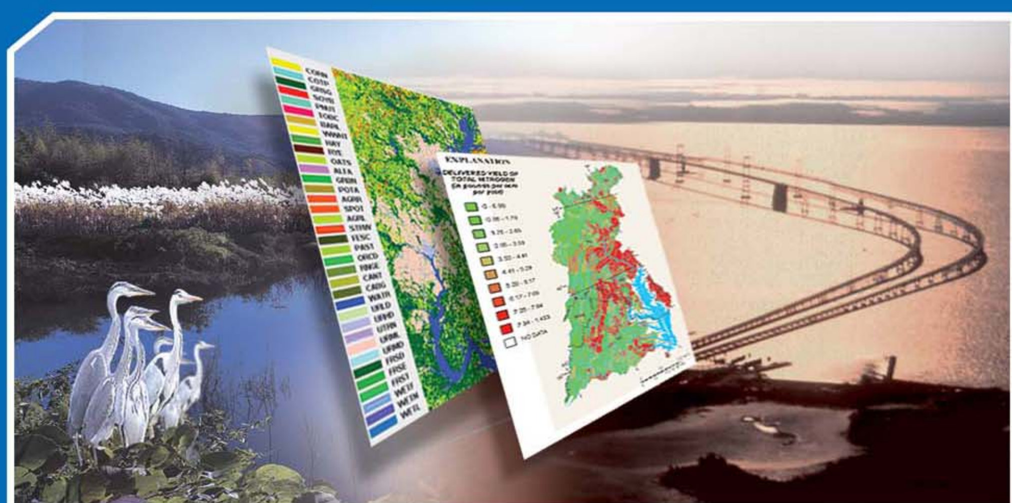
United States Environmental Protection Agency

Integrated Modeling and Analysis To Support the Management and Restoration of Large Aquatic Ecosystems

January 20 - January 21, 2010
Marriott at Metro Center
Washington, DC



Symposium Report

EPA Council for Regulatory Environmental Modeling
EPA Council for Large Aquatic Ecosystems

This report provides a summary of the discussions and proceedings of the symposium on “Integrated Modeling and Analysis to Support the Management and Restoration of Large Aquatic Ecosystems.” The symposium took place on January 20-21, 2010 in Washington, DC and attracted approximately 130 participants. The symposium was planned and hosted by the U.S. Environmental Protection Agency (EPA) Council for Regulatory Environmental Modeling (CREM).

About EPA’s Council for Regulatory Environmental Modeling (CREM):

Given the crucial role that models play in informing regulatory decision making, the EPA established the Council for Regulatory Environmental Modeling (CREM) in 2000 in an effort to improve the quality, consistency and transparency of the models for environmental decision making. The CREM is a cross-Agency council of senior managers charged with developing practices to ensure that EPA's use of environmental models is consistent and defensible.

About the CREM’s Integrated Modeling Program:

The CREM Integrated Modeling Program includes a set of activities that support CREM Strategic Goal 4 (Enhancing Integrated Modeling for Environmental Decision Making: to bridge disciplines and foster a more integrated and joined up thinking approach to modeling in environmental management and advance integrated modeling science and technology). These activities will help to facilitate the development of a strong integrated modeling capacity that supports environmental decision making at EPA.

The symposium on Integrated Modeling and Analysis to Support the Management and Restoration of Large Aquatic Ecosystems is the first of a series of symposia in the CREM Integrated Modeling Forum. The Integrated Modeling Forum seeks to create a cross-Agency forum for coordination and exchange of information on modeling activities related to high priority science and technology issues which would benefit from a systems analysis and integrated modeling approach.

Day One: January 20, 2010

SYMPOSIUM INTRODUCTION

Gabriel Olchin, EPA, Office of the Science Advisor

Dr. Olchin welcomed the participants, explained the format and overall purpose of the symposium, and introduced the first speaker.

Welcome
Pai-Yei Whung, EPA, Office of the Science Advisor

Dr. Whung, Chief Scientist in the Office of the Science Advisor, welcomed the participants to Washington, DC, and thanked the symposium organizers for their work. She explained that the Office of the Science Advisor focuses on cross-Agency scientific direction and science policy that can be applied to policy making and decision making. The office houses cross-Agency councils and forums, including CREM.

Since its establishment, the goal of CREM has been to bring the community together to apply modeling tools for environmental solutions, working with both Programs and Regions, to facilitate the Agency's use of models for policy and management decision making. The environment, by its very nature, is integrated; thus, the use of integrated approaches to environmental problems is crucial, not only for modeling but also for data analysis and the application of models to decision making. Integrated approaches to modeling and decision making are critical for solving many of today's most complex environmental problems, including those involving watersheds, airsheds, and climate change.

DEFINING INTEGRATED MODELING AND ANALYSIS: THE WHAT, WHY, AND HOW

Introduction
Noha Gaber, EPA, Office of the Science Advisor, and John Powers, EPA, Office of Water, Session Moderators

Dr. Gaber began her presentation by noting that the symposium participants included representatives from the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), state agencies, academia, and private consulting firms, as well as EPA, and that they included economists, engineers, policy makers, and experts from other disciplines as well as modelers. The focus of the symposium is on integration across environmental media, organizations, and disciplines, and the introductory presentations have been designed to help participants develop a shared understanding of integrated modeling (IM).

Although IM is important for understanding linkages in the environment, an even more important concept is integrating scientific understanding and analysis to support policy making and decision making. Large aquatic ecosystems (LAEs) exemplify the need for an integrated approach. To ensure their health and sustainability, numerous processes taking place in these systems must be considered. Seamless integration of data, models, and policy decisions is needed.

Dr. Powers emphasized the need to build great models to support great policy and to focus on the long trajectory of environmental policy, looking outside the traditional stovepipes and thinking on a systems level. Future policy making will place greater demands on models, as follows:

Because policies should be:		Models need to:
Forward-looking	→	Be capable of forecasting
Coordinated	→	Be capable of integrated policy analysis
Systems-based	→	Be comprehensive and integrated
Information-intensive	→	Produce useful output
Incentive-based	→	Be capable of optimization analysis

A simple conceptual framework for policy integration is needed, allowing integration within and between the chain of impacts connecting a change in policy to a change in human welfare. Policy actions prompt changes in behavior, which impact both ecological and market systems, leading to changes in both market goods and services and nonmarket ecosystem services produced and consumed, which lead in turn to changes in human welfare. This chain of impacts corresponds to a chain of technical disciplines, including law, engineering, ecology, and economics. Law and economics look at policy, engineering looks at behavior, ecology and economics look at the systems element, ecology and economics look at goods and services, and economics looks at human welfare. IM is multidisciplinary; the natural, physical, and social sciences all are involved. One of the purposes of this symposium is to examine how these disciplines fit together.

Keynote Address
Robert Costanza, Gund Institute for Ecological Economics, University of Vermont

Dr. Costanza began his presentation by emphasizing that IM must include humans embedded in ecological systems. Historically, natural and human systems were modeled separately, but this approach was not very effective. There is no one right way to do IM; intelligent pluralism is needed, using a range of modeling approaches and scales for different purposes.
Models can be used as a tool to build consensus, enabling the building of a shared understanding from the bottom up. If stakeholders are involved in the process of constructing the model, they will be better able to use its results and understand its limitations and uncertainties. There is a need for modeling on a longer time scale than has customarily been used, acknowledging the history of complex systems and the co-evolution of humans with the rest of nature. Efforts are being made to develop integrated models at various scales, ranging from small sites up to large watersheds or the global scale. The most comprehensive models include natural, built, human, and social capital.

In many systems, threshold effects are important. Pinpointing thresholds can allow safe boundaries to be determined so that critical thresholds will not be exceeded. Dr. Costanza described a project that attempted to determine a safe operating space for humanity with regard to multiple environmental variables. Several variables, including climate change, biodiversity, and the nitrogen cycle, already are beyond the safe limits; others are approaching the boundaries; and data for others are inadequate.

A balance is needed between expert modeling, which often leads to specialized models that receive little use because they lack stakeholder support, and mediated discussion, which may lead to a consensus on goals or problems but no information on how to achieve the goals or solve the problems. The ideal is to combine both approaches, increasing both the degree of understanding of system dynamics and the degree of stakeholder consensus. Modelers often tend to think that the higher the resolution of a model, the better. In practice, however, usability can be lost if models are too complex.

Humans can be included in models in three complementary and synergistic ways: (1) as stakeholders who participate actively in model conceptualization, development, testing, and implementation; (2) as players of the model who use it as a decision tool; and (3) as agents programmed into the model based on understanding of their goals and behavior as gleaned through steps 1 and 2. Human behavior is complex, and it is embedded in multi-scale, complex, adaptive systems. The concept of ecosystem services (i.e., benefits that humans derive from ecosystem function) is helpful in linking the natural and human parts of ecosystems. Ecosystem services can be classified according to rivalness and excludability, and valued in terms of efficiency, fairness, and sustainability. Prior work based on the assumption that people understand the benefits they are receiving from ecosystem services may not be valid.

Dr. Costanza described a valuation exercise based on a statistical model related to coastal wetlands and hurricane protection. U.S. coastal wetlands were estimated to provide $23.2 billion per year in storm protection services. He also discussed GUMBO (Global Unified Metamodel of the BiOsphere), an IM effort focused on ecosystem services at the global scale. This model has been calibrated historically and can be used to address future scenarios.

Two approaches are used in IM: (1) taking existing models and linking them together, and (2) taking existing models as legacy input and creating a new model. The MIMES (Multiscale Integrated Models of Ecosystem Services) project takes the latter approach. Its goals are to create a suite of dynamic ecological and economic computer models that integrate understanding across a range of spatial scales, with the development of new valuation techniques and Web-based delivery of the models and results.

LARGE AQUATIC ECOSYSTEMS FROM A SENIOR DECISION MAKING PERSPECTIVE

Introduction/Session Moderator
Dr. Pei-Yei Whung, EPA, Office of the Science Advisor

Dr. Whung explained that LAEs are a high priority for the Obama administration, which has placed renewed commitment and emphasis on attaining healthy and sustainable ecosystems and resources. EPA has dedicated itself to finding multiple approaches, in addition to its legislative authority, to improve and sustain resources. In this session, senior leaders in the Agency provided their perspectives on the Chesapeake Bay and Great Lakes ecosystems.

Chesapeake Bay
Chuck Fox, EPA, Senior Advisor to the Administrator on the Chesapeake Bay

Mr. Fox focused his presentation on how models interact with decision making, emphasizing that finding solutions is more important than an academic interest in modeling. He noted that in 1986, when efforts were being made to develop a Chesapeake Bay agreement, modelers said that a 40 percent reduction in pollution was needed. Today, despite extensive restoration efforts and despite the belief that the Chesapeake Bay models are the best models in use, modelers are still saying that a 40 percent reduction is needed. Thus, fundamental challenges still need to be faced.

Unlike the Clean Air Act (CAA), the Clean Water Act (CWA) has not lived up to expectations. The reason for the difference may lie in enforcement and accountability. As an example of the importance of accountability, Mr. Fox presented findings from an investigation of diplomats' parking violations in New York City. Differences in the frequency of violations by diplomats from different countries had been observed, and many cultural explanations for these differences had been proposed. Nevertheless, regardless of culture, violations dropped 90 percent after stronger enforcement was imposed.

Despite increases in gross domestic product, vehicle miles traveled, population, and energy consumption, aggregate emissions of six principal air pollutants have decreased substantially in recent years, when federal and state governments have been able to regulate emissions under the CAA. In contrast, many sources of the nitrogen, phosphorus, and sediment loads to the Chesapeake Bay are not regulated. In Mr. Fox's view, water quality cannot be improved without increased accountability and regulation. The Total Maximum Daily Load (TMDL) program may create greater accountability because EPA will be able to require states to have enforceable or otherwise binding policies for meeting TMDLs.

A challenge for modelers is to design models that will enable decision makers to identify the distinguishing factors of policy choices. If a specific policy is implemented, what will be the effect on nitrogen, phosphorus, and sediment in the Chesapeake Bay? Modelers also need to improve public understanding of the impact of water quality in the Bay. What does the difference between a "saved" Bay and a "dirty" Bay mean to people living in the watershed?

The uncertainties inherent in modeling need to be acknowledged. Recent Chesapeake Bay model runs have shown that some parts of the Bay have achieved their phosphorus goals, yet significant problems remain in those areas. The results, despite their uncertainties, were considered by the Virginia state legislature and had an impact on the state's stormwater regulations. The virtual world is not as precise as many people think; understanding this reality is important when formulating TMDLs or writing permits.

Great Lakes
Paul Horvatin, Branch Chief, EPA Great Lakes National Program Office

To understand the issues facing the Great Lakes, it is important to appreciate their size; they contain 20 percent of the world's fresh surface water and span more than 750 miles west to east, with a 10,000-mile coastline. Twenty percent of U.S. timberland, 20 percent of U.S. manufacturing, a $4.5 billion commercial/recreational fishing industry, and a $9.4 billion recreational boating industry are located in the Great Lakes Basin. The Great Lakes states make up the world's third largest economy, after the United States and Japan. If they were a country, it would be the 11th largest in the world. The Great Lakes face unique management challenges, including problems with invasive species and year-to-year changes in ecosystems. Modeling expertise is important to understanding and solving these problems.

The President's FY 2010 budget includes a new $475 million interagency initiative to address regional issues that affect the Great Lakes, such as invasive species, nonpoint source pollution, and contaminated sediment. This initiative represents new resources for Great Lakes restoration; it should not supplant existing resources. Programs and actions have been identified for 16 federal agencies. The objectives are based on the Great Lakes Regional Collaboration Strategy. The initiative's five focus areas are:

- Toxic substances and areas of concern
- Invasive species
- Near-shore health and nonpoint source pollution
- Habitat and wildlife protection and restoration
- Accountability, education, monitoring, evaluation, communication, and partnerships.

Sediments remain a major source of contamination; the removal of toxic substances is strongly driven by modeling efforts. Invasive species, of which Asian carp is only one example, are a huge problem in the Great Lakes. Phosphorus was an issue in the past; its significance has changed because of invasive species and will change again in the future. The economics and ecosystem of the Great Lakes change every 15 to 20 years. Strong and rapid development problems are occurring in near-shore areas, prompted largely by nonpoint source pollution. Habitats in some watersheds in the Great Lakes are severely degraded. Research is needed to examine the sustainability of restoration efforts before final management decisions are made and actions are carried out. Monitoring and evaluation involve a great deal of modeling and are being carried out in partnerships with the states and Canada.

Mr. Horvatin showed model projections regarding future polychlorinated biphenyl (PCB) concentrations in lake trout from Lake Michigan. If restoration programs are continued, the model predicts that recovery will eventually allow fish consumption advisories to be removed; without continued efforts, advisories would continue for many decades to come. Model predictions of this type are an important management tool.

A Request for Proposals under the Great Lakes Restoration Initiative to address the most significant Great Lakes ecosystem problems in the five focus areas listed above was announced in November 2009, with a due date of January 29, 2010. As many as 3,000 proposals may be received. A 5-year Action Plan was part of the President's budget release. The Action Plan will guide funding decisions through FY 2014, using the same five focus areas. The goals, objectives, and targets of the Plan are intended to align with those of Great Lakes state, tribal, and local governments. Progress will be tracked, with annual reports starting in 2011. Mr. Horvatin closed his presentation by explaining that the Great Lakes Water Quality Agreement (GLWQA) between the United States and Canada will be renegotiated and updated, with negotiations beginning in 2010.

Discussion

In response to a participant's question about the use of market mechanisms, Mr. Fox explained that market mechanisms for trading and offsets will be part of the regime for limiting nitrogen and phosphorus loads to the Chesapeake Bay. There is a need for a highly accountable way to offset new sources of these two pollutants. Fortunately, nitrogen and phosphorus are relatively easy to trade. State law and state authorities also may be used to create more accountability for nitrogen and phosphorus pollution in the Chesapeake Bay watershed.

A participant commented that an EPA guidance panel has stated that is not sufficient for modelers and decision makers to interact at the end of the modeling process; they should do so from the beginning to manage expectations. The participant asked Mr. Fox whether this has been done effectively for the Chesapeake Bay. Mr. Fox replied that he hoped that expectations have been managed and that the process of education has begun. It is not surprising, however, that there are opponents to additional accountability. Many interest groups that represent entities that contribute nitrogen and phosphorus to the Bay are working to discredit the model and the science and to suggest that accountability is not necessary. This has been happening for decades, but what is new in recent years is the ability to capitalize on an already-polarized populace and to use new communications media. Fortunately, at least for the Chesapeake Bay, there is a consensus that a need for change exists.

A participant stated that the situation with ammonia is different in the East than in the Midwest and West and asked what is happening with this pollutant. Mr. Fox replied that all of the data suggest that atmospheric sources of ammonia are not under control. Emissions come primarily from a sector that is difficult to manage in the near term. Mr. Fox urged researchers currently working on ammonia to continue their efforts and present their results, but he expects that meaningful policy responses are a few years away.

CASE STUDY 1: CHESAPEAKE BAY

Jeff Lape, EPA Chesapeake Bay Program Office, Session Moderator

Mr. Lape explained that the Chesapeake Bay program deals with the full spectrum of issues in the Bay, but the focus at this symposium will be on water quality, especially with regard to nutrients and sediment. The symposium's emphases on applying science and linking models to humans are very appropriate for the Bay because virtually every sector of human activity that contributes nutrients and sediment to the Bay needs to change behavior. For example, people need to learn to view fertilizing their lawns in the way people view smoking cigarettes today: as an outdated and increasingly unacceptable behavior. Mr. Lape introduced the speakers in this session and then directed participants' attention to challenging questions regarding modeling and the Bay, including:

- How much do we rely on the model to tell us what to do?
- How do we make the model useful to practitioners and decision makers?
- What is the ideal scale of implementation? Watershed scale? County level? Something else?
- How do we stay focused on implementation while the science of the models continues to improve?

The Chesapeake Bay TMDL
Michael Haire, EPA, OW

Mr. Haire explained that LAEs present a unique set of challenges:

- The scale of the problem and the solution
- The linkage between pollutant control and biological response
- Response time: forecasting and communicating
- Meeting competing goals and expectations
- Implementing equitable pollutant allocations
- Showing progress to maintain public and political support
- Having a defensible and understandable "Plan B."

In developing TMDL modeling strategies, it is important to take into account the location of the designated use impairments (single state vs. multi-jurisdictional); the nature and complexity of the receiving water body; the size of the use designation segments; the expression of the water quality criterion; the nature of the pollutants (conservative vs. reactive); the sources of pollutants (point sources, nonpoint sources, blended waters); the quantity and quality of existing data and information; whether linked ecosystem models are required; the implementation/allocation strategy at different scales (watershed, jurisdictions, major basins, "segment sheds"); and the implementation allocation strategy for source control (mostly regulatory, mostly voluntary, or a combination of both). The Chesapeake Bay watershed includes six states, but the targeted impairments are all in the tidewaters of Maryland or Virginia. The standards are very complex, varying laterally, vertically, and by season. The modeling strategy must factor in sediment, atmospheric input, and biological considerations. Also, uncertainties and economic consequences must be taken into account when applying model results to decision making. In achieving allocations, the following issues are being taken into consideration:

- Water quality and resource goals must be met.
- Areas that contribute the most to the problem must reduce the most (on a per pound basis).
- Prior reductions (since about 1984) are credited toward achieving cap loads.
- Adaptive implementation is used, based on milestones, progress, and refining assumptions.
- Meeting allocations will be a challenge; it will involve pushing practical limits on all sources, and increased growth will make the situation more difficult.

Current state target loads are in the millions of pounds of nitrogen and phosphorus. EPA is not micromanaging the states, but monitoring requirements exist. If states do not make adequate progress, there are possible federal consequences, such as assigning more stringent reductions to regulated point sources, objecting to state-issued National Pollutant Discharge Elimination System (NPDES) permits, limiting or prohibiting new or expanded discharges, and withholding, conditioning, or reallocating federal grants.

Crafting a modeling strategy is a dynamic process. Remaining challenges in Bay modeling include making atmospheric deposition refinements, incorporating the effects of filter feeders into the model, accommodating growth, and developing management options for the effects of dams. The Bay model will continue to provide the technical framework for analyses to support management decisions.

Chesapeake Bay Program – Integrated Models, Research, Monitoring, and Decision Making
Lewis Linker and Gary Shenk,[1] EPA Chesapeake Bay Program Office

Chesapeake Bay modeling has been a large-scale collaborative effort. The integrated models of the airshed, watershed, and tidal Bay need to be viewed as a whole. Together, they relate the watershed and airshed loads to water quality impairments in the Chesapeake. Management actions are the driver for Bay modeling, and decision makers are the key customers. They must set the allocations of the TMDL and set equitable 2-year goals, taking into account the forecasted urban growth in the watershed. The keys for the protection of living resources are the water quality standards for dissolved oxygen (DO), chlorophyll, and submerged aquatic vegetation (SAV)/clarity.

Great advances have been made in Chesapeake Bay modeling over the three decades. In the early 1980s, researchers were asking how much pollution comes from point versus nonpoint sources. Now, by the fourth-generation model, many specific segments, each consisting of separately modeled land uses, are being analyzed. The availability of a greater number of calibration sites allows accountability at finer scales. Decision makers now are asking what reductions are equitable; modelers must address this issue.

The airshed model used for the Chesapeake Bay is the Community Multiscale Air Quality (CMAQ) model, which is a continental model but is used at a finer scale 12 kilometer grid for the Chesapeake. The estuarine water quality model for the Bay assesses DO, chlorophyll, and SAV/clarity water quality standards. Because of tight coupling of processes, this aspect of Bay modeling is challenging. Living resources models involving oysters and menhaden are being linked to the water quality model. With the help of NOAA, full-scale trophic interaction simulation has been possible. Climate change is not part of the TMDL, but climate change modeling has pointed to long-term effects in the coming decades.

Research and monitoring are directly linked to modeling. The current state of the science considers that modeling without observations is not credible, monitoring without modeling is insufficient, and research is the foundation for all environmental restoration analysis. With the advent of inexpensive high-bandwidth sensors, a tidal wave of observational data has become available. IM helps to organize the flood of data to provide a basis for sound decision making.

[1] Lewis Linker made this presentation on behalf of both authors because Gary Shenk was unable to be present.

Use of the Community Model from the State-Level TMDL Program Perspective
Lee Currey, Maryland Department of the Environment

TMDL development requires: (1) identifying the problem, (2) performing a source analysis, (3) developing numeric targets, (4) linking targets and sources, (5) allocating loads, and (6) having a reasonable assurance of implementation. Maryland authorities must manage waters throughout the state, including 53 Bay water quality segments, each of which needs water quality standards. There is a need for watershed model delineation that works at this scale for the TMDL program.

It is necessary to determine the scale at which decisions are to be made. Maryland has 24 political jurisdictions: 23 counties and Baltimore City. The state has strong counties, and municipal separate storm sewer systems (MS4s) permits are issued at the county level. Thus, counties are a good scale for decision making.

The current model includes multiple land uses but still needs improvement. Some counties have better data than others. More detail is needed on some agricultural uses, and more refined data are needed at the local scale. For decision making, there is a need for data that support basin-scale management and political-scale management. If data are available at the county level, it becomes possible to begin to educate counties on where their water bodies drain.

Mr. Currey spoke of the benefits of a community modeling approach, in that it helps achieve consistency in analyses and greater collaborations. He also pointed out the need to think of the model as a decision support system that compiles useful information to find solutions. He supports developing a reduced model (based on the full model) for quickly targeting possible solutions. Such a reduced model would allow for communication with stakeholders and consideration of many scenarios, and it could be integrated with the full model. The reduced model could be used to provide preliminary answers to questions such as “If you change policy X, what will the consequences be?” Then, scenarios from the reduced model could be brought back into the full model, allowing results to be shown with the best tool. Ideally, a reduced model would be policy based, focusing on specific areas (e.g., septic systems, agricultural practices) and their effects on important output variables (loads, water quality response in Bay water quality segments, costs). It also would be desirable to provide a user interface that allows simplicity of input and output for stakeholders, such as a simple slider for input and graphs that show changes in loads for output. This type of simplified interface could be a powerful tool for communication and would allow for quick assessment of program and policy changes.

Mr. Currey concluded by noting that in Maryland alone, close to 200 TMDLs have been developed using the community model. This has been a tremendous and incredibly challenging effort.

Discussion

A participant commented that if the states are not compliant, stricter limits on point sources may be imposed, even though point sources are the only sector that has met load requirements. He asked the speakers whether a plan exists that might suggest alternatives to tighter regulations on wastewater treatment plants. Mr. Haire replied that this is a major challenge. Authority over other sources of nutrients is very limited. It may be necessary to either reduce point source values or facilitate trading and offsets with nonpoint sources. The question is whether there are markets for nonpoint sources that have not already been factored into the baseline. The participant followed up by noting that once a trade is set up, the point source is responsible if the nonpoint source does not meet the agreement, which penalizes the group that has been most responsive. He asked whether there are options more effective than penalizing the compliant group. Mr. Linker responded that this is an important question and interesting to contemplate. Will watershed implementation plans evolve? Many levers are possible. There may be a need for separate nitrogen and phosphorus markets. Mr. Haire noted that some other LAEs, such as the Gulf of Mexico, have even more nonpoint sources of nutrients than the Chesapeake Bay does, further increasing the complexity of controlling nutrient pollution.

Mark Tedesco of EPA's Long Island Sound Office commented that in an urgent situation, such as the one facing the Chesapeake Bay, it is difficult to think about equity. He asked what current modeling structure elements are helpful in dealing with questions of equity. Mr. Currey replied that questions about equity are important but difficult to answer because many definitions of equity exist. One can look at what various sectors can achieve for a particular cost or at costs related to the income of an area. With regard to nonpoint sources, equity decisions must be made between urban and agricultural nonpoint sources. It is necessary to choose the solution that is most equitable for a specific state or region. Mr. Linker commented that one area where there may be some common ground is equity with respect to atmospheric deposition. EPA has national controls in this area, and discussions about how to frame the allocation are beginning. Mr. Lape noted that different large interstate TMDLs have made different judgments about what is equitable. The role of modeling and science is to look back and determine an equitable distribution of the load in terms of past, present, and future growth. Mr. Haire noted that one challenge with multijurisdictional TMDLs is the assumptions made at the boundaries. Legally, upstream states must meet downstream standards. Mr. Currey said that in the Bay TMDL, there are two principles of equity: (1) all previous reductions are credited, and (2) those areas that contribute the most on a per pound basis must do more. Allocations are given to states at a very high level; it is the state's responsibility to bring them down to a smaller scale.

Jim Uphoff, from the Maryland Department of Natural Resources Fisheries Service, observed that fisheries ecosystem issues are addressed much more in the Great Lakes than in the Chesapeake Bay, where the focus has been on nutrients and the hypoxic zone. Some fisheries management issues, such as protection of spawning areas, are not nutrient or DO issues. Nutrient trading does not address all the issues that are important in the fisheries management context, and trading could have major unintended consequences for aspects of fisheries management that are not covered solely by managing nutrients. Mr. Linker responded that this is an important point. Nutrients are the current focus of management in the Bay because we have a deadline to finalize TMDL guidelines in 2010, but they are not the entire picture. Mr. Haire agreed that although TMDLs are very useful, they do not resolve all habitat and resources issues. Other, companion activities are needed. Mr. Currey explained that states have regulations for supporting aquatic life. Even though the focus in the Bay right now is on nutrients, aquatic life impacts must be considered.

Al Cimorelli from EPA Region 3 commented that simply predicting impacts is insufficient; there is a need to have decision support systems, and questions about equity and endpoints are important. The decision system is much more complex than the physical system. This participant and his colleagues have developed an approach (MIRA, Multi-criteria Integrated Resource Assessment) that examines all the input and tries to separate the science from the value judgments that go into decision making. Multiple communities and disciplines need to come together through a structured system that can then be tested. Mr. Linker replied that it may be possible to conduct this type of analysis after the urgent issues (TMDL) facing the Chesapeake Bay program in 2010 are completed.

CASE STUDY 2: GREAT LAKES

Paul Horvatin, EPA Great Lakes National Program Office, Session Moderator

Mr. Horvatin began the session by noting that the Great Lakes Basin faces unique challenges, especially with regard to the basin's binational location. Even if the technical components on the American and Canadian sides are the same, the management components are different.

The Great Lakes National Program Office
Glenn Warren, EPA Great Lakes National Program Office

The Great Lakes National Program Office (GLNPO), established in 1978, was the first EPA office with ecological rather than political or media boundaries. Its mission is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin ecosystem. Past and present problems in the ecosystem include excessive nutrient input (algal blooms, nuisance algae, hypoxia in Lake Erie and in large bays); toxics, particularly bioaccumulative ones; invasive species; botulism; and beach closings.

Ecological problems in the lakes have changed over time. Decades ago, high phosphorus loads led to the creation of a dead zone in the Lake Erie central basin. By 1983, the area of hypoxia had decreased, but more recently, it has increased again. Total phosphorus loads have decreased, but there has been an increase in the fraction of soluable reactive phosphorus which has perturbed the nearshore zones and increased DO depletion. PCBs are important contaminants, particularly in Great Lakes predator fish; levels in fish in Lake Michigan once were extraordinarily high. PCB concentrations have decreased but fish consumption advisories still exist, but it appears we are making great strides toward recovery.. Invasive species, including fish, mollusks, and algae, are a major problem. Due to changes in the form of phosphorus being delivered to the lakes and nutrient dynamic changes caused by dressenid mussels, the nuisance green alga, Cladophora is so abundant in some areas that the water is unsuitable for swimming.

GLNPO programs include monitoring, Lakewide Management Plans (LaMPs), Areas of Concern, the Great Lakes Binational Toxics Strategy (GLBTS), the Great Lakes Legacy Act (to reduce contaminated sediments), the Cooperative Science and Monitoring Initiative (with Canada), and large-scale modeling programs. Nutrient, biological, and contaminant monitoring is carried out on an annual basis, both in water samples and in fish taken at many monitoring sites. Emerging contaminants, such as brominated flame retardants, perfluorinated chemicals, pharmaceuticals, and personal care products, are an important area of emphasis in the monitoring program. The GLBTS focuses on 12 Level 1 persistent toxic substances; 10 of the 17 initial binational goals have been met. U.S. Areas of Concern focus on contaminated areas in the lakes—largely those with sediment contamination but also those with use impairments. The Cooperative Science and Monitoring Initiative focuses on providing lakewide management groups for each lake with the science and information they need on a 5-year rotational basis. Modeling programs have included the Green Bay mass balance project, which demonstrated that legacy contaminants in sediment rather than point sources were the dominant contributors of PCBs, and more recent general, large-scale models for each lake that incorporate hydrodynamics, transport and fate, eutrophication, meteorology, toxics, and invasive species have been conducted or initiated.

Great Lakes Integrated, Multidisciplinary Modeling Applications in Support of Policy, Management, and Programs

Russell Kreis, Jr., EPA, Office of Research and Development

The Great Lakes has a long history of modeling, including multiple situations where modeling has been the basis for implicit or explicit management programs. The models are multimedia, consistent with the ecosystem approach, and capable of providing predictions to forecast alternative futures. The flagship models of the Great Lakes program during the last few years have focused on the special characteristics and needs of this LAE, but there also has been cross-fertilization with the Chesapeake Bay program. Contaminants of concern in the Great Lakes include nutrients, with phosphorus being the primary limiting nutrient; PCB congeners; mercury, and the herbicide atrazine.

A series of models was constructed and run to examine eutrophication and phosphorus in the Great Lakes in the 1970s and 1980s. The models successfully aided in setting phosphorus load targets for each lake under the Great Lakes Water Quality Agreement, influenced wastewater treatment effluent discharge limits, helped to justify a ban on phosphate in detergents, and reduced the intensity and frequency of oxygen depletion. In the late 1990s, however, surprising changes were seen with changes in the form of phosphorus from watersheds, the effects of zebra and quagga mussels, and there was a reappearance of eutrophication in near-shore areas and starvation in off-shore areas. Invasive species, including zebra and quagga mussels, played an important role in these changes and Great Lakes nutrient models are being enhanced to include the role of invasive species.

Another important topic for modeling in the Great Lakes is PCBs, particularly in the Lower Fox River/Green Bay area, a very large watershed and embayment in Lake Michigan. Concentrations of PCBs in fish became so high that the fish were unsuitable for human consumption. Results of mass balance modeling showed that point sources, tributaries, and atmospheric deposition were negligible contributors of PCBs to Green Bay; sediments with legacy loads of PCBs were the dominant contributor. Modeling was been used to forecast PCB management consequences for the walleye fishery, comparing the consequences of no action with those of the most ambitious remediation. At present, PCB deposits are being removed or capped, at a total cost of $500 to $800 million.

To demonstrate the feasibility of PCB modeling in an entire lake for aiding management decisions, the Lake Michigan Mass Balance Study was conducted. A multidisciplinary modeling construct was applied and was supported by multi-media sampling of air, tributaries, water, sediment, and biological resources.
The mass balance indicated that atmospheric inputs were the major contributor of PCBs to the system followed by inputs from the watershed through tributaries. However, greater PCBs are presently being lost from the system through deep sediment burial and volatilization than thru external loads. Model forecasts of PCB concentrations in lake trout indicated that if the pace of remediation and recovery continued, fish consumption advisories could begin to be relaxed as early as 2033. Management implications for PCBs include the following:

- The end of a 100-year PCB legacy is coming in the foreseeable future.
- Prevention of entry of PCBs into Lake Michigan is a top priority because it will curtail cycling and promote recovery.
- The decline of PCB concentrations in lake trout can be accelerated by continuing a multifaceted remedial approach involving air, land, and watershed sources.
- Remedial priorities based on a quantifiable, scientific foundation for both local and lakewide perspectives should aid management decision making.
- Remediation should lead to economic and social benefits (e.g., the relaxation of consumption advisories for lake trout).

Advances in Integrated Modeling in the Great Lakes
Joseph DePinto, LimnoTech

IM in the Great Lakes has been a collaborative effort, involving researchers from government agencies, universities, and private industry. Changes that have occurred during the last 15 to 20 years have forced Great Lakes modelers to rethink the modeling paradigms that were successful in the 1970s and 1980s and to move more into the area of IM concepts.

IM is the process of converting data into a decision. The first step involves integrating data and modeling to yield additional information. Through analysis and visualization, the information then is transformed into knowledge and understanding, which then, through synthesis and forecasting, can support a decision. Feedback plays a key role in this process because decision makers are the ones who generate the questions that modelers try to answer. A major driver for IM in the Great Lakes is the recurrence of harmful algal blooms and near-shore nuisance algae, prompted by invasive species. Other drivers include concern about the relative impacts of multiple stressors on ecosystems; the need to quantify the linkages between land use/watershed actions and the lake trophic state; the need for ecosystem forecasting so that the ecosystem approach can be applied in the Great Lakes; and improvements in information technology (IT) that have made modern IM possible.

One example of IM in the Great Lakes is the Saginaw Bay Multi-Stressor Project, a large modeling project involving an adaptive integrated framework for managing multiple stressors. An advanced modeling framework has been developed that includes a sophisticated eutrophication model, with additional factors such as dreissenid mussels and the green alga *Cladophora* incorporated into it. The model is being run at a fine resolution (a 2-km grid) and has produced results that can guide management of the ecological problems in the bay.

Multimedia modeling—combining air, water, and sediment in the same model framework so that the feedbacks can be computed and understood—is an important development. Efforts are being made to develop a physically based multimedia model of the entire Great Lakes Basin. Such a model would be of value in assessing the potential basin-wide and location-specific impacts of emerging chemicals; assessing the relative importance of various exposure pathways; assessing progress toward achievement of specific risk reduction targets for emerging chemicals; and assisting in prioritizing research and monitoring programs. Future developments in Great Lakes modeling will include the continued development of several types of models, such as basin-wide models; multi-stressor, multi-response aquatic ecosystem models; fine-spatial-scale linked hydrodynamic-sediment-transport-water quality models; integrated models with modeling and management support systems; and models downscaled from global climate change models to allow analysis of climate change impacts on the Great Lakes region.

Discussion

A participant asked whether the speakers had given any thought to how to propagate uncertainty and communicate it to decision makers. Dr. Kries said that this has been done. There are several ways to communicate uncertainty to the public, including Monte Carlo-type simulations and simpler methods such as error bars from different statistical analyses. Post audits are a luxury but are desirable because they can show whether forecasts are being upheld by observed data, and as demonstrated today, the post audits exhibit good agreement between forecasts and newly measured. Dr. DePinto stated that as models become increasingly complex, it becomes difficult to use traditional uncertainty methods.

Therefore, it is important to think about nontraditional, creative ways to present uncertainty so that it can be understood.

A participant asked whether there is any way to take all the data generated from the models and combine them with societal values to permit prioritization. For example, if society values restoring fisheries over ensuring that beaches have water suitable for swimming, can the models be used to focus energies to reflect these priorities? Dr. DePinto replied that this is an excellent question but not one that is easily answered, although the issue is being considered in Great Lakes modeling projects, including the Saginaw Bay project. Information about societal values is being collected (e.g. does society value fish health more than swimming). Much more work needs to be done to focus efforts in ways that are in line with the values of the people who use a resource.

A participant asked how successfully management can be integrated across disciplines and jurisdictions. Mr. Horvatin responded that this is a question that has arisen for the restoration initiative. There will be a need to integrate data. There is no answer yet, but dialogue is taking place. Dr. DePinto explained that he had been involved in a team that developed a mass balance model for PCBs in Lake Ontario, a difficult project because most of the loads come from upstream lakes that are in different jurisdictions. Developing a TMDL for PCBs in the lake, as New York is doing, is challenging because it is not just a matter of a state deciding how to allocate loads that it can regulate; the state must deal with other entities, including a different country that does not have TMDLs.

BREAKOUT SESSION 1: CONCEPTUAL MODELS FOR LARGE AQUATIC ECOSYSTEMS

Charge for Breakout Session 1
Noha Gaber, EPA, Office of the Science Advisor

Dr. Gaber directed participants to the explanation of Breakout Session 1 in the Participants Guide. She explained that the purpose of this session is for each breakout group to develop a conceptual model for the LAE that it is discussing; this will tie into the second breakout session. To ground discussion, the breakout groups should focus on a number of policy scenarios at increasing levels of complexity and on the information requirements that they would ask the modeling and analysis in their ecosystem to provide.

General Coastal LAEs

John Lehrter, EPA, Office of Research and Development (ORD), Michael Hiscock, EPA, Office of the Science Advisor (OSA), and Mahri Monson, EPA, Office of Enforcement and Compliance Assurance (OECA), co-facilitated the discussion on environmental challenges faced by general coastal LAEs. The breakout group used the Driver-Pressure-State-Impact-Response (DPSIR) framework to discuss conceptual models for coastal LAEs and considered a general coastal ecosystem conceptual model in the context of the five policy scenarios explained in the Participants Guide.

The DPSIR framework was developed as a tool for organizing information regarding the condition of the environment while taking into consideration the economic and social aspects of environmental decision making. DPSIR evolved to examine and model systems of indicators within the context of the environment, specifically sustainable development.

According to the DPSIR framework, the chain of causal links begins with driving forces, or *drivers*, that represent the macroeconomic sectors and include the goods and services needed to maintain society (i.e., housing, transportation, industry, and energy). Each driver has consequences or *pressures.* Pressures, such as deforestation, are human activities that develop from drivers. Pressures then create changes in *state* (i.e., the environment or ecosystem). *Impacts* represent the loss or degradation of ecosystems (e.g., polluted water, contaminated fish, and shrinking coral reefs). Impacts include aesthetic as well as economic factors and result in *responses.* Responses are implemented to address impacts and include policy measures such as regulations, taxes, or public information about environmental problems.

A general coastal ecosystem conceptual model should facilitate trading and credit market initiatives. The model also should include decision support systems that allow decision makers to develop appropriate policies to support the model. Participants were encouraged to begin by considering the major economic sectors that impact ecosystems, such as development, transportation, shipping, and housing.

After discussions in small groups, participants identified the following aspects of the DPSIR framework related to general coastal LAEs, though they agreed that the list is by no means exhaustive:

Drivers

- Population growth
- Human health
- Energy extraction
- Agriculture
- Aquaculture
- Transportation, in particular shipping
- Industry
- Chemicals
- Mining
- Tourism
- Land use
- Natural disasters

Pressures

- Urban waste discharge
- Erosion
- Shoreline armoring
- Air pollution
- Rapid climate change
- Legacy pollution (e.g., PCBs)
- Fish harvesting
- Agricultural runoff
- Paving and development
- Dredging and diking
- Habitat loss
- Changes in salinity

State

- Water quality
- Level of biological contamination
- Biodiversity
- Level of sediment contamination
- Water circulation and mixing
- Eutrophication
- Vulnerability to natural disasters
- Changes in biochemical balance

Impacts

- Decline of fish stocks
- Contamination
- Hypoxia
- Harmful algae
- Toxin exposure

Responses

- TMDLs
- Waste discharge permits
- Fishery quotas
- Land use regulations
- Climate impact analysis
- Production bans on bioaccumulative toxins
- Contaminated site dredging

Participants agreed that policies should allow consideration of multiple, integrated, and multimedia issues and build a capacity for sustainable behavior. NOAA's ecosystem assessment method, environmental impact statements, and coastal zone management plans offer a regulatory framework that allows policy makers to use multiple systems when faced with coastal ecosystem challenges.

Within the context of a specific policy (policy scenario four—a watershed-wide point source to nonpoint source trading program in which point sources can buy offset credits from unregulated nonpoint sources to comply with regulatory obligations under a cap), TMDLs could be used to set an overall cap on human-generated discharge, for example. On a policy basis, an initial market dynamic will be set to allocate "pollution capital," which will maximize the incentive to trade; government will track and enforce the trade. Several participants noted that it is difficult to find a common language when addressing services, human value, and economic ramifications.

Discussion included the aging population as an example of a specific pollution prevention activity within the framework of DPSIR. The driver is increased pharmaceutical use, and the pressure is higher concentrations of medicines in waste streams. State includes higher concentrations of chemicals in water (drinking and ecosystem), sediment, and biota. The impacts include reproductive difficulties in aquatic organisms, human health, and loss of income (e.g., decline in fish population). Pharmaceutical take-back programs, changes in pharmaceutical management practices at hospitals and clinics, water treatment improvements, and public information programs would serve as typical responses to this problem.

Participants made the following observations regarding the DPSIR framework:

- The framework serves as a good starting point when working with a large group of people with varied expertise.
- It provides a logical, systematic, circular process to consider cause and effect of general coastal LAE challenges.
- Social scientists have particular expertise to analyze how specific interactions can work within the DPSIR framework.
- Drivers can lead to too many opposing directions.
- The framework is especially useful when considering whole systems and the interaction of ecosystems and humans.
- The value of an impact may be positive or negative depending on public viewpoint.
- Consequences of responses must be considered carefully.

General Freshwater LAEs

John Powers, EPA, Office of Water, and Kevin Sellner, Chesapeake Research Consortium, served as co-facilitators for the General Freshwater breakout session. The group's objective was to discuss real-life situations, examine the information requirements to support decision making, and examine adaptive management structures so that policies created based on the models also can be adaptive. Dr. Sellner advised the group to consider the drivers of stakeholder interest and to keep economics and the social sciences in mind; natural science models already exist.

A cross-media perspective is needed to address the disconnect between air and water. Regional impacts should be controlled with the best available technologies; some local sources of pollution may require additional controls, and nonpoint sources may need to be examined.

A participant discussed the need for policy makers to communicate to modelers what they want the model to tell them. Policy makers often are disconnected from the modelers who know what drives the system. Policies to control ammonia emissions from chicken farms are an example; policy makers do not understand the agricultural industry. Dr. Sellner added that in this example, food production infrastructure does not include the cost of dealing with chicken litter. Perhaps the food production system could be changed so that the consumer pays for the environmental cost of the food (litter cleanup), for example, with an eighth of a cent added to the price per pound. Dr. Powers mentioned that there are only a few large chicken buyers, and they hold tremendous power over the producers. An integrated policy would take both environmental and economic realities into account. A participant stated that policies can have unintended effects. If too many nutrient management plans are implemented in a state, small farmers may sell to big agribusiness or to developers, and the ensuing development has different environmental ramifications.

Participants discussed the link between integrated models and integrated policy. IM can inform policy options, and some policy options involve examination of an integrated supply chain. Policy makers should note the negative environmental impact and examine the supply chain until the cause is found. An understanding of what changes in land use will occur with different changes in scenarios is needed. Additionally, it must be taken into account whether an LAE was impaired before the issues being regulated became a problem, in which case regulatory mechanisms may not be enough to get a system back up to the point of health. IM needs to examine the likely effects of any policy that will be implemented with mechanisms to look for outcomes x, y, and z, for example. Dr. Sellner stated that adaptive management is meant to deal with unexpected results. If regulations are embedded into the models designed, the models will predict the outcomes. IM should be a circular process: policy drives the physical environmental drivers, with output placed back into the model. The Chesapeake Bay Program never examined whether monitoring was affecting change in policy; there was no adaptive management. If there is an environmental goal, the level of runoff or pollutants that can be emitted while still reaching that goal must be known, and sources must be controlled. States creating the strategies must determine whether, for example, a 20 percent reduction in pollutants is possible. Integrated models must examine the inventory of sources and combine them.

A participant pointed out that a problem in modeling land use is acquiring the input data; a model may be excellent, but lack of data is a real hindrance to efficiently modeling land use. Dr. Sellner added that land use decisions should be embedded into models, but the biggest deterrent to ecosystem-based modeling is that land use decisions are made at the local level. Dr. Powers added that local decision makers are disconnected from regional policy makers. Local governments and landowners need to feel safe enough to provide input data for models.

Additional points raised in the discussion included the following:

- Public policies need to manage nutrient reduction in the correct places: freshwater areas are phosphorus limited, while coastal areas are nitrogen limited. Dual nutrient management practices are highly successful.
- To model effectively, the ecosystem's function must be understood; multi-stressor modeling is needed.
- Modeling has become more complex throughout its history. The more costly the outcome, the more precise the models need to be. If modeling is done first and calibrated well, some of the less successful ideas can be eliminated.
- Data input must be automated, which would help with the predictive capability of the models. If land use changes from agricultural to industrial, the data could be input into the model immediately after the change rather than 10 years later.
- When modeling a policy, the goal is to understand all of its impacts even if regulators only can control for some of them. Modeling should examine scenarios leading to the problem at hand, or most representative for the conditions causing the problem. Moving those through the system is part of modeling, along with risk assessment and cost consideration.

Participants agreed that an integrated conceptual model should: specify a problem and specific policy goals; incorporate cultural, social, and economic elements from the beginning via participatory modeling, keeping in mind the goal for the local community; identify model components for the specific goal; and design policy incorporating performance measurement and accountability, which leads to adaptive management.

Great Lakes

Gabriel Olchin, EPA, Office of the Science Advisor, and Russell Kreis, EPA, ORD moderated the breakout session. Dr. Olchin explained that the objective was to: (1) develop a conceptual model that captures the interactions and processes in the Great Lakes ecosystem, (2) use this conceptual model to evaluate the impacts of policies and considerations, and (3) identify policies. Participants were given the option to modify or not consider policies and procedures in the Participants Guide, depending on their applicability.

Points raised in the discussion were incorporated into the following schema of restoration goals:

1. Re-establish healthy aquatic communities, considering the Great Lakes as an entire ecosystem
    a. Invasive species management

  b. Food web modeling
  c. Diversity, self-sustainability (i.e., fish populations)
    i. What other drivers will connect?
    ii. Spawning grounds
    iii. Diversity dependent on water quality
    iv. Are there specific communities to be considered and managed?
  d. Fisheries management
  e. Eliminate the human health concerns of fish consumption

2. Restore conditions in near-shore beaches to those of the pre-Dreissenid mussel period
  a. Phosphorus load, offshore desertification
    i. Point source/nonpoint source regulations
  b. Fertilizer regulation
  c. Nutrient cycling
  d. Point source location—relocate phosphorus load to offshore locations (pipes)
  e. *Cladophora* management
    i. Further reduce phosphorus loads
    ii. Water temperature
    iii. Negate phosphate sequestration in near-shore
    iv. Substrate alteration
    v. Eradicate mussels
    vi. Other chemical controls—water treatment techniques (calcium needs)
    vii. Costs—environmental or other
    viii. Pesticide control—costs, environmental, and economic

3. Restore shoreline and habitats
  a. Land use changes
    i. Hardening of the shoreline
      1. Hydrology
    ii. Timescale issues—with model

4. Watersheds—land use, nutrients, toxics, and water quality
  a. Atmospheric deposition
    i. Impervious surfaces
      1. Nonpoint sources/point sources; how can policies relate to urban land development?
  b. Land use changes
    i. Urban changes
      1. Transport efficiencies (driver)
      2. How related to land use history—timescales and lags
        a. Legacy land use vs. current land use
    ii. Tree growth → agricultural use
    iii. Swamps/wetlands drained → tile drained agriculture
      1. Efficiency of nutrient reception in waters
    iv. Hydrology changes
      1. Dams
        a. Fish, sediment, nutrients, and water temperature
      2. Stream flow rates and recruitment of walleye
  c. Agricultural management changes in lieu of biofuel demand
    i. Sediment load

        ii. Nutrient loads
        iii. Rotation/tillage management
            1. Soil nitrogen stocks
        iv. Subsidized
        v. Cost-benefit analysis—Conversation Reserve Program (CRP) leakage
        vi. Market policies
        vii. Natural Resources Conservation Service (NRCS)—nutrient demands, soil needs, and too much fertilizer applied
            1. Fertilizer timing, amount, and form of usage
    d. Total suspended solids and sediment loads
    e. Urban land use
    f. Surface groundwater flows
        i. Sources
        ii. Temperature
        iii. Quality

5. Social behaviors and values
    a. Political modeling
    b. Infrastructure
    c. Human health and welfare
    d. Economics
    e. Knowledge modeling and theory
    f. U.S. vs. Canadian perspectives (international values)

6. Economic components
    a. Crop rotations
        i. Corn prices, other crops
    b. Comprehensive
    c. Cost and benefits
    d. Existing markets and new markets
    e. What-if estimates and scenarios
    f. Commercial shipping and boating
        i. Water levels in Lake Ontario
            1. Hydropower—values
            2. Other impacts
        ii. Ballast blow out and invasive species
        iii. Closing locks and Great Lakes fishery
    g. Ecological services
        i. How to assign or determine value?
        ii. How does this change with time?
        iii. Asian carp

7. Chemical stressors—offshore sources
    a. Reduce and remediate
    b. Toxics
    c. Ecological effects
    d. Ties to environmental conditions
    e. Ecological risk
    f. Human health risk

i. Ties back to fish consumption and drinking water; other exposure
ii. Recreation
iii. Chemicals of emerging concern—which are a problem?
    1. Predicting exposure and effects of those chemicals
    2. How do they interact with each other and the environment?
    3. Exposure pathways—toxics and nutrients; pharmaceuticals; legacy contaminants
        a. Which source is causal—urban, industrial, or agricultural point and nonpoint sources

8. Hydrology
    a. Deepwater
    b. Basin hydrology
    c. Human regulation—(flows)

9. Policies
    a. Clean Water Act (CWA), Clean Air Act (CAA)
    b. Endangered Species Act
    c. U.S./Canada
    d. Canada/U.S. Great Lakes Water Quality Agreement (GLWQA)
    e. U.S. Department of Agriculture (USDA) Conservation Reserve Program (CRP)

10. Climate change
    a. Water levels
    b. Hydrology timing
    c. Riparian impacts
    d. Precipitation timing
    e. Species succession
    f. Ice cover—evaporation
    g. Foodweb dynamics (prey-predator)
    h. Habitat loss
    i. Human migration, densities, and behaviors

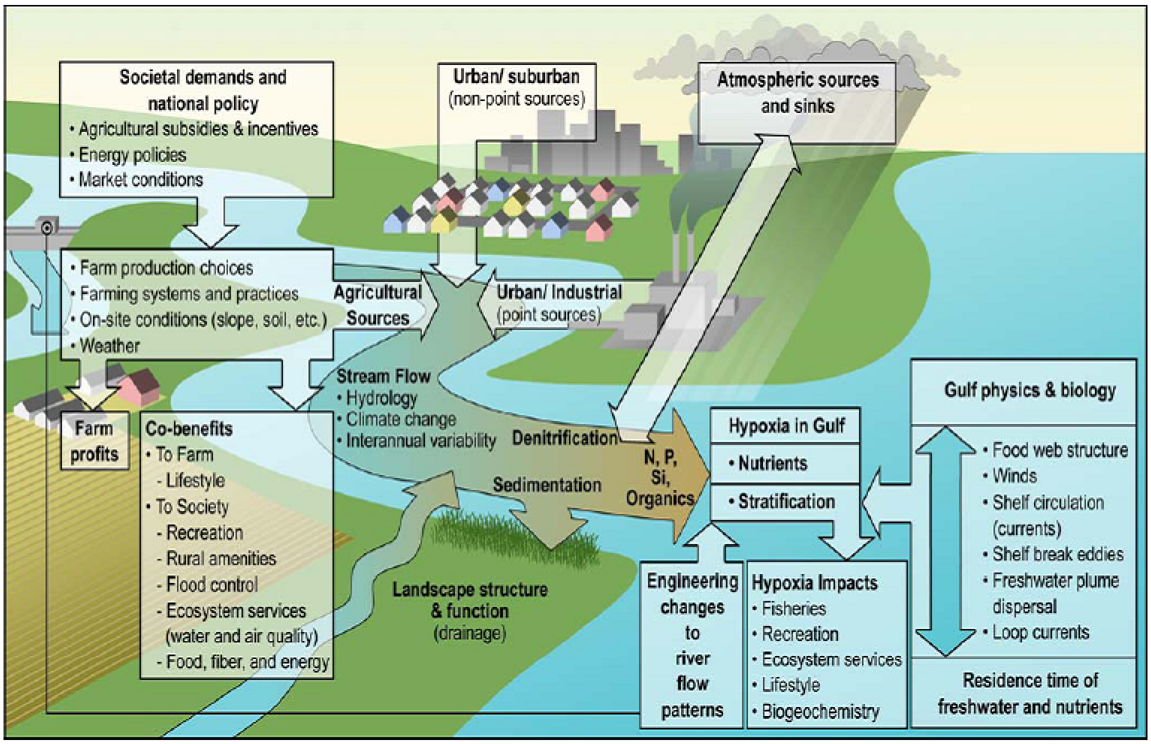
The group also developed a conceptual diagram with the following content: near-shore and beach conditions; aquatic populations; offshore water conditions/quality; shoreline habitats; economic components, risk (human and ecological); social behaviors; chemical stressors; atmosphere processes; watershed scale processes; and hydrology and basin scale issues.

Concluding the breakout session, participants brainstormed a list of authorities and laws relevant for the Great Lakes region, including the following: Beaches Act; National Pollutant Discharge Elimination System (NPDES); CWA; CAA; National Aquatic Invasive Species Act (NAISA); U.S./Canada Great Lakes WQA; Boundary Waters Treaty; Endangered Species Act; Conservation Reserve Act; National Environmental Policy Act (NEPA); Great Lakes Compact; Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA Superfund); Great Lakes Legacy Act; Water Resources Development Act (WRDA); Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA); Great Lakes Regional Collaboration (GLRC) Executive Order; Safe Drinking Water Act; Great Lakes Restoration Initiative (GLRI); Harmful Algal Bloom Act; Farm Bill; Toxic Substances Control Act (TSCA); Resource Conservation and Recovery Act (RCRA); and Critical Programs Act.

Chesapeake Bay

The Chesapeake Bay breakout group, moderated by Lewis Linker, EPA Chesapeake Bay Program Modeling Coordinator, and Alan Dixon, EPA, Office of Prevention, Pesticides, and Toxic Substances (OPPTS), began by considering all five policy scenarios listed in the Participants Guide but quickly focused on market trading as represented by Policy Level 5 in the graphic below. The group considered whether various types of trading should be allowed, including point source/nonpoint source trades across states, air-to-water trades, and cornfield to oyster filter feeder trades.

Policy 5: *A watershed-wide suite integrated models to support credit markets that allow competitively purchased credits for N, P, and sediment in order to accommodate future growth despite a cap on nutrients and sediment loads. The IM system would also allow for NGOs (through reverse auctions) to purchase credits for N, P and sediment.*



There were several motivations for focusing on this high level of integrated modeling and decision making. First, the level of integrated modeling the Chesapeake Pay Program is already mature, with airshed, watershed, estuary, ecosystem, and climate change models already fully operational. A key missing component to the Chesapeake Bay integrated models are economic models linked with the existing mass balance models that would assist decision makers in determining policies that are both environmentally effective and cost efficient. This is an emerging issue in the Chesapeake Bay Program because the cap loads that achieve the Bay water quality standards expected to be achieved by 2025 are not to be exceeded despite the watershed. This will require sophisticated nutrient trading to accommodate this growth and in order to get ready for this we need to begin planning our integrated modeling and analysis systems now.

The group assumed that a large point source like Blue Plains wastewater treatment plant serving the Washington, DC metro region needed to increase its nitrogen and phosphorus loads, which prompted the following series of questions. Do we allow point source to point source trades across States? Do we also allow point source to nonpoint source trades across States? Air to water trades? Cornfield to oyster filter feeder trades? What integrated models and analysis systems would be needed to accomplish this? Would we set up separate N and P markets in the Chesapeake? And finally, if NGOs competitively purchase credits for N and P (and sediment, carbon, habitat, and flood mitigation) through reverse auctions what analysis systems and integrated modeling are needed?

Based on this discussion the group started with the charge: Can we model, measure, and develop a market for trades in the Chesapeake?

Generally there was agreement that this analysis system was needed, and with some attention to development of robust economic models, would be feasible. While development of the nutrient trading integrated modeling analysis system was encouraged, participants also expressed caution about several aspects of trading. For example, they noted that it is important to carefully track the location at which nutrients enter the Bay as an element of a trade. Local water quality criteria need to be met even in the presence of trading.

Trading could lead to collateral damage to the Bay from other stressors. For example, an urban area that cannot meet its nutrient goal for stormwater or that chooses not to do so for financial reasons might trade with a rural farm area. Such a trade would not address pollutants and ecological concerns other than nutrients, such as flow, contaminants, and water temperature. Thus, the benefits of controlling additional stressors that would have been obtained if the urban area had upgraded its stormwater management would be lost. Trading in this situation might be economically efficient but would not be environmentally efficient. By ignoring factors other than nutrients, such trades would “sell the watershed cheap.”

The problem of “leakage” was discussed: for example, a farmer may receive credit for not growing corn and therefore not contributing nutrients from fertilizer to the watershed, but this may create a financial incentive for neighboring farmers to increase their own corn production, thus negating the benefit of the action taken by the first farmer.

Community buy-in for trading is crucial, and sophisticated pricing mechanisms are needed. The effect of a pound of nitrogen in one location may be equivalent to the effect of 10 pounds in another location; this must be taken into account. A credible accounting model for trading is necessary.

Incentives for trading that are designed to improve the health of the Bay may be detrimental to the health of local streams. A well-designed trading system should yield appropriate outcomes not only in the tidal Bay but also in the watershed and upstream communities. There needs to be some way to measure and give credit for actions that benefit upstream watersheds, such as reforesting banks and buffering around agricultural areas.

Many issues in Bay modeling reflect an imperfect understanding of physical and biological processes. Models must evolve with evolving science and need to be dynamic in terms of ecosystem changes. Models should have an economic component so that policy makers can explore the impact of actions such as taxation as well as best management practices in the watershed. An economic model needs to have the time component of environmental change built in.

Some approaches to trading simply may not be feasible. A participant drew the group's attention to California's failed attempt to have a competitive model for electricity. Similarly, a carbon trading market may not be feasible unless it is national, and national carbon trading could be inconsistent with goals for the Bay. On the other hand, trading sometimes leads to choices that are good for society. A participant cited an example of a community that engaged in trading rather than upgrading its sewage treatment plant; the community chose to upgrade its high school instead.

Trading is inherently scary for several reasons. It does not just involve dollars; it involves someone's backyard. States are experimenting with different approaches and learning from them, but these experiments may have unforeseen consequences. There is value to comparing different approaches to trading, just as there is value to comparing experiences in different watersheds. In addition, market-driven solutions should be compared with straight regulatory solutions. It is often presumed that trading will be more effective than straight enforcement, but participants advised turning to the model to evaluate the relative effectiveness of trading versus enforcement, rather than making assumptions.

Other points raised in discussion in the Chesapeake Bay breakout group included the following:

- The need to have integrated landscape models and environmental models.
- Local zoning and planning factors need to be included in models, likely as a constraint.
- The need to capture the fate of atmospheric deposition.
- Integrated human/economic modeling (utility theory).
- The communications challenge faced when trading is used while impairments still exist.
- What if nutrient goals and water quality standards are achieved, but this does not yield a restored Bay? It may be necessary to adjust levels to address impairments, and it may be difficult to communicate to the public that a delay exists between the achievement of numerical goals and the realization of visible benefits.
- Impacts from episodic events/seasonality/drought, and the need for dynamic management to address them.
- "We can't compute the uncomputable."
- Nesting capability is needed to get to different scales.
- Interaction of the public with the model, and the need for transparency.
- The market may be inefficient because of constraints to trading.
- Equity as a constraint and the difficulty of defining equity.
- Addressing elements absent from the current modeling approach.
- Various policy levers that are available.
- What should the user interface of the model look like?

An important point made by representatives of environmental regulatory programs was that environmental models are a just tool to enable regulators to analyze options and outcomes to better meet the goals of a strategic environmental plan (SEP). As such, the SEP and regulatory tools necessary to meet the SEP goals should remain as the central elements of any integrated environmental modeling system. The socio and economic aspects of implementing cap and trade policies for the Chesapeake Bay are important to regulators and though an area of little development to date economic models as part of the integrated modeling system will likely be more important going forward over the next 10 to 15 years.

JANUARY 20, 2010

BREAKOUT SESSION 1 REPORTING AND DISCUSSION

General Freshwater

Brenda Johnson, EPA Region 4, presented the report-back for the General Freshwater breakout group. She reported that the group was very small but deeply involved in the discussion and that it included people from diverse agencies and positions. The discussion centered on a hybrid adaptive management approach. Participants stressed the need for a clear definition of a problem. Getting stakeholders together also was emphasized. Stakeholders include not only those regulated by EPA but also advocacy groups, other agencies, and the public.

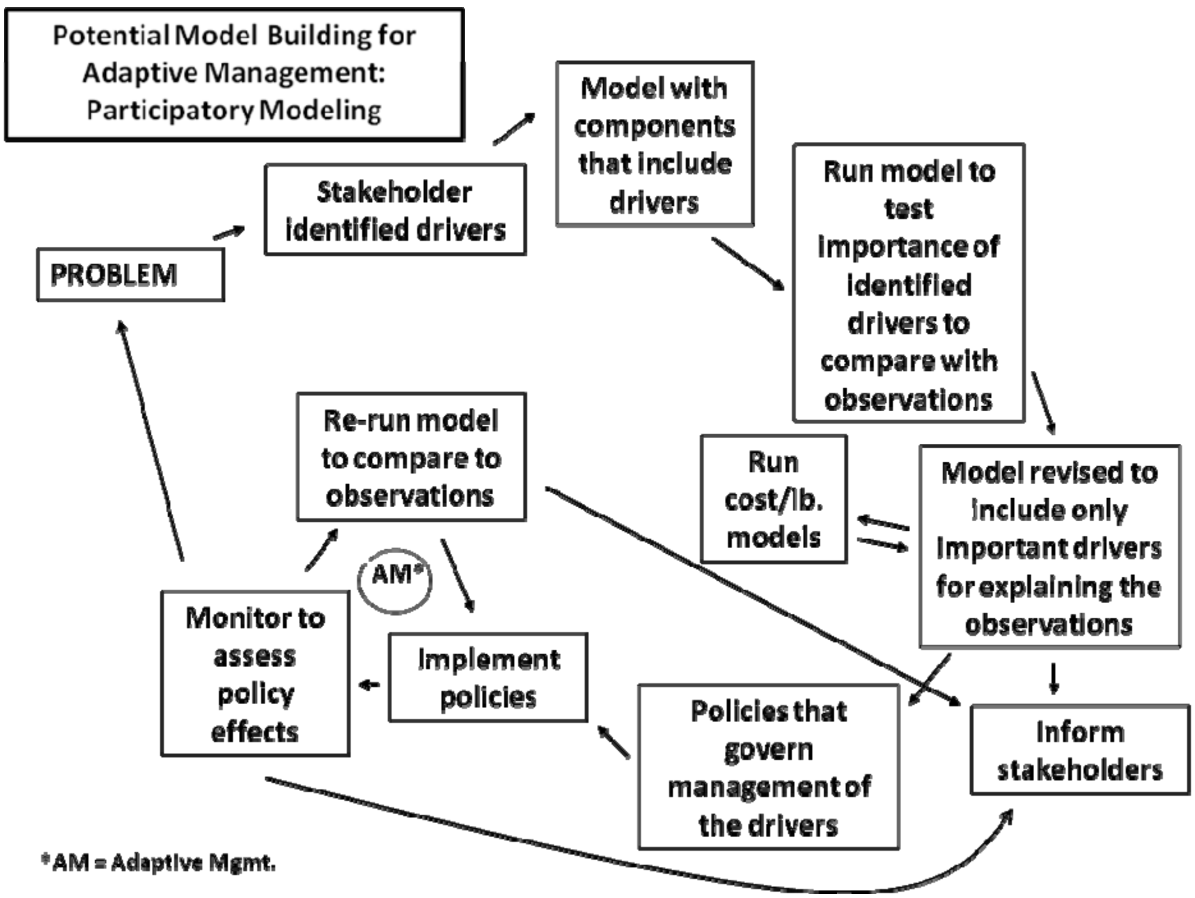
It is important to clearly delineate what is driving an impairment in an area. What is the spatial extent of the problem? Not everything has a local impact; sometimes, a situation must be viewed from a regional perspective. Temporal scales also are important. Different tools are needed for seasonal versus sporadic versus annual impacts.

Modeling involves iterations in response to new information and periodic reassessments; it cannot be performed only once. It is important to recognize that a model is just a tool for decision making; there are uncertainties in the input, the model formulations, the concepts, and the data used to run the model.

After a problem is identified, stakeholders should be brought together, and a decision should be made about the type of models needed. Models then should be run in several steps. In a LAE, both air and water impacts are important, so several different models are needed. There is an iterative process in running the model to develop strategies with stakeholders, but it is important for everyone to recognize that there is a time limitation on the process, so not all possible strategies can be investigated. Although stakeholders may not necessarily have knowledge of the technical process, they need to be kept informed. After a strategy is developed, the balance of cost impact versus environmental improvement must be examined. Some stakeholders, such as farms, face unique cost issues. After a decision is made as to whether the strategy is viable, implementation is the next step. Because this is an adaptive management approach, periodic reassessment and interim monitoring are part of the process.

An important issue that arose during the discussion was the problem of predicting future land use. For example, what might happen to farms with low profit margins? Will they be sold and become housing developments, thus raising a new set of environmental issues?

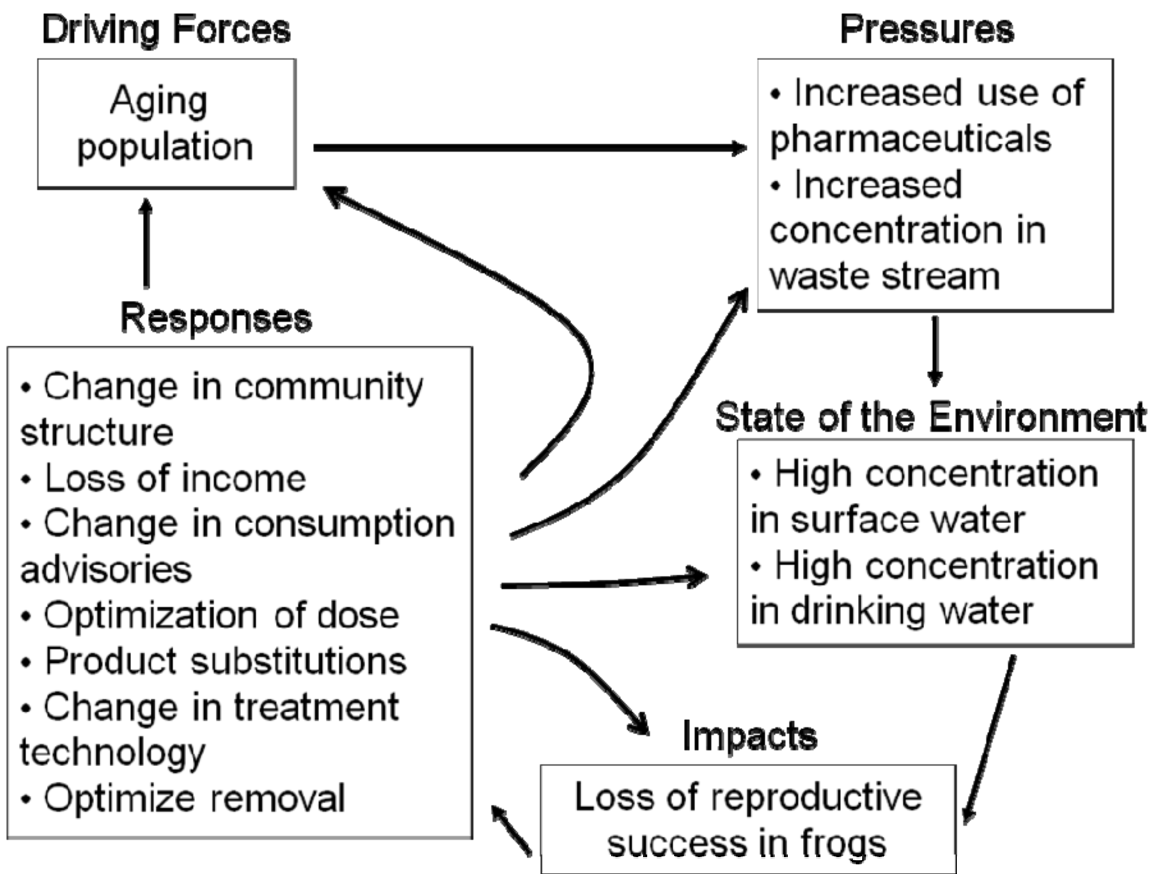
The group summarized its ideas in the following conceptual model:



General Coastal

John Lehrter, EPA, ORD, presented the report-back for the General Coastal breakout group. This group divided into subgroups and, as described earlier, made use of the DPSIR framework. One subgroup did not like working with this framework, but the others found it useful. Using this framework seems to become easier with the realization that it is not necessary to start with D (drivers); any part of the framework can serve as a starting point. DPSIR is helpful in working in the boundary areas between different areas of expertise.

As an example of how the DPSIR framework can be used, the group presented the following analysis of the environmental impact of the increased use of pharmaceuticals by an aging population (a topic prompted by the observation during the symposium that many of the speakers will reach retirement age within the next decade):



Chesapeake Bay

Lewis Linker presented the report-back for the Chesapeake Bay breakout group. He reported that the top five points emphasized in the group's wide-ranging discussion were as follows:

1. There was a sense of the group that we need economic models for markets and human/social responses linked with our environmental models.
2. We may be compelled to enter into a trading program, but we should have our eyes wide open. Trades may have unforeseen (and unpleasant) consequences.
3. If we enter into this model framework, adaptive modeling is a must. We have to roll with the punches and redesign the model/analysis system as needed as we go forward. The Chesapeake Bay in 2025 will be a very different place in terms of nutrient loads and trophic states.
4. Equity is a difficult and challenging concept. Would we know it if we see it? We need to consider equity at the starting point of trading and also equity, or the lack of it, as an impact (i.e., inequitable impacts from trading).
5. Trading is not limited to consequences in the Bay. We also need to look at upstream impacts to smaller areas and water bodies in the watershed. This is really pushing our level of analysis capability.

A participant asked for clarification about the unintended consequences of trading. Members of the breakout group described possible consequences involving stormwater runoff and "leakage," as detailed in the report of their breakout session. It is important to understand how trades work; will they actually achieve the desired consequences? We may be compelled to trade, but understanding the consequences of trading is challenging. Not everyone embraces the trading system.

A participant asked about the implications for model development. Mr. Linker replied that now is the time to be thinking of implications for 15 years in the future and to be considering a national strategy.

A member of the Chesapeake Bay group commented that the input from social scientists and economists to the breakout group's discussion was valuable. This is where modeling is going. Issues such as leakage, equity, transparency, and community reactions are not clearly understood, and social scientists and economists can help to clarify them.

A participant commented that there ought to be feedback from the economic model to others. Linkage is just feedforward; true coupling is when you have feedback and models work together.

A member of the Chesapeake Bay group commented that adaptive management is crucial when trading is implemented. Because not all of the impacts of trading are understood, the model will need to be redesigned and reconfigured; it is not static for all time.

A participant asked how policy control fits in. What if contaminants become concentrated in a specific area? The Bay as a whole could be in compliance but that specific area might not be. Mr. Linker replied that this is one of the types of unintended consequences that must be considered and that situations like this push the level of analysis capability.

A participant commented that it is important not to ruin the water quality at any point in the system.

Great Lakes

Gabriel Olchin, EPA, Office of the Science Advisor, presented the report-back for the Great Lakes group. The group identified the goals for the Great Lakes as having swimmable, drinkable, fishable water; healthy aquatic communities; and shoreline habitat. In response to these priorities, group members raised a long list of topics, which fit into 11 general categories. Although the group did not work with the DPSIR framework, the 11 categories fit well into that framework, as follows:

Drivers	Pressures	State	Impacts	Responses
Social behaviors	Land use change	Aquatic populations	Risk (human and ecological)	
Economic components	Climate change	Near-shore and beach conditions		
	Chemical stressors	Offshore water conditions		
	Atmospheric processes	Hydrology		

The "responses" category would include many acts and organizations. For the Great Lakes in particular, the international component is important. The group emphasized the need for social and economic models and information. Many of the topics brought up in discussion would require information from those areas.

Discussion

Ms. Johnson observed that the number of policies and acts related to LAEs is very large and asked how the existence of so many policies would affect a trading program. Mr. Linker replied that trading would have impacts on other markets, as well as many political impacts.

A participant commented that incorporating socioeconomic models and adaptive management into the modeling framework might require rewriting many laws and regulations that do not call for the use of adaptive management. Ms. Johnson replied that in practice, an adaptive approach is used even if regulations do not specify it. For example, when a permit is reissued, it has to be examined to see whether any changes that are made in it will have adverse effects. It is necessary to continuously monitor LAEs to determine whether problems are becoming better or worse. Mr. Linker agreed that the ability to look at environmental problems as an integrated whole is constrained by laws. A participant commented that it may be necessary to convince high-level decision makers to change laws and regulations to allow an integrated approach.

A participant noted that EPA is stovepiped. Without an integrated approach, there is no way to know whether one of several possible policies is better than the others in terms of pollutants other than the one specifically being addressed. For example, a nitrogen strategy that also provides ozone attainment may be preferable to other approaches. If we demonstrate through modeling that there are problems with the stovepipes, it may be possible to go to Congress and explain that the statutes are outdated. Ms. Johnson replied that in the Air program, many states are working on a one-atmosphere approach, looking at multiple pollutants at the same time. They do not want the strategy for one pollutant to adversely affect others. Thus, an integrated strategy is already happening for air but not for water. A participant added that a one-environment approach, not just a one-atmosphere approach, is needed.

A participant said that adaptive management seems to assume a quasi-steady-state situation and asked whether policies can be responsive to anomalous situations such as Hurricane Katrina. If anomalous situations are not addressed, we cannot be ready for them. Mr. Linker said that in the Chesapeake Bay model, they aim to simulate extreme events and have learned a great deal from those simulations. Dr. Lehrter said that in his work, there has been discussion of events that greatly redistribute sediment, but that this is beyond the state-of-the-art in water quality modeling at the present time. He noted that without modeling, you would not know that you have moved off the steady state. A participant drew attention to extreme drought as another anomalous situation to which policies must adapt.

A participant expressed the view that the larger research community should be viewed as stakeholders, not just in the beginning but in the longer term application of modeling. His experience has been that there is tension between modeling efforts and the research community. Ms. Johnson said that in her breakout group, there was discussion about how inclusion of stakeholders should be all-encompassing, and this would include academia. Academics should be involved early and often. Having technical people involved for longer or shorter periods is based on payment. Sometimes, they may not be able to stay involved beyond the initial project for reasons of funding. Tension exists, especially with those who are being regulated. They will perform their own analyses and contest EPA conclusions, but there also is synergism with them. Ms. Johnson also noted that her breakout group had discussed the problem of extreme events and agreed that they are very difficult to address.

A participant commented that open source is a fundamental core of the IM approach. Tensions can be resolved through multiple model runs to demonstrate whether claims agree with observations. Models should become a community resource to which all academics and managers have access. With regard to extreme events, this participant said that one of the drivers in the Chesapeake Bay is that living resources are at all-time lows. A major event could have devastating consequences. This problem can be addressed through resilience and thresholds. Basically, if there is sufficient biomass, an event can be overcome. Much of the restoration in many ecosystems is based on developing threshold resilience to enable recovery from an extreme event.

Mr. Linker reiterated that open source and public domain are important. Community modeling may be the next step. This point cannot be made often enough, in his opinion.

A participant explained that it may be difficult to implement short-term policy changes in response to catastrophic events. Such policy changes may be good for the environment but difficult to implement from an economic or business standpoint. How can a regulatory agency change an existing permit because of a drought? Companies need stability to operate. Another participant noted that in the 1970s, there was a concept of imminent suspension with danger. When trigger points hit, plans were in place. It is not feasible to plan for events of the magnitude of Hurricane Katrina, but one can plan for somewhat periodic exceptional events, such as drought. In the past, plans were in place for such occurrences, and temporary restraining orders sometimes were used. Therefore, precedents exist.

Another participant brought up the issue of the impact of policy changes in response to extreme events on markets and trading. If it is known that the rules may change midstream in response to unusual events, some people may be reluctant to trade.

With regard to the transparency issue, a participant explained that all NOAA models are transparent, with outputs provided to the public. Nevertheless, one must be very careful about providing raw model output to the public because raw output without interpretation can prompt poor decisions. Transparency is important, but there needs to be a level of synthesis and analysis before information is provided to the public. Ms. Johnson said that this approach is used in the Air program. Raw data are not sent out.

A participant explained that a model is one of many lines of evidence and tools. When you make a choice to go with a model, you are allocating resources to that model, rather than to other efforts, such as data collection or demonstration projects. The tradeoff between modeling and other projects needs to be discussed and considered. This participant also pointed out that a model is never really finished, but at some point it is taken from the modeler and used. As we move toward integration of many types of models, with adaptive management and feedback, we must make sure we do not put ourselves in an infinite to-do loop. There are clear points when tools must be applied for different levels of decisions. If this is not done, the process just keeps going and does not accomplish much.

A participant noted that adaptive management means that everyone who has an impact on a problem needs to be involved in its resolution. In the State of Maryland, the governor brought all departments involved in Bay issues together to work cooperatively and produce unified output in the BayStat effort. Even the Department of Agriculture was included. Stovepipes were dissolved to reach a goal. To really have adaptive management within EPA and across agencies, the same type of unification must happen. Actual cooperation, rather than just stated cooperation, is needed.

A participant asked whether models need to be broader to encompass extreme events. Mr. Linker responded that one approach is to add simulation, which could include extreme events. It is important to have observational data on the extreme event to make this feasible. A participant asked what models need to look like to address extreme events. Many models are steady-state. Extreme events are outliers. How can this be dealt with? Mr. Linker said that a simulation system can capture these outlier events. Dr. Gaber advised that further discussion of extreme events could be deferred to the afternoon breakout groups, which will examine modeling capabilities and linkages.

A participant explained that in the regulation of pesticides, much modeling is used, but pesticides are not regulated at anywhere near a steady state. Instead, they are typically regulated at 99.9 percent events for human health. It is not inordinately difficult to create a model that regulates not at a steady state but at a higher level event.

A participant said that climate change is a difficult challenge for modeling. Sea level rise is not the only consequence; climate change also affects precipitation, land use, and many other factors. There is a need to understand this and develop adaptive management for it, which will require new tools and new models. Climate change is a cross-agency issue. NOAA is looking at climate change; this could provide an excellent opportunity for agencies to work together. Models of LAEs generally do not extend to the continental shelf, but NOAA models do. Mr. Linker added that temperature and precipitation drive models of estuaries. He would like to look at extremes and projections for 20 years out. There is a need for an information database across agencies and across all LAEs. We should be bold, strategic, and national. Dr. Olchin noted that the Great Lakes breakout group identified many impacts of climate change, including how societal behavior may change as a result of climate change.

A participant asked whether government-wide models are being used. Dr. Gaber replied that she hopes this topic comes up in the afternoon breakout discussions.

A participant commented that the effect of climate change is not his primary concern. He said that it is clear to him that if you look at long records of temperature in estuaries, you see cool and warm decades. Typically, water quality models are tuned or tested for 1- or 2-year periods, but it would take 100 years before you see a 1-degree change. It is important to understand patterns in wind and add these to water flow and temperature.

Summarizing the discussion, Dr. Gaber said that a number of interrelated themes were emerging, including: (1) the need for adaptive modeling and management, and (2) the need for early planning to involve impacted stakeholders and those who have an impact on the problem in question. There is support for a participatory modeling approach. A useful framework is needed to overcome language differences between disciplines; the DPSIR framework may be of value but needs to be brought in early in the process. Another theme is the need for transparency—the question of whom to involve and when to involve them, and the benefits of transparency in terms of building confidence and stakeholder understanding. On the adaptive modeling theme, an important point is that modeling is just one tool that goes into decision making. Therefore, there is a need to balance the drive for perfection in modeling with the need to provide timely information for decision making.

MODELING ACTIVITIES IN OTHER LAES

John Lehrter, EPA, Office of Research and Development, Moderator

In introducing this session, Dr. Lehrter noted that the Great Lakes and Chesapeake Bay have extensive data and targeted missions. For other LAEs, data and resources are less extensive but the modeling challenges are just as complex. They may include tight deadlines for developing regulations (as is currently the case in Florida), the need to develop better computational methods, and the existence of open boundary conditions that make modeling more difficult.

Modeling Water Quality Impacts to Puget Sound: The Early Years (2005-2009)
Ben Cope, EPA Region 10; and Mindy Roberts, Washington Department of Ecology

Mr. Cope began the joint presentation on Puget Sound by explaining that the key issues in this LAE are toxics in marine mammals including orcas; endangered salmon runs; legacy pollution and ongoing urbanization; and naturally low DO in fjord-like deep waters, leading to concerns about the potential for dead zones. Drivers include urbanization, forestry, agriculture, and industry. EPA, the Washington Department of Ecology, and the Puget Sound Partnership all play roles in implementing the CWA in Puget Sound. Different agencies have built models to meet their individual needs, trying to answer specific questions with the limited resources available.

One modeling effort in this LAE is the Puget Sound Box Model for PCBs in water, sediment, and biota. This is a relatively low-resolution tool that has linked several existing models into a single framework. A proof-of-concept test for the model showed that it was successful in explaining observations in biota. The model can be used to examine PCB fluxes in and out of the entire Sound. Watershed sources are the largest contributors of PCBs to Puget Sound. Outflux and sediment burial are important factors because most of the PCBs are in the sediment. Because the available data are limited, there is large uncertainty about the external load and steady state mass of PCBs in the Sound. The model has shown that not enough is known about external loading to the system to answer the key question of whether the total mass of PCBs in the Sound is increasing or decreasing. Thus, this model is an example of a simple tool that raised a question for policy makers and demonstrated the need for additional data.

Dr. Roberts described three efforts involving modeling of DO and nutrient dynamics: one in Budd Inlet that was part of the active development of a TMDL, one in South Puget Sound that may lead to a TMDL, and one involving a Puget Sound-wide model. All three models address the same question: How much are humans contributing to low levels of DO?

Puget Sound faces important ongoing challenges. Managers are overwhelmed, and models often are not considered a necessity. People want to be able to take action, but there is uncertainty about whether proposed actions will represent the best use of funds and about when the data and modeling results are adequate to announce a finding. There is a need for modelers to communicate to policy makers that models are useful and sometimes vitally needed. Clear problem identification and thorough project plans are important. External modelers, agency policy staff, and stakeholders need to be involved in model development, and frank discussion of uncertainty and error in the context of decision making is essential.

Discussion

A participant from NOAA commented that NOAA's National Ocean Service (NOS) will be conducting a collaborative survey in the Puget Sound area that will help to fill data gaps for this LAE.

Integrated Modeling in Long Island Sound
Mark Tedesco, EPA Long Island Sound Office; Robin Miller, HydroQual, Inc.; and James O'Donnell, University of Connecticut

Mr. Tedesco began the group presentation on Long Island Sound by explaining that the current eutrophication model of this LAE is a second-generation model. A nitrogen TMDL was adopted in 2001, and the current model is being used to reassess it.

Dr. Miller explained that the reason why modeling was needed in Long Island Sound is hypoxia, which presents problems every summer. After years of model development, there is now a three-dimensional model that is fully time-variable and can run on ordinary computers. The resolution of the model is sufficient to address issues in the open Sound but less so for shore areas. Long Island Sound is an estuary within an estuary and has sharp gradients in dissolved inorganic nitrogen; these aspects of this LAE pose unique considerations and challenges for modelers.

There have been numerous regulatory applications of models in Long Island Sound. Nitrogen has been determined to be the limiting nutrient, and modeling was used as a decision support tool for the nitrogen TMDL. Nitrogen and carbon flux calculations have been calculated at connections to other water bodies, and many nutrient loading scenarios have been analyzed. The attainment of various versions of Connecticut and New York DO standards and federal marine DO criteria and living marine resource-based metrics has been calculated for numerous loading scenarios. Modeling also has been used to evaluate shellfish/seaweed aquaculture and biomass extraction as an alternate hypoxia management strategy.

Dr. O'Donnell discussed refinements of modeling in Long Island Sound, using insights from high-frequency time-series measurements. These investigations have shown that meteorology drives many of the seasonal fluctuations in Long Island Sound.

Skill in the modeling of DO was determined with reference to climatology. It was found that there was distortion in the model, with underestimation of both production and respiration, and adjustments were made to compensate. Buoy data showed that the bottom DO is modulated by wind stress in the along-

Sound direction, suggesting that wind stress may modulate the area of hypoxia. The experience in refining modeling in Long Island Sound has shown that models only can be improved if they are shown to be inconsistent with observations and uncertainty estimates. Quantitative measures of skill are essential, and long-term trends only can be detected if measurements and uncertainties are sustained. Data and model sharing and standards are essential. Multiple models and model runs allow uncertainty in predictions to be estimated.

Mr. Tedesco concluded the presentation on Long Island Sound by listing the enhancements that are desired in modeling in this LAE, including refinement of production and respiration rates, adding the macroalgae component to evaluate bioharvesting, evaluating climate change, and increasing segmentation for bays, which are the most intensively used parts of the Sound. The modeling work performed in Long Island Sound illustrates the benefit of incorporating high-frequency time series data into model development and evaluation.

A Synthesis of Models for Everglades Restoration
Christopher Madden, South Florida Water Management

Dr. Madden began his presentation by explaining that in the Everglades, researchers have begun to use multiple models in synthesis to approach some of the problems confronting that LAE. This strategy works well because the individual models are well targeted to their applications. The multiple models overlap somewhat; thus, they provide checks and balances and contribute multiple inputs of information to each other.

Lake Okeechobee is the headwaters of the Everglades, and the entire watershed feeds into Florida Bay. The system has been impaired since the late 1800s because of the presence of a variety of canals, impoundments, and consumption of about one-third of the land area of the Everglades by development. The sizes of the lake and of the total wetlands area have decreased dramatically, and water flow into Florida Bay has dropped by 30 to 50 percent.

In Florida Bay, which is where Dr. Madden concentrates his modeling efforts, the main issue of concern is decreased freshwater input. This is the primary driver behind modeling applications for the Bay. The Everglades are unique in that there is no definable point source to Florida Bay. There is no real division between surface and groundwater in South Florida, which makes modeling difficult.

Modeling efforts in Florida Bay are examining the hydrologic and salinity regime. The Bay is a very shallow system, with a complex geomorphology that makes it more like 47 almost-isolated lakes than like a single water body. The die-off of seagrass in the 1980s prompted modeling, using a flux accounting method. The first use of the model was to determine the minimum flows and levels of water necessary to protect the two types of seagrass that grow in the Bay, *Thalassia* and *Halodule*, which have different tolerances for variations in salinity and other environmental conditions. Restoration efforts are allowing more freshwater to flow into the Bay, thus allowing for the reestablishment of a mixed community of the two seagrasses—a situation that provides the best habitat stability.

Until a few years ago, nutrients were not thought to be a significant issue in Florida Bay, but in 2005, there was a massive bloom of phytoplankton in an area of the Bay where this had not occurred before. It was hypothesized that phosphorus brought into the area by the storm surge from Hurricane Wilma was responsible, and modeling supported this hypothesis by showing that a phosphate load similar to that brought in by the hurricane could cause a sustained rise in phytoplankton levels. Because nutrients are retained in the Bay, a single event such as this can lead to prolonged changes in the ecosystem.

Nutrients are now considered a concern in Florida Bay because it does not take much change to create a critical situation in this water body.

Modeling in the Everglades has shown that integrated hydrologic transport and ecological models make it possible to understand the consequences of changes in stressors to the phytoplankton and SAV communities. Models identify inflection or tipping points where there is a potential for system state changes. The combined factors of nutrient loading and the flushing and grazing rates can create sustained bloom conditions, which can be prolonged by SAV feedbacks. The model synthesis framework is now being used to develop regulatory freshwater requirements and to evaluate restoration designs in the context of global climate change.

BREAKOUT SESSION 2: DEVELOPING AN INTEGRATED MODELING AND ANALYSIS TOOLBOX FOR LARGE AQUATIC ECOSYSTEMS

Charge for Breakout Session 2
Noha Gaber, EPA, Office of the Science Advisor

Dr. Gaber asked participants to stay in the same groups for Breakout Session 2 as Breakout Session 1. She explained that in this second session, the emphasis should be action-oriented rather than conceptual. The goal is to develop a toolbox for IM analysis for LAEs. The breakout groups have been given an incomplete conceptual diagram and are asked to take a more in-depth look and help to identify where future work in this area needs to go.

To design the system, breakout groups should:

1. Identify the modeling and information management capabilities that exist, need to be refined, or do not yet exist;
2. Think strategically: determine which components are unique to your LAE and which can be generalized;
3. Estimate the resources and time required to refine, replace, or develop the needed models and capabilities; think in terms of funding.

General Coastal LAEs

To manage general coastal LAEs and better predict the effect of changes in coastal environments, IM of large coastal and estuarine areas is necessary. Such modeling requires components for both computing and analyzing data. Dr. Lehrter explained that the goal of this discussion is to identify the analysis capabilities and tools necessary for an IM toolbox. Other issues that need to be considered include: (1) effective ways to promote an overall IM effort, and (2) techniques that allow scientists to communicate complicated modeling data to the public.

As a first step, methods must be developed that allow researchers to link to coastal scale modeling particularly for boundary and initial conditions. Such linkages will become essential as upscaled data from estuary models are used more frequently. NOAA's National Ocean Service (NOS), for example, currently has patchy models in primary navigational estuaries with a long-term goal of creating models for the entire U.S. coastline.

As IM systems are developed and applied to more complex problems over larger coastal areas, additional computational resources will be needed, which could create models that are too complicated and opaque.

In addition, linking models remains challenging, as many computational models are not easily parallelized.

One participant noted that there is a modeling component to the Integrated Ocean Observing System (IOOS), but a better understanding of how linkages are established through regional associations is needed. A national framework that supports federal requirements also is necessary. EPA should be encouraged to develop a statement of requirement, which will provide impetus to local and regional offices that oversee coastal environments and offer solidity to the IOOS program and its attempts to expand its modeling tool.

Funders often want one integrated model, but creating a model that captures coastal systems and event-oriented incidents as well as steady states may not be possible. A modeling toolbox should include multiple modeling options based on different questions and regions, and modeling flexibility must be maintained.

The group discussed whether model output should be easily accessible to the public. If so, output data must be simplified so it can be interpreted and assimilated for stakeholders and the public by trustworthy sources. Research has demonstrated that the public is most likely to trust such data if the data are presented and distributed by universities and government institutions.

Questions were raised concerning the ability of models to be predictive. If, for example, a model is calibrated to capture steady-state data, is the same model capable of predicting one-time, extreme events? The time scales of the constituents relative to the model must be considered. As part of the calibration and skill assessment, the source of critical events to be captured also must be considered when developing an appropriate model.

When creating a model, there are advantages to starting with the simplest effective model, such as bounding calculations, to examine preliminary data before applying more complex and expensive modeling systems. Participants agreed that a source for modeling or a “standard operating procedure” guide that would include appropriate scales/times would be helpful when considering models for specific ecosystem problems. Performance expectations of modeling parameters such as sediment transport and bacteria must be realistic as well.

Based on the group’s discussion of developing an IM and analysis toolbox for general coastal LAEs, Michael Hiscock, EPA, Office of the Science Advisor, asked the group to rate various modeling capabilities and tools according to priority and availability (i.e., to identify “low-hanging fruit” that could be addressed quickly). The results of this evaluation are as follows:

Modeling Capability, Tools	Votes (Out of 15)	
	"Low-Hanging Fruit"	**Priority**
Standard Operating Procedure—A guidance document or "lessons learned" fact sheet for modeling (using appropriate scales, incremental building), useful for both stakeholder and modeler. Document to include conceptual flow chart, parameter performance expectations, and uncertainty expectations	12	14
Guidelines for uncertainty analysis	0	13
Update 1986 Rates, Kinetics, Constants book	3	7
Nationwide (e.g., SPARROW) loading estimates	2	6
Coastal Modeling National Framework, which could be downscaled to coastal LAEs (consistent boundary conditions, e.g., T, S, water quality)	0	5
Ensemble models	3	4
Post-processing tools (i.e., netcdf, hdf) that can be used as a community; GUI to be inclusive; Google Earth	2	4
Common output format (ASCII files)	0	4
Data assimilation (*in situ*, remote)	0	0

The following additional points were raised in discussion:

- Eutrophication modeling is dependent on consistent boundary conditions to determine correct freshwater data. Data gathered from unsteady boundary conditions are unreliable.
- Models that examine wetting and drying should analyze mass, not concentration. Such models also must take into consideration how transport is handled.
- Members agreed that modeling is important particularly for very dynamic coastal ecosystems that have constant exchange.
- Effective post-processing tools can save researchers time, but as modeling becomes more complex, researchers want more data and greater control over post-processing; several participants noted that they use Google Earth, which has the advantage of being easily understood by the public.
- Several participants commented that synthesis of performance expectations will differ according to the parameters used.
- Modeling for coastal sediment transfer is more defined than other ecosystem problems, which may help simplify model development.
- Sediment flux data consistently have demonstrated constant measures of central tendency, with only small measures of variability across many ecosystems.

General Freshwater

Dr. Powers, EPA, OW, noted that the goal for the second day's session was to develop an IM and analysis toolbox for LAEs, and that the group could consider generic resources that all LAEs would need. EPA OW has been developing a national-scale data system; the group could consider how to take advantage of large opportunities. Most LAEs have gaps in the knowledge needed to put all the relevant models together. Participants agreed that gaps in integration included the conceptual framework, standardization, sampling, uncertainty and error propagation, and optimization.

For policy-level analysis of a policy such as a TMDL, detailed modeling is not needed. However, with water quality data, it must be determined whether the correct parameters, locations, and frequencies are being monitored. Data needs must be identified for all the models; therefore, for all the LAEs, policies are needed to address these requirements. If the whole system could be modeled, a diagram would show a policy circle that would overlap with what the model has to address in terms of nutrients, heavy metals, and so on.

A participant noted that common factors that would inform any policy and its model include the interactions of air, water, climate, and land. That information is available, although there are some gaps that would take time and resources to address. However, agencies that will use the models need to have a common set of tools. On the federal level within and across agencies, for adaptive management to occur, any entity that will influence management must communicate its decisions. If a daily load is instituted, all groups that influence this daily load should have input into next steps: land use managers, for example, should conduct zoning activities in conjunction with water quality management groups.

Participants created a diagram of a circle as integrated data and modeling systems, with rays emanating from it representing various policies. If integrated data and modeling systems are built, policy making may improve. A participant suggested that the diagram should take into account the different skills and analyses that have to be incorporated. Another participant suggested three different circles, one each with policy, data, and models in the center, as the adaptive management process is multidirectional. Each process has a different focus. The area that is common to all three (the section that overlaps) is ecosystem-specific for each LAE.

Additional points raised in the discussion included the following:

- Data and modeling systems could be viewed as a shared resource, which is important for building consensus and trust.
- USDA supplements the national land cover dataset with additional levels of data (such as crop data), making it more detailed in terms of agriculture.
- Policies and recommendations for LAEs must address local issues. It would be useful to have as a baseline what federal agencies can provide nationally, then refine within that.
- Some data (e.g., on drinking water supplies and concentrated animal feeding operations [CAFOs]) have been confidential since 2001, but there is a middle ground between making data completely public and prohibiting all use of it.
- When discussing policy at the national level, data issues must be dealt with once rather than each time a dataset is needed.
- EPA discharge elimination system data on its Web site are 2 to 3 years old, although the PCS system is being upgraded, and data transfer from the states to EPA's database is 3 to 4 years behind. To avoid this type of problem, a system should be created in which data can be accessed wherever they are held, rather than being transferred from database to database. However, this is a software interface issue: every state can define data differently, and all the LAEs are multi-state.
- The CWA has more power delegated to the states than the CAA: the federal government has more authority to standardize in air regulation than in water regulation.
- Sampling is another problem area. Stream gauges, for example, may have continuous data only at one station out of 30. If only one reading is taken per month, water quality can appear better than it is.

- Economic modeling should focus on what it would cost to achieve a set goal. Do not focus on trading as an economic driver. Instead, examine the impact of, for example, one unit of ammonia from a chicken farm versus that of a point source discharge: the unit from the municipal waste plant may have more impact.
- The efficacy of a model depends on space and time. If examining a project in a lake, do you examine the 2-mile radius of lake, or 50 miles upstream?
- Much of the water in the United States does not have numeric nutrient standards. To determine what policy will lead to desired goals, first the goals must be identified, either by setting a standard or defining a biological standard. In many areas, goals are not defined.
- For evaluation of ecosystem services, the benefits of the policy must be identified. Take the environmental modeling as a step, then examine the impact of ecosystem services and other market goods and services.
- Methods to capture a national optimization process must be understood. Approaches would be either to maximize a net benefit or minimize cost.

Great Lakes

Dr. Kreis explained that the charge was to identify the modeling information that: (1) exists, (2) exists but will need to be refined and replaced, and (3) does not currently exist and needs to be developed. The group also could determine the models that are unique to the Great Lakes region and those that may be useful for all areas. A third objective was to estimate the level of resources and the time needed to develop new models; as Dr. Kreis noted, this was a rather difficult discussion subject.

To stimulate the discussion, Dr. Olchin presented an outline of a conceptual model that was developed after Breakout 1, based on the discussion in that session. The following is a summary of that outline:

1. Social behaviors (political impacts, infrastructure, human health and welfare, economic, knowledge modeling and theory, international values [U.S. vs. Canadian perspectives]).
2. Economic components (crop rotations [corn prices, other crops], comprehensive cost and benefits analysis, existing markets and new markets [what-if estimates and scenarios], commercial shipping and boating [water levels in Lake Ontario, ballast blow out and invasive species, closing locks and Great Lakes fishery], ecological services [How to assign or determine value? How does this change with time?], Asian carp).
3. Land use change (urban area density and location, land use history—timescales and lags [legacy and current land use, forests converted to agricultural land, swamps drained to “tile-drained” agricultural land], efficiency of nutrient reception in waters, shore line hardening, habitat restoration and time scales for it, hydrology changes [dams; fish, sediment, nutrients, and water temperatures; stream flow rates and recruitment of walleye; food web changes], total suspended solids and sediment loads; surface groundwater flows [sources, temperature, quality], CRP conversion for biofuel production [sediment load, nutrient loads, rotation and tillage management, subsidies, cost-benefit analysis—CRP leakage, market policies, nutrient recommendations [fertilizer timing, amount, and form]).
4. Climate change (water levels, hydrology timing, riparian impacts, precipitation timing and magnitude, species succession, ice cover [evaporation and impact on weather patterns], food web dynamics [prey-predator interaction and timing], habitat loss, and human migration, densities, and behaviors).
5. Chemical Stressors (reduce and remediate; toxics; ecological effects; ties to environmental conditions; risk assessment [ecological risk; human health risk including exposure pathways such as fish consumption, drinking water, recreation, and other exposures; chemicals of emerging concern and how to predict their exposure, effects, and interactions]).
6. Aquatic populations (food web dynamics; invasive species, including their population dynamics and management and control; biodiversity and its relation to water quality and keystone species; self-

sustainable populations, and their habitat and spawning grounds; fisheries management; exposure pathways for human consumption).

7. Near-shore conditions (phosphorus load [point source and nonpoint source regulations; point source location and relocation], nutrient dynamics and cycling, invasive species, *Cladophora* management [phosphorus and calcium, water temperature, substrate alteration, costs—environmental or other]; pesticides).
8. Atmospheric processes (atmospheric deposition, impervious surface [land use], nonpoint and point sources, urban land development and planning).
9. Hydrology (deepwater, basin hydrology, human regulation, watershed).
10. Policies and regulations (CWA, CAA, species endangerment, U.S/Canada, Great Lakes WQA, USDA CRP, FIFRA, RCRA, NEPA, CERCLA, NAISA, Farm Bill).

The moderators captured the ensuing discussion in the following schema:

<u>Hydrodynamic Modeling</u>

- Existing
    - Princeton Ocean Model
    - ELCOM
    - EFDC
    - Coordinated Great Lakes model (ACOE—water balance—water level forecast model)
        - Short/long terms
            - Coarse—can produce long-term simulations—but uncertainty increases
    - Large basin models (hydrology)
        - Water level changes
- Developing
    - Nest grids within larger lake model grids
    - Interest in groundwater resource modeling?
- Needs to be developed
    - Groundwater modeling
    - Need Princeton Ocean Model resolution in near-shore applications 200-500 m grid
    - Quadrilateral model segments need to be unstructured grid (triangular elements) (FVCOM)
        - Army—ADH—grid layout is dynamic with time (has been used in Puget Sound)
        - Moving past XY coordinate

<u>Eutrophication Models</u>

- Existing
    - Decision making algorithms for fish stocks
    - Bioenergetic models
    - FMDS
    - Population dynamics models for individual species (specialized, single species)
    - WASP and ICM-QUAL models
    - CMAQ Air Deposition models for nutrients (and contaminants)
- Developing
    - Invasive species are being incorporated into general eutrophication models
    - SWAT and SPARROW models applications are being enhanced in the Great Lakes Basin
- Needs to be developed
    - Need fisheries or ecosystem model that includes invasive species (i.e., Asian carp)
    - Connecting lower food web models with higher order ones
        - Disconnect between lower and upper productivity

            - Feedback interactions
            - Model coupling ← → rather than one-way interactions
            - Scale and structure of food webs
                - Connecting near-shore dynamics with offshore desertification
    - Aquatic ecosystem models
        - Integrating nutrients, weather
        - Full trophic structure
        - Be flexible enough to include new species

Lower Eutrophication Models

- Existing
    - WASP, ICM, AEM
    - Canadians have linked CADM to LCOM

Economic Models

- Existing
    - National Research Council (NRC) has compiled tools and approaches
        - Life-cycle costs
        - Return on investment
        - Contingent valuation
        - Nonmarket valuation
            - How does society determine value of nonmarket?
            - Value of remediation (Brookings Institute)
            - Spatial opinions of value (upstream/downstream)
    - Shared interest/vision model
        - Valuation of each interest if regulation plan caused decreases in hydropower, wetlands, and recreation
        - This is also being done for the upper Great Lakes
        - Valuation of other recreation activities
- Needs to be developed
    - Influence of human behavior
    - Broaden view of “models”
    - Environmental economists
    - Connection between social and political
        - Advocacy coalition framework

Socio-Economic Models

- LEGAL institute analysis model—preplanning

Climate Change

- Existing
    - Modular modeling systems for species succession
    - LBRM (Large Basin Runoff Model)
- Developing
    - CHARM—Combined Hydrologic Atmospheric Research Model
        - Coupled to regional atmospheric model
        - Built from LBRM
        - Uses boundary conditions from GCM
    - Work at Michigan State University
- Needs to be developed

- Are wind pattern changes important?
  - Temperature, hydrology, and wind will be changing
  - Need better understanding of other impacts wind changes could have
    - Evaporation and water levels
- In Great Lakes region, modular modeling systems that combine many models would be an ideal application
- Scale issues—Great Lakes region is too large for GCM because GCM should incorporate Great Lakes effect
- When these models are linked with other models, what needs to be considered?
- Cannot wait for downscaled models before we start forecasting the impacts on the other processes/modeling areas
  - Could we use our existing models to forecast by altering drivers → identifying key variables or indicative variables?
  - Running plausible "what-if" scenarios to identify impacts
- What does adaptive modeling look like in Great Lakes region

<u>Data Availability</u>

- Fish database (GLENDA for contaminants)

<u>QHEI</u>

- Probabilistic model

<u>Risk Assessment</u>

- Empirical
- Deterministic
- Mechanistic

<u>National and Regional Models</u>

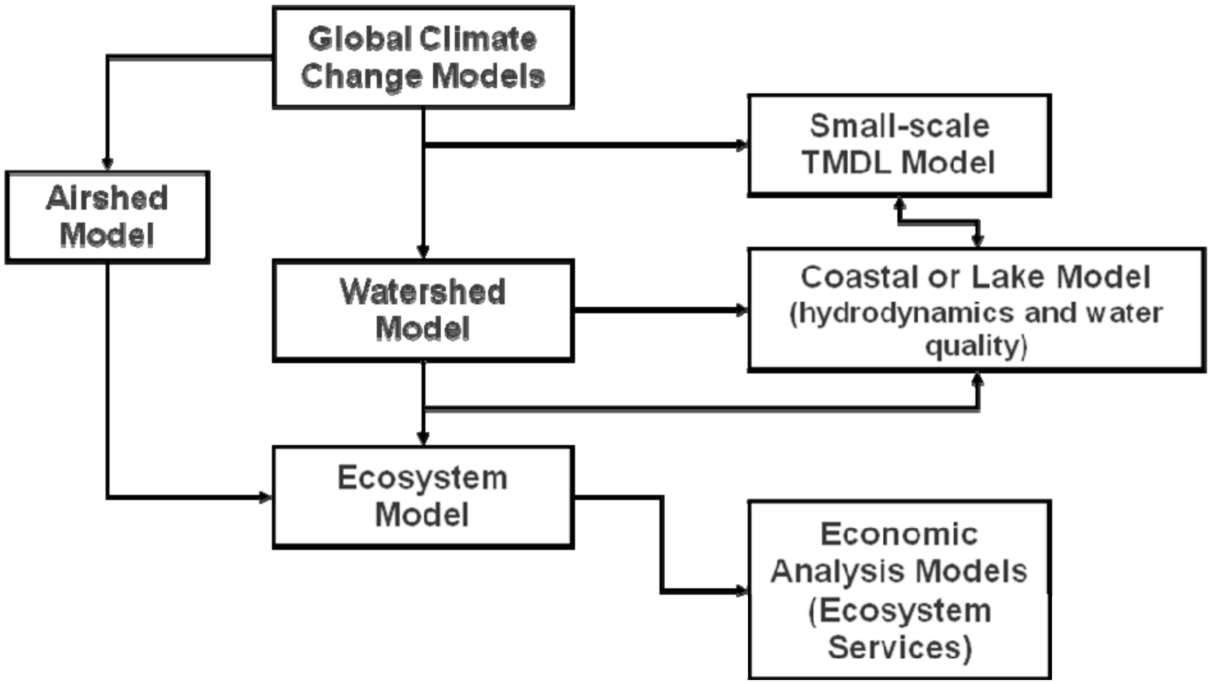
- National
  - National Atmospheric Deposition Network
  - CMAQ Air Deposition Model

<u>National and Regional Models</u>

- National
  - National pollution control model
- Great Lakes Regional
  - GLMOD
  - LBRM
  - IADN
  - GL GIS—Near shore habitat model

Chesapeake Bay

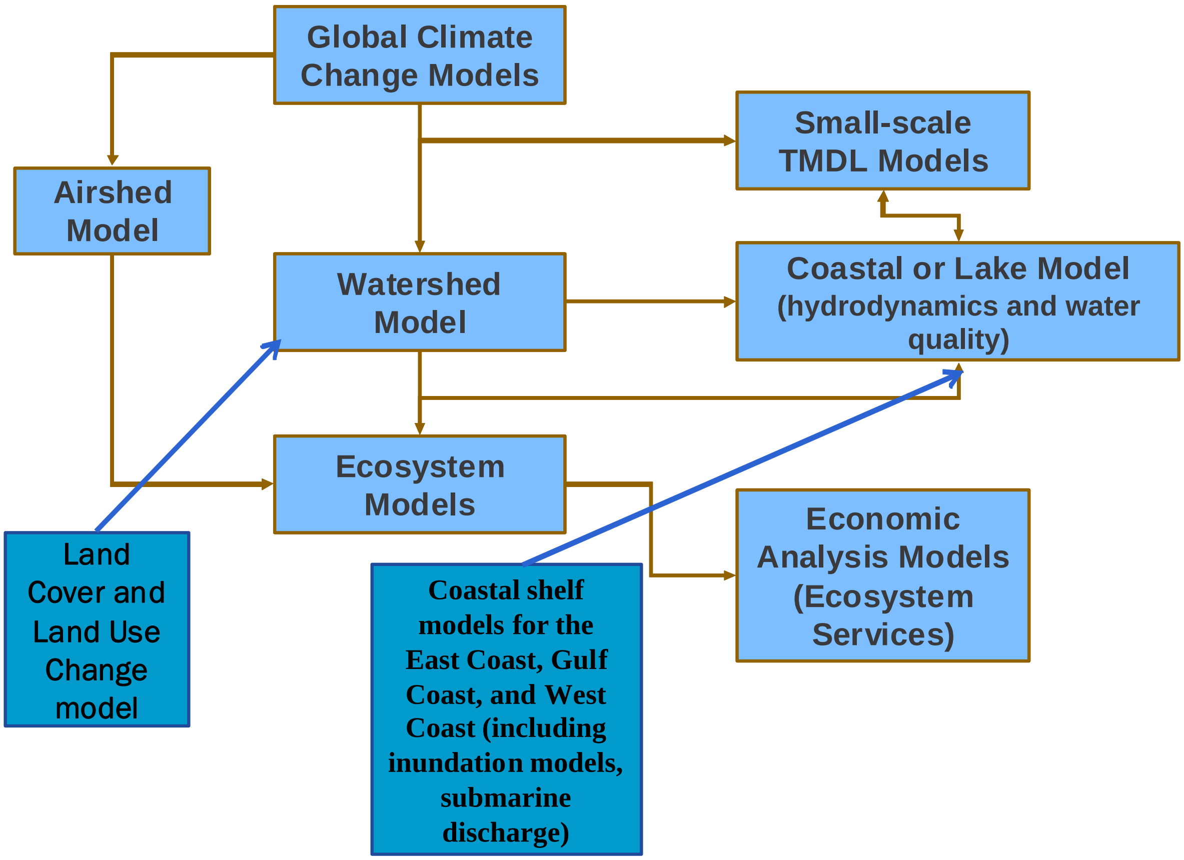
The Chesapeake Bay breakout group participants brainstormed about how to expand upon the following diagram of the components in an IM and analysis system, which was provided with the charge for the second breakout session.



The group suggested that this model could be expanded in the following ways:

- Decision makers and executive orders drive all these boxes, so they could be placed in the middle of the diagram or in an outer box encompassing it. Management actions are the driver for all modeling and need to be part of every element of IM and analysis. In the case of the Chesapeake Bay, a large box called the "Chesapeake Bay Plan" drives everything.
- Coastal shelf models, including inundation models and submarine discharge, should be added, with an arrow relating them to coastal or lake modeling.
- A land use and land use change model should be added, with an arrow relating it to the watershed model.
- Economic modeling should be incorporated into the schema in some way.
- Certain fundamental principles should be assumed throughout the entire modeling process, including shared data, IM and research, interagency cooperation, determination of skill metrics, and use of ensemble models. Models that do not represent the data and do not include shared information are not credible.

The following graphic illustrates these changes:



Three key areas were suggested as relatively low cost - high benefit actions that would provide a high level of support to all LAEs. An added advantage is that many of the thousands of TMDLs now due across the country could also take advantage of this uniformly developed national data library.

- A national land uses data base should be developed to support all LAEs and have representation of past current and future land uses on a decadal scale. A national scale data library of future land use of current as well as future 2020, 2030, and 2040 would be a high priority task. This could best be developed by accelerating ongoing USGS projects that have this objective.

- Data from global climate change models need to be downscaled for all LAEs. Important factors to include in the models include temperature, precipitation, and storm frequency, as well as sea level rise. Economic and agricultural parameters that change in response to sea level rise also should be taken into account. Accomplishing this task would be with the existing ensemble of climate change models downscaled to watershed scales on the order of about 50 square miles. National scale downscaled data for all LAEs or other practitioners. The data library should have future projections of 100yr, 50yr, and 20 yr for a suite of commonly used global climate change models.

- For the airshed model, a national-scale data library for nitrogen oxides, sulfur oxides, and mercury is needed to support all LAEs. This data library could be developed relatively easily with the existing tool of EPA's Community Multiscale Air Quality Model.

Other points made in the discussion included the following:

- Improving an integrated model's predictions involves interacting with other people and groups and incorporating their data into the model.
- Land use change modelers and climate change modelers do not interact much now, but they need to do so in the future because climate change and land use are closely connected. For example, if temperatures drop in Florida, it may no longer be possible to grow oranges there. The land then may be used in other ways, and people may move in or out.
- Government agencies need to work together. Each currently has its own models, but the problem is so large that all organizations need to work together to address it, especially in the long term.
- In the near future, NOAA will be providing a nationwide series of coastal and regional models, coupled to fine-scale estuary models. With cross-agency collaboration, these models could enable ecosystem forecasting.
- Standards of inter-model interoperability are needed so that models can work together.
- Airshed and climate change models are fluid over time and space, but watershed models are heterogeneous; each watershed has a unique landscape that completely drives the outcome.
- Groundwater needs to be considered in watershed models. Subsurface modeling is a key issue. In current models, the subsurface flow in the watershed may not be accurately addressed. There has been a tendency to draw a boundary around an estuary and its tributaries, without taking groundwater into consideration. The concept of a LAE should be expanded to include the aquifer that bounds it.
- The issue of the water-to-land interface is a challenge to modelers. Continuous topography and imagery are needed. Many agencies are contributing, but with different standards.
- Interplay at boundary regions is a significant issue. For example, the Delaware River feeds nutrients into the Chesapeake Bay. LAEs interact with the ocean, with both influx and outflux of water and contaminants.
- Skill metrics are needed. Model results need to be validated against measurements, and new scientific findings need to be continuously incorporated into modeling.

BREAKOUT SESSION 1 REPORTING AND DISCUSSION

General Freshwater

John Powers presented the report-back for the General Freshwater breakout group. He explained that the group focused on broad conceptual issues because they could not focus on a single LAE. The group emphasized finding ways to help LAEs that do not have the kind of resources available to the Great Lakes or the Chesapeake Bay. Building a common data and modeling system to support many policies would help to meet this goal. If policies emanate from data and models, all the policies likely could be improved because of the incorporation of the system dynamic into the analysis. All policies would be designed in an integrated fashion because their designers would be able to see the interactions between them.

The integration of data and models should be across disciplines. Within environmental modeling, an integrated data and modeling system that is nested and hierarchical should be developed; it should encompass climate, land, air, and water. Refinements then can be made within a given land use structure. The objective is to learn the economics of model development at the same time that communities' needs are addressed.

Gaps in model integration include the following:

- Conceptual framework
- Standardization
- Sampling
- Uncertainty and error propagation
- Optimization
- Economics
- The ecosystem services part of modeling, including the economics of evaluation of ecosystem services

A participant commented that it is important to use a hierarchical framework for each LAE. One must be on the ground at the local level to understand the system.

Dr. Powers said that much of the discussion during the breakout session was on how to maximize data integration so that everyone can benefit. Nevertheless, it is important to recognize that many decisions, particularly regarding water policy and land policy, are local.

General Coastal

Michael Hiscock summarized the following points, which had been emphasized in the General Coastal breakout group discussion:

- How do we promote IM? Everyone agrees that this is desirable, but it is unclear how best to accomplish it.
- How do we leverage modeling components from NOAA and the IOOS?
- When coupling between models, rather than creating a comprehensive model, code must be written to be parallelized.
- It should be assumed that computational resources will improve with time, but modelers should create models that can be used today (the ability to model 1 year per day is needed *now*).
- Models are becoming too complicated.
- It is important to use the appropriate tool for the question—incremental modeling.
- One size does not fit all; different approaches are needed for steady states vs. extreme events. It is not reasonable to expect one model to meet all needs.
- Multiple options and spatial scales are needed. Flexibility should be maintained. It is important to consider what events you are trying to capture.
- Should model output be easily accessible to the public? How could the output be simplified? Should there be a trusted intermediary to interact with stakeholders?

The group also discussed priorities for the development of modeling capability and tools (as detailed in the table included in the report from this breakout group). Almost all group members considered having a standard operating procedure to be a top priority. This also is an issue that can be addressed immediately (i.e., what is sometimes referred to as "low-hanging fruit").

Chesapeake Bay

Alan Dixon and Lewis Linker jointly presented the report-back from the Chesapeake Bay breakout group. They noted that one of the most interesting topics discussed by the group was strategic and national models and how they are limited by a lack of information on subsurface water flows. It is important to recognize that LAEs interact with one another and with the ocean.

Skill measurements, metrics, and validation against measured values also were discussed. As was emphasized in the Long Island Sound presentations, there is a need to perform such evaluations to ensure that models are correct.

As with the other breakout groups, the Chesapeake Bay group talked about interoperability between models. One point emphasized in the discussion was that interoperability sometimes is not a question of crunching numbers; the science that would permit linkage of the models may not yet exist. Arrows may be drawn on a diagram, but we may lack the science to make the arrows work.

The group discussed ways of expanding on the diagram of IM provided to all the breakout groups, as described earlier in the report on the breakout session.

Overall plans for regulation and policy are central to modeling; the group struggled with how best to represent this in a graphic explanation of IM.

A major theme of the group's discussions was that doing well for the Chesapeake Bay means doing well for all LAEs. For example, all LAEs would benefit from airshed model inputs from a nationwide dataset. The availability of national-scale data libraries for climate change and land use information also would be beneficial to all.

A member of the Chesapeake Bay group added that there is a need for a national digital elevation map of all coastal regions. It is important to be able to connect the water to the land. Only then will it be possible to truly evaluate climate change, sea level rise, and related factors.

Great Lakes

Russell Kreis presented the report-back for the Great Lakes breakout group. This group began its discussion with a general model; group members wanted to integrate air, water, land, economics, social factors, and human risk. They looked at the scale of the Great Lakes, knowing that there are different models at different scales. Model development has not been equal in the different lakes and their watersheds. Some lakes have been relatively neglected in comparison with others. Moreover, Canada and the United States have taken different approaches.

The group discussed identification of model resources. The new report 5018 SIR from USGS is one valuable resource; it will summarize some 60 models. CREM also maintains a modeling database, as do other agencies such as the Army Corps of Engineers.

The group evaluated current models, as follows:

- *Climate change and hydrology.* For both of these topics, there is no specific model for the Great Lakes but there are models that could be applied.
- *Eutrophication models.* Some models have been applied on the national level or in sites across the country, but there is a disconnect between lower food chain modeling (eutrophication) and fish modeling. There is a need for a model that encompasses the entire trophic structure for a lake, covering the food web and population dynamics.
- *Economic models.* These are sparse but some tools are available.

- *Socio-economic models.* There are some tools and there has been some discussion of demographic information, but no actual model that can be linked with an environmental model for the Great Lakes is available.

A variety of models and databases are used in the Great Lakes. One common national model that is used is CMAQ, which has applications for nitrogen, atrazine, and mercury. There are plans for Great Lakes-specific portions of other national models, including SWAT and SPARROW.

Dr. Kreis presented a list of important issues that need to be considered but that were not discussed in any detail during the breakout session. These include model management, data distribution, multi-stressor models, model accessibility, decision support, and model guidance.

Adaptive modeling requires the ability to make forecasts and evaluate theoretical scenarios. It is possible to force models to examine what we think is going to happen. Many of the models used in the Great Lakes have the capability to run what-if scenarios; thus, it is possible to do some adaptive modeling in the Great Lakes.

GENERAL DISCUSSION

Dr. Gaber began the general discussion by asking what is unique to a particular system and what could be developed and applied widely. A participant responded that one generic issue brought up in the Chesapeake Bay breakout was considering what level of government should be involved. Should EPA specifically lead the discussion of developing an interagency process and bringing it to the White House's Office of Science and Technology Policy (OSTP)? Mr. Linker commented that for some of these areas, the Chesapeake provides a natural lead. The white paper that will be developed from this symposium also can be used to encourage interagency cooperation. A participant asked who in the federal family would be the right group to lead an interagency effort. Others replied that probably several groups could be in the lead. In addition, there could be a variety of funding opportunities. There is a need for a mechanism to enable agencies to work together, especially if money is to be transferred from one agency to another.

A participant noted that no one had mentioned the community of practice that is under development and the goals of that program. If groups are going to be sharing model management, utilities, data accessing tools, etc., that is where it could happen. If a white paper is published as a result of this workshop, the role of the community of practice should definitely be mentioned.

Dr. Kreis asked whether this issue wraps into the issue of open source/public domain. The Department of Energy has an effort in progress; is it coordinated with other efforts? It is a community of practice with open source code. NOAA and USGS are cooperating in this effort, but Dr. Kreis was not sure whether EPA was involved.

A participant expressed the view that OSTP may be a good leader for an interagency process. A discussion of joint funding is needed so that resources can be pooled and models with cross-applications can be developed to address multi-policy endpoints. Half of the battle is EPA's own infrastructure issues concerning how to do this type of coordination. There is a need to streamline the process.

A participant commented that the modeling community can learn from the experiences of the IT community. The IT community has learned that when you have many different partners, the development of interfaces will never be agreed to unless there is a community of practice. If a community of practice is in place, it is possible to put forth budget initiatives for yourselves and for state and local partners and to leverage the funding of the national layers that are needed.

A participant said that there is a federal interagency modeling workgroup and a National Science Foundation-funded university consortium on modeling. Both could be helpful. Dr. Gaber explained that these groups are collaborating in the community of practice.

A participant said that making linkages between models is difficult. What are the specific requirements that people are asking for? These requirements have to be justified through Congress and the Agency to obtain the resources to make data available in the needed format. Well-stated requirements are very useful. Another participant asked what happens if everyone loves a model but it is wrong? What does this do to original thought? Similarly, if a model system has the stamp of all the federal agencies on it, how does this affect original thought? Dr. Gaber replied that CREM is not advocating for a single model for everyone but rather for collaboration, with people learning from each other. As an example of this, a participant mentioned that the National Weather Service’s official model for issuing weather data does not preclude others from developing improved weather models, but it still provides something that can be pointed to as the official forecast, and even that official model can change over time.

A participant cautioned that models should have error budgets. Uncertainty should be taken into account, and forecast limits should be known. Even if a model fits the data, it can be wrong. Mr. Linker replied that this is a good point and a challenge. The experience in the Great Lakes provides a precautionary note; when energy flows changed, everything had to be adapted, including models.

Several participants strongly advocated for making models open source, preferably by creating something like LINUX that is both open source and standardized. They also argued in favor of versioning, that is, having predetermined times when the system will be updated. The economics of open source were discussed: there is a need to create an incentive structure and forms of communication for those who find flaws. Rewards can be given, and they need not be monetary. They can consist of recognition, validation, or a thank you for someone who noticed a problem with an open source product. In an open source world, there can be many different “flavors” of the same type of software; the same can be true with models. The community is not necessarily heading toward a single model, but can be moving toward a single framework with a common interface. A community of practice can help to facilitate progress in this direction.

A participant who is familiar with dietary risk modeling for pesticides observed that the regulated community and non-governmental organizations evaluate EPA’s models in much more detail than the Agency itself ever could. Giving stakeholders with different priorities and agendas access to a model is an effective way to facilitate error checking because the stakeholders have a high incentive to find errors.

Another participant noted that although people say that academics will develop their own approaches, funding is a stumbling block. It may be necessary to set up some type of research and development exploration for the next iteration of a model so that academics can be involved. Transitioning from the research community to an operational entity can be difficult. A participant noted that regional associations want to work to improve models, but it is hard to obtain funding to do that.

Synthesis and Next Steps
Noha Gaber, EPA, Office of the Science Advisor

Dr. Gaber reminded participants that the objectives of the symposium were to:

- Provide a forum for coordination, discussion, and exchange of information;
- Identify successful model development practices that may be widely shared and applied;
- Help align model development with the policy design, management, and decision-making needs of the LAEs;
- Identify areas requiring further research and analysis, especially those with cross-media implications.

Several themes emerged during the presentations and discussions. One frequent theme was transparency, in the context of participatory and community modeling. The need to build consensus, buy-in, and the capacity to understand model results was emphasized. It is important to be transparent about the assumptions and limitations of modeling, thereby setting up realistic expectations.

Another major theme was the need for true integration and interoperability. True integration means integration across organizations, not just EPA and not just the federal government. This involves interoperability among mindsets and bridging disciplinary language barriers. It requires coupling and feedback between models, not just feedforward. Economic and human/social response models need to be integrated with environmental models, and policy impacts must be incorporated into modeling. The issue of how to capture unintended consequences needs to be addressed.

With regard to adaptive modeling and management, symposium participants emphasized that as the science evolves, models must continue to be improved. Management actions need to be reconsidered in light of new science and analysis. Pilot trials are needed for market-based adaptive management and trading.

IM can strengthen integrated environmental policy and strengthen the consideration of multimedia impacts in regulation development by telling a compelling story. This may be one way to help overcome the problem of stovepiping.

The next steps after this symposium will be the preparation of a summary report, followed by the writing of a white paper that outlines recommendations for further work. Publication of a paper in a peer-reviewed journal and publication of concept papers on proposed projects for IM and analysis for LAEs also are anticipated.

Dr. Gaber urged symposium attendees to collaborate with the CREM by participating in the development of the white paper/journal article; by participating in future CREM symposia (the next one of which will be on climate impacts); and by joining the Community of Practice for Integrated Environmental Modeling (CIEM), which will be launched at a meeting in Ottawa, Canada, in July 2010. The Web site of the community of practice, at iemHUB.org, currently is under construction. Dr. Gaber concluded by thanking the participants and the members of the organizing committee, who have been working together since May to put the symposium together.

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