



DIOXIN TASK FORCE

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Info ☐

Per Telecon ☐

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REMARKS:

Send copy
to G. Ill

FIVE YEAR RESEARCH STRATEGY
FOR
DYNAMICS AND AQUATIC TOXICOLOGY
OF
CONTAMINANTS IN THE GREAT LAKES

Draft

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U.S. Environmental Protection Agency
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including

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U.S. Environmental Protection Agency
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and

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P.O. Box 500
Monticello, Minnesota 55362

Note:
GCNFO
will be
seeking
comments
on this.

Note: HIGH RES
GC-MS ARRIVES
@ Duluth in
November then
10 chemists!

FAY

August 1983

Please Distribute to 1st tier of Dioxin TASK FORCE; SEE

PP8-13, 16-18
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Note references
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Introduction

The Great Lakes, their connecting channels and their tributaries, are a dynamic and complex freshwater ecosystem which supports numerous sensitive aquatic and terrestrial species. In addition the Great Lakes provides over 37 million people in eight U.S. states and one Canadian province with water for drinking, recreation, sport and commercial fishing, transportation, industrial development, and energy production.

During the past two decades, significant process has been made in reducing the amount of conventional waterborne pollutants entering the Great Lakes including watersheds. Nevertheless, today toxic pollutants are a major concern. Major sport fisheries are threatened with closure or harvest limits as the results of the present toxic substances in fish flesh.

Many local, state and federal jurisdictions share regulatory, research and planning responsibilities for Great Lakes water quality. The majority of the U.S. commitment to research, pollution abatement, surveillance and monitoring, and control programs are within the sphere of the United States Environmental Protection Agency.

The information presented within this strategy is the result of extensive coordination and discussion, not only within EPA but also with other Federal and States and with the academic community. It presents an affirmation of a continued commitment to effective Great Lakes research by the Environmental Protection Agency.

Purpose

The purpose of this strategy is to provide a five year framework for continued environmental research conducted and funded by EPA. The strategy

is based on the ecosystem approach which provides for a fuller evaluation and awareness of the consequences of the management decisions. This document presents a research strategy building on over a decade of research experience on the Great Lakes including both ongoing programs and initiatives by the Environmental Research laboratory-Duluth and its field stations and the scientific community within the Great Lakes Basin.

Strategy Perspective

Broad federal legislative mandates and the international objectives of the U.S.-Canadian Great Lakes Water Quality Agreement of 1978 serve as the driving force for this research strategy. Further, the underlying premise of this strategy is that state pollution control agencies will continue to have increased responsibility for water quality program administration and implementation. Moreover, U.S.-Canadian participants also recognize that the international character of the Great Lakes and the multi-media nature of its pollution problems that require a comprehensive Great Lakes water quality research and abatement program, which includes direct federal participation.

Currently, no organizational entity, short of the federal level, has a sufficiently broad overview to insure appropriate coordination of the integrated efforts on both the spatial and temporal scales required. The principal form of international communication for the protection of the lakes is through the federal governments of Canada and the United States. EPA has the lead role in developing and conducting the U.S. program. Communication is facilitated through the International Joint Commission. To assure that research is effective, emphasis must be placed on the use of the findings by the major media programs and the local and state agencies.

It will be necessary for both researchers and managers to increase their awareness of significant fundamental processes underlying Great Lakes pollution problems; to integrate within their own programmatic planning and specific

actions the basis for providing information and activities toward understanding control and abatement of those pollution problems; and to provide guidance and assistance in support of the efforts of the affected states.

Goal of Five Year Strategy

The principal goal of the five year research strategy for Dynamic and Aquatic Toxicology of Contaminants in the Great Lakes is to provide scientific information needed by the local, state, federal, and international governmental entities to:

1. To develop a scientific understanding of fundamental concepts of the numerous factors required to effectively manage the water quality of the Great Lakes,
2. To protect, restore and to enhance in a cost-effective manner the integrity of the Great Lakes ecosystem so that public health, welfare, and the environment are protected, and
3. To use the vast knowledge of the Great Lakes system in evaluating various alternative management approaches through a comprehensive ecological assessment of the impact of pollutants on the ecosystem.

Summary of Past Decade of Research Activities

Since the early 1970's, EPA has conducted research specifically related to the Great Lakes mainly through the Large Lakes Research Station in Grosse Ile, Michigan. The initial emphasis of the research program was the development of predictive tools that can be used in the assessment of the need for phosphorus control for eutrophication problems mainly in Lakes Erie, Ontario and Huron. A small research effort was also initiated on the impact of dredging activities.

In the mid-1970's a major initiative was begun on fundamental research to determine the sources, fate, pathways and effect of persistent toxic substances aimed at need for the protection of human health, fishery resources,

and wildlife of the Great Lakes Basin Ecosystem. The research activities focused mainly in three areas:

1. Determination of temporal and spatial trends in concentration of persistent toxic substances such as PCB, mirex, DDT, mercury and dieldrin, and of other substances known to be present in biota and sediment for the Great Lakes System.
2. Development and field verification of mathematical models to be used in the prediction-simulation of persistent toxic pollutants distribution, movement, losses and exposure.
3. Develop and field validate techniques to be used in the assessment of the exposure of toxic organic substances in lake systems.

The above three research activities were focused mainly on the "open lakes" ecosystem.

During the past three years, with the successful completion of the physical/chemical and food chain mathematical modelling of persistent toxic substances in the "open lake" ecosystem, a greater emphasis was placed on the effects of toxic substances on aquatic resources of the Great Lakes. In addition, the research expertise and facilities of the Large Lakes Research Station of ERL-D and of the main campus of ERL-D were combined including the Monticello Ecological Research Station at Monticello, Minnesota into a more integrated approach to the problem of toxic substances in fresh water ecosystems with special emphasis on the Great Lakes.

The integrated research activities included:

1. Development of protocols to assess the impact of persistent toxic substances on the quality and health of living aquatic systems.
2. Development and use of structure-activity correlations to predict environmental characteristics of chemicals.
3. Exploratory surveillance for new and unrecognized types and quantities of xenobiotic in the components of the aquatic and aquatic-related ecosystems.

4. Maintenance of data banks for storage of information on physical/chemical properties, toxicology, use and quantities in commerce of known and suspected persistent toxic substances.
5. Development of protocols to assess the interactive effects of residues of toxic substances on aquatic life and wildlife.

The combined expertise and efforts of the Large Lakes Research Station, Monticello Ecological Research Station and the main campus of ERL-D provides a unique opportunity to focus on the problems of toxic substances in the Great Lakes and other fresh water ecosystems by utilizing the combined talents as follows:

<u>Research Entity</u>	<u>Function/Expertise</u>
Main Campus of ERL-D	Aquatic Toxicology - Laboratories Studies
Monticello Ecological Research Station	Field Validation of Laboratory Toxicity Testing in Control Ecosystems
Large Lakes Research Station	Great Lakes Ecosystem Studies on the Distribution, Movement and Effects of Toxic Substances -- Contaminated Dynamics

Focus of the Five Year Strategy (1984-1998)

With the cleanup of many sanitary-type pollutants in the Great Lakes, such as BOD and nutrients, the fisheries resources of the Great Lakes are on the increase. In addition, active restocking programs are being conducted by the various Great Lakes states.

However, many of these fishes are contaminated with PCB's, dioxin, toxaphene and other organic compounds. There are fishing bans in certain "hot spot" areas, such as Saginaw Bay, Fox River, Raisin River, etc.

A paramount need exists for development of scientific framework for establishing regulatory action requirements to control the toxic chemicals which drastically limit the use of these fish because of potential human health effects. These toxic contaminants, if not controlled, will have a significant economic impact on the fisheries resources in the Great Lakes.

The major focuses of the five year research strategy will be to develop, validate and apply methods/models to measure, describe and predict the temporal and spatial distribution, movement, and resulting effects of polychlorinated organic chemicals on the "near-shore" movements of the Great Lakes. Major focuses will be on "in place" contaminants such as PCB's, toxaphene, dioxins, furans, naphthalenes, etc. While the entire "near-shore" ecosystem will be included in the research activities, special emphasis will be on the protection of fisheries resources.

The study of "in place" pollutants, especially in harbor areas, will have a dual purpose: (1) an early warning as to the entry of contaminants into the Great Lakes, thus requiring remedial action, and (2) the impact of the contaminants on the ecosystem. The second objective will require a greater level of understanding only provided through combined studies of the contaminant dynamics and toxicology. The integration of these two aspects of contaminant control will provide a quantifiable relationship between contaminant input and ecosystem protection.

The overall objectives of the five year strategy are to:

1. To identify the extent and degree of contamination of the environment in the Great Lakes Basin.
2. To develop a basic fundamental understanding of the sources, distribution and movement of the contaminants in the Great Lakes.
3. To determine the acute and chronic toxicity of organic pollutants to freshwater organisms.
4. To develop mathematical models which can be used in prediction/simulate the movement, losses and effects on aquatic life of various organic compounds.
5. To provide scientific data which can be used to conduct assessments of risk to aquatic resources, human health and the environment from exposure to these chemicals.
6. To identify areas requiring further followup study, source identification, and source control and/or reduction.

The chemicals of concern include many polychlorinated Dibenzo-p-dioxin and Dibenzofuran, naphthalenes, and other potential toxic xenobiotic organic compounds such as PCB's and toxaphene. Other pollutants, such as heavy metals, will also be put into a framework for amore complete analysis.

The combined approach of the Large Lakes Research Station, Monticello Ecological Research Station and the main campus of ERL-D will include the following thematic areas of research:

- I. Development of analytical procedures to detect trace analysis required in conducting the research program.
- II. Bioavailability and bioconcentration of these organic compounds.
- III. Determination of acute and chronic toxicity of these organic compounds to freshwater organisms, including establishing of water quality criteria.
- IV. Development of Quantitative Structure Analysis Relationships for bioconcentrations and toxicity of limited number of classes of these organic compounds.
- V. Identify and evaluate the sources, distribution and movement of these organic pollutants in the Great Lakes ecosystem including its various biotic compartments.
- VI. Maintenance of exploratory surveillance studies for new and unrecognized types and quantities of xenobiotic organics in the Great Lakes Basin.
- VII. Validation of toxicological properties of these organics including toxicity, bioavailability and bioconcentration in field and control test channels.

VIII. Development, validation and application of toxic substance models of fate, bioavailability and ecosystem effects.

The above eight areas are described in greater detail in the next section of this strategy.

Brief Description of Research Action in Eight Thematic Areas

Research Area I: Analytical Methods Development

1. Environmental Management Issue.

Analytical methods for many of the existing organic compounds are inadequate to detect the environmental concentrations at the ppt and ppq levels.

2. Research Need.

To develop chemical analytical methods required in conducting various bioavailability, bioconcentration, toxicology and fate-effect lab and field studies.

3. Specific Research Objectives.

Develop methodology to extend isolation and quantification of these organic compounds in particulate, water and tissue samples to 10^{-12} g sample levels.

4. Approach(es).

Improve chromatographic trace enrichment techniques and high extent resolution mass spectral sensitivity.

Research Area II: Bioavailability and Bioconcentration of Organic Compounds Such As Chlorinated Dibenzo-p-dioxins and Dibenzofurans

1. Environmental Management Issue.

Although much work has been reported or is in progress concerning the distribution of "dioxin" in environment, very little is known about the potential for bioaccumulation of the 75 different isomers of polychlorinated dibenzo-p-dioxin (PCDD) or the 135 different isomers of the closely related polychlorinated dibenzofurans. Any attempt at risk assessment associated with a particular occurrence of these compounds as contaminants of soils, sediments, waste materials, or aquatic organisms is severely impeded by our inability to predict their bioavailability and potential for reaching organisms

higher in the food chain, including man. Even the route of accumulation of 2,3,7,8-TCDD in fish is uncertain because of the extremely low water solubility and affinity of this compound for particulate matter. Reported occurrences in fish of disproportionately high concentrations of 2,3,7,7-TCDD and 2,3,7,8-TCDF in comparison to other TCDD and TCDF isomers should be investigated and explained in view of the extremely high mammalian toxicity of these two isomers.

2. Research Need.

To determine how these compounds are sequestered in freshwater environments, including sediments, and what physical, chemical, and biological factors control their bioavailability and bioconcentration.

3. Specific Research Objectives.

- a. Determine PCDD and PCDF isomer-specific bioconcentration factors.
- b. Develop a model membrane system for measuring relative availability of PCDD and TCDF isomers for uptake by fish under varying water exposure conditions.
- c. Determine under what physical, chemical, and biological conditions PCDDs and PCDFs associated with sediments are available for bioaccumulation and/or toxic effects.
- d. Determine the physiological and pharmacokinetic factors which influence relative bioconcentration factors for different PCDD and PCDF isomers.
- e. Evaluate the relative importance of gill versus ingestion exposure for PCDD and PCDF uptake by fish.
- f. Develop a method for predicting the bioavailability to fish of PCDDs and PCDFs on the basis of isomer physical and chemical properties, route of exposure, water chemistry, particulate interactions and pharmacokinetics of membrane transfer.

4. Approach(es).

Bioaccumulation and toxic effects observed in laboratory exposures of fish to specific PCDD and PCDF isomers will be related to exposure conditions, water chemistry, particulate interactions and physiological and pharmacodynamic factors for exposed organisms. Emphasis will be placed on the role of these factors in controlling the availability of each isomer for membrane interaction and transfer during exposure. Exposure conditions will be determined by consideration of environmental monitoring data and the nature of PCDD and PCDF sources for environmental contamination. Additional attention will be placed on rates of uptake, metabolism and elimination for exposed fish.

Research Area III: Toxicity of Organic Compounds and Complex Effluents to Freshwater Organisms

1. Environmental Management Issue.

Many of these organic compounds are present in the freshwater environment. Little or no toxicity data is currently available on these organic compounds.

The two principal ways in which effluent limits are established for the protection of aquatic and its uses are through the establishment of concentration limits to protect the organism itself and body burden levels to protect the wildlife and humans which feed upon the organisms. The protection against toxic levels can be through individual chemical criteria or effluent toxicity limits.

2. Research Need.

To determine, by laboratory and field bioassays, the acute and chronic toxicity of these chemicals to freshwater organisms. To determine what physical chemical, and biological factors affects the toxicity of these chemicals. There is a need to determine the relationship of effluent toxic and ecosystem impacts in Great Lakes harbor and near shore.

3. Specific Research Objectives.

- a. Determine the chronic "no effect" level of dioxins and other organic compounds to aquatic organisms.
- b. Determine the histopathological effects of dioxins and other organic compounds at environmental concentrations.
- c. Field validation of sub-lethal dioxin and other organic compound effects in tissues from contaminated river systems.
- d. Determine relationship of effluent toxicity receiving stream toxicity and ecosystem response.

4. Approach(es).

- a. Conduct full-life chronic tests with TCDD and related chemicals using aquatic organisms.
- b. Conduct thorough histological examination of fish exposed to dioxins and other organic compounds.
- c. Sample natural populations of rivers contaminated with dioxin and other organic compounds and conduct thorough histological analysis.
- d. Conduct chronic toxicity tests of effluents and receiving stream water and relate to ecosystem condition.

Research Area IV QSAR - Predictive Models.

1. Environmental Management Issue.

Many new and existing organic compounds have many isomers. Little or no toxicity data is available on the isomers of the existing and new compounds. Resources to conduct toxicity tests are very limited.

2. Research Need.

To develop QSAR for bioconcentration and toxicity of limited numbers of these classes of chemicals so that predictive models for toxicity and bioconcentration can be established for many of the isomers and other individual species.

3. Specific Research Objectives.

- a. Determine the acute toxicity of homologs and related polychlorinated planar chemicals to fathead minnows.
- b. Develop structure-toxicity relationships for planar molecules including dioxins.

4. Approach(es).

- a. Using the established reference test for acute toxicity, develop a reference set of data systematically for structural homologs.
- b. Apply established QSAR methods to the reference set and corresponding molecular descriptors.

Research Area V: Occurrence, Distribution and Environmental Impact

1. Environmental Management Issue.

The major route of PCDD, PCDF and other organic compounds to fish and other aquatic life is through direct uptake from water, ingestion with food, and indirectly from sediments. Most of the PCDD and PCDF will be quickly associated with sediments once it reaches the aquatic environment. The major issues are what is a safe concentration in the water, food organisms, and sediments to keep levels in the biota below action limits.

2. Research Need.

- a. Determine the extent of contamination in the Great Lakes including water, sediment and food organism concentrations.
- b. Determine the mechanisms of accumulation of PCDD, PCDF and other organic compounds in sediments.
- c. Determine the transport and distribution rates in aquatic systems.
- d. Determine if different isomers accumulate differently?

- e. Determine if organisms and fish accumulate PCDD, PCDF and other organic compounds from contaminated sediments? If so, at what rate?

3. Specific Research Objectives.

- a. Determine concentrations of PCDD, PCDF and other compounds in water sediment and biota in selected contaminated areas.
- b. Determine occurrence and distribution of PCDD, PCDF and other organic compounds through mass balances of impacted areas.
- c. Determine the role of sediments in the transport of PCDD, PCDF and other organic compounds.
- d. Determine the relative importance of routes of uptake of PCDD, PCDF and other organic compounds.
- e. Determine if accumulation is isomers specific.

4. Approach(es).

- a. In selected Great Lakes and river systems known to be contaminated with PCDD, PCDF and other organic compounds, measure ambient concentrations in water biota and sediments.
- b. Attempt to construct a mass balance of PCDD, PCDF and other organic compounds in a known area.
- c. Conduct studies on the relationship of sediment contamination and organic uptake, as to routes and rates.
- d. Conduct studies on the behavior of PCDD, PCDF and other organic compounds in sediments.
- e. Conduct studies using specific isomers to determine if differences exist in their accumulation.

Research Area VI: Exploratory Surveillance for Xenobiotic Chemicals

1. Environmental Management Issue.

The presence of xenobiotic chemicals in various compounds of the environment is not well known today. Fish are a good early warning indicator. A program of exploratory surveillance of xenobiotic chemicals is needed.

2. Research Need.

To maintain exploratory surveillance studies for new and unrecognized types and quantities of xenobiotic chemicals in the various components of the freshwater environments.

3. Specific Research Objectives.

Isolate, identify and quantify isotereomers of xenobiotic chemicals in sediment, water and biological tissue (fish, aquatic, birds) from select watersheds throughout the Great Lakes Basin and other WSA Watershed.

4. Approach(es).

Isostereomers of xenobiotic chemicals are to be isolated by select chromatography and analyzed by high resolution mass spectrometry.

Research Area VII : Field Validation of Laboratory Toxicological Information

1. Environmental Management Issue.

Before laboratory derived water quality criteria can be used in regulatory process, a need exists to field validate the products used in developing the criteria levels.

2. Research Need.

For these toxic organic compounds, the need exists to validate the products using a select number of toxic organic compounds in a control field environment.

3. Specific Research Objectives.

- a. Field validate the guidelines for deriving water quality criteria for the protection of aquatic life and its uses for various classes of organic compounds.
- b. Field validate the guidelines for modifying National Water Criteria.

4. Approach(es).

- a. Using the control channels at the Monticello Ecological Research Station conduct long term toxicological studies using select organic compounds.
- b. Conduct intensive surveys in highly contaminated areas to determine efficacy of laboratory-derived toxicological information such as in the Fox, Raisin and Tittabawassee Rivers.

Research Area VIII: Toxic Compound Impact Mathematical Models

1. Environmental Management Issues.

Existing mathematical models have limited capability in relating pollutant exposure to organic compounds. In order to evaluate various management alternatives for the organic compounds a need exists to enhance the modeling capability including incorporation of aquatic impacts.

2. Research Need.

It is necessary to develop and apply predictive techniques to determine the fate, bioavailability and ecosystem effects of toxic organic substances so that credible and defensible requirements can be established for the regulation of effluents discharging to tributaries of the Great Lakes. At the present time, the following methodologies are available to address this problem:

- 1) models of fate and transport of organic and inorganic chemicals in the water column and sediments of rivers and estuaries of the Great Lakes and of the open waters of the Lakes;
- 2) models of food chain uptake and transfer of chemicals from primary producers to top predators;
- 3) empirical relationships between the concentration of chemicals and chemical mixtures, and measures of toxic effect on the ecosystem.

However, there exists no integrated analysis and modeling framework that incorporates all of these components and permits an estimation of the toxicity effect on target organisms of a given discharge or group of discharges for a single chemical or for complex effluents. Further, full scale field validation of various modeling frameworks and associated hypotheses related to a variety of chemical fate, accumulation and toxicity issues is required in order to demonstrate the validity of any integrated framework.

3. Specific Research Objectives.

- a. Additional evaluation of state-of-the-art of chemical fate models for several classes of these organic constituents to determine exposure concentrations.
- b. Additional evaluation of state-of-the-art of food chain transfer models for several classes of these organic constituents to determine dose levels.
- c. Determine the degree to which toxicity as measured in toxicity units can be modeled by state-of-the-art fate and transport models and related to field/laboratory toxicity measurements.

- d. Test suitability of various hypotheses that relate individual chemicals to total toxicity to specified test organisms.
 - e. Investigate relationship between chemical body burden and effects on physiological behavior of organisms and chronic bioassay end points (e.g., reproduction).
 - f. Evaluate interaction between temporal and spatial variability in toxic substances concentration and body burden in specified organisms.
4. Approach(es).
- a. The modeling effort be modular to handle the five components of the generalized modeling framework. These components are: 1) single pollutant direct toxicity, 2) multi-pollutant direct toxicity, 3) sediment toxicity, and 4) food chain bioaccumulation and body burden, persistence, and bioavailability of specific organic compounds and its isomers.
 - b. The modeling effort be able to handle both steady-state and fluctuating exposures.
 - c. The algorithms be able to handle multi-pollutant discharging with various numbers of pollutants for discharge.
 - d. The model be able to incorporate basic water quality chemistry conditions, such as temperature, pH, hardness, and alkalinity, required to modify toxic relationships.

Research Priorities and Resources

The five year research strategy, including goals, needs, specific objectives and approaches will require detailed review by the various EPA Program Offices, Regions, ORD and scientific community. Once this review is completed a detailed technical research plan need will need to be developed for the five year period.

It is anticipated that the major source of funding for this strategy will come from various resources coming to ERL-D, including:

- 1) Great Lakes - Water Quality,
- 2) Water Quality,
- 3) Hazardous Waste, and
- 4) Toxics, and
- 5) National Dioxin Survey

Preliminary estimates of the five year research strategy is about \$1,500 K/Year of extramural resources with an intramural cost of about 8-10 FTE's/Year at a resource level of \$1,000 K/Year from the Great Lakes program element. These resources plus those in the base program and those from the National Dioxin Survey will allow ERL-D and its field station sufficient funds to complete the objectives of this five year study.

Outputs

Research Area I: Analytical Methods Development
(In conjunction with National Dioxin Survey)

<u>Outputs</u>	<u>Date</u>
Analytical methods for main isomer of dioxin and furans	1984
Analytical methods for additional isomers	1985
Procedures for concentration of water samples	1985
Analytical methods for other organic contaminant	1986-1989

Research Area II: Bioavailability and Bioconcentration
(In conjunction with ERL-D base program funds)

<u>Outputs</u>	<u>Date</u>
PCDD and PCDF isomer-specific bioconcentration factors	1984
Methods for predicting bioavailability	1985
Model membrane system for measuring relative availability	1986
Physiological and pharmacokinetic factors	1987
Final report on bioavailability and bio-concentration	1989

Research Area III: Aquatic Toxicology

<u>Outputs</u>	<u>Date</u>
Acute toxicity of main isomers	1984
Chronic toxicity of main isomers	1985-1986
Acute toxicity of other isomers	1985-1986
Chronic toxicity of other isomers	1986-1987
Acute/chronic toxicity of other organics	1988-1989

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Research Area VIII: Toxic Modelling

<u>Outputs</u>	<u>Date</u>
Model development	1984-1985
Model application	1984-1985
Raisin River	1984-1985
Fox River	1984-1985
Tittabawasse River)	
Wisconsin River)	1985-1988
Other areas)	
Final model documentation	1989

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Eastern District Office