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MERCURY RESEARCH MULTI-YEAR PLAN

Office of Research and Development

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Not Yet Externally Peer Reviewed

The Office of Research and Development's (ORD) multi-year plans (MYPs) present ORD's proposed research (assuming constant funding) in a variety of areas over the next 5-8 years. The MYPs serve three principal purposes: to describe where our research programs are going, to present the significant outputs of the research, and to communicate our research plans within ORD and with others. Multi-year planning permits ORD to consider the strategic directions of the Agency and how research can evolve to best contribute to the Agency's mission of protecting human health and the environment.

MYPs are considered to be "living documents." ORD intends to update the MYPs on a regular basis to reflect the current state of the science, resource availability, and Agency priorities. ORD will update or modify future performance information contained within this planning document as needed. These documents will also be submitted for external peer review.

PREFACE

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1.0 INTRODUCTION

Contamination caused by release of mercury into the environment is a growing concern. This release occurs due to a variety of anthropogenic activities and natural sources. After release, mercury undergoes complicated chemical transformations. The inorganic forms of mercury released into the environment can be converted, by naturally occurring biological processes, into species. This species is known to bioaccummulate in fish and marine mammals. Human and wildlife exposures to methyl mercury have been associated with serious neurological and developmental effects.

Since mercury is a natural metallic element, it will always be present in the environment in one form or another. According to the U. S. Environmental Protection Agency's (EPA's) *Mercury Study Report to Congress* (December 1997), mercury fluxes and budgets in water, soil, and other media have increased by a factor of two to five over pre-industrial levels. As the quantity of available mercury in the environment has increased, so have the risks of neurological and reproductive problems for humans and wildlife, making it a pollutant of considerable human health and environmental concern. Mercury is the most frequent basis for fish advisories. Almost 79 percent of all advisories in the United States are at least partly due to mercury contamination in fish and shellfish. For example, as of December 2000, mercury was the chemical contaminant responsible, at least in part, for the issuance of 2,242 fish consumption advisories by 41 states in one or more water bodies, and thirteen states had issued statewide mercury advisories. As of December 2002, 2,140 fish consumption advisories in 45 states were issued in part due to mercury concentrations. That same year, 19 states had issued statewide mercury advisories for freshwater lakes and/or rivers, and 11 states had issued coastal advisories. The growing concern over the number and spatial extent of fish consumption advisories due to mercury led ORD to launch a Mercury Research Initiative in FY 2000.

In the summer of 2000, ORD's Executive Council directed that Multi-Year Plans (MYPs) be developed for 16 different major ORD research programs including the Mercury Research Program. The purpose of the MYPs is to aid ORD as a planning and communication tool. They will provide a link between the Agency and ORD's strategic plans and our annual plans that serve as a basis for ORD's budget request. They will also provide a logic and sequencing for the ORD's research program.

In the Fall of 2000, the first iteration of the Mercury Research Multi-Year Plan (MYP) was developed in accordance with the framework and recommendations provided in ORD's *Research Strategy for Mercury* (2000). The first iteration of the MYP was presented to the Executive and Science Councils of ORD in December 2000 where it received critical review. Reflecting the evolving nature of the multi-year plans, a second iteration of the plan was provided to the Office of Science Policy in October 2001.

This is the third version of the Mercury Research Multi-Year Plan and reflects ORD's most recent interpretation of Agency research needs concerning mercury sources, control and treatment, environmental fate and behavior, impacts on ecological resources, and potential effects on human health. The plan includes research activities implemented and planned for the period 2002 through 2010. Resources for the implementation of these research activities are currently approximately $5.5 M and 8.0 FTE per year. The FY 2004 Clear Skies Initiative potentially could add approximately $1.5M to the total available for the implementation of the Multi-Year Plan.

2.0 BACKGROUND

2.1 State of the Science

The *Mercury Study Report to Congress* (Report to Congress) (EPA, 1997) described the magnitude of mercury emissions in the United States, identified mercury emission sources, assessed the health and environmental implications of those emissions, and evaluated the availability and cost of technologies for emission control. It is the most comprehensive human health and environmental investigation of mercury and methyl mercury available. The *Report to Congress* serves as the foundation for EPA's understanding of the risk assessment and risk management issues associated with mercury and methyl mercury. It contributes significantly to the strategic directions and the key scientific questions posed in the *Mercury Research Strategy*.

In the *Report to Congress*, EPA concluded that a plausible link exists between human activities that release mercury from industrial and combustion sources in the United States and methylmercury concentrations in humans and wildlife. In preparing the report, EPA conducted a quantitative human health risk assessment of methyl mercury. The assessment estimated that between one and three percent of women of childbearing age (i.e., between the ages of 15 and 44 years) in the United States eat sufficient amounts of fish for their fetuses to be clearly at risk from methyl mercury exposure and that 7 percent exceeded USEPA's recommended reference dose and, therefore, could be at risk . Since then, that estimate has been confirmed by monitoring data, collected through CDC'S NHANES survey, which have shown that approximately 8 percent of women of childbearing age in the United States have concentrations exceeding the reference dose.

The *Mercury Study Report to Congress* also concluded that mercury poses risks to various wildlife, including some birds and fur bearing mammals such as loons, mink, and otters. The *Report to Congress* comprehensively identified research needs to improve both mercury risk assessment and risk management.

2.2 Science Questions

While *The Mercury Study Report to Congress* supports a plausible link between mercury emissions and the presence of methyl mercury in humans, a number of major uncertainties related to both the risk assessment and risk management of mercury and methyl mercury remain. To address these uncertainties, EPA, in an intra-agency effort coordinated by the Office of Research & Development, developed the *ORD Mercury Research Strategy*, which poses these uncertainties as the following six key scientific questions that need to be addressed.

1. How much methyl mercury in fish consumed by the U.S. population is contributed by U.S. emissions relative to other sources of mercury (such as natural sources, emissions from sources in other countries, and re-emissions from the global pool); how much and over what time period, will levels of methyl mercury in fish in the U.S. decrease due to reductions in environmental releases from U.S. sources?

2. How much can mercury emissions from coal-fired utility boilers and other combustion systems be reduced with innovative mercury control technologies; what is the relative performance and cost of these new approaches compared to currently available technologies?

3. What is the magnitude of contributions of mercury releases from non-combustion sources; how can the most significant releases be minimized?

4. What are the risks associated with methyl mercury exposure to wildlife species and other significant ecological receptors?

5. What critical changes in human health are associated with exposure to environmental sources of methyl mercury in the most susceptible human sub-population? How much methyl mercury are humans exposed to, particularly women of child-bearing age and children among highly-exposed population groups; what is the magnitude of uncertainty and variability of mercury and methyl mercury toxicokinetics in children?

6. What are the most effective means for informing susceptible populations of the health risks posed by mercury and methyl mercury contamination of fish and seafood?

2.3 Agency Priorities and Regulatory Program

Numerous Program Office commitments related to mercury must be addressed over the next five to ten years. These include:

2.3.1 Regulatory Commitments:

- Mercury Controls for Utilities - One of the most important commitments is the Office of Air and Radiation's (OAR's) implementation of the Clean Air Act, as amended (the Act). As required by section 112(n) of the Act, EPA made a determination (December 15, 2000) that regulation of Hazardous Air Pollutants (HAPs), including mercury from oil- and coal-fired utilities was necessary and appropriate. EPA is now required to propose regulations by December 15, 2003 and to promulgate final regulations by December 15, 2004. Full compliance by

the utility industry would be expected to occur by December 15, 2007. As necessitated by the decision to regulate, development of technical information and data on the performance of options to reduce emissions from these utility boilers will be needed. Information in these areas will also be needed if proposed legislation known as the Clear Skies Act of 2003 is enacted by Congress.

- MACT Rules for Chlorine Production, Municipal Solid Waste Landfills, and Industrial/Commercial/Institutional Boilers - Under section 112 of the Clean Air Act, EPA is required to develop national emission standards based on maximum achievable control technologies (MACT) for major sources of HAPs listed in section 112 (b) of the Act. Several of these source categories, such as chlorine production, municipal landfills, and industrial, commercial, and institutional boilers, are required to address mercury emissions. Each of these rules are discussed in more detail below. Generally, sources are required to be in full compliance with these rules three years after promulgation of the final rule. In addition, within eight years EPA must consider whether any additional standards are needed to protect public health if "residual risks" exist after MACT standards are fully implemented.
- Chlorine Production - The EPA is developing a rule that will limit mercury emissions from plants that produce chlorine using the mercury cell method. The EPA plans to issue a final rule by August 2003 that will be based on best available control technologies and on stringent management practices.
- Municipal Solid Waste Landfill Rule - The OAR has developed a rule that addresses emissions of HAPs from municipal solid waste landfills. This rule also addresses contiguous geographical space/facilities receiving household waste, and other types of Resource Conservation and Recovery Act (RCRA) Subtitle D waste, such as commercial solid waste, non-hazardous sludge, conditionally exempt small quantity generator waste and industrial solid waste. The rule was promulgated in January 2003.
- Develop Initial Urban Area Source Standards (50%) - The Integrated Urban Air Toxics Strategy, which was published in the Federal Register on July 19, 1999 (64 FR 38706) is an important part of EPA's national air toxics program. It is a framework for addressing air toxics emissions in urban areas. Under the national air toxics program, EPA has and will continue to develop a number of national standards for stationary and mobile sources to improve air quality in urban and rural areas. The Urban Air Toxics Strategy complements the existing national efforts by focusing on achieving further reductions in air toxics emissions in urban areas.
- The Urban Air Toxics Strategy outlines actions to reduce emissions of air toxics, as well as assessment activities to improve EPA's understanding of the health and environmental risks posed by air toxics in urban areas. The strategy includes a list of 33 air toxics (including mercury) judged to pose the greatest potential

health threat in urban areas. Through three separate listings (including a list in the Urban Air Toxics Strategy), EPA has identified a total of 70 area source categories, which represent 90 percent of the emissions of the 30 listed air toxics. Of these 70 area source categories, 14 have been regulated and the remaining area source standards are under development or will be developed in the future.

- Wildlife Water Quality Criterion for Mercury - The Office of Water (OW) published a revised human health water quality criterion in January 2001. There is still a need for a wildlife criterion, however, which would protect birds and terrestrial animals from the effects of mercury.
- Total Maximum Daily Loads (TMDLs) - OW is conducting two pilot projects for water bodies impaired by airborne deposition of mercury. States may be able to use the modeling approaches developed under the pilots to support TMDLs for water bodies impaired by air deposited mercury. EPA is also developing nation-wide mercury deposition data to assist States in developing TMDLs.
- Revise Land Disposal Restrictions for Mercury-bearing Hazardous Wastes (Proposal)- The Office of Solid Waste and Emergency Response (OSWER) is continuing to evaluate land disposal restrictions on mercury to consider alternatives to mercury recovery and incineration. In January, 2003, the EPA published a Notice of Data Availability which contained data on the performance of different treatment technologies on elemental mercury and on waste sludge contaminated with mercury. The Agency has asked the public for any additional information which would be useful for evaluating treatment alternatives for wastes containing mercury.
- Phase 2 MACT Rule for Hazardous Waste Combustion (Proposal)- OSWER is planning to issue a proposal establishing MACT standards for emissions of HAPs, including mercury, from boilers and industrial furnaces which burn hazardous waste. This rule follows on the Phase 1 hazardous waste combustion MACT rule which set standards for incinerators, cement kilns, and lightweight aggregate kilns which burn hazardous waste. A proposed revised MACT rule for hazardous waste combustion is expected in December 2003, with a final rule by May 2005.

2.3.2 Other commitments:

In addition to the Agency's regulatory commitments with respect to mercury, there are also several legislative proposals and special Agency initiatives and activities that will likely influence future mercury research priorities:

- The Bush Administration has proposed legislation that includes mandatory caps to reduce emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and mercury from utility boilers over the next fifteen years. This multi-pollutant approach

was introduced as the Clear Skies Act (CSA) of 2003 by both the US House of Representatives (HR 999) and the US Senate (S485) on February 27, 2003. The goal is to provide a flexible market-based approach that will simultaneously protect the environment from the impacts of emissions associated with power plants while at the same time providing regulatory certainty that can be used by the industry to make long-term investments in pollution control equipment. If the proposal is passed by Congress, regulation of mercury emissions from electric utility steam generating units under Section 112 of the Clean Air Act would be precluded because it would be rendered unnecessary by the market-based mercury emission reduction program. In addition, passage of the proposal would authorize an extensive research program to support implementation of the various provisions of the CSA. Major elements of the science section (482) are to: (1) expand current research and knowledge of the contribution of emissions from electricity generation to exposure and health effects associated with particulate matter and mercury; 2) enhance current research and development of promising multi-pollutant control strategies and CEMS for mercury; 3) produce peer reviewed scientific and technology information to inform the review of emissions levels under section 410 of the CSA; 4) improve environmental monitoring and assessment of sulfur dioxide, nitrogen oxides and mercury, and their transformation products, to track changes in human health and the environment attributable to emissions reductions; and 5) periodically provide peer-reviewed reports on the costs, benefits, and effectiveness of emission reductions.

- In early April 2003, proposed legislation known as the “Mercury Reduction Act of 2003" (S616) was introduced in the US Senate. A similar bill is still in committee in the US House of Representatives. The goal of this bill is to reduce the quantity of mercury in the environment by limiting the use of mercury fever thermometers and by improving the collection and proper management of elemental mercury. Included in this proposed legislation is a requirement for EPA to conduct research, development and demonstration of mercury stabilization technologies and long-term storage measures that will ensure minimal release of mercury to the environment.

- EPA is developing a Mercury Action Plan (MAP) that will outline the Agency’s strategy for addressing multi-media mercury pollution and exposure over the next several years, within the framework of current statutory authorities. When completed, this document will present the Agency's mercury goals, commitments to priority actions to reduce mercury, and plans for measuring progress towards goals. The Plan will also include a baseline of mercury health and environmental data, and a description of how existing regulatory and

voluntary mercury programs at EPA and elsewhere are addressing aspects of mercury health and environmental concerns. EPA expects to publish a new draft Mercury Action Plan for public comment in the fall of 2003, and to issue a final Mercury Action Plan in the fall of 2004. In order to make progress toward goals in the MAP to reduce and prevent mercury releases into the environment, several Agency programs are pursuing voluntary as well as regulatory activities. Some examples are as follows:

- The Office of Prevention, Pesticides, and Toxic Substances (OPPTS) and the Great Lakes National Program Office (GLNPO) are undertaking voluntary efforts to remove mercury from wastes, products, and processes, with a goal of a 50 % reduction by the mid-2000s.

- The Office of Solid Waste and Emergency Response (OSWER) is undertaking a voluntary effort to reduce the volume and content of persistent, bioaccumulative toxics (PBTs) (including mercury) in hazardous wastes by 50% before the end of FY 2005.

2.3.3 Bilateral and Multilateral Program Commitments:

A number of bilateral and multilateral programs offer the United States an opportunity to promote and engage in cooperative efforts to better understand and ultimately reduce the risks of mercury and methyl mercury exposure. While some opportunities are voluntary and others entail legally binding commitments, EPA's involvement in international efforts is conducted within the context of its existing statutory authority, especially with respect to the Clean Air Act. Rather than being driven by, or reacting to, international initiatives on mercury, the Agency is trying to influence them proactively. These include:

- The 1998 Aarhus Protocol to the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (LRTAP) on Heavy Metals (UNECE, 1998)
- The Arctic Environmental Protection Strategy (AEPS) - Arctic Council, particularly the Protection of the Arctic Marine Environment (PAME) and Arctic Monitoring and Assessment Program (AMAP) programs (eight member countries) (Arctic Council, 2000)
- The North American Regional Action Plan on Mercury
- The Great Lakes Binational Toxics Strategy: Canada-United States Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes (Canada and the United States)
- The Northeastern States and Eastern Canadian Provinces Mercury Study: A Framework for Action (NESCAUM, 1998)

- The United Nations Environment Program's decision (February, 2003) to undertake a global mercury program, based on its 2002 global assessment of mercury.

Other issues related to mercury that need to be given consideration include:

- The Office Directors' Multimedia and Pollution Prevention (M2P2) Forum's decision to give cross-Agency efforts on the Mercury Action Plan a high priority in the coming years. An important issue to be addressed is the need for mercury disposal technology for both mercury-containing wastes and elemental mercury. This is an issue that will receive increasing attention from OSW and OPPTS as the United States moves from "mercury as a commodity" to "mercury as a waste". Major sources of elemental mercury include: (1) the DOD mercury strategic stockpile, (2) the excess mercury resulting from the closure of mercury cell chlor-alkali plants, and (3) the increased emphases on mercury product take back programs by the States and other entities. There is a need to develop alternative ways to deal with mercury-containing products and mercury-containing wastes in addition to the traditional retorting and recycling approach.
- The Regions and States along with other jurisdictions question how best to address mercury Total Maximum Daily Loads (TMDLs) for various water bodies. This appears to be an important issue for the States (e.g., ECOS) in light of the long-range and transboundary nature of mercury air emissions and deposition.

While this plan does not address routine ambient monitoring or monitoring of mercury activities performed by the various Program Offices, it should be recognized that there are research needs associated with improved monitoring of mercury for various media. It can be anticipated that this plan will support and reflect those research plans for mercury being recommended under the Agency's persistent, bioaccumulative and toxic (PBT) Monitoring Strategy, whose goals are to provide information to allow discernment of long-term trends in various media and the extent of overall effectiveness of risk management programs.

Finally, it can be anticipated that EPA will be called upon to support the White House Interagency Working Group on Methylmercury, which was established in 2002 under the Committee on Environmental and Natural Resources (CENR) of the National Science and Technology Council. The mission of this Working Group is to provide an interagency forum for the advancement of effective interagency coordination, strategic planning and research and development to better understand the impact of methylmercury on human health and to identify potential solutions. The initial focus of the Group is on mercury contamination and exposure in the Gulf of Mexico area.

3.0 MERCURY LONG TERM GOALS

The Mercury MYP has two long term goals: 1) To reduce and prevent release of mercury into the environment, and 2) To understand the transport and fate of mercury from release to the receptor and its effects on the receptor. Each of the questions in ORD's Mercury Research Strategy, which could conceivably be a long range goal in themselves, are addressed by the various Annual Performance Goals in the Multi-year Plan. These long range goals are intended to support multiple Program and Regional Offices. The major emphasis, particularly in the earlier years of the Plan, however, is the support of OAR's Mercury Control of Utilities, since this is the most immediate regulation facing the Agency with regard to mercury and since the most significant releases of mercury in the United States occur as a result of emissions to the atmosphere from anthropogenic sources, particularly the combustion of fossil fuels containing trace amounts of mercury including industrial processes and the incineration of municipal and medical wastes [*The Mercury Study Report to Congress (1997)*]. Other customers of the plan, as indicated above, include the Office of Water, the Office of Solid Waste and Emergency Response, the Office of International Activities, and the Office of Prevention, Pesticides, and Toxic Substances.

Basically the APGs in the MYP reflect the research needs for: risk management research for managing emissions from coal-fired utilities, risk management research for non-combustion sources of mercury, fate and transport of mercury from environmental sources of mercury to fish, health and ecological risk assessment for mercury, and risk communication research. These areas were considered the most critical in terms of support of the Agency's regulatory needs as described above and in response to the science questions posed by the *Research Strategy for Mercury*. EPA's ability to provide the best results for the regulatory efforts and response to the scientific questions will be dependent on the research of other Federal agencies, such as the Department of Energy and the U.S. Geological Survey.

The relationships between the APGs that comprise each of the two long-term goals are shown in the figures in Appendix 1. Under the first goal there are 5 APGs. Two (FY 2003 and FY 2008) relate to the risk management research to support the comprehensive evaluation and assessment of technologies for managing emissions from coal-fired utilities. Although a proposed rulemaking on coal-fired utilities is expected in December 2003 and a final rulemaking in December 2004, compliance is not expected until December 2007. Research developed for the FY 2005 APG (Provide a comprehensive evaluation and assessment of technologies for managing emissions from coal-fired utilities.) will be very helpful to the utilities in their efforts to achieve compliance. If the utilities regulation developed under the existing Section 112 of the Clean air act is finalized in 2004, risk management research on combustion sources of mercury is expected ro remain level through FY 2004 and then slowly decrease as the deadline for compliance nears. However, an APG for FY 2008 is included to reflect anticipated work needed to support the Clear Skies Act of 2003, or other multi-pollutant

legislation. If the Clear Skies Act is enacted, the emphasis of this combustion research beyond FY 2004 will need to be revisited and likely maintained at least at the FY 2004 level.

The other two APGs supporting the first long term goal relate to non-combustion sources of mercury. One APG (FY 2005) emphasizes efforts to characterize air emissions from non-utility mercury sources and to conduct preliminary studies of options to treat and dispose of non-utility mercury wastes while the other APG (FY 2010) continues this effort with more emphasis on providing final testing of options to manage emissions from non-utility sources.

Under the second long term goal (Understand the transport and fate of mercury from release to the receptor and its effects on the receptor), there are 7 APGs. Four of these APGs address the fate and transport of mercury (FY 2004, FY 2006, FY 2008, and FY 2010) from environmental sources to fish tissue. The first of these four APGs was developed to provide critical information for the rule-making on coal-fired utilities. The FY 2006 APG focuses on a watershed modeling goal and is intended to be local to regional in nature. The subsequent APG in FY 2008 will then focus on understanding fate from mercury sources to deposition. As a result, this APG focuses on atmospheric fate and is regional to global in nature. Research under this APG will focus on characterizing atmospheric processes and global background concentrations of atmospheric mercury. Two APG's in FY 2009 will focus on assessing the health risks of mercury exposure to humans and other ecological receptors. Finally, in 2010, the source to deposition and the deposition to fish modeling approaches will be linked in a multimedia model and the resulting APG will lead to a better understanding of the transport and fate of mercury from source to fish concentrations.

The assessment of potential mercury effects on ecological resources and human health is represented in two APGs. The APG focusing on the ecological effects of mercury (Assess the risks of mercury exposures to ecological receptors) contains five APMs. Efforts are focused on characterizing mercury effects on avian species, focusing on understanding the toxicokinetics and toxicodynamics of methylmercury from site-specific studies (FY 2006). An additional effort is planned to evaluate the performance of mercury bioaccumulation models in fresh water streams (FY 2006). The mercury ecological assessments build toward a regional ecological risk of methylmercury, to be completed in FY 2009.

Human health studies are planned that will provide answers to some of the questions that were raised while setting and evaluating the current RfD for methylmercury (NRC 2000). These studies address the relationship between maternal and cord blood levels of mercury (FY 2006), explore the potential adverse effects of methylmercury on cardiovascular function, and assess impacts and synergistic relationships relating to exposure to mercury and commonly co-occurring environmental pollutants, such as dioxin, PCBs, and DDT (FY 2008). Combined, these studies serve as background and prepare the Agency for a reevaluation of the RfD for methylmercury in FY 2009.

One APG (FY 2008) will provide risk communication methods and tools for mercury. The need for risk communication research on mercury (as well as other pollutants) has been repeatedly emphasized by the Program Offices and Regional representatives. It was also a strong recommendation of the peer review panel which reviewed the Agency's *Research Strategy for Mercury*. Funding for the APMs is expected to come partially from PBT funding. Resources for risk communication are expected to remain level from 2002 through 2008.

The relative emphasis over time of each of the research areas in this plan is described in Table 1. Changes are not needed in ORD capability and/or capacity to accomplish the LTGs although it is important to note that accomplishment of the MYP is dependent on external leveraging with other Agencies and organizations as well as internal leveraging with the STAR grants program to address the research issues (a necessity given the relatively small size of the base ORD mercury program). It has also become dependent on resources in other areas such as PBT and Superfund.

Table 1. Mercury Research Area Emphases from 2002 through 2010
(Assumes level funding and may change due to the pending Clear Skies Act of 2003.)

Area	Emphasis in MYP Planning Window
Risk management research on combustion sources of mercury	Level through 2004, then decreasing
Risk management research on non-combustion sources of mercury	Level through 2004, then increasing
Fate and transport research	Level through 2005, then decreasing
Health assessment research	Level
Ecological risk assessment research	Level
Risk Communication	Level, then decreasing

Other research areas which could benefit from leveraging and which should be explored include:

- Collaborative efforts with USGS as related to source identification, routine, and specialized monitoring, and ecological research.
- Joint efforts with NOAA and CDC on areas of common interest related to mercury transport, transformation, and fate and human health monitoring (NHANES), respectively. NHANES has been funded through the PBT program.

- International engagements with organizations in other countries or in multiple countries addressing the global issues related to mercury. This can best be done through the new UNEP Mercury Program and development of a possible future treaty on methyl mercury.
- Collaborations with the Environmental Commission of the States (ECOS). There are potential opportunities with ECOS in the area of mercury in wastes and elemental mercury, and perhaps in other areas.
- Engagement with industrial and other private-sector stakeholders addressing non-combustion sources of mercury (e.g., mining, petroleum refining) to characterize and develop controls for these emissions.
- Joint efforts with DOD regarding their Mercury Strategic Stockpile. This is best done in collaboration with OSWER, who will review the EIS being prepared by DOD on the stockpile.
- Collaboration with the Florida Dept. of Environmental Protection on an atmospheric chemistry study, "BRACE" at Tampa Bay, FL.

Shortfalls in resources will prevent ORD in the near term from conducting risk management research on non-combustion sources of mercury, health risk assessment research, and monitoring and modeling research. Shortfalls in later years (beyond FY 2004) would likely diminish ORD's research efforts to conduct risk management research in combustion resources of mercury, health and ecological risk assessment, and monitoring and modeling.

If additional resources are available, they would be used for ecological risk assessment, risk management research on retirement of mercury, and the global mass balance of mercury. More detail on how the additional resources will be spent may be found in Section 5.0.

4.0 RESPONSE TO REGULATORY ACTIVITIES

The primary logic behind the flow diagrams in Appendix 1 was to develop a plan that was responsive to the Programs in their regulatory activities, particularly the OAR's plan to issue final regulations on mercury from coal-fired utilities in December 2004. Some APGs, because of their complexity, could not be completed by December 2004 but were needed to address the science questions. To assist the OAR with their 2004 promulgation, however, interim APGs or APMs were created where an APG went beyond the 2004 deadline.

Where there were multiple APGs related to a particular area (risk management research on combustion sources of mercury, fate and transport) the APGs built on each other. There was less interdependence among the APGs for the different areas however (e.g., fate and transport, risk communication, risk management research on noncombustion sources of mercury, risk management research on combustion sources of mercury).

As indicated above, Agency APMs are dependent on funding sources other than those in the mercury budget (e.g., PBT funds, Superfund, Ecosystem Protection, OIA funds). They are also dependent on the work of outside Agencies (e.g., DOE, USGS).

The LTGs relate directly to the science questions framed in the *Research Strategy on Mercury*, each of the APGs relating directly to one of the questions. The MYP is intended to directly support multiple Program Offices including OAR, OW, OPPTS, OSWER, and OIA. It will also support the Agency's Great Lakes National Program, the PBT Program, and various international efforts. Current efforts and expertise have already made a significant contribution to the United Nations Environment Program's effort to conduct an international assessment on mercury.

There is considerable interaction already in place between ORD and the Program Offices with respect to the mercury research results. The Program and Regional representatives have been active members of the MYP planning effort. It is expected that most of the results will be communicated in the form of reports and personal interaction between ORD scientists and Program and Regional representatives. It was recommended that the Regional Science Councils be used as a vehicle to distribute information to the Regions as well as the Regional Risk Assessors meeting and that where possible, research results be described by Region. Discussion with Program and Regional representatives with respect to workshops to review the results of research will be made when critical masses of research information become available. The possibility of an Agency-wide interactive web site for mercury allowing one to "drill into" the site and find links to the various Agency programs on mercury (e.g., the fish advisories from OW, ORD reports on mercury, etc.) was raised. Links to other web sites (USGS, DOE, etc.) could also be made.

5.0 FUTURE DIRECTIONS WITH INCREASING FUNDS

If the research base were to be increased by 20%, proposed work would consist of the research activities outlined below.

5.1 Ecological Risk Assessment.

Background. According to the *Mercury Report to Congress*: "Concentrations of mercury in the tissues of wildlife species have been reported at levels associated with adverse effects in laboratory studies of the same species. However, field data are insufficient to conclude whether piscivorous wading birds or mammals have suffered adverse effects due to airborne mercury emissions. Modeling analyses suggest that it is probable that individuals of some highly exposed wildlife subpopulations are experiencing adverse effects due to airborne mercury.
Proposed Research. Current research is examining the effects of mercury on avian species and then expanding that research into the field to assess population risk Additional resources in this area of research would be used to expand the assessment of population risk in the field for several avian species. The additional resources would also be used to evaluate the immunotoxic effects of mercury. Current data are suggestive on an immunotoxic effect of mercury which could have significant population effects on avian and mammalian species.

5.2 Retirement of Mercury Stockpiles

Retirement of Mercury Stockpiles

Background. The ultimate disposal of mercury stockpiles is of considerable concern. Large stockpiles already await disposal. For example, the Department of Defense currently manages a mercury stockpile of approximately 4,400 metric tons. The total amount of stockpiled mercury in the United States will be increasing as mercury cell chloralkali plants close and the number of federal, state and local programs to reduce mercury use and to recycle mercury products increase.

Proposed Research. ORD working closely with OPPTS, OSW and other Agency Offices, will identify further research that is needed. This work could include evaluation and development of techniques for determining unit effectiveness, such as leaching tests and structural integrity tests of containment units. This research would be leveraged with other agencies, particularly for (expensive) full-scale testing/demonstrations.

5.3 Global Mass Balance of Mercury

Background. EPA needs to begin the development of a global scale model for mercury transport, transformation, and fate, including improved emission inventories. Preliminary calculations indicate that remote sources approach the magnitude of local and regional sources for mercury deposition at many sites in the US and that the US is a net exporter of atmospheric mercury to the global pool. Thus, although local risk reduction will require control of local and regional sources, the long-range transport, including the contributions of nonanthropogenic sources, and the atmospheric reactions that lead to the production and deposition of reactive mercury must be characterized for effective management of global pools of mercury, including management of international risks and for US risks in a global context. In February 2003, the United Nations Environmental Program (UNEP) Governing Council agreed that further international action is warranted to reduce risks to human health and the environment from mercury and thus created a UNEP global mercury program in order assist developing countries in this effort. Its technical basis for action was a December 2002, UNEP Global Mercury Assessment report, which reflected significant funding and technical support by USEPA.

Proposed Research. A better understanding of mercury flux from existing mercury pools and long-range anthropogenic sources needs to be established, based on measurements of atmospheric speciated mercury at remote sites and long-range modeling of mercury transport and atmospheric reactions. There is also a need to characterize natural emission processes, including re-emissions, from oceans, wetlands, aquatic sediments, Arctic tundra and ice sheets (and wherever else it is sequestered), and meteorological and atmospheric conditions (such as Arctic sunrise) that give rise to global transport and deposition patterns.

6.0 RELATED NON-EPA RESEARCH

Based on the input received from the various members of the Mercury Research Strategy writing team, direct contacts with other organizations, and a review of the literature (both hard copy and on- line), a number of Federal organizations can make contributions to the long range goal. Some of these organizations and the work they perform are briefly described below.

6.1 Federal Activities

National Institutes of Health and the National Institute for Environmental Health Sciences

The National Institutes of Health (NIH) and the National Institute for Environmental Health Sciences (NIEHS) have been investigating the adverse human health effects of methyl mercury for a number of years. Investigations address the mechanisms of action of methyl mercury on the nervous system and evaluate its effects on other systems (*e.g.,* endocrine, immune).

National Center for Health Statistics and the Food and Drug Administration

The National Center for Health Statistics (NCHS) collects biomonitoring data on mercury concentrations in hair and blood of examinees for the National Health and Nutrition Examination Survey (NHANES) IV. This survey provides information on the distribution of mercury exposures in the general United States population, but does not provide information on specific sub-populations that may have higher than typical exposures. The Food and Drug Administration (FDA) monitors mercury levels in fish sold in interstate commerce.

U.S. Geological Survey

The U. S. Geological Survey (USGS) supports research programs to evaluate the mechanisms of methyl mercury bioaccumulation in fish and wildlife species. One program has correlated mercury concentrations in sediment, water, and fish at a number of sites nationally with water and sediment parameters (Krabbenhoft et.al, 1999). Determining the role of sediment microbial communities in the methylation of mercury is another important USGS program. Much of the research is associated with regional assessments, such as those in the Great Lakes or the Florida Everglades. In addition, USGS continues to collect data on mercury and has been conducting a program to address mercury releases from mining operations in the western United States. The USGS conducts research in the aquatic and terrestrial transport, transformation, and fate of mercury. ORD has worked closely with the USGS to establish a coordinated research program for the investigation of ecological processes in the field and the

collection of environmental data for model development and validation, particularly in studies related to the restoration of the South Florida Ecosystem.

Department of Defense

In the context of the mercury life cycle, ORD is interested in one of the most challenging issues facing the United States over the long-term, mercury retirement. Mercury retirement is currently being considered by the Department of Defense (DoD) for its strategic stockpile of elemental mercury. At a workshop in Baltimore in the Spring of 2000, DoD personnel presented their efforts in addressing the mercury strategic stockpile and invited workshop participants to join them in addressing this issue. They stressed that DoD was not proposing to conduct research on retirement alternatives, but was relying on a call for retirement technologies to be considered as part of an Environmental Impact Statement they are preparing.

National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration's (NOAA) Atmospheric Research Laboratory (ARL), in coordination with EPA and the U.S. Department of Energy (DOE), develops numerical simulation models for atmospheric mercury and other air toxics. Thus far, ARL has focused on Lagrangian-type numerical frameworks (*i.e.,* HYSPLIT), rather than three-dimensional fixed grids with high-resolution nesting and complex chemistry like EPA's Models-3/CMAQ. The National Exposure Research Laboratory's (NERL) Atmospheric Modeling Division is a division of NOAA's ARL that has been assigned to work for ORD. The division reports to the Director of ARL, so there is close coordination between EPA and NOAA's research activities.

Department of Energy

DOE has undertaken an extensive program in pilot and field evaluations of control technologies for mercury emissions from coal-fired utilities. EPA's National Risk Management Research Laboratory (NRMRL) will participate in these evaluations with DOE and the Electric Power Research Institute (EPRI). The emphasis will be on technology performance and cost effectiveness. DOE, in coordination with ORD, is also studying non-thermal disposal alternatives to mercury-bearing mixed wastes (including soils), and alternatives to mercury use in fluorescent light bulbs. DOE's Oak Ridge National Laboratory is conducting studies on the Arctic sunrise phenomenon and collecting data on landfill emissions and emissions measurement techniques. DOE will also need to address the problem of disposing of wastes containing mercury from the nuclear weapons program. This includes radioactive mercury that was used for shielding reactors and such, and mercury mixed with other toxic materials.

6.2 State and Regional Activities

Many states conduct regular monitoring of mercury levels in game fish that are used in setting fish consumption advisories. In addition, many states conduct fish surveys to assess methyl mercury fish tissue concentrations. Examples of state-specific and regional mercury research activities are presented below. Engagement with these regions and states provides a geographic component that informs the *MRS* and allows for the leveraging of information and data that have been collected over the years.

EPA's Region IV and the State of Florida

The state of Florida's South Florida Mercury Science Program is an effort by a multi-disciplinary team (state and federal agencies, universities, industrial groups and associations) to understand and address mercury bioaccumulation in Florida. The major focus of the research is on the Florida Everglades. Research topics include the following: risks to humans and wildlife from mercury, methyl mercury concentrations in the food chain, pathways for transformation of mercury to methyl mercury, source identification and transport of mercury species in air and water, and actions to reduce mercury levels in fish and wildlife. ORD already has an excellent working relationship with the state officials leading this effort and has been involved in the research aspects of the Program for a number of years.

Region IV has teamed with ORD and Florida's Department of Environmental Protection on the Everglades since 1992. The Region manages a team of researchers who provide quantitative, large-scale spatial and temporal biological, water, and soil data on mercury and methyl mercury in South Florida. This data provides more multimedia information on mercury and methyl mercury than any other geographical location in the United States. Results from this effort are being developed into an empirical model which addresses the interactions of numerous variables affecting mercury bioaccumulation in the Everglades. It will provide the basis for an ecological risk assessment, leading to management recommendations affecting the restoration of the Everglades ecosystem. Numerous new methods have been developed for sampling, analysis and interpretation as part of this undertaking (Stober, 2000).

New England States

The New England governors, in concert with the Eastern Canadian premiers, have developed a Mercury Action Plan to support research and analysis that improves regional understanding of mercury sources, impacts, and cycling in the environment (NEG/ECP, 1998). In this plan, two objectives were identified relating to research, analysis, and strategic monitoring. These objectives are: (1) research and analysis to improve understanding of mercury sources, impacts, and cycling in the environment, and (2) strategic monitoring of mercury emissions, deposition, and fish tissue levels and environmental indicators to measure and track progress.

6.3 Private Sector Activities

Scientific activities are under way in some industrial sectors to assess mercury use and releases. ORD is already working with various industries and industrial research and trade organizations to address research and technical issues related to mercury emissions and improved characterization of both emissions and releases. These efforts will inform both industry and the Agency on mercury and methyl mercury risk assessment and risk management for the industrial sector.

Electric Power Research Institute

The Electric Power Research Institute (EPRI) has supported a comprehensive research program on mercury for many years. EPRI works with the electric utility industry to: collect data on fuels (*e.g.,* coal, oil), measure mercury emissions and deposition of those emissions, develop and test models on mercury fate and transport, conduct integrated assessments of exposure and risk, and evaluate control measures to reduce mercury emissions. EPRI has sponsored research covering a broad spectrum of mercury issues related to coal combustion. It has been supporting the utility industry's data collection effort in response to EPA's Information Collection Request (ICR) on the mercury content of coal and mercury emissions from coal-fired utilities. Since the 1980s, EPRI has sponsored a series of international conferences on mercury as a global pollutant, one being held in Rio de Janeiro, Brazil, in 1999 and another in Minamata, Japan, in 2001. Additional information on EPRI's mercury research program can be found at their web site (http://www.epri.com).

The Chlorine Institute

The Chlorine Institute is working with its members in the chlor-alkali industry to reduce mercury use by 50% as part of the Binational Toxics Strategy (EPA, 1997b). In the spring of 2000, ORD in cooperation with The Chlorine Institute, EPA Regions IV and V, and OAR conducted a mercury emissions sampling program at a chlor-alkali plant in the southeastern United States. ORD plans to continue this cooperative relationship to gain an improved understanding of mercury emissions from calor-alkali plants and to resolve mercury mass balance issues associated with plant operations.

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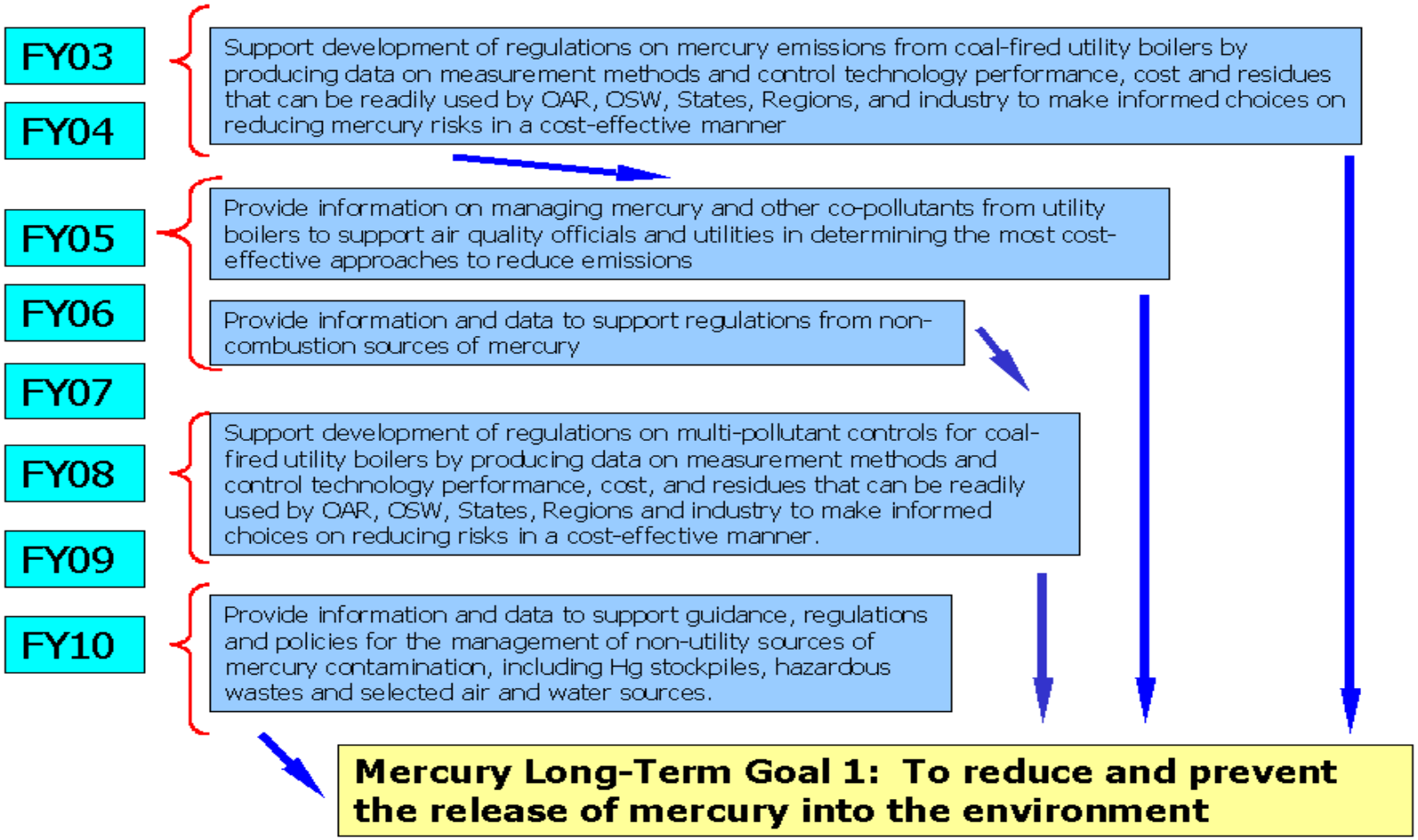
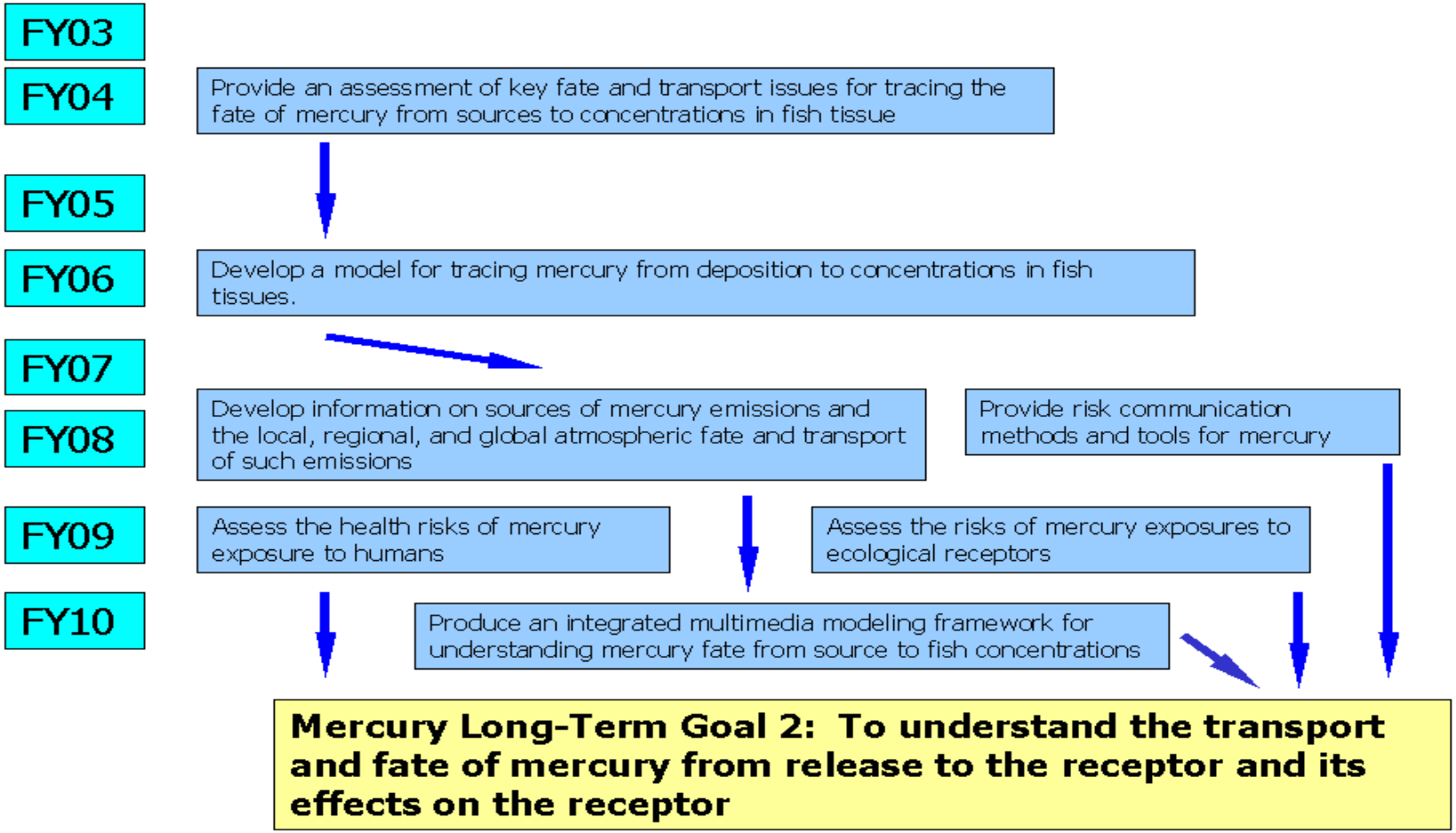
Appendix 1.
Relationships Between Annual Performance Goals (APGs) For Each Long Term Goal and Associated Regulatory Time frame

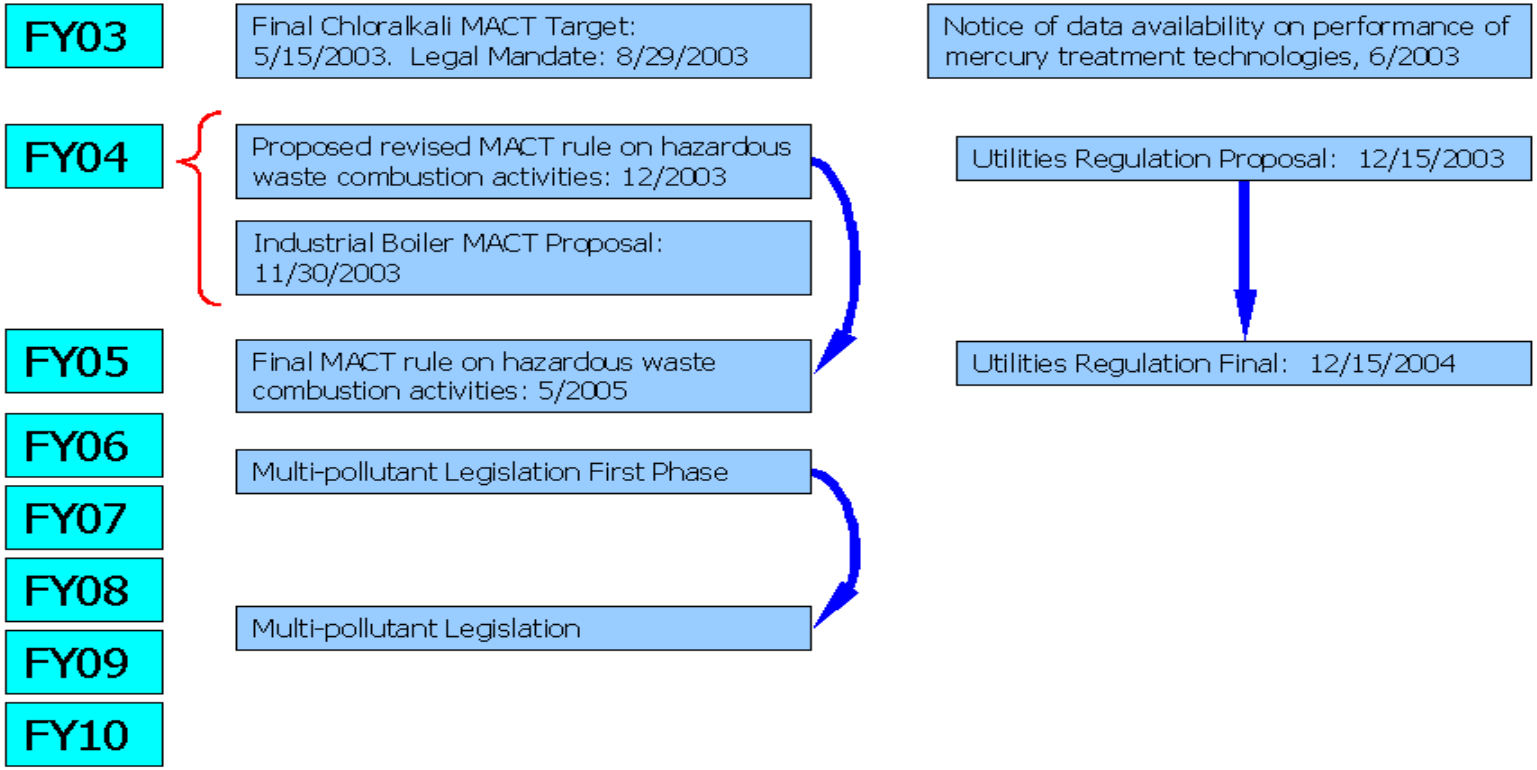
Relationships Between APGs for Long Term Goal 1



Relationships Between APGs for Long Term Goal 2



Regulatory Timeframe



Appendix 2.
Long Term Goals and Annual Performance Goals and Measures for Mercury Research

Table 1: Annual Performance Goals and Measures for Long-Term Goal 1

Long-Term Goal 1: To reduce and prevent the release of mercury into the environment.			**2010**
Annual Performance Goals and Measures		Year	Lab/center
APG - Support development of regulations on mercury emissions from coal-fired utility boilers by producing data on measurement methods and control technology performance, cost, and residues that can be readily used by OAR, OSW, States, Regions and industry to make informed choices on reducing mercury risks in a cost-effective manner		**2003**	**ORD**
APM	Report(s) on the parameters that impact both the species of mercury in coal-fired utility boiler flue gas and the performance of promising mercury control technologies	2002 Completed	NCER** NRMRL*
APM	Complete report on mercury speciation in coal combustion and gasification flue gases (Center for Air Toxic Metals)	2002 Completed	NCER
APM	Report describing the parameters that impact the species of mercury in coal-fired utility boiler flue gas and the performance of promising mercury control technologies	2003	NCER** NRMRL*
APM	Produce a status report on the performance of Continuous Emission Monitors (CEMs) used to measure total gas-phase mercury and mercury speciation based on both lab and field testing.	2003	NCER** NRMRL*
APM	Report on the performance/cost of reducing mercury emissions taking into account coal properties, combustion conditions, and flue gas cleaning.	2003	NCER** NRMRL*
APM	Report on the impact of selected mercury control technologies on the characteristics of their coal combustion residues and how selected utilization/disposal practices impact the fate of mercury residues.	2003	NCER** NRMRL*

APG - Provide information on managing mercury and other co-pollutants from utility boilers to support air quality officials and utilities in determining the most cost-effective approaches to reduce emissions		**2005**	**External ORD**
APM 120	Produce a technical assessment of the effect of air pollution control systems on the characteristics of mercury-contaminated residues, and increased costs or environmental risks from their management.	2004	NRMRL
APM	Produce updated report on performance and cost of devices to continuously measure and control air emissions of mercury and co-pollutants to enable stakeholders identify optimal management approaches	2005	NRMRL
APG - Provide information and data to support regulations from non-combustion sources of mercury		**2005**	**ORD**
APM	State of the art practices in macroencapsulation and microencapsulation of hazardous wastes	2002 **Completed**	NRMRL
APM	Materials flow analysis report on the uses and releases of mercury in the U.S.	2002 **Completed**	NRMRL
APM	Complete a report on the performance of selected treatment technologies on priority mercury-bearing wastes.	2002 **Completed**	NRMRL
APM	*Characterization and Eh/pH-based leaching tests of mercury-contained mining wastes from the Sulfur Banks Mercury Mine, Lake County, California (funded by Superfund)*	*2002* ***Completed***	*NRMRL*
APM	*Analyze technical alternatives for the disposal or retirement of mercury (funded by PBT funds)*	*2002* ***Completed***	*NRMRL*
APM	Evaluation of chemically bonded phosphate ceramics for mercury stabilization	2003	NRMRL

APM	Interim report on distribution of MeHg in aquatic systems for use in identifying MeHg treatment options	2003	NRMRL
APM 121	Report estimating the mercury content in the US petroleum supply addressing uncertainties in the national emissions estimate from this non-combustion source to support future risk management decisions	2005	NRMRL
APM	*Evaluate the physical and chemical processes that control the speciation and distribution of Hg in mine wastes and its release from mine sites. (funded by Superfund)*	*2004*	*NRMRL*
APM	Report on the physical and chemical processes that control the speciation and distribution of Hg in mine wastes and its release from mine sites (#R827634)	2004	NCER
APM	Report on Hg wastes treatment, containment, and disposal technologies: an update [Current scope of report: ORD Hg research. Setting up meeting to discuss broadening]	2005	NRMRL
APM	Report on bench-scale tests of methods for stabilizing mercury in contaminated sediments to minimize transport to water and aquatic receptors	2005	NRMRL
APG - Support development of regulations on multi-pollutant controls for coal-fired utility boilers by producing data on measurement methods and control technology performance, cost, and residues that can be readily used by OAR, OSW, States, Regions and industry to make informed choices on reducing risks in a cost-effective manner.		**2008**	**ORD**
APM	Report on the control of Nox and Hg emissions in units equipped with selective catalytic reduction (SCR) systems	2004	NRMRL
APM	Report on the role of coal properties and combustion conditions in adsorption of Hg by fly ash and sorbents	2005	NRMRL
APM	Journal article on models for speciation and adsorption of Hg in coal-fired boilers	2006	NRMRL

APM	State-of-Art report on CEMs for coal-fired boiler that are subject to multipollutant emission control requirements	2006	NRMRL
APM	State-of-Art report on multipollutant control technologies for subbituminous coals and lignite	2006	NCEA NRMRL*
APM	State of Art report on fate of Hg and other metals from land application of coal combustion residues	2006	NRMRL
APM	Performance and cost report on new multipollutant control technologies	2007	NRMRL
APM	Report on the potential formation of organo-mercury from anaerobic decomposition of coal combustion residues	2007	NRMRL
APM	State of Art report on dry- and wet-FGD systems for multipollutant control of pollutants from combustion of bituminous coals	2008	NRMRL
APM	Report on fate of toxic metals from land disposal and commercial use of coal combustion residues from plants equipped with multipollutant control technologies.	2008	NRMRL
APG - Provide information and data to support guidance, regulations, and policies for the management of non-utility sources of mercury contamination, including Hg stockpiles, hazardous wastes and selected air and water sources.		**2010**	**ORD**
APM	Report on the long term management of Hg stockpiles	2005	NRMRL
APM	Publish an estimate of the amount of Hg contained in the US natural gas supply for use in determining the significance of this industry for potential Hg emissions	2006	NRMRL
APM	Identification of critical points for Hg release from petroleum extraction and processing facilities to identify where improved controls are needed.	2007	NRMRL

APM	Report on field trial of in situ treatment of mercury in sediments	2007	NRMRL
APM	Identification of critical points for Hg release from natural gas extraction and processing facilities to identify where improved controls are needed.	2008	NRMRL
APM	Report on characterization of air emissions from a priority Hg source (e.g., arc furnaces)	2008	NRMRL
APM	Provide a summary report on characterization and control for priority non-utility sources of mercury releases to the environment to public and private decision makers and other stakeholders	2008	NRMRL
APM	Synthesis document on the effective management of non-utility sources of mercury	2010	NRMRL

* Indicates the reporting lab in the Integrated Resources Management System (IRMS).
** Indicates NCER portion of APM is completed, not in (IRMS).

Table 2: Annual Performance Goals and Measures for Long-Term Goal 2

Long-Term Goal 2: To Understand the Transport and Fate of Mercury from Release to the Receptor and its Effects on the Receptor.			**2010**
Annual Performance Goals and Measures		**Year**	**Lab/center**
APG - Provide an assessment of key fate and transport issues for tracking the fate of mercury from sources to concentrations in fish tissue.		**2004**	**ORD**
APM	Provide predictive model for assessing spatial distribution of mercury exposures in South Florida	2002	NERL
APM	Interim report on disruption of mercury methylation in aquatic sediment systems	2003	NRMRL
APM	Hold workshop/SOS on mercury with emphasis on Fate and Transport in watershed(s) and ecosystem impacts	2004 Completed	NCER
APM	Reports on evaluating mercury cycling in complex ecosystems; including, air/water interface to accurately assess TMDLs for Hg and predict methylmercury concentrations in water and fish. Focus is on human exposure as the ecological endpoint.	2004	NCER
APM	Provide a report on the impacts of atmospheric deposition and lake and watershed processes on mercury exposures of fish and piscivorous wildlife in New England lakes (REMAP project with Region 1).	2004	NERL
APG - Develop a model for tracking mercury from deposition to concentrations in fish tissues.		**2006**	**ORD**

APM	Provide to the states and regions a model capable of supporting a TMDL assessment of methylmercury levels in fish resulting from atmospheric deposition, point sources, and internal watershed processes.	2004	NERL
APM	Provide watershed and water body modules for a prototype integrated multimedia model for mercury to evaluate risk reduction at the local and regional scales.	2006	NERL
APG - Provide risk communication methods and tools for mercury.		**2008**	**NRMRL**
APM	Provide a report on target audiences regarding risk communication messages for mercury.	2004	NRMRL
APM	Develop and demonstrate improved methods of risk communication on mercury to fish-eating populations of concern.	2005	NRMRL
APM	Provide an evaluation of the effectiveness of tools currently being used for Hg risk communication use by EPA, the States and others in determining the appropriate tools to use, and to help in development of new tools.	2006	NRMRL
APM	Develop new risk communication tools for States and others that address identified gaps and inconsistencies in risk communication messages for mercury.	2007	NRMRL
APM	Develop a consensus report outlining Best Practices for mercury risk communication.	2008	NRMRL
APG - Develop information on sources of mercury emissions including the regional/global atmospheric fate and transport of such emissions		**2008**	**ORD**
APM	Report on the relative importance of coal combustion on observed mercury wet deposition in Ohio.	2004	NERL
APM	Report on oxidation of elemental gaseous mercury to reactive gaseous mercury in the marine free troposphere and the implications on long range mercury transport.	2004	NERL

APM	Preliminary evaluation for the use of mercury in tree growth rings as an indicator for historic rates for mercury deposition.	2007	NCEA NERL
APM	Report(s) on developing an understanding of the chemical and physical transformations of mercury in air and cloud water	2008	NCER
APG - Assess the risks of mercury exposures to ecological receptors		**2009**	**ORD**
APM	*Habitat suitability indices to support population models for projecting relative risks of multiple stressors including toxic chemicals and habitat alteration to common loons (from Water Quality MYP)*	*2004*	*NHEERL*
APM	*Population models that project the relative risks of multiple stressors (toxics, habitat alterations) to piscivorous birds (from Water Quality MYP)*	*2004*	*NHEERL*
APM	Characterization of the effects (including toxicokinetics and toxicodynamics) of methylmercury on avian receptors (external peer review draft)	2005	NCEA
APM	Evaluation of the performance of mercury bioaccumulation models in lotic systems (submitted journal article)	2006	NCEA
APM	Report on the impact of numerous stressors on Common Loon productivity, including an assessment of mercury exposure and mercury bioaccumulation in avian species. (#R829085)	2006	NCER
APM	Characterization of the effects (including toxicokinetics and toxicodynamics) of methylmercury on avian receptors (final report)	2007	NCEA
APM	Regional ecological risk assessment of methylmercury on a representative avian species using state of the science techniques (submitted journal article)	2009	NCEA
APG -Assess the health risks of mercury exposure to humans		**2009**	**ORD**

APM	Assess the toxicokinetics of methylmercury in various human subpopulations including the maternal-fetal unit, and the kinetic variability within and between populations (external peer review draft)	2006	NCEA
APM	Perform benchmark dose analyses of adverse effects of methylmercury on cardiovascular effects on adult humans. (external peer review draft)	2006	NCEA
APM	Update and collate fish intake in various human subpopulations, including anglers and subsistence populations (external peer review draft)	2006	NCEA
APM	Assess the impacts from aggregate exposures and synergistic relationships of mercury and commonly co-occurring environmental pollutants (e.g., dioxin, PCBs, dibenzofurans, DDT) (external peer review draft)	2008	NCEA
APM	Reevaluation of human RFD for methylmercury (external peer review draft)	2009	NCEA
APG - Produce an integrated multimedia modeling framework for understanding mercury fate from source to fish concentrations.		**2010**	**ORD**
APM	Provide a demonstration of integrating multimedia information with a model of atmospheric processes	2006	NERL
APM	Development of an integrated multimedia modeling framework for the complete scientific understanding of mercury fate/transport and atmospheric chemistry/processes	2010	NERL* NRMRL NCER

*Indicates the reporting lab in the Integrated Resources Management System (IRMS).