National Advisory Council for Environmental Policy and Technology

September 22, 2008

The Honorable Stephen L. Johnson
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

***Re*: White Paper on Integrated Modeling for Integrated Environmental Decision Making**

Dear Administrator Johnson:

The U.S. Environmental Protection Agency (EPA) has requested the National Advisory Council for Environmental Policy and Technology's (NACEPT's) critical review of the White Paper on "Integrated Modeling for Integrated Environmental Decision Making" (hereinafter White Paper). In response to the charge, NACEPT formed a work group consisting of eight NACEPT members and five external members, who were selected for their experience in the field of environmental modeling (see attached list of workgroup members and their affiliations). The workgroup conducted its review over a 3 month period, from late May to August 2008. This advice letter represents the consensus view and recommendations of the work group and of the full NACEPT council.

NACEPT would like to commend EPA staff for preparing a well-written and comprehensive White Paper on such a broad and complex topic as integrated modeling. Our investigation resulted in general concurrence with the White Paper, and confirmation that computational models are useful tools that play an increasingly important role in the decision-making process. We agree with the White Paper that integrated modeling encompasses a broad range of approaches and configurations of models, data and assessment methods to describe and analyze complex environmental problems, often in a multimedia and multidisciplinary manner. Furthermore, as environmental issues that require decision-making become more complex, the panel believes that integrated modeling will become increasingly important to EPA.

NACEPT believes that the White Paper deserves serious consideration and follow-up by senior level EPA managers. EPA should give high priority to the systematic development and deployment of integrated models to inform EPA decision-making. To a large extent, the science and technology are already available within and outside EPA; what is needed is strategically directed funding and Agency-wide, organized, and systematic implementation of the action plan outlined in the White Paper.

NACEPT offers the following three findings and recommendations, which, generally, support and reiterate points made in the White Paper:

Finding:

1. Integrated modeling is a significant cross-cutting science and technology tool that is worthy of broad-based strategic review and support within EPA. EPA's Science Policy Council may be the most appropriate internal coordination body to vet the role of integrated modeling and how best to ensure its most efficient and effective use.

Recommendations:

- The EPA Administrator should direct the Science Policy Council or other appropriate body within EPA to analyze and offer its recommendations on the following:
  (1) Estimating the initial investment required to move toward the increased and coordinated use of integrated modeling;
  (2) Determining if the development and application of integrated models is suited to most regulatory timeframes;
  (3) Identifying a discrete number of projects that demand integrated modeling approaches and would lend themselves as potential case studies for development of an integrated modeling organizational structure;
  (4) Evaluating the potential effect on staffing, budgeting, and environmental protection from using integrated modeling; and
  (5) Evaluating the importance of the coordinating function among the research teams developing integrated models and the program and regional office staffs using those models.

- The Science Policy Council, or other appropriate body, should provide its findings and recommendations to the EPA Science Advisor. The Science Advisor should collaborate with the EPA Deputy Administrator on priority setting and organizational and budgeting issues relating to additional efforts to develop and use integrated modeling (IM).

Finding:

2. The White Paper demonstrates the need for a community of practice (CP), which can serve as a knowledge base, develop and disseminate standard operating procedures/protocols for integrated model development and application, and provide means to link the modeling activities of different offices. NACEPT wholeheartedly supports the community of practice concept. A community of practice will reduce redundancy in model development, help with model dissemination, and guard against misapplication of models. A community of practice will not, however, address all organizational challenges including priority setting, budget allocation, cross-program collaboration, and stakeholder involvement.

Recommendations:

- NACEPT believes that addressing organizational challenges will be an iterative process and recommends that EPA build its IM organizational infrastructure organically rather than superimpose an artificial structure that may render IM dissemination more cumbersome. Consequently, NACEPT recommends that EPA initiate a pilot integrated modeling project, such as biofuels full life cycle assessment, using the Science Policy Council as the forum in which to discuss model development and application, and for formulation of organizational/institutional recommendations for supporting IM within EPA.

- NACEPT recommends that EPA exercise due diligence to guard against misuse and misapplication of all simple as well as integrated models. While we agree that EPA's modeling work should be made more broadly available, a community of practice should help distinguish site- and case-specific models from more generic/evaluative models. This will ensure that models are effectively matched to the problems they are attempting to solve. EPA can employ the CP as a means to advance the establishment of IM both within and outside of the Agency. The CP should be broadly available to all users, inside and outside EPA.

- NACEPT recommends that EPA support a research program aimed at developing a quantitative understanding for the processes that require integrated multi-media and multi-disciplinary modeling.

Finding:

3. Data flow, or more generally "information flow", within integrated modeling systems is critically important.

Recommendations:

- EPA should automate and standardize the process for accessing, retrieving, and processing data from nationally available sources (databases) for use in integrated models. The exchange of information among modeling components and the processing of model outputs should be standardized. EPA should look for ways to streamline the model-building process by adopting more uniform formats for handling and moving information between databases and models and adopting a common set of methods and software tools that will service a broad range of models with only minor adjustments. Such tools (or "integrated model utilities") will support data acquisition, input and output, visualization, pre- and post-processing, evaluation, decision support, and sensitivity and uncertainty analyses. Close coordination between EPA's Office of Research and Development (ORD) and Office of Environmental Information (OEI) will be important in addressing this issue.

In conclusion, NACEPT is generally supportive of the White Paper and hopes this review provides useful feedback to the Administrator in order to take the next steps towards

implementing its recommendations. Attached are the specific answers to the questions posed in our charge. We wish to express our sincere appreciation for the valuable contribution of our five ex-officio work group members, as well as the EPA staff that provided valuable support to this effort: Noha Gaber, Environmental Engineer, US EPA; Lara Autry, Senior Advisor for Measurement, Monitoring, and Laboratory Science, US EPA; and Gerry Laniak, Environmental Engineer, US EPA. We appreciate the opportunity to work on this important topic and offer any additional advice that you may require in the future.

Sincerely,

/Signed/

John L. Howard, Jr.
NACEPT Chair

Attachment

cc: Arleen O'Donnell, Workgroup Chair
Marcus Peacock, Deputy Administrator
Charles Ingebretson, Chief of Staff
Ray Spears, Deputy Chief of Staff
George Gray, Assistant Administrator for Research and Development
Pai-Yei Whung, Chief Scientist
Rafael Deleon, Director, Office of Cooperative Environmental Management
Sonia Altieri, NACEPT Designated Federal Officer

RESPONSE TO CHARGE QUESTIONS

In developing responses to the charge questions, four key themes resonated throughout the White Paper and helped focus NACEPT's discussions: (1) identifying multiple perspectives on integrated modeling; (2) automating the process for transporting data from sources to models and between models; (3) managing uncertainty; and (4) building a modeling community of practice. It is important to review these themes here to provide context for NACEPT's response to the questions posed.

Identifying Multiple Perspectives on Integrated Modeling

Environmental systems are inherently linked through an intricate web of processes and feedbacks. Integrated modeling can be defined as a continuum of increasing complexity: conceptual integration of existing models (without feedbacks), full coupling of existing models (with feedbacks), and integrated system models (developing fully-coupled discrete models). Institutional integration also is important to facilitate communication and coordination among the disciplines.

Automating the process for transporting data from sources to models and among models

A key source of delay in the use of integrated modeling (IM) is the need to move large amounts of data from diverse, often incompatible databases into a large environmental modeling system. When an integrated modeling system has been developed by linking models, there also is a need to pass output data from one model to another model as input in a compatible form. Much of the delay and opportunities for error can be reduced substantially by harmonizing and automating the process by which data are collected and transferred. The water quality exchange (WQX) effort for EPA Office of Water's STORET database is a good example of how data collection and exchange can be facilitated and improved.

Managing uncertainty

Multiple sources of uncertainty arise in modeling systems and can be a problem for managing IM systems. Sources of uncertainty include variation in measured data, incompatibility of scales (spatial, temporal, or functional) among model components, disagreement between alternate sources of information, under-determined model parameterization (i.e., more unknown coefficients than stated variables), natural heterogeneity, the selection of one model over another, simplifications of model structure, extrapolation (prediction) errors, and value judgments. Uncertainty in IM can compound that of simple models. When one links two models together, the uncertainty in the integrated model can exceed that in either model alone. Choosing the appropriate model complexity to suit the problem definition and the available data resources is crucial. If the model is too simple, it will not answer the management questions and therefore will have low utility. If the model is too complex, it likely will have insufficient

data for calibration and confirmation, leading to a level of uncertainty that is not acceptable, thus having low utility for decision support.

Building a community of practice (CP)

A community of practice is an organizational concept in which practitioners share knowledge, leverage experiences, and improve individual and collective capacity to contribute to the success of the organizations with which they are affiliated. A community of practice may help to address such issues as managing uncertainty, how to apply IM through single and linked systems models, and how to make science and technology transparent to decision makers. Building a community of practice will help institutionalize skill sets and knowledge bases, including advice on how to avoid misapplying models that might work in one situation but not another.

1. **Does NACEPT agree with the White Paper's focus on the importance of integrated modeling to inform EPA decision making?**

NACEPT agrees that integrated modeling is an important component of EPA decision making. However, follow up work is needed to make decisions on how it can be better utilized within EPA to solve environmental problems. The importance of IM could be better understood if the range of IM was articulated with examples of appropriate applications to ensure a common understanding of the forms of integrated modeling and their use. A concern shared by NACEPT and the authors of the White Paper is that some readers will assume that linking together a set of established and widely evaluated models should provide a reliable IM system. However, integrated modeling is only useful if the model is appropriately matched to the problem it is intended to solve.

Another issue in need of further elaboration is the difference between scientific (research) and regulatory models. Research modeling seeks to advance the state of the science by identifying knowledge or data gaps, by posing and testing hypotheses, and by generally investigating how processes function and interact in environmental systems. Regulatory models use the best practical science, requiring some compromises or simplifications to be made for the models to be useful for regulatory purposes. When there is incomplete information, regulators often must make decisions based on conservative assumptions, default options, or worst-case scenarios. In other words, regulatory models should be using the "best practical science".

2. **Does the White Paper make a compelling case for the need to implement an organization-level solution to promote consistency and repeatability of integrated modeling analyses?**

NACEPT believes that the White Paper makes a compelling case for implementing an organization-level solution to promote consistency and repeatability of IM. A community of practice will go a long way towards providing consistency. The most effective and efficient organizational EPA structure within which IM can thrive is less clear. Organizational options could be explored by piloting a few complex IM applications and

letting "form follow function" (and, if a more formal process is desired, the Kaizen Method could be employed). Good pilot candidates would be cross-media issues involving a systems approach to problem solving such as:

- Biofuels: Examine full life cycle costs based on impacts to air quality, climate change, water resources, and energy.

- Gulf of Mexico hypoxia: Examine atmospheric and land-based nutrient inputs and their fate and transport characteristics, and develop hypoxia reduction scenarios based on the optimization of costs and benefits of various control strategies.

- Community health/comprehensive environmental assessment: Assess multiple stressors on community health (EPA/CDC joint project) or an ecosystem such as the Great Lakes, and model various outcomes based on different control strategies.

There is general agreement that a CP is needed to formulate guidelines to share, disseminate, and ensure proper use of models that EPA provides or has developed. For example, a portfolio of archetypal models (a form of "generic" models) might be considered with respect to a CP. For EPA's modeling work to be made more broadly available, community practice guidelines such as precautionary notes regarding adjustments that are needed for accurate application would be instructive to the user.
No group of experts can offer one set of rules about the correct modeling approach. The knowledge needed to determine the best approach in each case must be built through a CP, which is tied into the science as well as the modeling process. Much of the infrastructure needed for the CP is forming: CREM, EPA's internal modeling program, is building a community and culture. This is important because the group can provide continuity and technical knowledge and become a repository for case studies to help create guidelines for understanding capabilities.

Most environmental organizations are still stove-piped based on media or management focus (e.g., toxics modelers versus eutrophication modelers). The community of practice concept could be effective in helping modelers come together to solve what are increasingly cross media problems. EPA should define a framework that establishes a community of modelers or interdisciplinary science teams and builds a community that serves as a reservoir of knowledge and skills on how to approach model design. The Agency needs an institutional memory, and to develop one EPA needs to think about building a cohesive group of people with problem solving skill sets. Examples follow:

- The CREM has been building a Models Knowledge Base on the web that could be continued and enhanced and integrated with the CP concept.

- The Science Policy Council (SPC), under the OSA, consists of senior-level officials from the different EPA program and regional offices, and examines cross-cutting issues in science and technology. This group makes

recommendations to the Science Advisor, and could be more involved in the discussions on IM. The SPC is in a unique position because its membership includes senior EPA staff members, many of whom have moved among different program offices and up the chain of command. These people may be in the best position to understand how useful IM could be in the various aspects of priority setting and problem solving. The EPA Administrator could refer this advice letter to the SPC, and that the SPC could report back to the Administrator with recommendations. It would be useful to apply a pilot project such as biofuels IM using the SPC as a forum in which to discuss the model development and application, and as a source of recommendations for organizational options to support IM within EPA.

- At the National Aeronautics and Space Administration (NASA), new science is enabled through satellite missions; forecasting models are created and handed off to the National Weather Service (NWS). These are adapted to various regions. There is always a transition when attempting to add the new state-of-the-science developments that will improve the forecast into complicated forecast models that have developed skill in their particular regions. This is done in major releases rather than sharing a continuous model, and there is a transfer of science and technology between developers and users. At EPA, this approach can be applied by having the research team develop an integrated model and at the point when there is confidence in its ability to predict, it would be handed off and tuned per region as groups become familiar with the model and adapt it for their localities. When the science team creates another major release, they need to work with the applied community to determine when they have an improvement, and how to understand the nature of the improvement's impact on regulations. The developers also will ensure that the models are applied to the problem appropriately at the regional level, and incorporate feedback from the regions into model refinement. Localized knowledge can be added to each model. EPA should examine the NASA/NWS modeling process, and perhaps the SPC could be the coordinating body if the NASA/NWS approach is adopted at EPA.

3. Is the concept of integrated modeling clearly captured in terms of its meaning and its emerging role in EPA and greater scientific community?

In general, the White Paper adequately captures the meaning and emerging role of IM, and is quite forward thinking in its approach; however, the White Paper could benefit from more in-depth analysis of how IM could be effectively implemented. For example, most problems require site-specific model adjustments determined on a case-by-case basis to address specific management issues, differences in environmental system properties, time constraints, and other factors. A set of pre-packaged models cannot be pulled off the shelf and linked to address any question. NACEPT shares this concern with the authors of the White Paper. The Agency, through the CREM, has already drafted a guidance document for regulatory model development and application; this document also applies to integrated modeling.

Another important issue is the assessment of whether and how to include feedback in integrated models. Feedback between models and within models, where appropriate based on the ecosystem being modeled, is an ideal, desirable property of an integrated modeling system. In practice, however, it is not always feasible to implement complete feedback. The Chesapeake Bay Program (CBP) is an example of an integrated modeling application that features various degrees of feedback at multiple levels of model integration. At the topmost, whole-system level, CBP links the airshed, watershed, and estuary water quality models in a linear (sequential) pattern with little or no feedbacks. Each of these component models is fully integrated in itself, however, with complete feedbacks built in. For example, in the estuary water quality model, the water column production submodel provides organic matter deposition to the sediment submodel, which in turn exerts sediment oxygen demand on, and provides nutrient fluxes back to, the water column. Even the water column submodel includes feedbacks representing nutrient–food chain interactions. Thus, at the component model and submodel levels, the CBP modeling system exhibits appropriate feedback. The panel recommends that careful consideration be given to the need for feedback processes and to the formulation of those processes in the development of integrated modeling systems.

4. Are the challenges associated with assimilating and applying integrated modeling methods and technologies complete and accurate?

Although we recognize that integrated modeling is an investment in better science, it is not without challenges. The White Paper presents three broad categories of challenges associated with IM: science, technology, and institutional. Science challenges include design of the integrated analytical framework, development of a better, quantitative understanding of processes in environmental systems that integrate heretofore separate environmental problem domains, model evaluation and uncertainty analysis, education, and knowledge management. Technology challenges include achieving interoperability; automated data access, retrieval, and processing; and the development of decision support interfaces. Institutional challenges include organizational stove-piping and an imminent shortfall in human capacity.

As noted in the forward to the White Paper, EPA's challenge is difficult: to produce scientifically compelling and pragmatic linkages between fate and transport, human exposure, risk, ecological effects, and/or economic models in which few such connections currently exist. This requires an understanding of the way all of the components fit and how to optimize system performance and characterize resultant uncertainty. This is a tremendous challenge worthy of our concerted effort.

The Executive Summary of the White Paper notes that "the major challenge facing environmental protection today is to eschew the single-chemical, single-medium, single-pathway view that existing environmental statues have fostered, in favor of a view of organisms and the environment as they really are: an integrated whole. Yet the realization of the benefits of this approach is hampered by a number of challenges, including the lack of a community-wide interchange and consistency and harmonization across these various efforts."

The White Paper also notes "the disconnect between the manner in which EPA programs are organized, and the fluid interconnectedness among pollutants and their environmental consequences across all media. This dichotomy presents a significant challenge for scientists and decision makers to develop effective and efficient environmental protection strategies and to understand and communicate environmental outcomes". Our recommendations may help to address some of these challenges.

5. Are the recommendations for advancing awareness, appreciation, and application of integrated modeling effective? Will they be sufficient to overcome the challenges? Are there other recommendations you would suggest?

NACEPT believes that the White Paper's recommendations are thoughtful and likely to be effective, but they will not be sufficient to overcome the challenges without adequate funding, higher visibility within EPA, and a concerted effort to sort out the next level of inquiry on how IM is most effectively implemented. A very important and early science challenge – developing a quantitative understanding for the processes that require integrated multi-media and multi-disciplinary modeling – has not been adequately addressed in the White Paper's recommendations. NACEPT believes that EPA should consider supporting a research program to address this critical science challenge to ensure successful IM implementation. By itself, a community of practice will not be able to meet this challenge.

In addition, NACEPT firmly believes that the following actions are key components to the success of integrated modeling within EPA:

- An evaluation should be made of the up-front investment needed to implement the White Paper's recommendations;

- Within a short period of time, a community of practice should be established and all modelers within EPA should be expected to follow those practices;

- Integrated modeling should be showcased, and organizational issues simultaneously addressed, by applying integrated modeling to a high profile, complex, cross media issue such as biofuels or the Gulf of Mexico hypoxia. One or two such "case studies" can be the focal point for establishing protocols, examining organizational relationships and identifying key stumbling blocks along the way. Scientists and modelers with cross-media perspectives and problem solving skills from across offices within EPA should be pulled together work on this, and they should work with the Science Policy Council to evaluate the process in "real time."

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