In this White Paper, data on the atmospheric deposition of dioxin to Lake Michigan are presented and discussed. Included is information on the role of atmospheric deposition relative to other dioxin loading pathways, the amount of dioxin deposited, and the relative contributions from different dioxin sources. The essential steps used in developing estimates and the policy implications of this research are presented.

In addition, the degree of certainty for which each of the information elements are known is discussed. The reasons and relative importance of different sources of uncertainty are outlined, and potential steps for reducing key uncertainties is recommended. It is hoped that this White Paper will be useful to both policy-makers and scientists in discussing "why we need to know", "what we think we know", "how well we know what we think we know", “what good is what we know”, and "what we don't know" about atmospheric dioxin deposition to Lake Michigan.

In order to design effective policies regarding toxics reduction in the Great Lakes (or any other receptor) for any given pollutant, the following information is needed:

An analysis and discussion of the effects of dioxin contamination in Lake Michigan is far beyond the scope of this White Paper. However, there are a wide range of potential concerns due to dioxin contamination in Lake Michigan. There is concern, for example, regarding human consumption of Lake Michigan fish due to contamination by dioxin and other toxic substances. There appears to be some uncertainty in the relative contribution of dioxin in the suite of human and ecosystem effects. The IJC Science Advisory Board has recommended that “the IJC advise the Parties to collaborate on the preparation of a comprehensive statement, for the entire Great Lakes basin, of the threat to human health posed by critical pollutants...”[1].

preumting There is some adkerhe effece of concern,one musnt etermtire theesigifticenr pathways – liquid effluent discharges, atmospheric deposition, contaminated sediment, etc. One must have some idea of this, because it guides the rest of the analysis – which gets more and more involved. This is the seemingly "easy" question at the beginning of, but it is important to get the answer approximately right, so that attention can be focused on the most significant pathways and resources are not wasted on insignificant pathways.

Table 1 shows two available relative estimates of dioxin pathway loadings to Lake Michigan that could be found in the literature.[2,3] Cohen .[3] looked only at atmospheric deposition and liquid effluent discharge. Other pathways, such as contaminated sediments and groundwater were not included in the analysis. Pearson [2] compared dioxin homologue profiles in sediment cores with estimates of profiles in atmospheric deposition, to estimate the proportion of the material found in the sediments that arrived via

Furthermore, the information that does exist is typically very uncertain and generally controversial.

"Models", in the context of this paper, are defined as mathematical/conceptual descriptions of one or more real-world phenomena. A model is necessarily a simplification; the real world will generally be more complicated than the level of detail that can be handled in a model. In order for a model to be successful, enough of the key processes and/or interdependencies in the system must be adequately characterized to allow a sufficient degree of accuracy in the simulation. One of the principal uses of models is that they can be used to examine different large-scale scenarios, scenarios that cannot be easily tested in the real world (e.g., different emissions reduction scenarios).

Another valuable feature of models is that they provide a synergistic complement to measurements. By themselves, measurements do not generally provide detailed information regarding the processes and contributing factors influencing the observed levels. A model can assist in interpreting and understanding the measurements that have been made. At the same time, models without measurements are of limited use – measurements must be used to "ground truth" any model. Finally, models can help fill in the spatial and temporal gaps between measurements, in order to provide a more complete description of a given system. Thus, it can be argued that models and measurements are of greatest value when they are undertaken together.

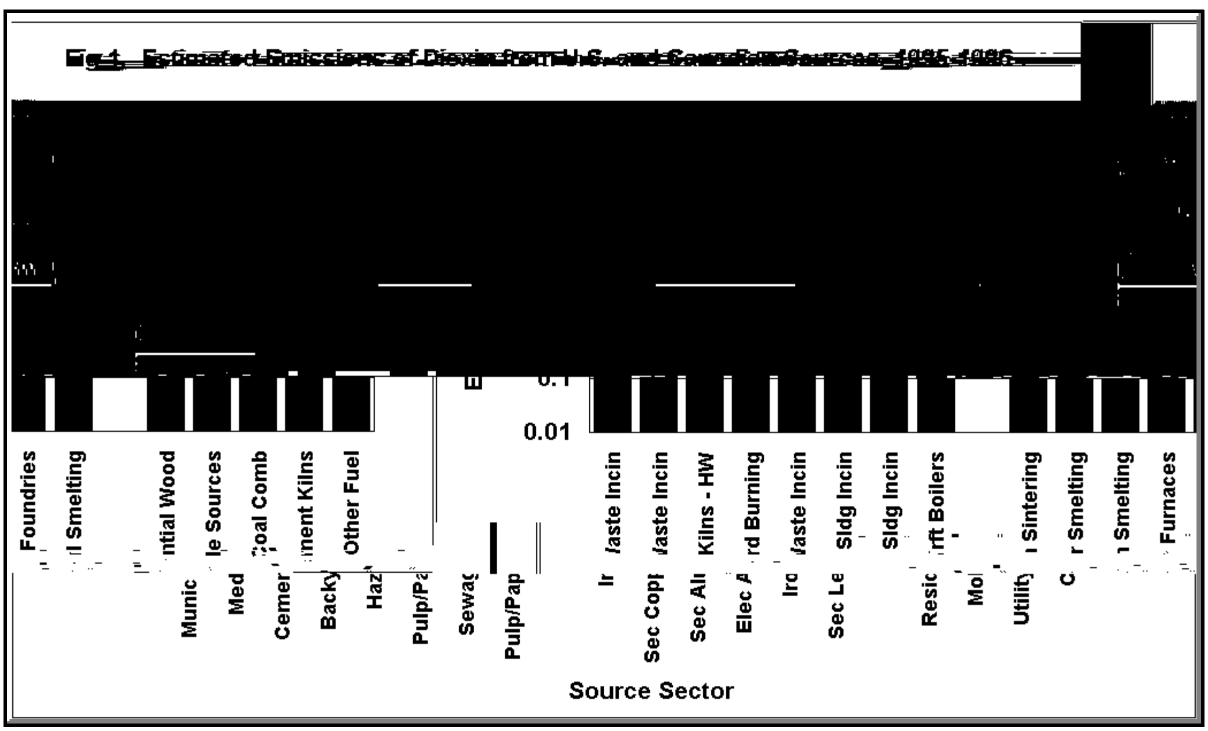
Models attempt to put together everything important that is known about a given system. If a model fails to provide a reasonable simulation, then this generally means that we don't understand enough about the system. Thus, in a very real sense, models provide a "test" of our knowledge.

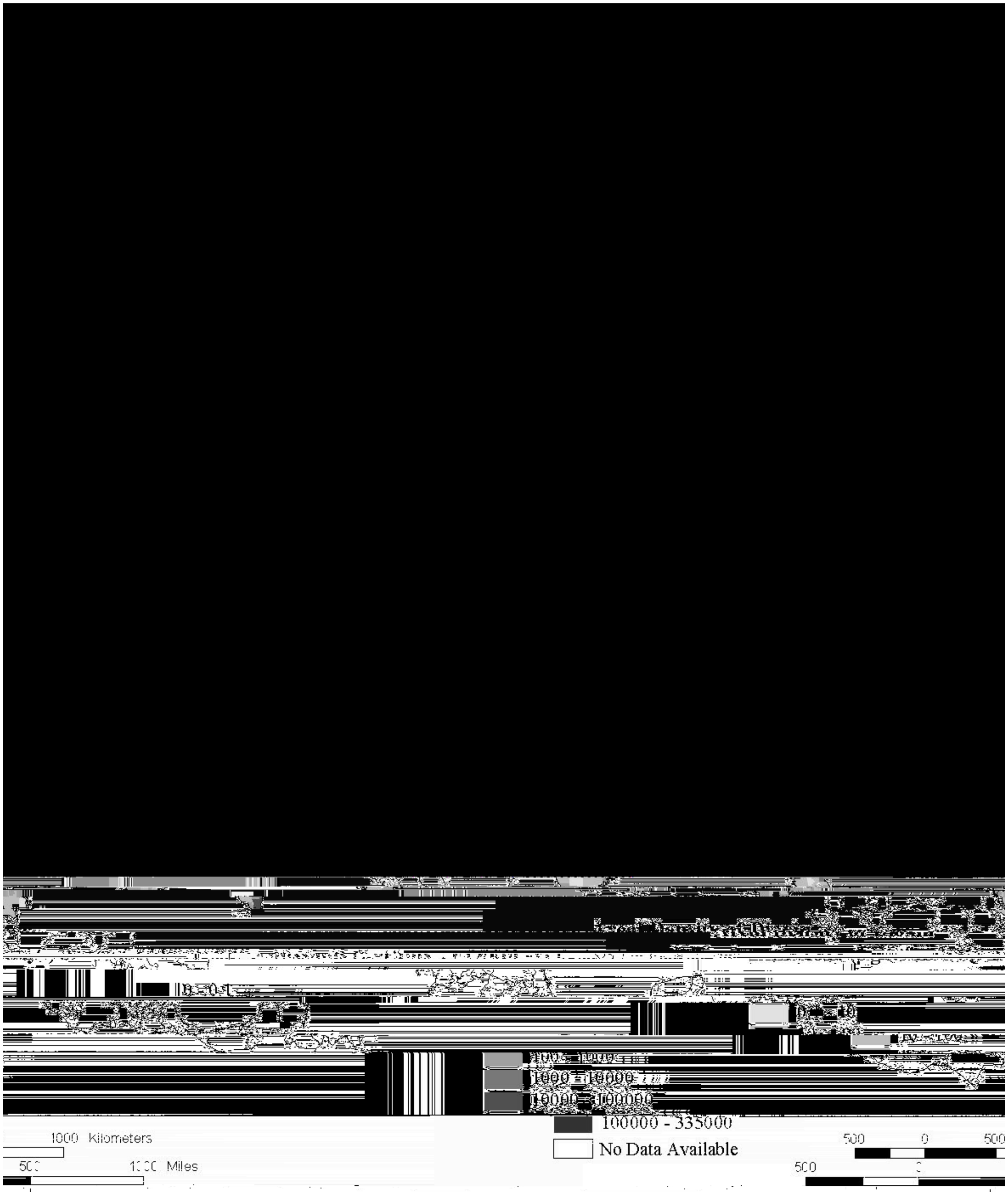
It can be noted that models of various types are used in essentially all approaches in developing approximate answers to each of the above three fundamental question areas (i.e., effects, causes, and costs). Adequate knowledge regarding of the these areas is necessary in order to make the most well-informed decision; decision-making with insufficient information in any one area is obviously far from ideal.

This paper focuses primarily on the relative contribution of different air emissions sources to the overall atmospheric deposition of dioxin to Lake Michigan. This analysis builds on earlier work analyzing the transport and deposition of dioxin to the Great Lakes[3,5,6,7,8]. The analysis include an emissions inventory and a model that simulates the atmospheric fate and transport of emitted dioxin, including its potential transport to and deposition to Lake Michigan (and the other Great Lakes). The modeling system used here is somewhat unique, in that comprehensive source-receptor information is developed in the analysis.

This case study is for 1996, and attempts to describe the impacts of dioxin air emissions sources in the United States and Canada on Lake Michigan in that year. Emissions from some sources may have changed since 1996; thus, obviously, the results presented here do not necessarily represent the current situation. It is noted that the only substantial impediment to carrying out the analysis for the current situation (in addition to a lack of funding) is the lack of current, accurate, geographically resolved emissions inventories. All other elements of the analysis – the model, the requisite meteorological data, and ambient measurements for model evaluation – are readily available for carrying out a more up-to-date analysis once a more recent, accurate inventory is made available.

A U.S. dioxin emissions inventory[6]



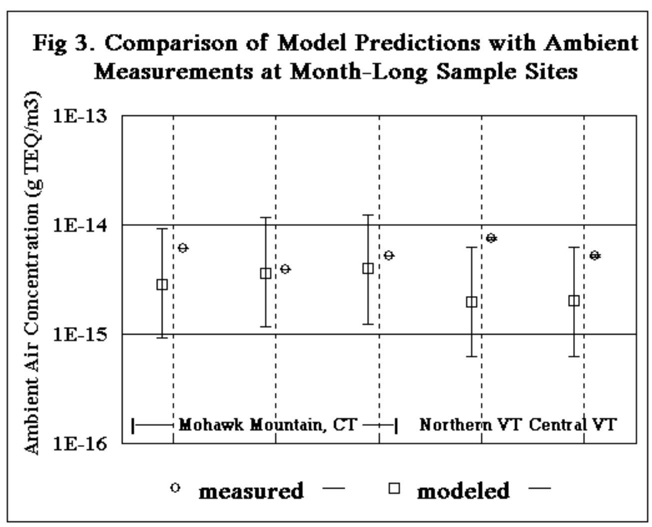

100000 - 335000
No Data Available
1000 Kilometers
Miles

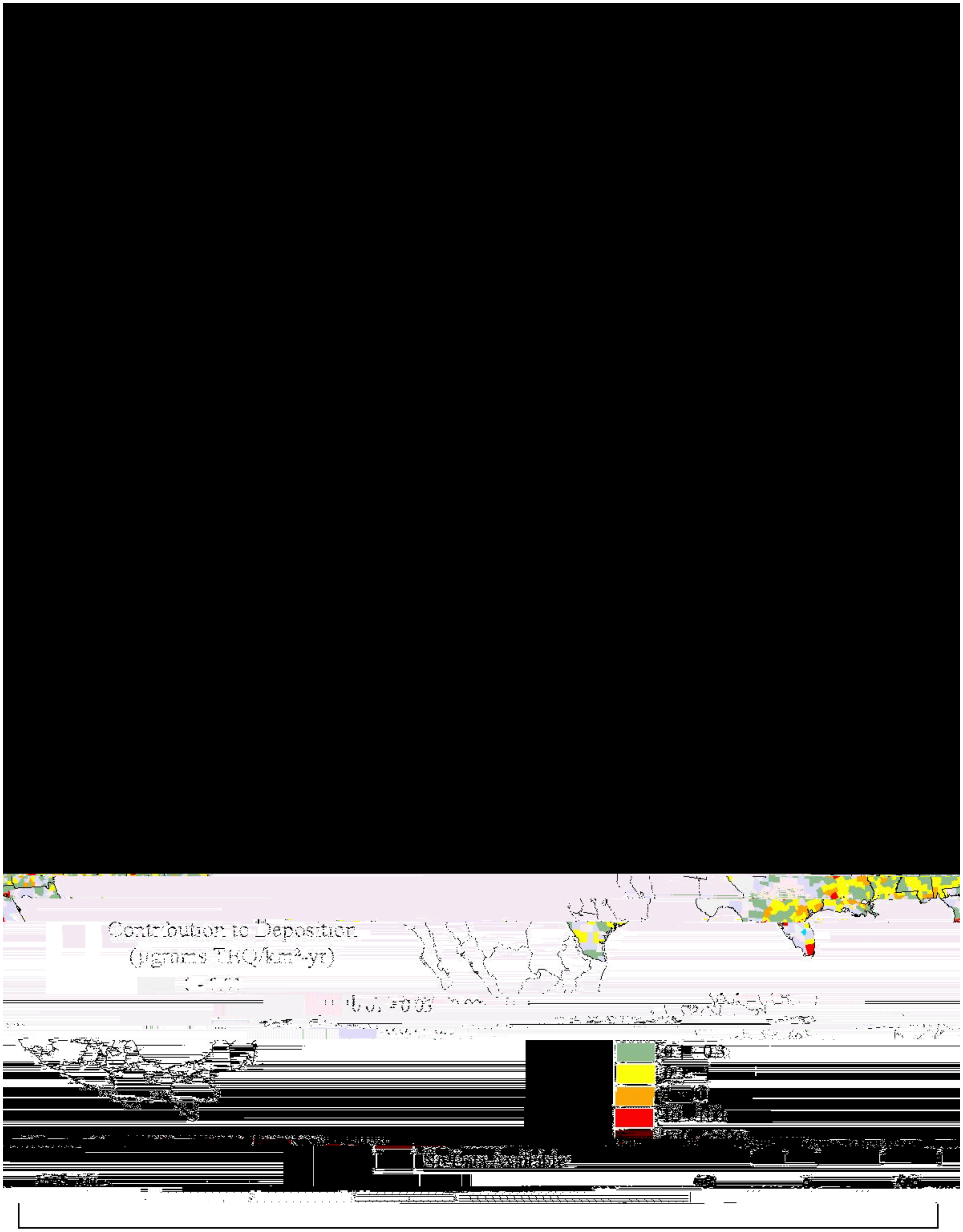
The uncertainties in the estimated overall dioxin emissions in the U.S. and Canada are significant -- on the order of a factor of three on either side of the mid-range estimates for each source category shown in Fig. 1. Uncertainties in the estimated emissions from any given individual source in the inventory is generally even greater than this. Few sources have been tested for dioxin emissions. Even for facilities that have been tested, there have generally been very few tests; given that dioxin emissions often appear to be highly variable -- frequently depending intimately on even small changes in feedstocks and process variables -- it cannot be said that a small number of stack tests will necessarily serve to adequately characterize the emissions from a given facility.

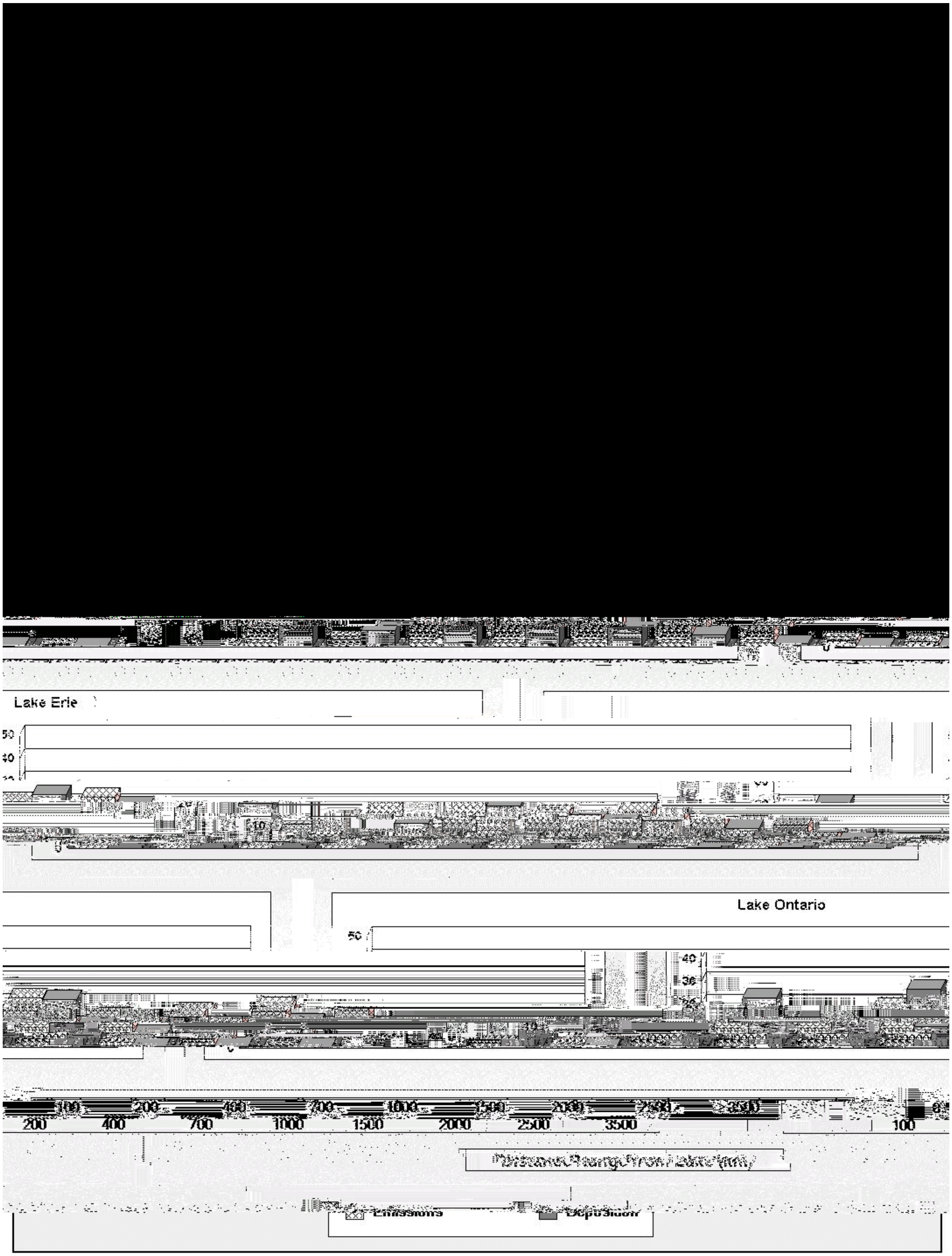
For essentially all the emissions inventory used in this analysis (except for many municipal waste incinerators), an emissions factor approach has been used to estimate emissions. In such an approach, (e.g., grams of dioxin emitted per metric ton of material processed by a given facility) are multiplied by (the amount of material processed by a given facility, e.g., metric tons per year) to obtain estimates of the facility's emissions. The emissions factors used are based on a critical review of existing emissions data for a given type of source, and where data allow, attempt to include information regarding differences in emissions due to differences in the type(s) of air pollution control equipment present, key process factors, and the nature of the material processed by the source. There is effectively no choice available in the matter of whether this approach should be used or not, as most individual sources have never been measured. It can be argued, however, that emissions factors mayarily serve to adequatel sporadic stack tests (even if they were available), given the potential variability in emissionsarily serve t1 Tc 0.0 developing emissions factors and toeiu3p1n.understand the variability in emissions from individual facilities; (3) regular, accurate updates on basic source information from significant sources, such as data on processes, air pollution control equipment, and activity factors. Only modest resources would be required to collect and disseminate such data (toeiu3p1n.quantify the 03ercausessurt), especially when considered in relation toethe potential costs of reducing emissions and the potential scale of adverse effects if no action is taken.

In addition, the inventories used in this analysis have at least the following omissions: (a) the U.S. inventory does not contain estimated emissions from residential or commercial coal combustion, magnesium manufacturing, or small commercial incinerators; (b) neither the U.S. nor the Canadian inventories include emissions from open-burning of PVC-coated wires (e.g., structure and vehicle fires), asphalt production, landfill fires and landfill gas combustion, coke

A modified version of the NOAA HYSPLIT[12] (Hybrid Single Particle Lagrangian Integrated Trajectory) model was used to simulate the atmospheric fate and transport of dioxin from sources in the United States and Canada to the Great Lakes. HYSPLIT is a Lagrangian model, in which puffs of pollutant are emitted from user-specified locations, and are then advected, dispersed, and subjected to destruction and deposition phenomena throughout the model domain. Similar to many atmospheric fate and transport models, HYSPLIT uses gridded meteorological data obtained from other sources. For these simulations, archived output from NOAA's Nested Grid Model (NGM), a sophisticate meteorological simulation model, was used. The modeling of the atmospheric fate of a dioxin performed here includes simulation of




Contribution to Deposition
(μgrams TEQ/km²-yr)


Lake Erie
Lake Ontario

Michigan originates from within 100 km of the lake. For all of the other lakes, the fraction of the deposition originating from sources within 100 km is less than this. The estimated total dioxin deposition flux to Lake Michigan for 1996 is on the order of 17 grams TEQ/year and the uncertainty range due solely to the estimated uncertainties in the emissions is 5 - 53 (approximately a factor of 3 on each side of the central estimate).

uncertainty in such estimates. However, to consider policy options, it can be argued that the exact contributions of individual sources to a given problem do not need to be known. Indeed, it may be enough to know about a few key issues:

- What is the geographical extent of the problem, i.e., is the problem predominantly local, regional, continental, etc., or some complex mixture of these different scales? While every effort should be made to develop the most accurate possible answer to this question, even rough approximations to the answer are useful for policy considerations. For example, it does not particularly matter, in the development of policy, if 40% or 30% of the contributing air sources arise from within 100 km of the Lake – the policy response will be similar in either case.

- Which source categories are the most significant contributors? Again, while every effort to develop the most accurate estimates should be made, approximate answers are still useful in the development of policy. For example, it does not matter that much whether municipal solid waste incinerators contribute 20% or 40% to the deposition – the policy response will likely be very similar.

There are three basic areas of knowledge necessary for developing toxics reduction strategies for dioxin in Lake Michigan -- effects, causes, and the costs of addressing the causes. The degree of knowledge in each of these areas is limited, and that this uncertainty plays an integral role in the discussion of toxics reduction strategies. Uncertainties in the assessment of atmospheric deposition should be considered along with uncertainties in other aspects of the overall policy analysis.

More “exact” answers to questions regarding atmospheric loading can and should be pursued. However, the rough approximations that are available now are a useful starting point for policy deliberations. To the extent that additional accuracy is desired, there are some relatively straightforward actions that can be taken to decrease many of the uncertainties in the analysis of the atmospheric deposition pathway for dioxin loading. These include, but are not necessarily limited to, the following:

- Ambient monitoring for dioxin must be increased in the Great Lakes region. This will allow model evaluation and independent semi-empirical estimates of atmospheric deposition to be made.

- Additional efforts to improve the accuracy of emissions inventories – including

‘ More information on other non-atmospheric loading pathways needs to be collected in order to more accurately place the atmospheric contributions in their proper context.

These recommendations are technically and administratively very manageable. They are small but necessary steps toward providing better answers for the development of toxics reduction strategies.

1. International Joint Commission (2000). , Windsor, Ontario.

2. Pearson, R.F., D.L. Swackhamer, S.J. Eisenreich, and D.T. Long (1998). “Atmospheric Inputs of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans to the Great Lakes: Compositional Comparison of PCDD and PCDF in Sediments.” J. Great Lakes Research 24(1): 65-82.

3. Cohen, M., , 1995. Flushing, NY: CBNS. Final Report to the Joyce Foundation.

4. Commoner, B., M. Cohen, , 1996. . Flushing, NY: CBNS. Excerpts reprinted in New Solutions , 1995.