Summary of Results from the Huron to Erie Corridor (HEC) Technical Hydrodynamic Modeling Workshop

March 15-16, 2006
Port Huron, Michigan

Background

Modeling the hydrodynamics of the waterways connecting Lake Huron to Lake Erie has drawn consistent emphasis from local, state/provincial and federal agencies engaged in the binational area surrounding this water corridor. At the local level, the Macomb / St. Clair Inter-County Watershed Management Advisory Group has recently begun examining potential benefits of expanding their real-time water quality monitoring/notification system to include a continuously operating hydrodynamic model for the St. Clair River and Lake St. Clair for real-time particle tracking.. The counties are also seeking to implement recommendations from the Lake St. Clair Management Plan, which could benefit from coordinated monitoring and modeling both upstream and downstream of the lake. Other local governmental groups, such as the Southeast Michigan Council of Governments (SEMCOG), have also promoted integrated real-time monitoring/modeling systems throughout the region.

The State of Michigan and the Province of Ontario regulatory and resource management programs would benefit from better integrated information systems for this geography. At the federal level, the U.S. Army Corps of Engineers, National Oceanic and Atmospheric Administration, U.S. Geological Survey, U.S. Environmental Protection Agency, Environment Canada and the Canadian Department of Fisheries and Oceans and other federal agencies have been engaged in monitoring and hydrodynamic model development within the same domain. The Lake Erie Millennium Network has long supported hydrodynamic model development throughout the HEC and has led to significant academic interest and involvement in model development and use within the corridor.

Through past efforts, one-dimensional (1-D) and two-dimensional (2-D) models have been created for various reaches of the HEC, but are not used to simulate or forecast water movement on a continuous or real-time basis. Most of these models have limited, if any, capabilities for assessments of complex cross-channel and vertical mixing that may be occurring within the water courses. A three dimensional (3-D) model is being considered for use with the real-time monitoring system being managed by the Macomb – St. Clair Inter-County group. The 3D model is anticipated to be a flexible tool that could be used for multiple purposes, including: plume tracking; (spill response and clean-up); riverbed movement (contaminated sediment transport/ erosion studies); ice movement and corresponding flow dynamics; and pathogen movement needed for public health protection at swimming beaches within the corridor).

The Great Lakes Observing System (GLOS) is a broad stakeholder-driven group of government, academic, maritime, and business, who are coordinating the operations, maintenance, and reporting of data from observing, modeling and monitoring instruments around the Great Lakes. High among regional GLOS priorities is the integration of observations and modeling within the HEC. A proposal for integrating modeling, monitoring and observing operations within the HEC has been developed by the Great Lakes Commission, acting as secretariat for the GLOS (available online at www.glos.us/hec).

On March 16-17, 2006 GLOS and SEMCOG co-hosted a technical workshop at the Thomas Edison Inn in Port Huron, Michigan to develop an implementation strategy to assess the prospects for hydrodynamic model development within the corridor within the 2007-2009 timeframe. Nearly 50 individuals representing a broad cross section of binational stakeholders engaged in the HEC participated in the two-day workshop. Agencies representatives in attendance included most U.S. and Canadian federal, provincial, county and municipal governments, regional academic institutions, binational regional agencies, commercial interests and other stakeholders with strong modeling interest/expertise.

The specific objectives of the workshop included the following:

- Clarifying the objectives of the project;
- Identifying the monitoring needs to be addressed via hydrodynamic modeling;
- Identifying the types and details of hydrodynamic models that will be required;
- Identifying unmet data needs for hydrodynamic model development and data inputs;
- Developing requirements for model outputs and access;
- Identifying the costs and timelines associated with model development, testing and implementation;
- Identifying the roles of agencies in model development, testing and implementation; and,
- Developing and refining advocacy approaches for securing resources (limited to regional and local participation).

Presentations

The workshop began with a series of presentations intended to familiarize participants with the background of the workshop and to provide a common context for the group discussions to follow. Chuck Hersey of SEMCOG gave the workshop welcome and provided a brief overview of the workshop's origin and purpose. Roger Gauthier of the Great Lakes Commission discussed the objectives of the workshop and the discussion process to be taken, as well as providing a historical overview of monitoring and modeling activities within the HEC. Eric Barnowski of Ira Township gave a presentation on the Macomb – St. Clair Inter-County Water Quality Monitoring activity. He was followed by Scudder Mackey of the University of Windsor who discussed the Lake Erie Millennium Network and the associated monitoring objectives within the corridor.

Following lunch, Dave Holtshlag of the U.S. Geological Survey and Aaron Thompson of Environment Canada provided an overview of the current status of 2-D model development and applications within the HEC. The were followed by Ronnie Health of the U.S. Army Corps of Engineers who discussed recent trends and developments in the multi-dimensional modeling arena, including the development of 3-D models. Finally, Mark Vincent of the National Oceanic and Atmospheric Administration (NOAA) discussed that agency's Physical Oceanographic Real-Time System (PORTS) and Coastal Operations (CO-OPS) modeling programs. Presentation slides for each speaker are available at www.glos.us/hec/.

Discussion Groups

The bulk of the workshop consisted of the division of the workshop into four groups to conduct discussions on a series of questions. Following each break-out session, the groups reconvened to compare the outcomes of their discussion and share overarching observations. The questions addressed in each of the four break-out groups were the following:

Session I: User Needs

- What outputs from modeling are desired?
- Are there specific geographic areas that require higher spatial/temporal resolution?
- What temporal characteristics are desired (e.g., historical analysis, near real-time forecasting)?
- What additional modules are needed (e.g., sediment transport, ice dynamics, pathogen movement)?
- What specific agency programs would modeling support?

Session II: Model Characteristics

- What modeling scale is needed to meet mission requirements (e.g., 1D, 2D, 3D)?
- What modeling resolutions are needed (e.g., finite element/difference mesh, timesteps)?
- What model output delivery is desired (e.g., internet, hard copy)?
- What sensor inputs and additional data collection/validation is necessary?
- What model calibration/validation is necessary?

Summary of Results

A significant amount of consensus was reached on the following key points:

1. Three dimensional modeling is needed over the entire geography of the HEC from Port Huron, MI / Port Edward, ON to Rockwood, MI / Bar Point, ON.
2. The 3-D model should be used initially to support refinements to real-time monitoring operations, with high detail in critical areas of the system, including the upstream portion of the St. Clair River north of confluence of the Black River, around all water intake facilities and in the delta areas of the St. Clair and Detroit rivers.
3. Initially, the 3-D model should be used to develop fate and transport predictions for a suite of potential hazardous spills within the system.
4. The 3-D modeling should be public domain (e.g., USACE RMA-10 code); that is, source code should be available to all for continual model enhancement by a broad user base.
5. In the immediate future, the existing RMA-2 models for the St. Clair River, Lake St. Clair, and Detroit River should be utilized to their maximum benefit in the design and implementation of the real-time monitoring system. Significant care needs to be exercised to insure that expectations meet reality in terms of model output.

The following next steps were identified:

1. Continue seeking funds to support 2-D model implementation, 3-D model development, and additional sensor deployments (e.g., meteorological sensors, in situ current meters, remote sensing)
2. Identify the costs and timing for conducting detailed hydrographic surveys of Lake St. Clair.
3. Support continuation of USACE flow calibration surveys within the system.
4. Continue coordination of model plans with managers of real-time monitoring program.

Detailed Discussion Group Outcomes

What outputs from modeling are desired?

Potential user groups and uses of a hydrodynamic model for the HEC are numerous. General categories of use listed by the workshop participants included:

- tracking of toxic spills/releases;
- sediment transport mechanisms including those dealing with contaminated sediment movement;
- study and prediction of pathogen movement affecting contamination at public bathing beaches;
- predictions of conveyance to optimize commercial transportation of goods and material;
- protecting drinking water from contaminant inflows;
- improving safety for recreational boaters and fishermen;
- emergency response including search and rescue;
- assessing fisheries and habitat changes;
- assessment of water chemistry and nutrients (e.g., salinity, phosphorous, etc.);
- optimization of monitoring programs; and
- analysis of historical or proposed changes to the waterway.

While each of these uses may require slight additions or modifications to the model, certain basic model properties or outputs are common to many or most uses.

The basic model functionality is accurate prediction of water levels and flows. Many applications will depend heavily on accurate prediction of the three-dimensional hydrodynamics, including turbulence. It was therefore widely agreed that the ability to model hydrodynamics in three dimensions would be an essential feature. Where certain applications may require only 2- or 1-dimensional modeling, the 3-D model could be collapsed to these scales.

Many uses rely on the ability to track the movement of water and dissolved or suspended materials as they flow through the system. Generally, this is desired to be done in both reverse (source tracking) and forward (fate tracking) modes. In order to predict flows through the whole system, two to three days is the minimal amount of time a model will need to be able to represent. Accurate computation of transit time for water between two points is also essential, as is calculating the dispersion of a chemical load as is moves through the waterway. Although it may not be necessary to have the model continuously operating, the capability for the model to run in real-time and/or in a predictive mode, such as in the event of an emergency, is important. In addition, users should have the ability to rapidly access the model, configure it for a given situation and run real-time or predictive scenarios. For many applications, use of the model to pre-define source/receptor relationships for a variety of standard meteorological conditions should enhance rapid response capabilities.

Specific uses will require several additional outputs and capabilities. Many users may be interested in conducting models of specific historic or potential future scenarios, such as under pre-development conditions, an altered future climate conditions, or with modified inputs to the system, etc. The ability of the model to link with inputs and outputs of models for the larger lakes, as well as with models of the surrounding watersheds will be important for many applications.

Many users will require modeling of the interactions between the water and the sediment, such as deposition and resuspension. Some users may be interested in including specific chemical or biological components into the model, such as the degradation of an organic chemical, or the growth of aquatic vegetation. Although these functionalities may not be a basic component of the hydrodynamic model, the modeling framework should be conducive to integrating them. Users may also want the ability to adjust model parameters, such as the boundaries (shoreline), the bed elevation, and the channel configuration. Representing inputs to the system from sources such as groundwater or contaminated sediments may also be necessary for some users.

Are there specific geographic areas that require higher spatial/temporal resolution?

There are many cases in which high spatial resolution in the model will be desired. To use the highest possible resolution throughout the model may unnecessarily expend excessive run-time and computer resources. It is therefore important to identify which portions of the model may require higher resolution and which would require lower resolution. The workshop participants listed many specific locations throughout the system where it may be desirable to have higher resolution, at least for some purposes.

Generally, there was agreement that within Lake St. Clair, higher resolution is needed in the nearshore areas as opposed to the middle of the lake. In addition, high resolution is desired near sensitive areas (water intakes, contaminated sites), areas with high turbulence, near system inputs (areas of confluence), transition zones (e.g., channel to lake), spawning habitat, beaches, industrial outfalls, and structures (for navigation). In addition, there may be some larger regions, such as the lower Detroit River, or the St. Clair River delta for which higher resolution is desired over a wider geographic range. It was recognized that in many locations the usefulness of a fine resolution grid may be limited by input parameters, such as bathymetry resolution. In addition to specific geographies, there may be specific events that require higher temporal or spatial resolution than would generally be desired as default settings. These include things like reversal of flows, ice damming and chemical spills.

What temporal characteristics are desired (e.g., historical analysis, near real-time forecasting)?

The temporal characteristics of the model will depend somewhat on its use. While some workshop participants noted preference for a model that is capable of being run continuously, others noted that real-time capabilities are a lesser priority than other model aspects. In addition to assessing current conditions, ability for predictive and historical analyses are important considerations. For operational forecasting, a timespan of about two days was thought to be appropriate for making predictions regarding levels and flows. Because of differing needs for different uses, a flexible model timestep is preferred. A minimum duration for a single model run is several days to weeks.

What additional modules are needed (e.g., sediment transport, ice dynamics, pathogen movement)?

In addition to those activities relying solely upon hydrodynamic predictions, the model will support a wide variety of other activities that build upon this hydrodynamic capability. There may therefore be many additional modules that are needed to support these uses. Such modules that were suggested by the workshop participants include: sediment transport and tracking; water quality (pathogens, toxics, loadings, reactions); wildlife habitat and productivity (fish, macrophytes, etc.); sediment resuspension; ice dynamics; pathogen tracking and prediction; nutrient assessment; wave dynamics; vegetation; ecological modeling; biochemical terrorist attack impacts; and assessment of variations due to weather patterns or other environmental conditions.

In addition to these specific uses, development of modules to assist in running of the model was suggested. A training module that explained the use of the model in layman's terms was recommended. In addition, an input module with quality controls for easily varying parameters and creating scenarios was suggested. Sensitivity and uncertainty analysis should also be incorporated as a specialized module. Finally, a robust data viewing and analysis module was seen as essential.

What specific agency programs would modeling support?

Workshop participants recognized that an advanced hydrodynamic modeling framework for the HEC would support numerous governmental agency programs including those conducted by local, state, provincial and federal agencies which are active within the region. Source water protection programs (local, state and provincial agencies) were mentioned prominently, as were programs to protect and regulate water quality and quantity within the corridor. Local drinking water utilities could derive significant benefit in their routine operations. Habitat and fisheries programs, such as those under the U.S. Fish and Wildlife Service and the Great Lakes Fisheries Commission, would be supported by the model creation and application. Sediment loading assessment, dredging, and other engineering and maintenance activities would benefit.

Law enforcement and border security within the corridor would be supported by the proposed model. Local health departments could potentially employ the model in determining beach closings and/or water supply warnings. Federal, state and provincial programs for emergency and spill response could make use of the model, such as those under NOAA, EPA, the Coast Guard and the Ontario Ministry of the Environment. Coastal zone management and permitting activities might use modeling results, as might watershed-scale planning activities and the Remedial Action Plan (RAP) groups operating within the corridor. States might also use the model for development of Total Maximum Daily Loads (TMDLs). Finally, the model is anticipated to have significant research applications both for academic and governmental researchers, including NOAA's Oceans and Human Health initiative and the Lake Erie Millennium Network.

What modeling scale is needed to meet mission requirements?

Throughout the workshop, a significant focus of discussion on model characteristics was placed on spatial scale and the dimensionality of the model. As has been mention above, 3-D capabilities are viewed as essential, especially to support activities where accurately accounting for cross channel and vertical mixing is important. The 3-D model can easily be modified to produce 1-D and 2-D representations.

It was felt that a single modeling framework should be developed that can apply to the entire corridor, including immediately adjacent sections of lakes Huron and Erie. Capability is needed so that the hydrologic watershed surrounding the corridor is accurately represented as inflows from the Clinton and Thames rivers can change levels and flows within a short time period.

Model resolution needs will very from application to application. It was expressed that a high resolution is preferred as a default, as it is easier for a user to make the resolution coarser and virtually impossible to make the resolution finer.. The ability to modify the resolution for different portions of the model is essential. In many cases, the need to accurately model mixing will determine the required scale. At high resolution, the resolution or quality of input data may become a limiting factor, such as the density of bathymetric surveys for Lake St. Clair.

Many participants expressed the importance of developing the model as an open source code, so that a diversity of users can access, modify and run the model to suit their individual needs and constraints. Taking advantage of the latest trends in computing, such as parallel processing and grid computing was also recommended. A careful study of the latest modeling advances, such as adaptive grid resolution and Extensible Model Data Framework (XMDF) is mandatory prior to initiation of the model creation.

What modeling resolutions are needed (e.g., finite element/difference mesh, timesteps)?

Participants also provided valuable input regarding the spatial and temporal resolution of the model. Model resolution needs will vary from application to application. The ability to modify the resolution for different portions of the model is essential. As has been noted above, a finer resolution is needed in certain areas, such as near intakes, beaches, confluences, outfalls, islands, structures, etc. In many cases, a coarser resolution elsewhere would be justifiable. It was expressed that a high resolution is preferred as a default, as it is much easier for a user to make the resolution coarser than finer and finer resolution would not provide improved accuracy. In many cases, the need to accurately model mixing will determine the required scale. At high resolution, the resolution or quality of input data may become a limiting factor.

The temporal resolution of the model will also be application dependant. It was noted that time-steps as short as 15 to 30 minutes may be desired near intakes or outfalls and near beaches. If the model is intended to run on an one-hour timestep, its computational demand must be addressed within this timeframe (i.e., the model could not take 65-minutes to run when it needed to be updated every hour). The model will also likely be used to do near-term (e.g., 30 hours) forecasting, or may be used to run longer duration simulations.

What model output delivery is desired (e.g., internet, hard copy)?

The basic set of model outputs should include all relevant output parameters. For some users a simplification of the results will be needed, where as others will be interested in seeing all details. Participants mentioned the desirability of having a data viewing module that would assist users in seeing the model output in a format suitable to their intended purpose. In addition, output modules should provide capabilities for creation of basic reports which could be printed in hard copy.

Broad online accessibility to basic modeling results is highly preferred whenever possible. In some cases, it may be necessary to restrict access to more detailed modeling results, if it is deemed they may present a security risk.

For a model running in real-time and evaluating parameters relevant to health risks, an automated system to notify local health departments is highly desirable. For such systems, operation in extreme conditions (e.g., power outages) is an important consideration.

Other innovative options for accessing model outputs, such as water level data through a phone service or visual animations available at park kiosks were also mentioned. Such outreach activities will help build the public support needed to maintain the model over the long-term.

For the most part, users will be interested in the model results, not necessarily the ability to run the model themselves. Therefore, a heavy focus on data availability and convenience for use with analysis tools such as Geographic Information Systems (GIS) and other spatial modeling systems is important. Finally, it was noted that model outputs will need quality control / quality assurance components.

What sensor inputs and additional data collection/validation is necessary?

To support model development, validation and the full range of applications and programs mentioned above, the model would require a wide range of data collection and inputs. Some of these are already available, others may need to be developed. Among those mentioned by workshop participants are:

- Better Lake St. Clair bathymetry, especially in the nearshore (15cm accuracy)
- Better bathymetry for input and output of rivers
- Outputs from NOAA's lake models for Lake Erie and Huron conditions
- Vertical profiling
- More buoys in Lake St. Clair to collect basic parameters, such as air and water temperature, climatological variables and water levels
- More gauges in the delta area
- Bacteriological data
- Temperature profiles
- Nutrient data
- Chemical / pollutant concentrations
- Turbidity
- Dissolved oxygen
- Whole effluent toxicity data
- Distribution of fish
- Boundary conditions
- Regular monthly field measurements of flows in selected sections of the corridor
- Bottom textures and macrophyte distribution
- Stratigraphy
- Airborne and spaceborne remote sensing data, such as digital orthoimagery
- Shoreline characterization
- Acoustic Doppler Current Profiler installation
- Data from the Lake St. Clair C-MAN station
- Gauging of tributaries
- Aquatic vegetation with hyperspectral imagery
- Ice cover / jams
- Sediment budgeting
- Near-bed suspended solids
- Grain size distribution (dredging data)
- Substrate/sediment distribution
- Recreational boating contributions.
- High-frequency radar or other surface current observations
- Real-time ice data

For many of these parameters, it was noted the continuous or semi-continuous data collection would be needed to adequately support a continuously running model. In all cases, quality metadata detailing the time, location and methods of data collection is important to document the inputs to the model.

What model calibration/validation is necessary?

Participants noted that an extensive process of calibrating and validating the model is needed, especially if the model is to be used operationally to support many of the important programs for which it is envisioned. Validation is a process to confirm that the modeling code works properly; calibration uses field results to tune outputs and uses field results to confirm quality of the results from a calibrated model. In addition to initial validation, a system should be created to allow for continuous validation.

If over time the model proves to be producing inadequate results, as recalibration may be needed. Among the types of information that participants suggested might be used to calibrate and validate the model are flow measurements, water level data, turbulence data, water temperature data, tracers/floats (such as buoys or SF6 gas tracing).

In addition to the basic model, additional modules that are developed would require additional validation. Demonstrating appropriate verification of results will be important for getting wide support for future model use.

For further information, contact:

Roger Gauthier
Great Lakes Observing System
734-971-9135, x113
gauthier@glc.org

or

Jon Dettling
Great Lakes Commission
734-971-9135, x125
dettling@glc.org