6	0.8
NJ_Counties_bordering_NY/NJ_Harbor	0.5	0.8
CT_Mid-Connecticut_Project_(CRRA)	0.5	0.7
MA_SE_Mass_RRF	0.5	0.7
PA_Harrisburg_WTE	0.5	0.7
ME_Mid_Maine_Waste_Action_Corp.	0.5	0.7
WV_Other_utilities	0.4	0.6
MD_Brandon_Shores	0.4	0.6
NY_Counties_bordering_NY/NJ_Harbor	0.4	0.6
WV_Mt._Storm_Power_Station	0.4	0.6
KY_Ghent	0.3	0.5
CT_Southeastern_Connecticut_RRF_(American)	0.3	0.5
MD_Chalk_Point	0.3	0.5
MD_Other_utilities	0.3	0.5
CT_Mattabassett_Regional_Sewage_Authority	0.3	0.4
VT_Residential_Fuel_Combustion	0.3	0.4
MD_Morgantown	0.3	0.4

Tagged Sources to New Hampshire)	kg	%
OH_Cardinal	0.3	0.4
OH_W._H._Sammis	0.3	0.4
WV_John_E_Amos	0.3	0.4
NC_Roxboro	0.3	0.4
MI_Sources_in_Detroit_Metro	0.3	0.4
PA_Bruce_Mansfield	0.3	0.4
NY_American_Ref-Fuel_Co_Niagara	0.2	0.4
PA_General_Electric_Company	0.2	0.3
NY_Counties_bordering_Lake_Ontario	0.2	0.3
OH_Conesville	0.2	0.3
RI_Zambarano_Memorial_Hospital	0.2	0.3
NY_Niagara_Mohawk_Pwr_Corp	0.2	0.3
NY_Niagara_Falls	0.2	0.3
CT_Naugatuck_Treatment_Company	0.2	0.3
WV_Fort_Martin	0.2	0.3
NJ_Co_Steel_Sayreville	0.2	0.3
MD_Baltimore_Res_Co	0.2	0.3
WV_Mitchell_(WV)	0.2	0.3
MI_Monroe_Power_Plant	0.2	0.3
IN_Other_Utilities_outside_Gary,_IN_MSA	0.2	0.3
OH_Eastlake	0.2	0.3
VA_Chesterfield_Power_Station	0.2	0.3
NJ_Hudson	0.2	0.2
WV_Philip_Sporn	0.2	0.2
OH_Kyger_Creek	0.1	0.2
RI_Woonsocket_WWTF/NET_Co	0.1	0.2
NC_Belews_Creek	0.1	0.2
IN_Rockport	0.1	0.2
RI_Rhode_Island_Hospital	0.1	0.2
KY_Big_Sandy	0.1	0.2
ME_Greater_Portland_Region_RRF	0.1	0.2
NJ_Camden_RRF	0.1	0.2
RI_Narragansett_Bay_Commission_Fields_Pt.	0.1	0.2
DE_Indian_River	0.1	0.2

Tagged Sources to New Hampshire)	kg	%
MD_Phoenix_Services_ Inc._(Formerly_Medical_ Waste_Associates)	0.1	0.2
IL_Other_utilities_outside_ Chicago_MSA	0.1	0.1
DE_Occidental_Chemical _Corporation	0.1	0.1
NH_Schiller_	0.1	0.1
NC_Marshall	0.1	0.1
VA_NASA_Refuse-fired_Steam_Generator	0.1	0.1
MI_Central_Wayne_Co._ Sanitation_Authority	0.1	0.1
IL_Other_non-utility_sources_inside_Chicago_MSA	0.1	0.1
OH_ASHTA_Chemicals_ Inc.	0.1	0.1
DE_Edge_Moor	0.1	0.1
TN_Kingston_Fossil_Plant	0.1	0.1
KY_Paradise_Fossil_Plant	0.1	0.1
GA_Scherer	0.1	0.1
GA_Bowen	0.1	0.1
VA_Norfolk_Navy_Yard	0.1	0.1
MO_Labadie	0.1	0.1
IN_Clifty_Creek	0.1	0.1
MI_J._H._Campbell	0.1	0.1
WV_PPG_INDUSTRIES_-_INC.	0.1	0.1
VA_Chesapeake_Energy_ Center	0.1	0.1
IL_Powerton	0.1	0.1
KY_H._L._Spurlock	0.1	0.1

Tagged Sources to New York	kg	%
PA_Other_utilities	41.6	5.9
PA_Montour	33.7	4.8
PA_Keystone	28.8	4.1
PA_Homer_City	27.4	3.9
NY_American_Ref-Fuel_Co_Niagara	22.4	3.2
PA_Shawville	20.1	2.9
NY_Counties_bordering_Lake_Ontario	19.8	2.8
NJ_Essex_Co._RRF	19.5	2.8
NY_Niagara_Falls	19.4	2.8
NY_Niagara_Mohawk_Pwr_Corp	19.1	2.7
NY_Counties_bordering_NY/NJ_Harbor	17.0	2.4
OH_Other_utilities	16.5	2.3
NY_Wheelabrator_Westchester	12.6	1.8
NJ_Counties_bordering_NY/NJ_Harbor	11.5	1.6
PA_Harrisburg_WTE	10.4	1.5
MA_Pittsfield_RRF	9.2	1.3
WV_Other_utilities	8.7	1.2
WV_Mt._Storm_Power_Station	8.0	1.1
OH_Eastlake	7.0	1.0
OH_Cardinal	6.7	0.9
MI_Sources_in_Detroit_Metro	6.4	0.9
OH_W._H._Sammis	6.4	0.9
PA_Bruce_Mansfield	6.2	0.9
PA_General_Electric_Company	6.1	0.9
OH_Conesville	5.5	0.8
WV_John_E_Amos	5.2	0.7
MI_Monroe_Power_Plant	5.1	0.7
KY_Ghent	4.9	0.7
WV_Fort_Martin	4.7	0.7
WV_Mitchell_(WV)	4.5	0.6
MD_Brandon_Shores	4.4	0.6
MD_Other_utilities	4.3	0.6
NJ_Hudson	3.5	0.5
CT_Bridgeport_RES_CO_(Wheelabrator)	3.4	0.5
NJ_Co_Steel_Sayreville	3.3	0.5
WV_Philip_Sporn	3.2	0.5

Tagged Sources to New York	kg	%
MD_Chalk_Point	3.2	0.5
IN_Other_Utilities_outside_Gary,_IN_MSA	3.2	0.5
OH_Kyger_Creek	2.9	0.4
MD_Morgantown	2.9	0.4
MD_Baltimore_Res_Co	2.5	0.4
KY_Big_Sandy	2.4	0.3
MA_Springfield_RRF	2.3	0.3
NC_Roxboro	2.2	0.3
OH_ASHTA_Chemicals_Inc	2.1	0.3
MI_Central_Wayne_Co._Sanitation_Authority	2.0	0.3
IN_Rockport	1.7	0.2
IL_Other_utilities_outside_Chicago_MSA	1.6	0.2
IL_Other_non-utility_sources_inside_Chicago_MSA	1.6	0.2
NC_Belews_Creek	1.5	0.2
VA_Chesterfield_Power_Station	1.5	0.2
MD_Phoenix_Services_Inc._(Formerly_Medical_Waste_Associates)	1.3	0.2
TN_Kingston_Fossil_Plant	1.2	0.2
MI_J._H._Campbell	1.2	0.2
KY_Paradise_Fossil_Plant	1.2	0.2
NJ_Camden_RRF	1.2	0.2
MI_St_Clair_Power_Plant	1.1	0.2
GA_Bowen	1.1	0.1
WV_PPG_INDUSTRIES_-_INC.	1.0	0.1
IN_Clifty_Creek	1.0	0.1
NC_Marshall	1.0	0.1
AL_Gorgas	0.9	0.1
MA_Brayton_Point	0.9	0.1
IL_Powerton	0.9	0.1
IL_Other_utilities_inside_Chicago_MSA	0.9	0.1
DE_Indian_River	0.9	0.1
AL_Gaston	0.8	0.1
DE_Occidental_Chemical_Corporation	0.8	0.1
CT_Mid-Connecticut_Project_(CRRA)	0.8	0.1

Tagged Sources to New York	kg	%
IN_Tanners_Creek	0.8	0.1
CT_Naugatuck_Treatment _Company	0.8	0.1
MO_Labadie	0.8	0.1
IN_Gibson_Generating _Station	0.8	0.1
CT_Mattabassett _Regional_Sewage _Authority	0.7	0.1
DE_Edge_Moor	0.7	0.1
GA_Scherer	0.7	0.1
KY_H._L._Spurlock	0.7	0.1
WI_Pleasant_Prairie	0.7	0.1
AL_Miller	0.7	0.1
NH_SES_Claremont _RRF_(Wheelerbrator _Claremont)	0.7	0.1
VA_NASA_Refuse-fired_Steam_Generator	0.6	0.1
CT_Southeastern _Connecticut_RRF _(American)	0.6	0.1
IL_Joliet_29	0.6	0.1
MA_SE_Mass_RRF	0.5	0.1
VA_Norfolk_Navy_Yard	0.5	0.1
IL_Waukegan	0.5	0.1
TN_Gallatin_Fossil_Plant	0.5	0.1
GA_Wansley	0.5	0.1
NH_Merrimack	0.4	0.1
TN_Johnsonville_Fossil_ Plant	0.4	0.1
VA_Chesapeake_Energy _Center	0.4	0.1
AL_Sources_in_the _Mobile_Bay_area	0.4	0.1
IA_Other_utilities	0.4	0.1
VA_Jewel_Coke _Company_LLP	0.4	0.1
TX_Monticello	0.4	0.1
NC_BMW_NC	0.4	0.1

Tagged Sources to Rhode Island	kg	%
CT_Southeastern_Connecticut_RRF_(American)	2.7	14.4
RI_Zambarano_Memorial_Hpt.	1.1	5.9
MA_Brayton_Point	0.9	4.8
MA_Springfield_RRF	0.8	4.4
MA_Pittsfield_RRF	0.5	2.7
PA_Other_utilities	0.4	2.0
MA_SE_Mass_RRF	0.3	1.8
NJ_Essex_Co._RRF	0.3	1.8
RI_Rhode_Island_Hospital	0.3	1.8
CT_Mid-Connecticut_Project_(CRRA)	0.3	1.5
CT_Mattabassett_Regional_Sewage_Authority	0.3	1.5
RI_Narragansett_Bay_Commission_Fields_Pt.	0.3	1.5
PA_Montour	0.3	1.4
CT_Bridgeport_RES_CO_(Wheelabrator)	0.2	1.3
NJ_Counties_bordering_NY/NJ_Harbor	0.2	1.0
NY_Wheelabrator_Westchester	0.2	1.0
PA_Keystone	0.2	1.0
PA_Homer_City	0.2	0.9
RI_Woonsocket_WWTF/NET_Co	0.2	0.9
NY_Counties_bordering_NY/NJ_Harbor	0.1	0.8
PA_Shawville	0.1	0.7
CT_Naugatuck_Treatment_Company	0.1	0.6
OH_Other_utilities	0.1	0.5
MD_Brandon_Shores	0.1	0.5
PA_Harrisburg_WTE	0.1	0.5
WV_Mt._Storm_Power_Station	0.1	0.4
NH_SES_Claremont_RRF_(Wheelerbrator_Claremont)	0.1	0.4
NJ_Co_Steel_Sayreville	0.1	0.4
NH_Merrimack	0.1	0.4
MD_Chalk_Point	0.1	0.4
MD_Morgantown	0.1	0.3
MD_Other_utilities	0.1	0.3
NJ_Hudson	0.1	0.3
WV_Other_utilities	0.1	0.3

Tagged Sources to Vermont	kg	%
MA_Pittsfield_RRF	9.1	13.2
NH_SES_Claremont_RRF _(Wheelerbrator _Claremont)	3.6	5.2
PA_Other_utilities	3.0	4.3
PA_Montour	2.0	2.9
VT_Residential_Fuel _Combustion	1.8	2.6
PA_Keystone	1.8	2.5
PA_Homer_City	1.7	2.4
NJ_Essex_Co._RRF	1.2	1.7
OH_Other_utilities	1.2	1.7
PA_Shawville	1.0	1.5
NY_Wheelabrator _Westchester	0.9	1.3
MA_Springfield_RRF	0.8	1.2
NJ_Counties_bordering _NY/NJ_Harbor	0.7	1.0
PA_Harrisburg_WTE	0.7	1.0
WV_Other_utilities	0.6	0.9
NY_Counties_bordering _NY/NJ_Harbor	0.6	0.8
MD_Brandon_Shores	0.6	0.8
NH_Merrimack	0.5	0.8
WV_Mt._Storm_Power _Station	0.5	0.7
CT_Bridgeport_RES_CO _(Wheelabrator)	0.5	0.7
KY_Ghent	0.5	0.7
NY_Counties_bordering _Lake_Ontario	0.4	0.7
OH_Cardinal	0.4	0.6
NY_American_Ref-Fuel_Co_Niagara	0.4	0.6
NY_Niagara_Falls	0.4	0.6
MI_Sources_in_Detroit _Metro	0.4	0.6
NY_Niagara_Mohawk_Pwr _Corp	0.4	0.6
OH_W._H._Sammis	0.4	0.6
MA_Brayton_Point	0.4	0.6
PA_General_Electric _Company	0.4	0.6
MD_Chalk_Point	0.4	0.6
MD_Other_utilities	0.4	0.6
OH_Eastlake	0.4	0.6

Tagged Sources to Vermont	kg	%
PA_Bruce_Mansfield	0.4	0.6
OH_Conesville	0.4	0.6
MD_Morgantown	0.4	0.5
MI_Monroe_Power_Plant	0.3	0.5
WV_John_E_Amos	0.3	0.5
WV_Fort_Martin	0.3	0.5
NC_Roxboro	0.3	0.5
WV_Mitchell_(WV)	0.3	0.4
IN_Other_Utilities_outside _Gary,_IN_MSA	0.3	0.4
MA_SE_Mass_RRF	0.3	0.4
NJ_Co_Steel_Sayreville	0.3	0.4
MD_Baltimore_Res_Co	0.3	0.4
WV_Philip_Sporn	0.2	0.3
NJ_Hudson	0.2	0.3
CT_Mid-Connecticut_Project_ (CRRA)	0.2	0.3
OH_Kyger_Creek	0.2	0.3
NC_Belews_Creek	0.2	0.3
IN_Rockport	0.2	0.3
VA_Chesterfield_Power _Station	0.2	0.3
CT_Southeastern _Connecticut_RRF _(American)	0.2	0.3
KY_Big_Sandy	0.2	0.2
NJ_Camden_RRF	0.2	0.2
CT_Mattabassett _Regional_Sewage _Authority	0.1	0.2
OH_ASHTA_Chemicals_Inc	0.1	0.2
IL_Other_utilities_outside _Chicago_MSA	0.1	0.2
NC_Marshall	0.1	0.2
MI_Central_Wayne_Co. _Sanitation_Authority	0.1	0.2
MD_Phoenix_Services_Inc. _(Formerly_Medical_Waste _Associates)	0.1	0.2
ME_Mid_Maine_Waste_ Action _Corp.	0.1	0.2
CT_Naugatuck_Treatment _Company	0.1	0.2

Tagged Sources to Vermont	kg	%
IL_Other_non-utility_sources_inside_Chicago_MSA	0.1	0.2
DE_Occidental_Chemical_Corporation	0.1	0.2
KY_Paradise_Fossil_Plant	0.1	0.2
RI_Zambarano_Memorial_Hospital	0.1	0.1
GA_Bowen	0.1	0.1
DE_Edge_Moor	0.1	0.1
MI_J._H._Campbell	0.1	0.1
DE_Indian_River	0.1	0.1
IN_Clifty_Creek	0.1	0.1
TN_Kingston_Fossil_Plant	0.1	0.1
RI_Rhode_Island_Hospital	0.1	0.1
WV_PPG_INDUSTRIES_-_INC.	0.1	0.1
GA_Scherer	0.1	0.1
NH_Wheelabrator_Concord	0.1	0.1
KY_H._L._Spurlock	0.1	0.1
IL_Powerton	0.1	0.1
MO_Labadie	0.1	0.1
AL_Gaston	0.1	0.1
RI_Narragansett_Bay_Commission_Fields_Pt.	0.1	0.1
AL_Gorgas	0.1	0.1
IN_Gibson_Generating_Station	0.1	0.1
IL_Other_utilities_inside_Chicago_MSA	0.1	0.1
RI_Woonsocket_WWTF/NET_Co	0.1	0.1
IN_Tanners_Creek	0.1	0.1
MI_St_Clair_Power_Plant	0.1	0.1
VA_NASA_Refuse-fired_Steam_Generator	0.1	0.1
AL_Miller	0.1	0.1
WI_Pleasant_Prairie	0.1	0.1
GA_Wansley	0.1	0.1
NC_BMW_NC	0.1	0.1
TN_Johnsonville_Fossil_Plant	0.1	0.1

7. APPENDIX B: QUALITY ASSURANCE PROJECT PLAN

1.1 Title and Approval Page

Quality Assurance Project Plan for the NEIWPCC Mercury Project

January 23, 2008

New England Interstate Water Pollution Control Commission (NEIWPCC)
116 John Street
Boott Mills South
Lowell, MA 01852-1124
978.323.7929

Northeast States for Coordinated Air Use Management (NESCAUM)
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Boston, MA 02114
617.259.2000

APPROVAL SIGNATURES

_____	_____
Arthur Marin, Executive Director, NESCAUM	Date
_____	_____
Michael Jennings, Quality Assurance Manager, NEIWPCC	Date
_____	_____
Charla Rudisill, Quality Assurance Manager, NESCAUM	Date
_____	_____
Susannah L. King, Project Manager, NEIWPCC	Date
_____	_____
Paul J. Miller, Project Manager, NESCAUM	Date
_____	_____
John Graham, QA Reviewer, NESCAUM	Date
_____	_____
Jeri Weiss, Project Officer, U.S. EPA Region 1	Date
_____	_____
Quality Assurance Officer, U.S. EPA Region 1	Date

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1.2 QAPP Distribution List

Arthur Main, NESCAUM, Executive Director
Paul Miller, NESCAUM, Deputy Director & Project Manager*
Susannah L. King, NEIWPCC, Project Manager*
Michael Jennings, NEIWPCC, Quality Assurance Manager
Gary Kleiman, NESCAUM, Science and Technology Team Leader
Charla Rudisill, NESCAUM, Quality Assurance Manager
John Graham, NESCAUM**,** QA Reviewer
Jeri Weiss, U.S. EPA Region 1, Project Officer
U.S. EPA Region 1, Quality Assurance Officer

*Primary Contacts

1.3 Purpose and Background

Purpose

The purpose of this project is to compile existing REMSAD modeling information on mercury deposition in the NEIWPCC region and apportion it by source region and major source category. This will be useful in regulatory and policy decisions, for example relating to TMDLs for mercury-impaired water bodies. Specifically, the NEIWPCC states will use the REMSAD information to identify and rank (in a relative sense) source regions and individual sources that the model identifies as making a contribution to atmospheric mercury deposition in a NEIWPCC state and in the NEIWPCC region. These source regions and individual sources, therefore, can have an impact on exceedances of a regional Northeast mercury TMDL.

Background

The U.S. Environmental Protection Agency (EPA) has developed a mandatory Agency-wide Quality Assurance Program that requires all organization performing work for EPA to develop and operate management processes for assuring that data or information collected are of the needed and expected quality for their intended use. It also required that environmental technology used for pollution control is designed, constructed, and operated according to defined specification and protocols. These requirements apply to all organizations that conduct environmental data operations on behalf of EPA through contracts, financial assistance agreements, and interagency agreements.

This document states the Quality Assurance Project Plan (QAPP) by the New England Interstate Water Pollution Control Commission (NEIWPCC) and the Northeast States for Coordinated Air Use Management (NESCAUM) for compiling existing information from modeled mercury deposition in the Northeast. In all data collection activities, it is NESCAUM's intent to provide procedures that ensure the highest level of quality assurance that is appropriate for the intended use of the data.

1.4 Project Objectives and Use of Secondary Data

Objectives

NESCAUM will assist the NEIWPCC states in clarifying various upwind contributions to mercury deposition in the northeastern United States to improve the understanding of mercury deposition in the NEIWPCC region.

Mercury emissions have become of increasing concern in recent years due to mercury's role as a persistent, bioaccumulative, neurotoxic pollutant. When released into the environment and deposited or carried into water bodies, mercury is easily converted to methylmercury, a particularly toxic form of mercury. Methylmercury readily passes up the food chain, accumulating in the tissues of fish and other animals. Ingestion of methylmercury can cause numerous adverse effects in plants, birds, and mammals, including humans.

Use of Secondary Data

NESCAUM and EPA have independently conducted modeling simulations using the REMSAD regional air quality model to better understand the impact of various emitting sources and regions on local ecosystems and populations. A unique aspect of the modeling work is the Particle and Precursor Tagging Methodology (PPTM) feature. The PPTM approach permits the user to track emissions from a specific source, source category, source region, or combination of these by assigning a "tag" to the emissions. The tagging scheme is an accounting system that follows species through space and time in the model without disturbing the physical or chemical processes affecting that species. With careful consideration, the user can establish a model run to assess the impact and influence of several specific modeled sources, source categories, or control measures. This work has supported efforts by the Northeast States under the New England Governors/Eastern Canadian Premieres' Mercury Action Plan (MAP) and other state and federal initiatives to control mercury emissions.

The secondary data used in this project consist of the modeled mercury deposition outputs from the two previous tagged mercury REMSAD modeling investigations. The previous modeling efforts incorporate mercury emission inventory data developed by EPA, the NESCAUM states (CT, ME, MA, NH, NJ, NY, RI, VT), and others. Total mercury deposition outputs from these modeling efforts will be summarized according to upwind contribution from sources or source regions to specific downwind receptors (e.g., defined by state borders or watershed topography). We will use standard Microsoft® Access database management software to summarize the modeled outputs. The Access software is an aid for summarizing the existing modeled data according to various criteria we choose to aggregate the information by, and does not change the values of the modeled data.

1.5 Secondary Data Needed

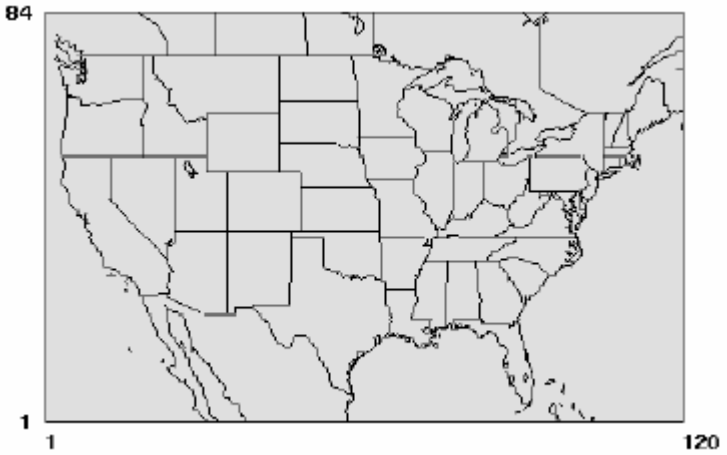
The secondary data in this project come from two sources:

1. REMSAD modeling by NESCAUM. NESCAUM previously modeled the impact of various mercury source categories on receptors (grid cells) downwind by analyzing the mercury concentrations located in the surface layer and deposited via wet and dry deposition. A QAPP was separately done for this modeling effort in November 2004 and approved by EPA (EPA Region 1 Project Manager Alison Simcox – see Appendix A). NESCAUM completed the modeling in January 2006 with a final report in October 2007.

The NESCAUM work employed the Regional Modeling System for Aerosols and Deposition (REMSAD version 7.13), which is a three-dimensional Eulerian grid model developed by Systems Applications International, Inc. EPA and others have used the model to simulate the physical and chemical atmospheric processes relevant to atmospheric pollutants, including fine particles and air toxics. The model relies on the continuity equation, which represents the mass balance of each species by mathematically tracking emissions, advection, diffusion, chemical reactions, and removal processes. The requirements and parameters of the modeling exercise are listed below.

Modeling Specifications

REMSAD v7.13
National Domain (lat/long)



Modeling Domain

120 (E-W) by 84 (N-S) grid cells
Cell size (~36 km)
1/2 degree longitude (0.5)
1/3 degree latitude (0.3333)
E-W range: 66º W - 126º W
N-S range: 24º N - 52º N
Vertical extent: Ground to 16,200 meters (100mb) with 12 layers

Datasets

Emissions Inventories – The emission inventories developed or obtained by NESCAUM were the subject of a previous QAPP (separate from the modeling QAPP referenced above) in November 2004, and approved by EPA (EPA Region 1 Project Manager Alison Simcox – see Appendix B).

Mercury emissions:

- For emissions outside Northeast:
  - EPA's 1996 Hg inventory for the Clear Skies Act
  - 2000 Canadian Hg Emissions (inventory provided by EPA)
- For emissions within Northeast
  - NESCAUM's Hg updated inventory for 2002/03

Criteria pollutants emissions:

- 2001 "proxy" surface and point emission files for criteria pollutants provided by EPA via Clear Skies Act of 2003.

Meteorology

- 1996 36 km 12 layer meteorology (provided by EPA)

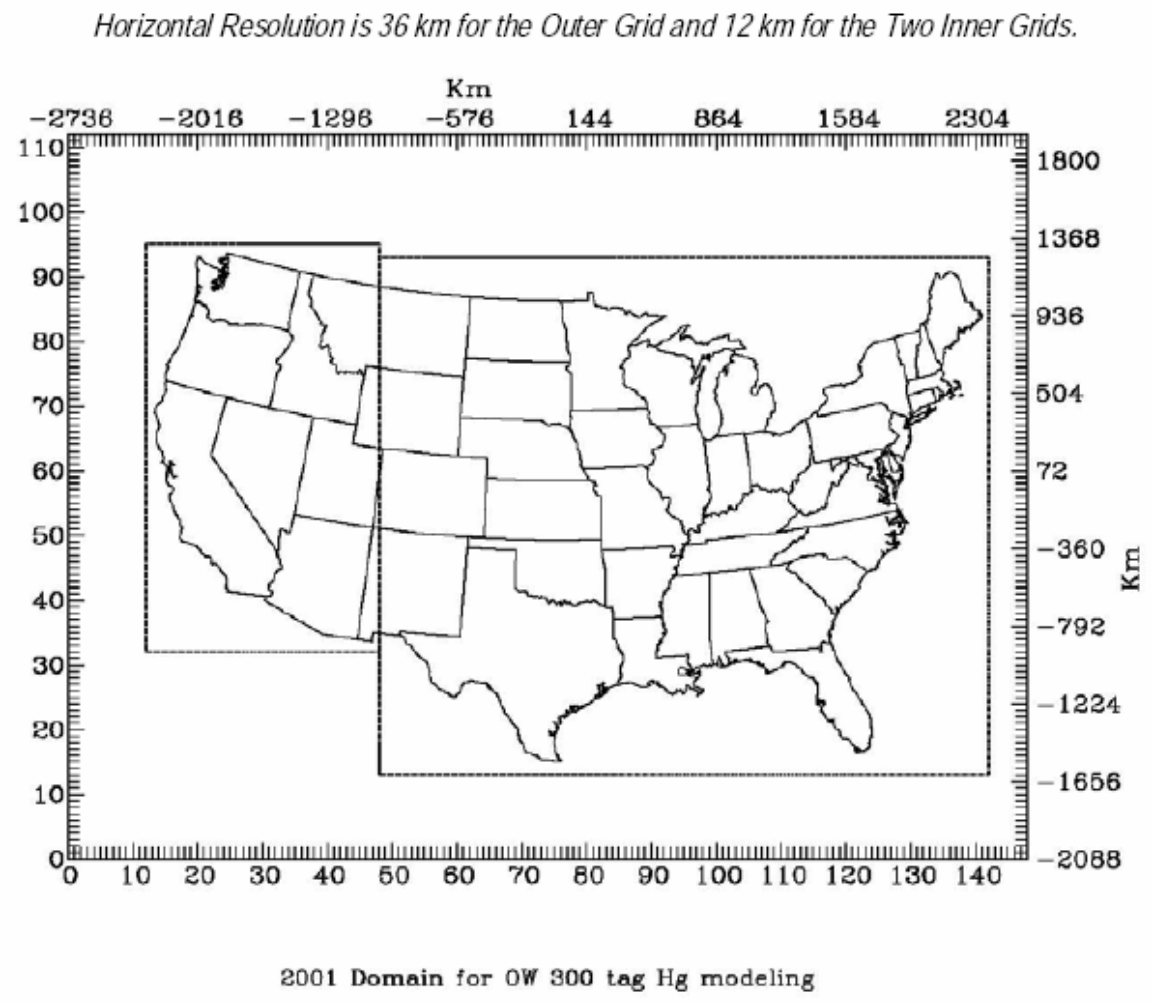
2. REMSAD modeling by ICF International under contract to the EPA Office of Water. This effort for EPA applied REMSAD to support an analysis of the sources of airborne mercury and their contribution to water quality impairment and fish contamination throughout the continental U.S. The objective of the study was to use atmospheric deposition modeling to quantify contributions of specific sources and source categories to mercury deposition within each of the lower 48 states. The results of the study were expected to provide state and local air and water quality agencies with 1) an improved understanding of the sources and mechanisms contributing to mercury deposition and 2) supporting information for future analyses of Total Maximum Daily Loads (TMDLs) and identification of effective control measures for achieving water quality standards. The final report to EPA on this work is dated November 30, 2006.

Modeling Specifications

REMSAD v8
National Domain (lat/long)

Modeling Domain (see figure below)

36 km outer grid
Two 12 km nested inner grids over eastern three quarters and western quarter of U.S., encompassing entire U.S. at 12 km scale grid resolution



Datasets

Emissions Inventories

Mercury emissions:

- U.S. and Canada - 2001 Clean Air Mercury Rule inventory from EPA with documented state-specific changes from EPA regional offices and their member states where necessary (described in ICF report).
- Mexico – 1999 point source mercury emissions from the Commission for Environmental Cooperation, *Preliminary Atmospheric Emissions Inventory of Mercury in Mexico, Report No. 3.2.1.04*, 2001 (www.cec.org).

Criteria pollutants emissions:

- 2001 emission inventory for criteria pollutants prepared by EPA for the Clean Air Interstate Rule.

Meteorology

- 2001 36 km meteorology from MM5 prepared by EPA for the Clean Air Interstate Rule and Clean Air Mercury Rule

1.6 Data Analysis

NESCAUM will take the extensive individual source-tagging already conducted by the EPA Water Program and use Microsoft® Access database management software to provide a state-by-state source apportionment of contributing upwind states to downwind mercury deposition in selected areas. Summarizing the REMSAD data with Access will not create new or alter existing data from the modeling studies (hence it does not introduce additional uncertainty sources to the modeled data). It will summarize and display the existing REMSAD mercury deposition outputs according to regions of interest selected by NESCAUM.

1.7 Responsibilities

Commitment to and direct responsibility for the quality objectives and operations detailed in this QAPP begins with the NESCAUM Executive Director and continues through to the Project Managers. The authority and responsibility for directing QA activities within NESCAUM and NEIWPCC have been delegated to the designated QAMs. The QAMs will not be directly involved in compiling and evaluating data and data sources.

Paul Miller, NESCAUM, and Susannah King, NEIWPCC, the Project Managers, will oversee the compilation and reporting of data taken from existing sources (i.e., secondary data). QA review will be conducted by John Graham, NESCAUM QA Reviewer. Jeri Weiss is the EPA Region 1 Project Manager.

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	EPA Region 1, Quality Assurance Officer	EPA New England Regional Laboratory 11 Technology Drive North Chelmsford, MA 01863		

1.8 Project Schedule and Deliverables

NESCAUM will compile and summarize the modeling data sources in a draft report for delivery on or before February 15, 2008. NESCAUM will consider and revise the draft summary report on or before March 15, 2008.

2.1 Sources of Secondary Data

The two REMSAD modeling information sources are:

1. Northeast States for Coordinated Air Use Management (NESCAUM), *Modeling Mercury in the Northeast United States*, (Boston, MA) October 2007. Submitted to the Massachusetts Department of Environmental Protection and U.S. EPA Region 1.

2. ICF International, *Model-based Analysis and Tracking of Airborne Mercury Emissions to Assist in Watershed Planning*, Final Report (San Rafael, CA) November 30, 2006. Prepared for EPA Office of Water, Washington, DC.

2.2 Data Generators

The secondary data used in this project were generated by the organizations listed in Section 2.1 above. Inventory information used as inputs into the modeling studies largely come from EPA inventories, with specific corrections provided by EPA regional offices, states, and internal quality checks by each organization. The modeling information was generated over the 2005-2006 time period.

2.3 Source Hierarchy

There is no data source hierarchy in this project.

2.4 Data Source Selection Rationale

The data sources are the only two modeling efforts that generated tagged mercury deposition data specific to the region of interest in the Northeast. Both efforts used emission inventory inputs developed and reviewed by EPA and the states.

2.5 Identification of Data Sources

The sources of secondary data gathered in this project will be identified in the project deliverable.

3.1 Data Quality Requirements

The REMSAD modeling performed by NESCAUM, along with the mercury inventory inputs, were subject to prior QAPPs approved by EPA Region 1 (Alison Simcox, Region 1 Project Officer). The generated data are specifically intended for their use in this project – modeling the contribution of mercury emissions from upwind regions or sources to downwind total mercury deposition. Likewise, the REMSAD modeling performed by ICF International generated data that is specifically intended for the same use as this project. The ICF modeling data were prepared for the EPA using EPA emission inventory inputs.

3.2 Determining Data Quality

Given that EPA has used the REMSAD model for mercury, we assume that a certain amount of model validation has been performed already. In this project, we will assess data quality in both the NESCAUM and ICF studies by relying on each study's reported model performance evaluations. In each study, modeled deposition results were compared to studies using different models (e.g., RELMAP, CMAQ), as well as available monitored data, although this is known to be both sparse and of variable quality.

The sources of uncertainty in REMSAD outputs, similar to other Eulerian-based air quality models, include incomplete knowledge of atmospheric mercury chemistry, wet and dry deposition, initial and boundary conditions, emission inventories, and domain grid resolution. ICF noted in its report to EPA on its REMSAD modeling results that, "all model simulation results include some uncertainty, and that uncertainty is often difficult to quantify. Therefore, although [ICF] may report contribution values to tenths of a percent, this is done to cover values that range widely in magnitude, not because of actual precision to that level. The contribution results should be viewed in a relative sense more than an absolute sense." This is the manner in which this project is using REMSAD modeling data.

3.3 Special Training/Certifications

The data in this project are provided by EPA and require no certification to use. While there is no special training specific to this project, Dr. John Graham and Dr. Paul Miller are Ph.D.-trained scientists familiar with the handling of large datasets and have many years experience in evaluating and interpreting air quality modeling results. Dr. Graham has relevant direct experience in applying REMSAD and its tagging feature for assessing mercury deposition contributions in the Northeast. Dr. Miller has relevant direct experience in developing mercury emission inventories for modeling applications.

3.4 Documents and Records

Document and record storage at NESCAUM is the responsibility of individuals charged with performing the tasks associated with this function. NESCAUM has established a

controlled-access central file system. All NESCAUM employees have access to these files during normal business hours.

So that NESCAUM may assure availability of requested information, members of the public are required to schedule an appointment to review NESCAUM files. All files will remain in the possession of NESCAUM.

Confidential documents are stored in secure areas. Procedures for chain of custody and confidentiality for evidentiary documents and records are documented in all QAPPs and other quality assurance plans.

File maintenance is the responsibility of all NESCAUM employees. Employees are required to file their own documents or have this task done by support staff according to NESCAUM policy. Files are kept on-site.

NESCAUM is providing the following information under this project:

1. Summary tables of mercury deposition values generated by REMSAD, in Microsoft® Access.
2. One draft and one final report (with copies) in Microsoft® Word and hardcopy to be submitted to NEIWPCC describing the summary of the REMSAD results contained from item 1 above. Elements in report are described in Section 4.3 below.

Version control, updates, distribution, and disposition are maintained or performed by the NESCAUM Project Manager Paul Miller and the NESCAUM QA Manager Charla Rudisill.

NESCAUM stores both financial and programmatic files for the appropriate length of time as determined in NESCAUM's Federal Assistance Agreements.

NEIWPCC may implement, at its discretion, various audits or reviews of this project to assess conformance and compliance to the quality assurance project plan in accordance with the NEIWPCC Quality Management Plan.

4.1 Data Reduction Procedures

There are no data reduction procedures *per se* in this project. Initially, NESCAUM planned to use a software data management tool developed by the consultant ESRI under a contract from EPA called AggreGATOR to manage and visualize the REMSAD deposition data according to various attributes. AggreGATOR is a GIS database tool (an enhanced version of ARC-Hydro) that allows users to extract the REMSAD deposition results for any grid cell or combination of grid cells and calculate the simulated contribution from each tagged source or source category to any location, area, or hydrologic zone in the modeling domain. EPA provided a beta version of this tool to NESCAUM.[1]

After initial trials, NESCAUM has decided it is more efficient to use standard Microsoft® Access database management software to manage the REMSAD output data rather than using the AggreGATOR tool. While it is different software, the intended uses are identical. NESCAUM will use Microsoft® Access to extract the REMSAD deposition results for any grid cell or combination of grid cells and sum the simulated contribution from each tagged source or source category to the grid or collection of grid cells (the cells can correspond to any location, area, or hydrologic zone in the modeling domain). NESCAUM is using the Access software for database management, and will not alter the REMSAD data. Therefore, use of Access introduces no additional uncertainty to the modeled data beyond that already associated with the REMSAD model.

4.2 Data Validation Procedures

No new data are being created by this project. Secondary data drawn from previous NESCAUM modeling of mercury deposition using REMSAD were created under previous QAPPs (modeling and emissions inventory) approved by EPA Region 1. Data from the ICF REMSAD modeling effort supported by EPA will be used as provided. While the two modeling outputs are not directly comparable due to differences in year modeled (i.e., meteorology) and emission inventory inputs, NESCAUM will qualitatively cross compare the results and document any major differences.

4.3 Project Product

The project product will be a report to NEIWPCC summarizing the REMSAD mercury deposition modeling relevant to the NEIWPCC states with source attributions. This is expected to help support future consultations among the NEIWPCC states and with out-of-region contributors to mercury deposition in the region as the NEIWPCC region seeks to achieve its regional mercury TMDL targets.

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[1] Personal communication from Dwight Atkinson, EPA Office of Water, Washington, DC, Atkinson.Dwight@epa.gov, 202-566-1226 (2007). Additional details drawn from a Powerpoint presentation by Atkinson, in June 2007.

The report will include the following elements:

1. Description of ICF REMSAD modeling effort that identifies model inputs (e.g., emissions inventory, meteorology) and summarizes its comparison of modeled deposition outputs to monitored wet deposition data from the Mercury Deposition Network. The description will also include the applicability of the REMSAD data for the intended purpose of this project and identify sources of uncertainties in the REMSAD model outputs.
2. Summary tables of mercury deposition contributions to receptor areas generated by the ICF REMSAD results. The criteria used for the summary tables will include:
   - Contribution of each contributing state to entire NEIWPCC region (New England + New York)
   - Contribution of each contributing state to each of NEIWPCC states
   - Contribution of each major source (individual sources tagged by ICF) in contributing states to entire NEIWPCC region
   - Contribution of each major source in contributing states to each of NEIWPCC states
   - Contribution of entire NEIWPCC region to entire NEIWPCC region
   - Contribution of each NEIWPCC state to each of the other NEIWPCC states

   To the extent any data are excluded, it will be based on a *de minimis* contribution level, i.e., considered an insignificant contributor to total deposition in a receptor region. If a *de minimis* level is used, the level and reasoning for choosing such a level will be given in the report.
3. Qualitative comparison of NESCAUM REMSAD results with the ICF REMSAD results.

Appendix A: Quality Assurance Project Plan for the Mercury Modeling Project

November 30, 2004

Northeast States for Coordinated Air Use Management (NESCAUM)
101 Merrimac Street
10th Floor
Boston, MA 02114
617.259.2000

APPROVAL SIGNATURES

Executive Director, NESCAUM

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Kenneth A. Colburn Date

Quality Assurance Manager, NESCAUM

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Charla Rudisill Date

Project Manager, NESCAUM

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Arthur Marin Date

Inventory Manager, NESCAUM

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Matthew Irvine Date

QA Reviewer, NESCAUM

_____ _____
Jung-Hun Woo Date

Project Officer, USEPA Region I

_____ _____
Alison Simcox Date

Table of Contents

1.0 Background and Project Definition

Background

The US Environmental Protection Agency (EPA) has developed a mandatory Agency-wide Quality Assurance Program that requires all organization performing work for EPA to develop and operate management processes for assuring that data or information collected are of the needed and expected quality for their intended use. It also required that environmental technology used for pollution control is designed, constructed, and operated according to defined specification and protocols. These requirements apply to all organizations that conduct environmental data operations on behalf of EPA through contracts, financial assistance agreements, and interagency agreements.

This document states the Quality Assurance Project Plan (QAPP) for modeling the 2003 mercury point and area source inventory by the Northeast States for Coordinated Air Use Management (NESCAUM). In all data collection activities, it is NESCAUM's intent to provide procedures that ensure the highest level of quality assurance that is appropriate for the intended use of the data.

It is the policy of NESCAUM that all NESCAUM activities that generate environmental data will be part of a Quality Assurance Program (QAP) and will be documented within the framework of a Quality Assurance Management Plan (QAMP). This project is subject to the overall QAP for NESCAUM, which is attached in Appendix A. The environmental data generated in this project will also be subject to the following QA Project Plan (QAPP), which specifies the detailed procedures required to assure production of quality data. This QAPP has been prepared by the project manager, and reviewed and approved by the Quality Assurance Manager (QAM) prior to the start of any data collection.

Problem Definition

Fish consumption advisories are in effect in the northeast region due to the potentially hazardous levels of mercury that bioaccumulate in freshwater and marine fish. Mercury is a potent neurotoxin affecting children and the developing fetus. The principal source of mercury to the aquatic food chain is known to be atmospheric deposition from local and long-range emission sources. In 1998, the Northeast states worked with the U.S. EPA to model mercury deposition based on an updated emission inventory of stationary sources in the region. The study was designed to provide a better understanding of the dispersion and deposition of mercury emitted by sources within the region, outside the region, and the relative contribution of the global reservoir. Currently, the northeast states are in the process of updating the mercury inventory for the northeast region used in the 1998 report by including new sources and improving emission estimates for existing sources. This project will model the updated mercury inventory to provide

deposition estimates in the region. The project will provide input to a broader effort that is developing an integrated approach for assessing the effects of mercury from the atmosphere and from point and non-point sources on watersheds and, ultimately, fish populations.

2.0 Project Objectives, Organization, and Responsibilities

Project Objectives

The purpose of this project is to conduct deposition modeling of mercury in the Northeast region of the U.S., based on an updated inventory.

Two specific goals are:

1. To determine mercury deposition in the NESCAUM region and apportion in by source region and major source category.

2. To provide input (i.e., loading) values to aquatic and ecological models that may prove useful in regulatory and policy decisions, for example relating to TMDL development for mercury impaired water bodies.

The data quality objective (DQO) is to provide first order estimates of mercury deposition by modeling the improved (2002-3) emission inventory for mercury in the northeast along with other air quality model inputs provided by EPA from its regulatory development for Clear Skies.

NESCAUM Organization

Commitment to and direct responsibility for the quality objectives and operations detailed in this QAPP begins with the Executive Director and continues through to the Project Manager, and Inventory Manager. The authority and responsibility for directing QA activities within NESCAUM have been delegated to the designated QAM. The QAM will not be directly involved in generating, compiling, and evaluating raw data.

Arthur Marin, the Project Manager, and Matthew Irvine, Inventory Manager, will oversee the technical review of the inventory. QA review will be conducted by Emily Savelli and Jung-Hun Woo, QA Reviewers. Alison Simcox is the EPA-NE Project Manager.

Distribution List

Kenneth A. Colburn, NESCAUM, Executive Director
Arthur Marin, NESCAUM, Project Manager
Matthew Irvine, NESCAUM, Inventory Manager
Charla Rudisill, NESCAUM, Quality Assurance Officer
Emily Savelli, NESCAUM, QA Reviewer
Jung-Hun Woo, NESCAUM**,** QA Reviewer*
Alison Simcox, EPA-NE, Project Manager

***Primary Contact**

Responsibilities

Name	**Title**	**Mailing Address**	**Phone number**	**Email address**
Ken Colburn	NESCAUM, Executive Director	NESCAUM 101 Merrimac St. 10 floor Boston, MA 02114	617-259-2000	kcolburn@nescaum.org
Arthur Marin	NESCAUM, Project Manager	NESCAUM 101 Merrimac St. 10 floor Boston, MA 02114	617-259-2017	amarin@nescaum.org
Matthew Irvine	NESCAUM, Inventory Manager	NESCAUM 101 Merrimac St. 10 floor Boston, MA 02114	617-259-2000	mirvine@nescaum.org
Charla Rudisill	NESCAUM, Quality Assurance Officer	NESCAUM 101 Merrimac St. 10 floor Boston, MA 02114	617-259-2036	crudisell@nescaum.org
Emily Savelli	NESCAUM, QA Reviewer	NESCAUM 101 Merrimac St. 10 floor Boston, MA 02114	617-259-2034	esavelli@nescaum.org
Jung-Hun Woo	NESCAUM**,** QA Reviewer	NESCAUM 101 Merrimac St. 10 floor Boston, MA 02114	617-259-2087	jwoo@nescaum.org
Alison Simcox	USEPA-Region 1	1 Congress Street Suite 1100 Boston, MA 02114	617-918-1684	simcox.alison@epa.gov

3.0 Specific Tasks

The modeling team is conducting quality control and verification checks on the input to ensure accuracy and completeness. Quality assurance of inventory development/prepeartion, emissions modeling/processing, and air quality modeling results is very important. Since we will develop an updated Hg inventory for the Northeast US for 2002-2003, it is important to analyze differences 1) by years, 2) by regions, and 3) by source sectors to estimate their impacts on Hg emissions and deposition. Air quality modeling combines many complex procedures that include disparate datasets and numerous processing steps. Therefore, it is critical that quality assurance be performed on each step (e.g. inventory development/preparation, emissions modeling/processing, air quality modeling) prior to being used by the next step.

Task 1: Review/validate NESCAUM and other inventories

A separate QAPP has been developed for the Hg emissions inventory development/preparation component of this project. The review process includes the following:

- Margaret M. Round and Matthew Irvine, Inventory Manager will develop the NESCAUM emissions inventory by coordinating a review with the NESCAUM Hg Inventory Workgroup and appropriate EPA staff, investigating other emissions databases, and scientific research results. Any emission inconsistencies among years/regions/sectors without properly documented reasons will be investigated and corrected.

- Emily Savelli and Jung-Hun Woo, QA reviewers at NESCAUM, will prepare summary contents of data to help identify errors.

- Matthew Irvine of NESCAUM will provide a final inventory in SMOKE/IDA-friendly format to the QA Reviewers for QA and further processing.

- NESCAUM has the 1996 Clear Skies Act (CSA) Hg and 2001 CSA criteria emission inventory for point, area, and mobile sources in-house. They will be downloaded from EPA's ftp site [2]in SMOKE/IDA format.

- NESCAUM will obtain a copy of a recent Canadian Hg Emissions Inventory from the US EPA and process it for integration with US data.

[2] (ftp://ftp.epa.gov/pub/modelingcenter/Clear_skies/CSA2003/Emissions/1996/)

Task 2: QA Reviewers will conduct appropriate QA review for emissions processing

Emissions processing will be conducted using SMOKE emissions processor and some other processing software developed internally at NESCAUM. Emissions processing can be classified into three major components: a) SMOKE-ready inventory preparation, b) emissions tagging by regions and by source sectors, c) air quality model-ready emissions processing using SMOKE.

a. SMOKE-ready inventory preparation

QA tasks include (1) check consistency in SCC codes to ensure whether emissions inventories are classified in the correct classification system, and (2) check any unexpected source dropping or double counting during inventory processing.

b. Emissions tagging by regions and by source sectors

Tagging emissions is necessary to model/analyze concentration/deposition fields for pre-defined scenarios. Emissions tagging will be conducted using software developed in-house by NESCAUM. This software will tag emissions and then generate the corresponding SMOKE/IDA format input file. However, the SMOKE emissions processor has to be changed since the present SMOKE version cannot recognize tagged emissions. An emissions data consistency check for pre- and post- NESCAUM in-house processing as well as the updated-SMOKE emissions processing will be conducted to ensure no loss or gain of emissions occurs.

c. Air quality model-ready emissions processing using SMOKE

After preparing the SMOKE-ready tagged emissions inventory and modifying the SMOKE parameter files, standard emissions processing (e.g., spatial/temporal allocation and chemical speciation) will be conducted. We will import the desired inventories into SMOKE using the Smkinven program then apply the profile data using the necessary SMOKE programs (Grdmat (spatial), Spcmat (speciation) and Temporal). The scripts, configuration, and assigns files used will be checked to ensure that correct input data and environment variable settings are used. Any possible technical errors will be found and corrected by examination of log files in each of the processing programs. The pre- and post- data consistency check for each program will be conducted using Smkreport. The gridded inventory will be visualized using tools (e.g., PAVE) to create plots with the scale set to a very low value to determine whether there are areas omitted from the raw inventory or if emissions sources are erroneously located in water cells. We will visualize the gridded inventory using PAVE plots for each inventory pollutant to evaluate emissions distributions and look for erroneous state trends (groups of states or counties with excessively high, low or missing emissions).

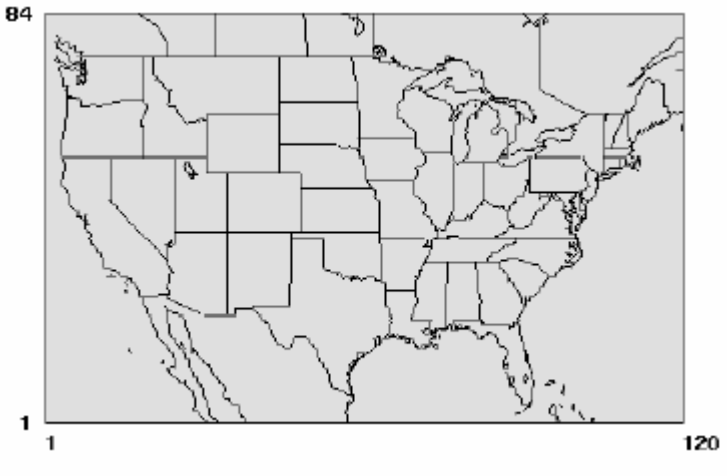
Task 3: Atmospheric Modeling

Model

The objective of the modeling is to investigate the impact of various source categories on receptors (grid cells) downwind by analyzing the Hg concentrations located in the surface layer and deposited via wet and dry deposition.

Modeling Specifications

REMSAD v7.13
National Domain (lat/long)



Modeling Domain

120 (E-W) by 84 (N-S) grid cells
Cell size (~36 km)
1/2 degree longitude (0.5)
1/3 degree latitude (0.3333)
E-W range: 66º W - 126º W
N-S range: 24º N - 52º N
Vertical extent: Ground to 16,200 meters (100mb) with 12 layers

Datasets

Emissions Inventories

Hg emissions:

- For emissions outside Northeast:
  - US EPA's 1996 Hg inventory for CSA
  - 2000 Canadian Hg Emissions (inventory provided by US EPA)
- For emissions within Northeast
  - NESCAUM's Hg updated inventory for 2002/03

Criteria pollutants emissions:

- 2001 "proxy" surface and point emission files for criteria pollutants provided by US EPA via Clear Skies Act of 2003.

Meteorology

- 1996 36km 12 layer Meteorology (provided by US EPA)

Modeling Run

The model will be run to determine the impact of different source categories and regional emissions in the northeast.

Specifically:

- Assess deposition of source categories that are tagged in four regions: New England vs. Northeast (i.e., NY & NJ) vs. Rest of US vs. Canada.

Therefore, the runs are based on:

2001 proxy criteria pollutant inventory +1996 Hg inventory + Northeast Hg inventory with NESCAUM's 2002/03 Hg inventory +Canadian inventory

Modeling Tags

Mercury Region-Tags:

(1) New England
(2) NY + NJ (Northeast = Tag (1) + Tag (2))
(3) Outside the Northeast (i.e., rest of US)
(4) Canada*

Mercury Source-Tags:

(1) utility boilers
(2) municipal waste combustors (MWC) and medical waste incinerators (MWI)
(3) sewer sludge incinerators (SSI)
(4) rest of point sources (not tagged above)
(5) area sources (stationary area + non-road)
(6) on-road mobile

* Only limited source tag will be applied to Canadian emissions inventory

Task 4: Quality Assurance of other inputs for and results from the model

Given that EPA has used this model for mercury it is assumed that a certain amount of model validation has been performed already. The meteorology will be used as developed for EPA's previous REMSAD applications. Other input files (e.g., land cover) will also be used as provided. Boundary (BC) and Initial (IC) condition files will be developed using available information from literature and previous applications of the model. One approach that may be used to assess the impact of mercury flux through the boundaries will be to tag those inputs. This will provide a means to evaluate extra continental transport and other long range transport, given the atmospheric lifetime of

elemental mercury. If the boundary conditions are deemed to be erroneous, a first order correction on the results could be achieved without re-running the model, providing a separate tag is available for the BCs.

Model results will be compared to available monitored data, although this is known to be both sparse and of variable quality. Since the combination of model inputs are a mixture of data from different years (1996 meteorology, various EI, BC/IC based on available information), a true model validation cannot be performed. Instead, the comparison seeks only to assess the various ranges and spatial characteristics of modeled deposition results versus monitored results.

Task 5: Documentation and Modeled Output

A final report will be prepared at the completion of the project. This report will summarize the motivation for the project and briefly review the development of the NESCAUM region emission inventory, referencing the detailed emission inventory development documentation. The model set up and inputs will be overviewed with appropriate caveats and limitations noted. Emission totals will be tabulated by region and by source sector (tag). Results of the modeling will be presented graphically, displaying deposition totals as annual and seasonal averages with regional and categorical divisions.

The annual and seasonal deposition and surface layer concentration results will be provided to EPA for use as input values for other ongoing efforts including deposition modeling (Dartmouth College), modeling of spatial distribution of mercury in fish (MERGANSER model by USGS). Long-term average results will be formatted as GIS (ArcInfo or Arcview) gridded files, in addition to the simple gridded ASCII model averaged output. Additional detailed output files will be saved and provided to EPA and will include results for all modeled species in addition to mercury. These data files will also contain all model vertical levels and hourly time resolution, along with deposition results.

4.0 Documents and Records

Document and record storage at NESCAUM is the responsibility of individuals charged with performing the tasks associated with this function. NESCAUM has established a controlled-access central file system. All NESCAUM employees have access to these files during normal business hours.

So that we may assure availability of the requested information, members of the public are required to schedule an appointment to review NESCAUM files. All files will remain in the possession of NESCAUM.

Confidential documents are stored in secure areas. Procedures for chain of custody and confidentiality for evidentiary documents and records are documented in all QAPPs and other quality assurance plans.

File maintenance is the responsibility of all NESCAUM employees. Employees are required to file their own documents or have this task done by support staff according to NESCAUM policy. Files are kept on-site.

- Appendix B: Quality Assurance Project Plan for the Mercury Emissions Inventory Project

November 30, 2004

Northeast States for Coordinated Air Use Management (NESCAUM)
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APPROVAL SIGNATURES

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Charla Rudisill Date

Project Manager, NESCAUM

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Arthur Marin Date

Inventory Manager, NESCAUM

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Matthew Irvine Date

Project Officer, USEPA Region I

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Alison Simcox Date

Table of Contents

1.0 Background and Project Definition

Background

The US Environmental Protection Agency (EPA) has developed a mandatory Agency-wide Quality Assurance Program that requires all organizations performing work for EPA to develop and operate management processes for assuring that data or information collected are of the needed and expected quality for their intended use. It also requires that environmental technology used for pollution control is designed, constructed, and operated according to defined specification and protocols. These requirements apply to all organizations that conduct environmental data operations on behalf of EPA through contracts, financial assistance agreements, and interagency agreements.

This document states the Quality Assurance Project Plan (QAPP) for updating the mercury point and area source inventory by the Northeast States for Coordinated Air Use Management (NESCAUM) for 2000-2003. In all data collection activities, it is NESCAUM's intent to provide procedures that ensure the highest level of quality assurance that is appropriate to the intended use of the data.

It is the policy of NESCAUM that all NESCAUM activities that generate environmental data will be part of a Quality Assurance Program (QAP) and will be documented within the framework of a Quality Assurance Management Plan (QAMP). This project is subject to the overall QMP for NESCAUM, which is attached in Appendix A. The environmental data generated in this project will also be subject to the following QA Project Plan (QAPP), which specifies the detailed procedures required to assure production of quality data. This QAPP has been prepared by the project manager, and reviewed and approved by the Quality Assurance Manager (QAM) prior to the start of any data collection.

Problem Definition

Fish consumption advisories are in effect in the northeast region due to the potentially hazardous levels of mercury that bioaccumulate in freshwater and marine fish. Mercury is a potent neurotoxin affecting children and the developing fetus. The principal source of mercury to the aquatic food chain is known to be atmospheric deposition from local and long-range emission sources. The inventories will be used to support state and federal activities related to the assessment and control of mercury emissions in the region. This includes the regional GIS-based models of Hg in fish tissue. These models, which integrate air deposition, watershed characteristics, and fish tissue data, are intended to be a tool for assessing mercury impaired water bodies through the region. In addition, the inventory will be used to support fulfillment of the NEG-ECP Mercury Action Plan milestones of 50% reduction in emissions from 1998-2003 and 75% reduction in 2010.

2.0 Project Objectives, Organization, and Responsibilities

Project Objectives

The purpose of this project is to prepare a comprehensive emissions inventory for point and area sources for the year 2003 for the Northeast region. The approach will use the U.S. Environmental Protection Agency (EPA) National Emissions Inventory for the year 1999 as a starting point. This 1999 inventory will be updated through a state review process for all states in the Northeast region, with states revising the 1999 inventory to levels reflective of 2003 emissions.

NESCAUM Organization

Commitment to and direct responsibility for the quality objectives and operations detailed in this QAPP begins with the Executive Director and continues through to the Project Manager, and Inventory Manager. The authority and responsibility for directing QA activities within NESCAUM have been delegated to the designated QAM. Charla Rudisill is the QAM at NESCAUM. The QAM will not be directly involved in generating, compiling, and evaluating raw data.

Arthur Marin, Project Manager and Matthew Irvine, the Inventory Manager, will oversee the technical review of the NESCAUM emissions inventory by coordinating a review with the NESCAUM Hg Inventory Workgroup and appropriate EPA staff, investigating other emissions databases, and scientific research results. Any emission inconsistencies among years/regions/sectors without properly documented reasons will be investigated and corrected.. Project managers are responsible for including appropriate QA requirements in all projects. Project managers are responsible for assuring all data generated for a monitoring project is sufficiently reviewed and/or validated to assure its usefulness for the project and that it meets the data quality objective stated in the QA project plan.

Distribution List

Kenneth A. Colburn, NESCAUM, Executive Director
Arthur Marin, NESCAUM, Project Manager*
Matthew Irvine, NESCAUM, Inventory Manager
Charla Rudisill, NESCAUM, Quality Assurance Officer
Alison Simcox, EPA-NE, Project Manager

***Primary Contact**

Responsibilities

The 1999 National Emissions Inventory (NEI) Input Format Version 3.0 (NIF 3.0) files will be distributed to the Mercury Inventory Workgroup[3]. EPA has extensively quality assured the 1999 NEI Version 3.0 based on input for Versions 1 and 2 from the Hg Inventory Workgroup. This inventory will be further reviewed by designated staff from each of the Northeast state air quality agencies that are participating in the Mercury Inventory Workgroup, revised, and returned to NESCAUM. NESCAUM will conduct quality assurance (QA) activities on the inventory submitted by each state to identify any format and/or data content problems. Resolution of any outstanding issues will be conducted through consultation with the Mercury Inventory Workgroup.

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Charla Rudisill	NESCAUM, Quality Assurance Officer	NESCAUM 101 Merrimac St. 10 floor Boston, MA 02114	617-259-2036	crudisill@nescaum.org
Alison Simcox	USEPA-Region 1	1 Congress Street Suite 1100 Boston, MA 02114	617-918-1684	simcox.alison@epa.gov

[3] List of Mercury Inventory Workgroup

CT	Ellen Pierce	ellen.pierce@po.state.ct.us	617-574-6801
ME	Doug Saball	doug.saball@state.me.us	860-424-3412
MA	Azin Kavian	azin.kavian@state.ma.us	207-287-2437
NH	Tom Niejadlik	t_niejadlik@des.state.nh.us	603-271-6865
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VT	Jeff Merrill	Jeff.Merrell@anr.state.vt.us	802-241-3840

3.0 Data Quality Objectives

The main data quality objectives that NESCAUM will work to fulfill include:

- Accuracy and Representativeness– The accuracy and representativeness of the inventory will be determined by the Mercury Inventory Workgroup. Emission calculations will be spot-checked by NESCAUM once the revised inventories are submitted to the Inventory Manager;

- Completeness – As part of the quality control (QC) process, the NESCAUM inventory Manager will identify any significant missing data from the inventories submitted by the Workgroup. If data are missing, the Inventory Manager will contact the state designee directly to fill in any gaps.

It should be noted that the NEI has also undergone extensive QA/QC by U.S. EPA in two rounds of review by the state and local agencies. Specific information on these activities may be found at the following website: www.epa.gov/ttn/chief/eidocs/qa_training.pdf

4.0 Specific Tasks

Task 1: Acquisition of 1999 NEI mercury inventory

NESCAUM will obtain a copy of the 1999 NEI (Version 3) mercury inventory for point and area sources for each of the Northeast states from EPA's CHIEF website in Microsoft Access and covert each state file to a Microsoft Excel worksheet.

Task 2: Distribution of Mercury Inventory to Mercury Inventory Workgroup

The NESCAUM Project Manager will distribute the 1999 NEI mercury inventory to each designee on the Mercury Inventory Workgroup. Each designee will then review the 1999 information within the excel spreadsheet to look for any errors; recent changes, and make appropriate updates. Categories to be reviewed or updated include: plant names, stack information, plant locations, mercury emissions, source classification codes (SCC), source closures and new sources. Upon completion, the updated excel file with changes noted will be returned to NESCAUM.

Task 3: Coordinate states in the review of the mercury inventory

NESCAUM will host a series of conference calls with the Mercury Inventory Workgroup to discuss the review of the inventory, updating of the emission estimates and other information, and resolution of any outstanding issues. The review process will be focused on the accuracy, representativeness, and completeness of the inventory. Any significant changes to the inventory will be documented in the final report for this project.

Task 4: Each state will provide a revised version of the inventory to NESCAUM

Task 5: NESCAUM will undertake QA procedures to ensure the accuracy, representativeness, and completeness of the inventory

The Energy Information Administration (EIA) was used as a comparable database to ensure accurate state emission estimates for utility boilers. The 1999 National Emissions Inventory (NEI) was employed to ensure all sources operating were included in the inventory as well as completing missing portions of information for the inventory. These procedures along with those in Task 3 serve to ensure an accurate and complete inventory for the entire Northeast region. Any changes to the inventory resulting from this task will be documented in the final report for this project.

Task 6: The inventory will be prepared in SMOKE/IDA compatible NIF3.0 export format

Inventory Data Analyzer (IDA) format is a text format that is simpler than NIF3.0 and can be input directly into SMOKE. However, the spreadsheet (e.g. MS Excel) or database (e.g. MS Access) format is an easier format to correct and update during the initial QA process since the user is able to manipulate numbers by field and record. The flat spreadsheet formatted NIF3.0 export files, which include all necessary fields for SMOKE/IDA, are created in EXCEL for easier update and faster conversion into the IDA text format.

NESCAUM will pull annual mercury emissions from these NIF3.0 Emission tables for each source sector and state into one “base” table that will then be used to prepare summary charts and maps. This table will also be designed to include all the necessary fields for SMOKE/IDA format input files. NESCAUM will compare state by state totals as the files are processed. First, emission totals in the base table will be compared to the emission totals generated from the NIF 3.0 tables to ensure that all data are retrieved from the NIF 3.0 tables to support the summaries. The final check will compare emission summaries in the base table to the emission summaries generated from the in-house tagging software to ensure that all data are correctly converted into SMOKE IDA text format.

Task 7: Documentation

Throughout the project an on-going documentation of how the final inventory was generated will be undertaken. The initial documentation will be from EPA’s documentation of the 1999 NEI for point and area sources. The comments in the NESCAUM report to EPA will include each emission category estimate documented in terms of the assumptions underlying the estimate, source of the data, degrees of uncertainties, and appropriate considerations governing its use. Emphasis will be focused on major categories such as municipal waste combustors, medical waste incinerators, sewage sludge incinerators, and electric utilities.

5.0 Documents and Records

Document and record storage at NESCAUM is the responsibility of individuals charged with performing the tasks associated with this function. NESCAUM has established a controlled-access central file system. All NESCAUM employees have access to these files during normal business hours.

So that we may assure availability of the requested information, members of the public are required to schedule an appointment to review NESCAUM files. All files will remain in the possession of NESCAUM.

Confidential documents are stored in secure areas. Procedures for chain of custody and confidentiality for evidentiary documents and records are documented in all QAPPs and other quality assurance plans.

File maintenance is the responsibility of all NESCAUM employees. Employees are required to file their own documents or have this task done by support staff according to NESCAUM policy. Files are kept on-site.