FY13 GLRI Funding Request

Program/Project: Modeling Atmospheric Mercury Deposition to the Great Lakes

Summary Description: This project will use the NOAA HYSPLIT atmospheric fate and transport model to determine the amount of and source attribution for atmospheric mercury deposited to each of the Great Lakes and each of the AOC's. The information regarding the relative importance of different source regions and source types will be useful in prioritizing and assessing the impacts of actions to reduce mercury loadings to the Great Lakes and individual AOC's. Relative to earlier year's work, this FY13 project represents an *enhancement* (e.g., the addition of analysis for AOC's; incorporating new scientific findings into the model) and an *update* (e.g., comprehensive analysis for a more recent year -- e.g., 2010 vs. 2005 – in which the impact of recent emissions trends can be assessed), and will also benefit greatly from the vastly increased amount of ambient monitoring data available for "ground-truthing" in recent years compared to 2005 and before.

FY12 Planned Funding per 7/29/11 RWG: $190,000

FY13 Proposal ($): $190,000

This project would likely not be possible to carry out if funding was reduced from the current level. All of the activities envisioned are essentially "required", e.g., collection and assembly of model input data, carrying out of model simulations, post-processing analysis to elucidate source-attribution information, and quality assurance processes throughout. There are few if any shortcuts or reductions in scope that could be implemented that would (a) reduce the actual project work significantly and (b) not lead to significant decrease in the accuracy and usefulness of the results. Further, it is unlikely that significant alternative funding could be obtained from NOAA base or other sources.

FY13 Measurable Output: Information generated in this project regarding the atmospheric mercury deposition impacts to each of the Great Lakes and to each of the AOC's of alternative, policy-relevant emissions scenarios will support actions to prevent and minimize mercury contamination in the Great Lakes basin in general and at AOC's in particular. Relative to the Action Plan, this project will support efforts to reduce toxic substance loading to the Great Lakes and AOC's (**Focus Area 1/Measures 1,2,3,5**) and protect wildlife (e.g., reduce mercury exposure of fish-eating birds) (**Focus Area 4/Measures 5,6,7**), and will also support a variety of educational, evaluative, and planning activities among stakeholders (**Focus Area 5/Measures 1,3**).

FY13 Annotations (add'l info, explanations for increases, etc): In a new project feature, guided by the EPA-identified priority on Areas of Concern, atmospheric mercury deposition to

each AOC will be estimated. Historically, point sources (e.g., effluent discharges) and riverine inputs have tended to be the largest loading pathways of contaminants for many AOC's. However, in many cases, contributions from these sources have been dramatically reduced from historical levels, due to pollution control and prevention actions. Because of this, atmospheric deposition may have emerged as one of the largest contemporary loading pathways. (To a certain extent, this is what has happened for the Great Lakes as a whole, as contributions from large point sources effluent loadings -- e.g., discharges from chloralkali plants -- have been dramatically reduced.) In addition, many Areas of Concern are located in the very regions within the Great Lakes basin that have relatively large local atmospheric emissions sources. Accordingly, it will useful to have estimates of the amount mercury deposition to each AOC so that the relative importance of atmospheric mercury loading can be assessed. It is understood that mercury is only one of many pollutants that may be affecting a given AOC. However, for AOC's where atmospheric deposition of mercury is a potentially significant ongoing contamination pathway, it will be useful to know the relative importance of different local, regional, and more distant sources. Thus, in addition to updated deposition estimates for each of the Great Lakes and their watersheds, estimates of mercury deposition to each AOC will be made, including detailed case-study analyses for AOC's for which atmospheric mercury deposition is potentially important. It is difficult to assign percentages to the AOC-related components of this modeling project, as there are numerous overlapping aspects. For example, meteorological data, emissions inventories, ambient monitoring data, and a "working model" are all required whether one is estimating deposition to the Great Lakes as a whole or to a set of AOC's. So, it could be argued that essentially all of the work done on the project will support the above AOC-related analysis.

Addresses EPA-identified Priorities (AOCs, invasives, or phosphorus reduction): Yes, addresses Areas of Concern (AOC's)

Additional Justification in Support of Proposed NOAA FY13
GLRI Project Involving Atmospheric Mercury Modeling (Oct 25, 2011)

This document provides additional explanation and justification for a proposal for FY13 GLRI funding involving atmospheric mercury modeling. The proposal primarily consists of an update of earlier funded work, but also includes a new feature relevant to some of the AOC's in the Great Lakes basin.

I. <u>There is value in updating the earlier funded GLRI work, estimating the amount and source-attribution for atmospheric mercury deposition to the Great Lakes</u>

1. The previously funded FY10-12 work is for 2005; the proposed FY13 basin-wide analysis will be for a more recent year, e.g., 2008, or perhaps even more recent, if emissions inventory information from the EPA is available.

2. As in previous work, the amount of mercury deposited to each of the Great Lakes and their watersheds will be estimated, arising from natural and anthropogenic sources throughout the world. Source-attribution for the deposition will be estimated. Model results will be "ground-truthed" by comparison against ambient measurements.

3. The proposed updated analysis will provide policy-relevant information on the impact of recent changes in mercury emissions in the U.S., Canada, and globally.

4. The proposed updated analysis will provide policy-relevant source-attribution estimates to inform decisions regarding mercury source reduction at local, state, regional, national, continental, and global scales.

5. The proposed updated analysis will benefit from the vastly increased amount of ambient atmospheric mercury monitoring data available in recent years – relative to 2005 – for model "ground-truthing".

6. The proposed updated analysis will be able to provide additional inputs to mercury aquatic cycling models (e.g., USGS GLRI Template #79).

7. Recent multi-stakeholder synthesis coordinated by the Biodiversity Institute indicates that mercury remains an important issue in the Great Lakes basin (Evers et al., 2011, plus 35 new peer-reviewed articles in special issues of *Ecotoxicology* and *Environmental Pollution*).

8. The proposed work will continue to leverage other investments, including emissions inventories, meteorological data/modeling, and environmental mercury measurements.

9. For all of the above reasons, the proposed atmospheric mercury deposition analysis for the Great Lakes basin stands on its own and is worthy of funding consideration.

II. <u>The proposed work will improve understanding of mercury pollutant concerns at AOC's, with very little additional cost</u>

1. In addition to the basin-wide project described above, this FY13 proposed work contains a new feature: estimation of mercury deposition loadings to each AOC.

2. As stated in the original proposal, it is understood that mercury is not the most important pollutant of concern in every AOC; however, heavy metals (including mercury) are stated to be significant in at least some of the AOC's.

3. Because of the high-priority given to the AOC's *and because analysis of atmospheric mercury deposition to the AOC's can be added to the overall project with only marginal additional resource requirements*, this proposal for FY13 includes analysis of AOC's as a new feature.

4. Once the modeling system is set up, including key inputs such as meteorological data and emissions inventories, carrying out local simulations for AOC's can be accomplished with little additional effort, on top of the basin-wide analysis being proposed as described on the previous page.

5. Figure A (below) shows that many of the AOC's are located in areas that have significant atmospheric mercury sources. As illustrative examples, more local views are shown in Figure B (Grand Calumet River AOC) and Figure C (AOC's in the western Lake Erie region).

6. To the extent that ongoing atmospheric deposition contributes to mercury concentrations in fish and wildlife at a given AOC, such deposition will affect the time scale of recovery and delisting, as well as the long-term ecological health of the area. Therefore, it would seem to be useful to have an estimate of such loadings. For some AOC's, mercury deposition will likely not be a critical factor. For others, it may at least contribute a non-trivial amount to environmental contamination at the sites. For planning purposes and to help interpret time-trends of monitoring data, it will be helpful to know if atmospheric mercury deposition needs to be factored in.

7. Newly deposited mercury can be more bioavailable than "legacy" mercury (Harris et al., 2007). That is, even if large amounts of mercury are present in sediments from historic contamination, the impact of that mercury on local fish and wildlife concentrations may be less, pound for pound, than newly deposited mercury to the system. So, ongoing atmospheric deposition could have a disproportionate impact on fish and wildlife mercury concentrations in a given AOC.

8. Moreover, recent GLRI-funded work in the Great Lakes (Krabbenhoft, 2011) suggest that mercury methylation in the water column may be as important or even more important than methylation in sediments, at least in some locations. To the extent that this is true in a given AOC's ecosystem, ongoing atmospheric mercury deposition might be even more relevant to the

levels of methylmercury in AOC biota. This is because water-column concentrations of dissolved Hg^{+2} – the form of aquatic mercury that is methylated -- can respond essentially "immediately" to loading of RGM [reactive gaseous mercury, Hg(II)] from the atmosphere. That is, deposition of atmospheric RGM leads directly to dissolved Hg^{+2} in the water column.

9. In the next section, a brief screening-level plausibility analysis is presented suggesting that atmospheric deposition at AOC's may be significant. The proposed work will carry out this analysis in a much more comprehensive way, and we note that *the HYSPLIT-Hg model is ideally suited to estimating the impacts of local/regional sources*. While the model will also estimate the impacts of more distant sources, including global sources, the model includes local-scale simulations of near-field source impacts, with a resolution generally much finer than typical atmospheric mercury models.

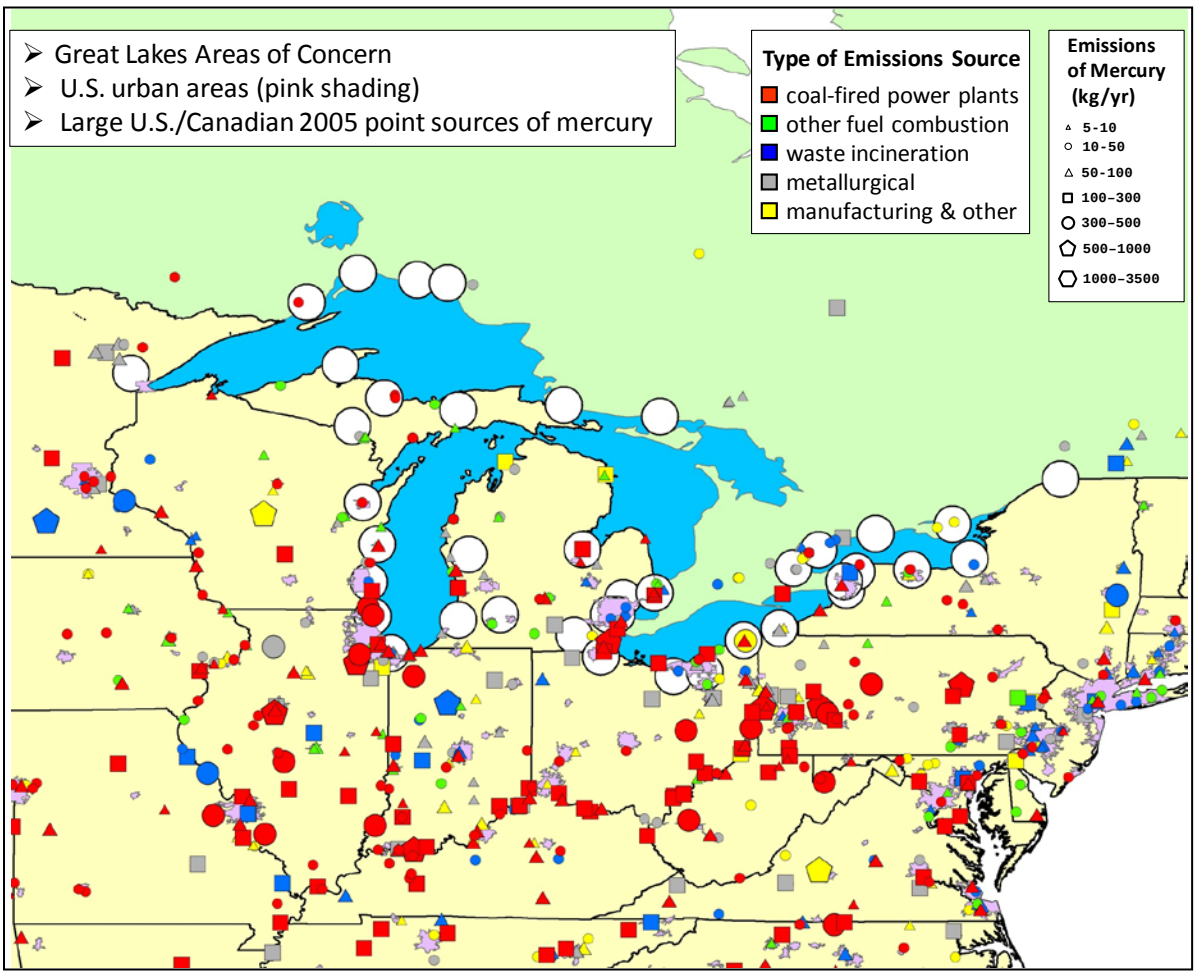

Figure A. Great Lakes AOC's (white circles) and large 2005 mercury emissions point sources.

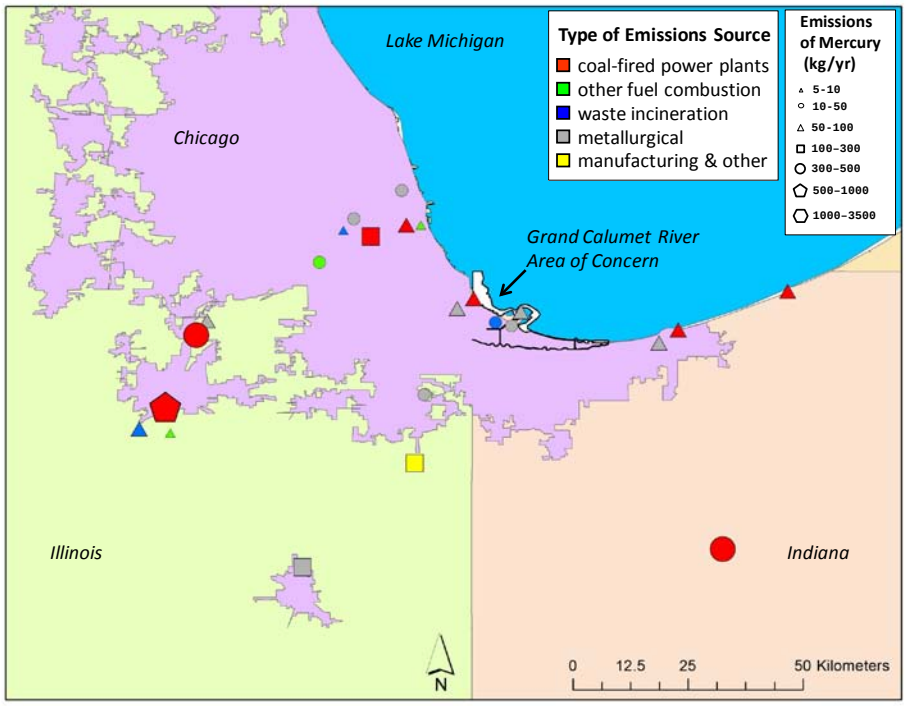

Figure B. Large atmospheric mercury emissions sources in the vicinity of the Grand Calumet River AOC, according to the 2005 USEPA National Emissions Inventory

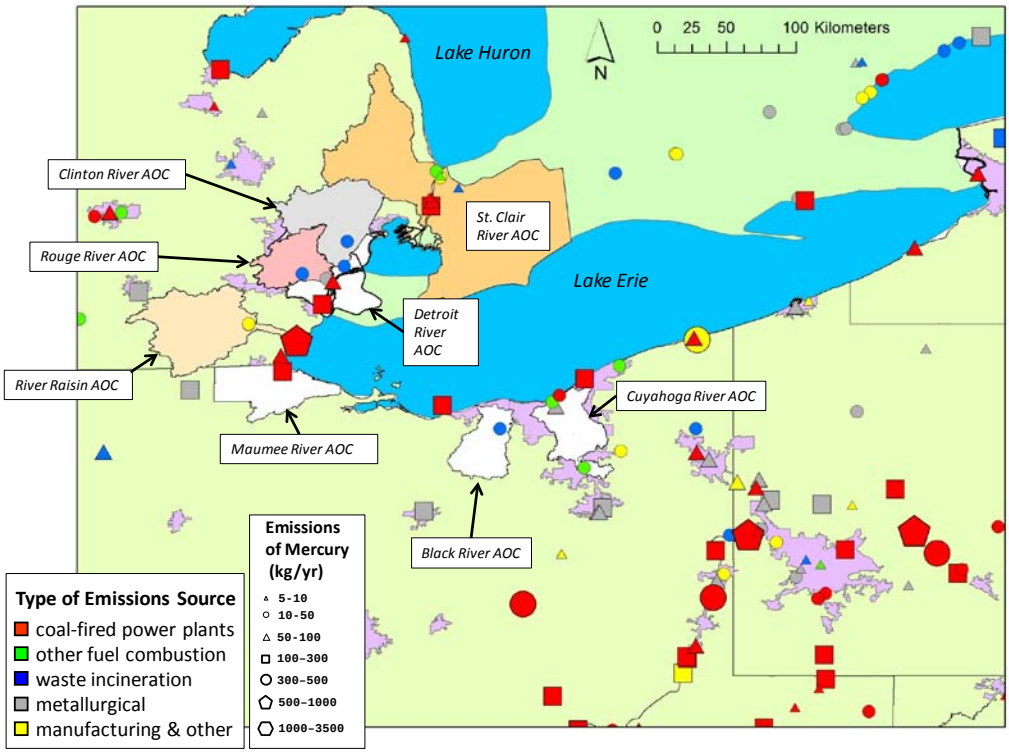

Figure C. AOC's and large atmospheric mercury emissions sources in the western Lake Erie region, according to the 2005 USEPA National Emissions Inventory.

III. Local emissions sources can lead to enhanced atmospheric deposition of mercury

1. Atmospheric deposition flux from nearby emissions sources can be relatively large and have a disproportionate impact on local deposition (e.g., Cohen et al., 2004). Figure D shows an illustrative example of how the deposition falls off as a function of distance from the source (from Cohen et al., 2007). The simulation shown in this figure is for a source emitting 1 kg/day (365 kg/year) from an effective stack height of 250 meters.

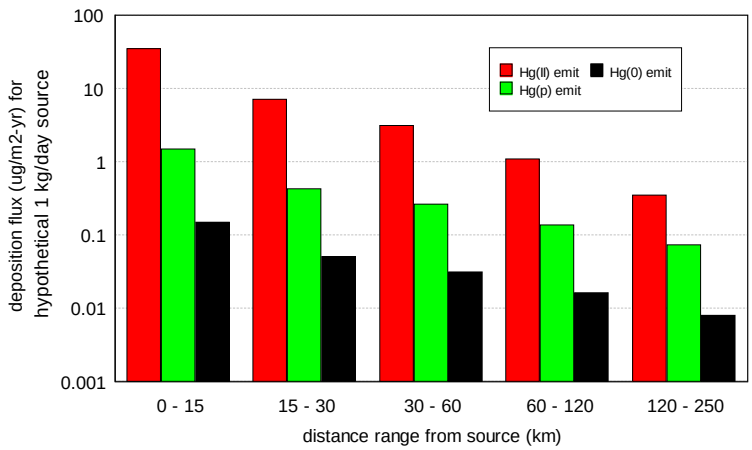

Figure D. Deposition vs. distance for emissions of different mercury forms (logarithmic). These data are for Hg(II) [ionic], Hg(p) [particulate], and Hg(0) [elemental] emissions from an effective stack height of 250 meters.

2. Figure E shows the emissions (based on data from the USEPA 2005 National Emissions Inventory) of different forms of mercury in different distance ranges away from the Grand Calumet River AOC, based on the data shown in Figure B above. This preliminary analysis includes only anthropogenic point sources. It does not include "area", "re-emissions", or "natural" sources, and so it is a lower bound on emissions. [These additional source categories could be included in future analysis]

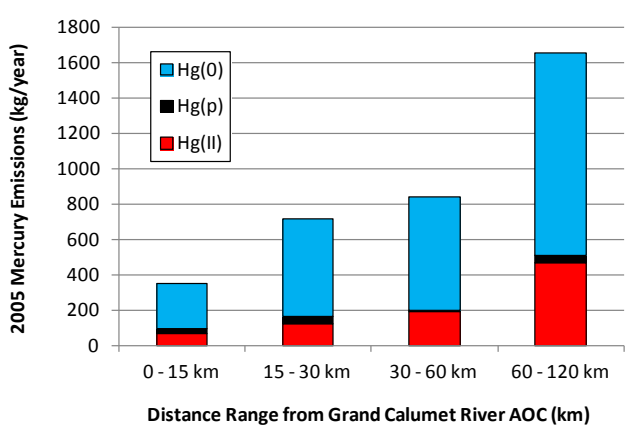

Figure E. Anthropogenic point source mercury emissions within different distance ranges of the Grand Calumet River AOC

3. Figure F shows the cumulative estimated deposition flux – estimated by essentially multiplying the data from the above two figures – in successive distance ranges away from the Grand Calumet River AOC. It can be seen that – estimated in this limited way -- the local sources may contribute a deposition flux on the order of 12 ug/m2-year. This is probably an underestimate because only point sources were included and also because a relatively high screening-level stack height of 250 m was used. The total atmospheric deposition to the Grand Calumet River AOC will of course be made of these local contributions as well as contributions from all of the rest of the sources in the world. *For comparison, this contribution from local sources alone is greater than the total wet deposition flux at rural Mercury Deposition Network sites in the region, which typically have wet fluxes in the range of 6-10 ug/m2-year.*

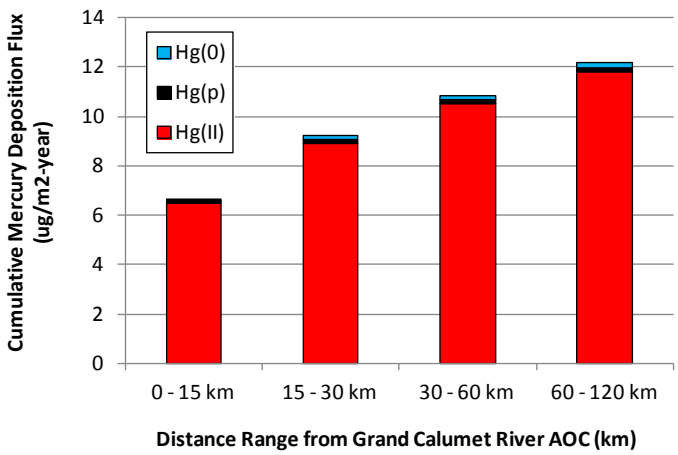

Figure F. Cumulative deposition flux contribution from local anthropogenic mercury point source emissions in the vicinity of the Grand Calumet River AOC

4. It is noted that mercury contamination is listed as an issue for the Grand Calumet River AOC, and that atmospheric deposition is considered a potentially significant loading pathway (USEPA, 2011). *However, it is not being argued based on this very preliminary analysis that mercury or atmospheric deposition of mercury is necessarily important at the Grand Calumet River AOC*. The above is just a screening level analysis to demonstrate the plausibility of considering atmospheric deposition impacts at AOC's. In this example, it appears that atmospheric mercury deposition may be enhanced significantly over background levels due to emissions from local sources. The significance of this enhanced deposition would have to be assessed.

5. If the proposed work is funded, the analysis will be done far more comprehensively, with explicit modeling of the fate/transport of emissions from local sources. As stated in the proposed work, the analysis will be carried out for each AOC, and more detailed analysis will be carried out for any AOC's for which atmospheric mercury deposition may be significant.

References

Cohen, M., Artz, R., Draxler, R., Miller, P., Poissant, L., Niemi, D., Ratte, D., Deslauriers, M., Duval, R., Laurin, R., Slotnick, J., Nettesheim, T., and McDonald, J. (2004). Modeling the atmospheric transport and deposition of mercury to the Great Lakes. *Environmental Research* **95**(3):247-265.

Cohen, M., Artz, R., and Draxler, R. (2007). *Report to Congress: Mercury Contamination in the Great Lakes*. NOAA Air Resources Laboratory, Silver Spring, MD. 162 pages.

Evers, D.C., Wiener, J.G., Driscoll, C.T., Gay, D.A., Basu, N., Monson, B.A., Lambert, K.F., Morrison, H.A., Morgan, J.T., Williams, K.A., Soehl, A.G. 2011. *Great Lakes Mercury Connections: The Extent and Effects of Mercury Pollution in the Great Lakes Region*. Biodiversity Research Institute. Gorham, Maine. Report BRI 2011-18. 44 pages. http://www.briloon.org/mercuryconnections/greatlakes

Harris, R. C., J. W. M. Rudd, et al. (2007). Whole-ecosystem study shows rapid fish-mercury response to changes in mercury deposition. *Proceedings of the National Academy of Sciences of the United States of America* **104**(42): 16586-16591.

Krabbenhoft, D. (2011). Mercury Cycling in Great Lakes (USGS GLRI Project #79). Presentation to the Lake Superior Work Group, March 30, 2011.

U.S. EPA (2011). Grand Calumet River Area of Concern. http://epa.gov/glnpo/aoc/grandcal.html