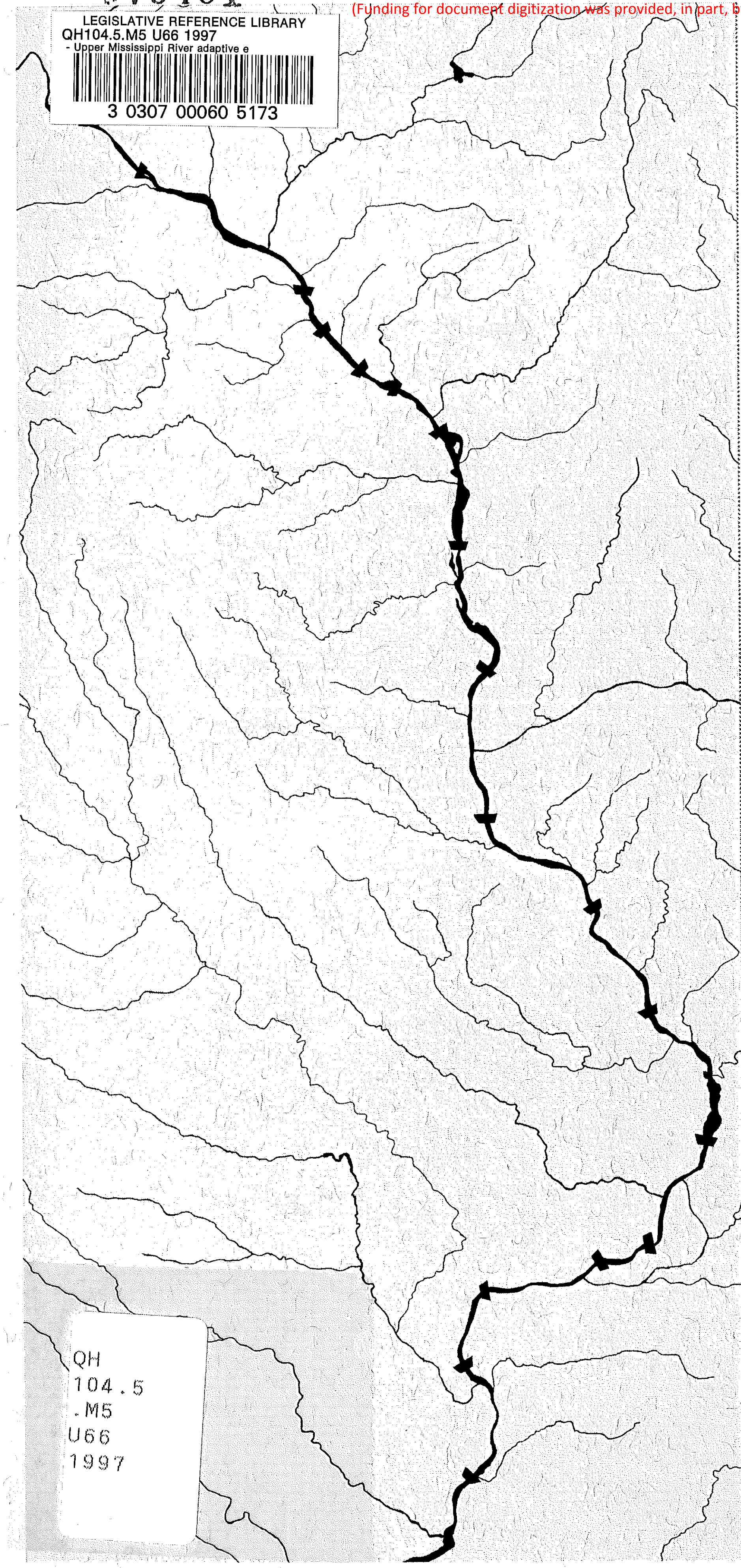


Upper Mississippi River Adaptive Environmental Assessment

Phase I Report

Developed by the
Adaptive
Environmental
Assessment
Steering Committee
and Modeling Team

June 1997

Acknowledgments

The Adaptive Environmental Assessment (AEA) project would not have been possible were it not for the commitment, leadership, energy, and enthusiasm of the members of the AEA Steering Committee:

Adele Binning	Science Museum of Minnesota
Mike Davis	Minnesota Department of Natural Resources
Barry Drazkowski	Resource Studies Center, St. Mary's University
Jon Duyvejonck	Upper Mississippi River Conservation Committee
Bob Gaugush	U.S. Geological Survey, Environmental Management Technical Center
Barry Johnson	U.S. Geological Survey, Upper Mississippi Science Center
Steve Johnson	Minnesota Department of Natural Resources
Dick Lambert	Minnesota Department of Transportation
Steve Light	Minnesota Department of Natural Resources
Ken Lubinski	U.S. Geological Survey, Environmental Management Technical Center
Dave McConville	Resource Studies Center, St. Mary's University
Terry Moe	Wisconsin Department of Natural Resources
Barbara Naramore	Upper Mississippi River Basin Association
Holly Stoerker	Upper Mississippi River Basin Association

The Steering Committee thankfully acknowledges the special contributions of:

- **Carl Walters**, **Josh Korman**, **Lance Gunderson**, and **Garry Peterson**, whose many years of experience in AEA and brilliant computer modeling skills were instrumental in shaping the dialogue and the modeling tool.

- **Steve Light** for his vision and leadership in sparking and nurturing the project.

- **Mike Davis** for his dedication and support of the project.

- **Susen Fagrelius** for her facilitation skills and sage advice.

- **Holly Stoerker** and **Barb Naramore** for their roles as honest broker and fiscal agent and for their commitment to a quality process and product.

- **Harland Hiemstra** for excellent work in editing and **Linda McNary** for layout and design of the final document.

Finally, all those involved in the AEA project gratefully acknowledge the generous financial support of the following contributors:

Legislative Commission on Minnesota Resources*
McKnight Foundation
National Biological Service
Mike Davis

*Funding for this project approved by the Minnesota Legislature, 1996 Minnesota Laws, Ch. 407. Sec. 8, Subd. 5 as recommended by the Legislative Commission on Minnesota Resources from the Minnesota Future Resources Fund.

Upper Mississippi River Adaptive Environmental Assessment

Phase I Report

INTRODUCTION

Adaptive Environmental Assessment (AEA) employs computer simulation as a tool for understanding complex natural systems and exploring alternative management scenarios for those systems. The technique has been used in such areas as the Everglades, Columbia River, and Canadian forests, which, like the Upper Mississippi River, have competing scientific explanations for how they function and controversies regarding how they should be managed.

In 1995, an AEA process was initiated on the Upper Mississippi River (UMR). This report describes the accomplishments of the first phase of that process and summarizes the remaining work to be accomplished. (See Attachment 1 for a list of other reports related to Phase I of the UMR AEA.)

BACKGROUND

A Time for Decisions

The Upper Mississippi River is a national resource facing a growing number of demands as it moves into the 21st century. Shipping interests want to see the river improved as a transportation corridor. Boaters, anglers and hunters flock to the "Mighty Miss" for a variety of recreational pursuits. Biologists and conservationists hope to preserve the river as a healthy and complex ecosystem. Out of those multiple demands arise differing opinions on how the river should be managed.

In the next few years a number of key decisions on river management will be made with lasting consequences for the economic and ecological future of the Upper Mississippi River (see Figure 1). As decision time approaches and the differences that separate people become more prominent, scientists and other experts will be called upon to support people's positions and to defend the merits of various assertions. People will expect science to provide clear answers based on irrefutable evidence.

Figure 1

The Path Less Travelled?!

Abraham Lincoln's House Divided Speech—

"If we could first know where we are..." | "...and whither we are tending..." | "...we could better judge what to do and how to do it."

ECONOMY

International agricultural breadbasket

Over 60% of US grain exports travel the Mississippi

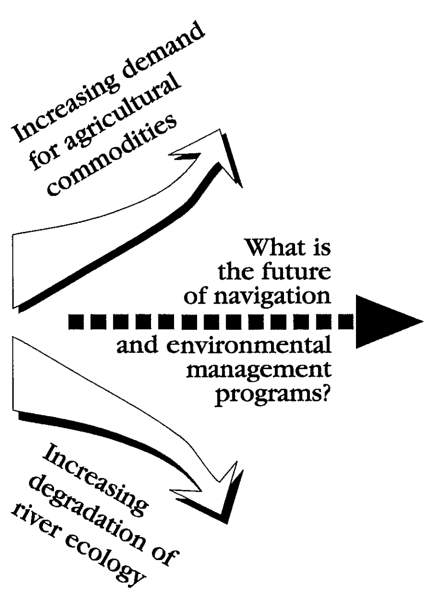
Increasing barge traffic

ECOLOGY

World class river resource

Vital floodplain ecosystem

Mid-continent flyway



VICIOUS CYCLES

WHAT?
"Railroad this plan through!"

"Stop it dead in its tracks!"

HOW?
Disinformation campaigns

Lawsuits

Character assassinations

VIRTUOUS CYCLES

"Take destiny into our own hands"

"Identify each other's real needs"

Be realistic—no easy answers

Simplify the complex

Learn new ways

In a system as complex as the Mississippi, though, there are no easy answers, and clarity is often lost in the details, buried in the volumes of analytical data. If science is to productively advise the decision-making process, it must be used in an alternative fashion that prepares us to make choices by helping us develop a more thorough understanding. It must embrace an approach that avoids the temptation of "the answer," focusing instead on the big picture, and multiple views of the future.

Piecing the River Puzzle Together

There are two types of science – the science of parts and the science of the integration of parts. The science of parts (i.e., deduction) helps us test an idea and explain what happens. The science of the integration of parts helps us understand the range of ideas that might be useful in solving a problem. The two modes of science complement each other. The integrative mode attempts to make sure we are solving the right problem, while the deductive mode tells us whether we have the right solution. Both modes are useful for different reasons. But we tend to rely on only the deductive mode and rarely use the integrative one.

The science of parts fails us when we need to comprehend big-picture questions. Experts, for example, can tell us how many tons of commodities go up and down the river, how many ducks migrate through each year, or the number of days people spend boating or fishing on the river. But how will all these demands work together? How does the river accomplish the myriad of things we expect of it and rejuvenate itself as well? And how can we be certain that future generations will continue to benefit from a vibrant river?

Even with all the information at our command, no computer can predict the river's future, because both the river and the demands we place on it are constantly interacting and changing in the process. The very act of management transforms ecosystems into new entities in order to create economic and social opportunity. To further our understanding of such a complex and changing system, we need to apply the power of integrative science.

Humans often solve problems by creating mental models of how they think the world works, and then testing them. Earlier ideas that the earth was flat or that the sun revolved around it, for instance, fell apart when those views failed to account for observations. In many ways, the variety of scientific and policy perspectives on the Upper Mississippi River system constitutes a giant puzzle consisting of a collection of alternative perspectives. When these views of the river and their underlying assumptions are examined and compared, common elements emerge that can be used to build a composite framework. In this way, science can be understood and used by citizens, policy makers, and scientists alike. It can help us identify and understand the differences that separate, and discover new ways of working together.

Even though we can never know all the puzzle pieces, by working with a combined understanding of science-based perspectives and human needs for the river, a great deal can be learned. Surprising new insights and opportunities emerge that have not been considered before. That's what AEA attempts to bring about.

The Role of AEA

With all the studies and reviews of river management going on, one might well ask why we need yet another. The shelves are full of people's perceptions and agencies' plans for the river. What could possibly be gained through another assessment? AEA, however, is different from these other approaches (Figure 2). It is not a vision-led or a planning-led approach. AEA is a cost-effective, learning-led approach to making optimum use of existing data for assessing the uncertainties, problems, and opportunities on the river. The AEA project for the Upper Mississippi River has two objectives:

- develop an integrated, science-based understanding of the river as a natural system; and
- explore alternative ways of reconciling the competing demands for the river resource.

Figure 2

Traditional Adaptive Approaches to Problem Solving

Traditional Approaches	*Adaptive Environmental Assessment*
Deductive	Inductive
Narrow focus	Broad focus
Snapshot of problem	Dynamic evolutionary perspective
Analysis of parts	Integrates understanding
Eliminate uncertainty	Highlights uncertainty
Results are conservative and unambiguous; approach perpetuates fragmented management strategies.	Results are composite solutions at appropriate scales based on how resource problems define themselves.

AEA is a process that brings scientists, policy makers, river managers, stakeholder groups, and citizens together in a series of workshops to foster science-based dialogues. Within the workshops, a group of scientists with special training takes people's ideas and perceptions, together with existing data, and develops them into a computerized simulation model that attempts to portray the collective wisdom and ignorance of the group. The model becomes a representation of how people collectively think the river works (i.e., it uses the science of the integration of parts).

AEA does not try to ignore or avoid what we don't know about the river; in fact, people's doubt and skepticism are invited. The modeling of people's notions of how the river works makes ideas and assumptions explicit. Participants are encouraged to admit what they don't know. This is no easy task, but it leads to marvelous things happening. Instead of driving a wedge between people, acknowledgment of doubt and wonder about the river actually fosters honesty and integrity — the forerunners to building trust among people.

AEA is not a conflict resolution method and does not aspire to be one. Rather, it's a learning tool. The approach develops a living description of how the river works. The model produces graphs and charts that illustrate river responses to the demands and uses that we ask of it. Computer simulations become a way of establishing and building a science-based dialogue among participants. Instead of science being used as proof that one line of argument is more right than another, science helps people structure their knowledge in ways that facilitate understanding. Participants are encouraged to challenge how the model is being assembled and what questions it will answer. The model becomes intelligible, not a "black box" that just spits out answers.

AEA is a disciplined search for creative synthesis, relying on people's ingenuity. It is not a research project. AEA relies on existing information in an attempt to learn how all the pieces of knowledge we have fit together. The process, which takes place over a period of months or years, sharpens distinctions, builds clarity, and then begins to probe for flexibility and irreversibilities. It seeks to identify policy and management options that achieve both economic and ecological goals. Alternative ways of solving the river puzzle are proposed and examined. In the end, no single solution emerges. Instead, several composite solutions drawn from a variety of ideas are recognized, but the real product consists of shared insights and understanding.

Recognizing that the real world is very complicated, AEA attempts to simplify the complex in ways that aren't simplistic. It applies science in a way that invites the complicated worlds of policy and public values to the table with scientists. AEA helps define problems from a management perspective, in ways that informed citizens can comprehend the problems being addressed and participate fully in the dialogue.

Origins and Progress of the Upper Mississippi AEA Project

The AEA process grew out of the findings of the Upper Mississippi River Workshop and the International Large Floodplain Rivers Conference, which drew researchers from all over the globe to LaCrosse, Wisconsin in 1994. Conference participants concluded that the system of river control structures on the Upper Mississippi may have created an initial increase in habitat diversity that was essentially unsustainable. An annual floodpulse, channel-forming floods, and infrequent droughts are major factors sustaining floodplain river ecosystems. The lock and dam system and related channel maintenance activities mute the impacts of these forces, leading many conference participants to conclude that the navigation system is as an important factor in the slow but progressive degradation of the river's ecology. At the same time, it was recognized that the navigation system on the Mississippi supports considerable economic activity that is significant at regional, national, and international scales. To explore what flexibilities might exist in water control regimens and in natural systems, conferees recommended that an ecosystem assessment be completed for the Upper Mississippi River System to determine the potential for restoring the natural river hydrograph, floodplain connectivity, and energy dynamics.

Over the next several months, the Minnesota Department of Natural Resources' Mississippi River Team met with river scientists from the five-state region and assembled an ad hoc steering committee to pursue an AEA. Since then, the Upper Mississippi River AEA Steering Committee has planned and implemented Phase I of a multi-part effort. This first phase has focused on identifying key factors in the way the river works, describing those factors' interrelationships, and developing a computer simulation model that attempts to capture these basic interactions. Funding for Phase I of the UMR AEA was provided by the Legislative Commission on Minnesota Resources, McKnight Foundation, and National Biological Service.[1]

The Upper Mississippi River Basin Association has administered the Phase I funding.
The balance of this report describes the progress that has been made through two Phase I workshops and related model development efforts. The report is intended to bring closure to Phase I of the UMR AEA and set the stage for Phase II, which will focus on using a refined simulation model to explore various management scenarios, with an emphasis on identifying promising ways to reconcile competing demands on the river.

DETERMINING THE SCOPE OF THE ASSESSMENT—*Workshop #1*

AEA usually begins with a scoping workshop, where key resource issues are defined, the types of policy actions or interventions are identified, and the critical processes and indicators of ecosystem response are developed. The scoping process leads to the next stage of assessment, when the pieces identified in the scoping session are put into a computer model. On December 5-7, 1995, a scoping workshop was held at the Alverna Center in Winona, Minnesota to begin a series of structured conversations to assess environmental issues on the Upper Mississippi River. The workshop brought together approximately 45 people with a wide range of experiences, disciplinary backgrounds, and understanding about the river. (See Attachment #2 for a list of Workshop 1 participants.) The scoping workshop for the UMR AEA was organized around a series of plenary and small working group sessions aimed at developing a framework and ingredients for a computer model. Participants discussed resource issues, potential management actions, and the spatial and temporal scale of the analysis. Technical guidance was provided by a team of modeling consultants with considerable AEA experience.

[1] Phase 1 funding for the UMR AEA totaled $100,150, of which $57,000 was provided by the Legislative Commission on Minnesota Resources, $18,000 by the McKnight Foundation, and $25,000 by the National Biological Service.

Resource Issues

Attendees at the December 1995 workshop concluded that resource issues on the Upper Mississippi can be grouped into physical, biological, and human components. The physical issues include changes to the natural hydrograph of the river and geomorphological modifications of the river channel and floodplain, including dams, wing dikes, levees, and the effects of impoundment. These changes affect the relationship between stage and discharge, and the movement of water and sediments between the main channel and the floodplain and within the floodplain. The primary biological issues stem from the effects of physical modifications, including a decrease in the abundance and diversity of habitat types within the river and the riparian zone, loss of biotic diversity and of individual species, and changes in the movement patterns and abundance of fish. Human issues include the economic effects of commercial navigation, public access for recreational use, and future trends in population growth and floodplain development.

Management Actions to be Simulated

Workshop participants identified a variety of potential management actions to be addressed by modeling including those that could be applied within the river and others relating to the upland drainage area. Key physical variables that they wanted to manipulate with the model included the stage of the river, distribution of flow within the main channel and backwaters, and changes in land contours in backwater or impounded areas (e.g., building or removing levees, dredging deep holes). Participants also identified key management variables related to navigation, including changes in the channel depth and dredging policy, changes to the carrying capacity of barges, and alternative forms of transportation.

Spatial and Temporal Scale for Modeling

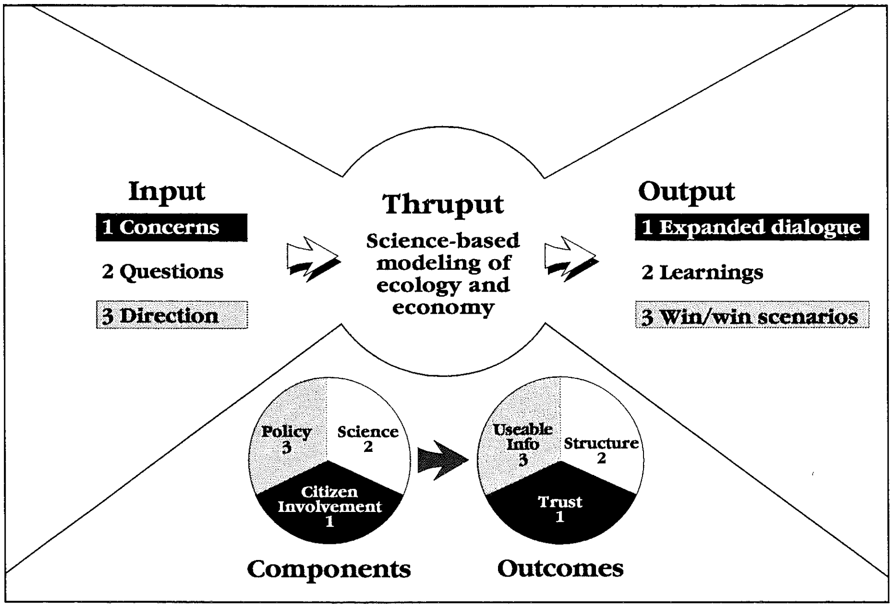
Workshop participants agreed to take a system approach, with the system defined as the Upper Mississippi River from Minneapolis to its confluence with the Ohio River. With this approach, modeling would be confined to processes occurring within the corridor of the floodplain; and processes occurring over the larger watershed or beyond would not be directly modeled. However, factors not specifically modeled can still be addressed by projecting how changes in these factors would affect the model's driving variables (e.g., a change in land use might increase demand for shipping and reduce sediment input from tributaries). Participants also determined that the minimum spatial scale for modeling within the river corridor must be small enough to simulate changes in vegetation type and to represent major structures on the floodplain (e.g., levees, dams). The time frame for modeling must allow enough time for policies to produce effects (perhaps 50-100 years), yet be short enough to capture seasonal effects in components such as vegetation growth, ice-up, winter habitat for fish, and shipping. It was agreed that the model would not consider short-term effects such as barge passage or wake effects from recreational craft. Even within these temporal and spatial restrictions, it was recognized that the proposed model would be too large. Participants concurred with the modeling consultants' recommendation to develop two models — a river system model that could span the entire UMR and a pool scale model to capture finer details.

DEVELOPING THE MODEL

A unique characteristic of the AEA process is the use of computer models to help integrate and test ideas and assumptions among a diverse set of actors with different backgrounds (Figure 3). As such, these models are vehicles designed primarily for facilitating communication and testing the collective grasp of a belief or idea. Only after withstanding repeated challenges and rigorous testing can the credibility of the model be sufficient to address key policy and resource issues. The modeling process is adaptive and organic; initial constructs are likely to change based upon workshop participants' feedback to the modeling team (Figure 4).

Figure 3

Upper Mississippi River AEA Process



As a starting point, the AEA modeling team constructed two models or views of the river that were linked. Both models operate by balancing inputs, outputs, and storage of sediment and water over time. One model, called the river system model, covers the Upper Mississippi River corridor and deals with processes pertinent to that scale — i.e., hydrology, sediment dynamics, land use, soil erosion, and key features of the economic system. The second model, called the pool model, focuses on ecological dynamics of the area between two successive dams (i.e., a pool). This model captures vegetation community succession in response to key physical dynamics, but maintains links to hydrologic and sediment features of the system model (Figure 5).

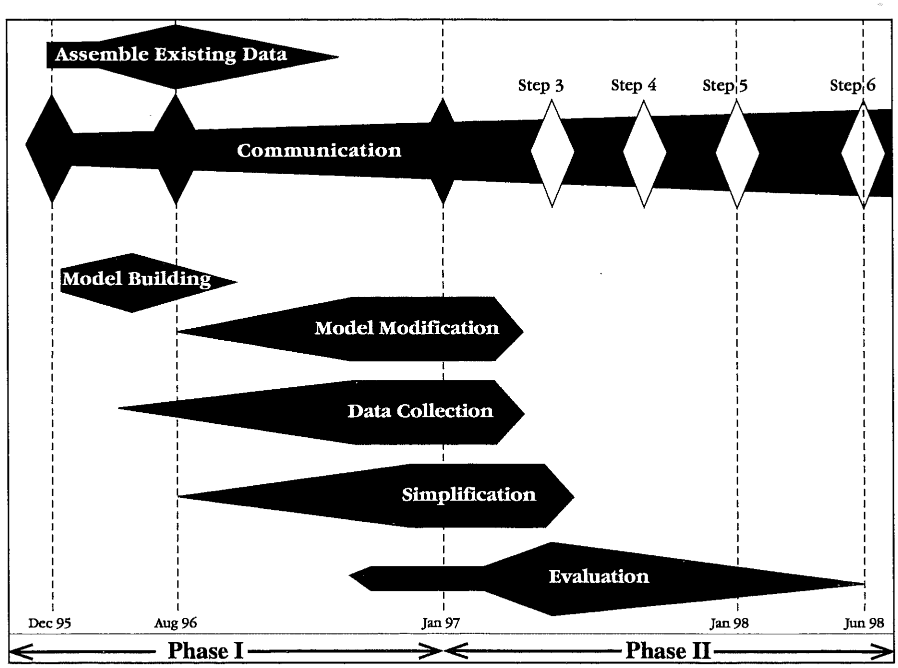
Model developers have attempted to balance mathematical computational time with the need to explore a variety of management options in a timely manner and at an appropriate level of detail. Efforts have been made to assure that the models are calibrated to real life observations and measurements. The models are written in Visual Basic, operate with a user-friendly graphical interface, and require a Pentium computer using a Windows 95 or NT operating system.

The River System Model

The river system model simulates the movement of water and sediment between navigation pools, incorporating the operating constraints of dams, natural seasonal and interannual variability in discharge, and sediment loads delivered from major tributaries. The model was designed to operate over Pools 2 through 26.

Figure 4

Stages of Model Development in AEA

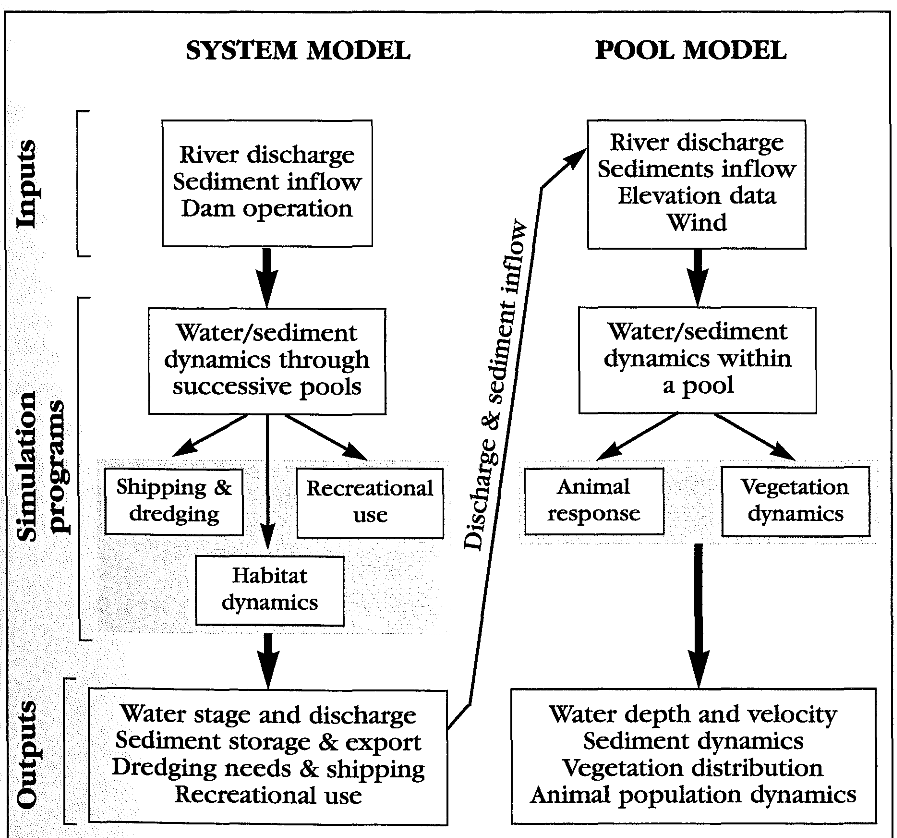


However, due to constraints of time, data, and budget during development, the initial model operates only on Pools 2 through 10 — i.e., the pools within the Corps of Engineers' St. Paul District. Key elements of this model evaluate the movement of water, including stage and discharge, and calculate sediment dynamics. Current and planned model outputs include changes in stage, sediment storage and outflow, area of different habitat types, tonnage of barge traffic, an indicator of recreational uses, dredging requirements, and an indicator of riparian zone area flooded. Issues raised by workshop participants that are currently outside the scope of this model include exotic species, water quality, and contaminants. The model does not attempt to quantify in monetary terms the public costs and benefits provided by the environment.

The model operates on a daily timestep and is driven by historical data on discharge and sediment input from 1959-1995. Calculation of sediment input from tributaries is based on tributary discharge and pool water levels. The model allows the user to set a stage height policy on a monthly basis over the year for one or more pools. For each day in each pool, the model calculates the daily inflow, adds that value to the current water volume of the pool, then calculates a new water elevation for the pool. The water elevation is compared to a user-defined target elevation and water is released as needed, within the operational constraints of the dam, to reach the target level. The amount of sediment exported from a pool is based primarily on water velocity in the main channel, which is a function of discharge and water depth. The model assumes that the channel depth will be maintained at 12 feet, thus all new sediment stored in the channel is assumed to be dredged annually. A navigation/economic component predicts shipping potential in each pool on a monthly timestep based on the average channel depth over the month and operating constraints of the lock and dam system.

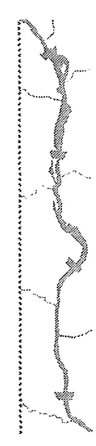
Figure 5

Components of the AEA Simulation Model



The Pool Model

The pool model covers the are between two successive dams, commonly referred to as a pool, with a spatial grid using 100 meter cells. The model evaluates changes in timing and duration of water levels, flows, and sediment deposition and resuspension among cells, which are then linked to distribution of floodplain topography and vegetation communities. Currently, the model simulates Pool 8, for which the 100 meter grid results in about 30,000 cells. A vegetation module models changes in vegetation types, ranging from open water to upland forest. Plant growth and mortality are linked to water depth, turbidity, and



duration of flooding.
Regeneration and establishment of plants are related to available seed sources, soil saturation, and number of years of dry or wet stress. A stand-alone submodel was also developed that models relative abundance of various fish species based on different combinations of water depth and current velocity as determined by the pool model.

The user can modify information on land and water elevations within a pool (e.g., to incorporate levees or deep holes) by changing values on maps representing initial conditions. Water flows from upstream and tributaries can be modeled as historical flows (from 1959-1995), as a specific scenario defined by the user, or as "natural system" flows which operate as if no dams were present. The user can also modify any parameters for flow and sediment dynamics as well as parameters for vegetation and fish response.

ASSESSING THE MODEL

Workshop #2

The first-cut simulation model was developed based on the December 1995 workshop, with data provided by a variety of government agencies and guidance from the UMR AEA Steering Committee. The Steering Committee held a small technical review session in August 1996, at which an initial version of the model was assessed and the modeling team was asked to make some relatively modest modifications. A second workshop was then held on January 15-17, 1997. Approximately 45 participants, representing a wide range of organizations, disciplines, and experiences, were asked to review the first-cut simulation model, recommend refinements, and consider how they would like to use the model to explore various management scenarios. (See Attachment #3 for a list of Workshop #2 participants.) A User's Guide describing the first-cut simulation model and electronic access to the model were provided to participants in the second workshop.

Views of the River

The January 1997 workshop served in part to clarify the very basic ways in which people perceive the Upper Mississippi River. The essence of these perspectives can be captured as caricatures, which are admittedly over-simplified, but also informative representations of how people view the current status of the river. Each caricature typifies or exaggerates a different ecological process or structural component, with economic and social implications as well. Although not explicitly stated as such, at least four different caricatures emerged during the two Phase 1 UMR AEA workshops.

The Tamed River

This perspective indicates that the hydrologic character of the river has been constrained and controlled by humans. The rhythms or cycles of water flow and water depths have been dampened or tamed. Spatial and temporal variation in hydrology and other processes has decreased due to the regulated management associated with the lock and dam system. Water levels and flows are controlled, so that the distribution of areas wetted over time has been changed, with some areas staying wet longer and others staying dry longer.

The Flattened River

This caricature refers to the loss of topographic diversity within the river corridor. The loss of topographic complexity is associated with changes in the hydrologic patterns and sediment movement. Sediment is accumulating in tributary deltas, many off-channel areas, and portions of the main channel. Wind and wave action serve to further reduce topographic diversity by flattening open water areas of the river. This caricature also includes the results of manual manipulation of sediment, as cases where dredge and spoil placement from channel maintenance have led to a decrease in topographic diversity. This topographic homogenization has led to a change in vegetation patterns and animal habitats.

The Beaded River

In this view, the braided, meandering river of the past has been replaced by one with two distinct characteristics — i.e., riverine and pooled areas. The area downstream of a dam retains much of its riverine character until it meets the impounded water upstream of the next dam, which creates lake-like habitat. No longer truly riverine, the current river is like a beaded necklace, a set of pools connected by remnants of the pre-impoundment river.

The Dirty River
Although not widely discussed at the two workshops, this metaphor focuses on human-induced water quality changes associated with development and watershed modifications. A recent U.S. Geological Survey report analyzes where and how the river has become more eutrophic, either from nutrient laden runoff from land use activities within the basin, or from sewage plants along the river. Increases in a suite of other contaminants also contribute to this caricature.

Each of these caricatures suggests aspects of the complexity of the river and can be used in part to judge whether the model captures what is important about the way the river works. They also point out how the river has changed and perhaps what might be done to address those changes. As such, they can also be useful in helping to identify policy-relevant resource issues on the Upper Mississippi River.

Management Issues

The key issue for the ongoing AEA of the Upper Mississippi is the search for flexibility in two sectors of the system, i.e., ecological and economic. This assessment is searching for the flexibility both between and within these two subsystems. That is, the assessment seeks to identify policy and management options for reconciling economic and ecological goals. Nested within the range of scales of geography over time are incredible opportunities to address over-riding economic and ecological concerns (Figure 6).

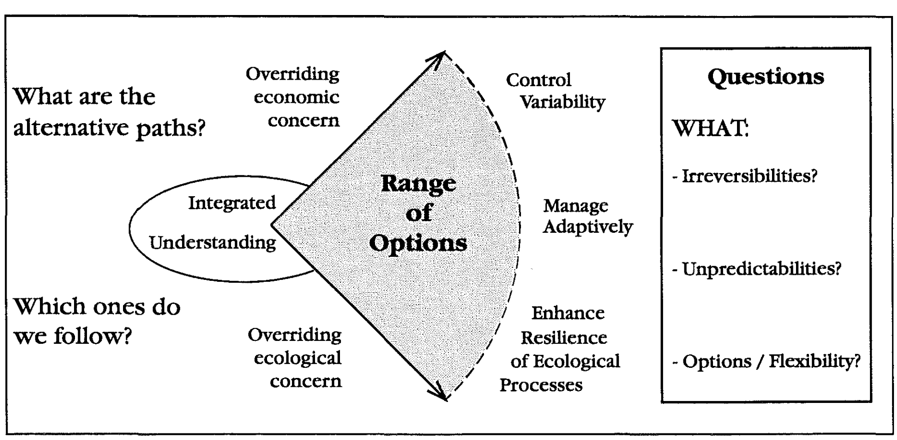
The project entails a search for win-win management opportunities that resolve the issues related to river changes as described in the metaphors mentioned above.

The management-relevant ecological issues for the Upper Mississippi appear to fall into two general categories — i.e., sediment distributions and habitat restoration. Sediment distribution has been altered in the tributaries and the mainstream river. Changes in distribution are associated with changes in sediment input and changes in water flow. In the tributaries, upland practices have increased sediment loading. Sediments tend to fill in the main channel, creating constant dredging requirements. In the shallow areas, sediments are resuspended by wind and waves. Habitat changes have been observed for a suite of organisms, including many threatened and endangered species. Changes in vegetation patterns have ranged from shifts in the types of species that are dominant to wholesale loss of vegetative community types. The reversal of these unwanted changes is at the focus of ecological restoration in the Upper Mississippi Basin.

The economic issues all deal with direct use and modification of the river to meet human needs. A key issue is the maintenance of a main channel for commercial navigation. This involves channel depth and how the depth changes over time due to water control, hydrologic variation, and sedimentation. The management of sediments from dredging has large ecological and economic dimensions. Another major issue that needs to be addressed is the

Figure 6

Exploring Sustainable Futures Realistically



recreational use of the river and how management and other uses may constrain or provide opportunities for this purpose. Other significant human uses of the river, including public and industrial water supplies and wastewater assimilation, also depend on the maintenance of adequate water depth and quality.

Highlighting Uncertainties

Much of the January 1997 workshop focused on defining and highlighting uncertainties surrounding these management issues. The computer models provided a focus for discussions by small groups, each of which was assigned a set of topics. The groups discussed possible management scenarios, indicators and evaluators of scenarios, and gaps or weaknesses in the models. Several broad areas of uncertainty emerged from these discussions.

Hydrologic Modification
A large uncertainty has to do with how much of the historic hydrologic variability can be restored, and over what time periods proposed modifications should be developed and evaluated. Alternative shapes of hydrographs also were discussed, and questions were raised regarding the time of year when drawdowns or free-flow might be attempted (winter or summer), and how these annual objectives would mesh with longer term natural variations that occur over several years. Participants also discussed uncertainty regarding the types of structural modifications that would allow for flexibility of river uses and management options. Some of these alternatives for structural modification are identified later in the report, under the scenario development discussion.

Sediments
Uncertainties related to sediments centered around problems of modeling transport dynamics. For the river system model, a question was raised regarding potential errors in calculating tributary discharges based on reported discharges at the locks and dams, and how those errors may propagate across river segments or pools. Another problem was how to distinguish between types of sediments carried in wash and bedloads, and how to account for different proportions of these materials in different parts of the river. The group also identified the need to augment the model with an indicator of sediment storage in each pool.

Vegetation
The vegetation group discussed both the testing or evaluation of the existing model of vegetation dynamics and the need for alternative models. One uncertainty was how well predictions of the current model agreed with historic or observed changes in vegetation patterns. That is, the group was unable to test the current set of rules, although the model can qualitatively match current patterns. Another gap was how to model longer term vegetation dynamics, especially how communities respond to chronic disturbances such as flooding stress and re-establishment following different levels of flooding. Another item discussed was the need for a nutrient submodel, which would link hydrology, sediments, and vegetation dynamics.

Habitats
The habitat group's discussions focused on weaknesses in indicators. Questions arose as to whether it would be better to model responses of key species or to develop habitat indicators. Related to the development of habitat indicators, participants were uncertain whether enough empirical information exists to model habitat changes based only on depth and duration of inundation or if other factors need to be considered. As with the vegetation sub-group, model credibility was a key source of uncertainty, and participants cited the need to test the submodel against historic data.

Human Uses: Navigation and Recreation
Uncertainties related to human activities on the river included gaps in information and the need to determine appropriate indicators. For example, is data available to determine how different management changes would affect key commercial and recreational uses of the river? Other identified gaps include the need to model negative interactions between recreational and commercial traffic, and a need to accurately identify changes in dredging requirements associated with different management schemes.

Confronting Uncertainties

In order to address the information gaps and uncertainties described above, workshop participants suggested a variety of model refinement, model assessment, and scenario development activities.

Model Refinement

A number of suggestions were made regarding potential model refinements. These involved modifications to existing submodels, creation of new submodels or routines, and additions to the user interface.

One debate at the workshop was whether to continue development of two models (i.e., at the pool and system scales), or to concentrate work on a system scale model with aggregated or broad scale indicators for sediment, vegetation, and habitats. This was compounded by the difficulties of simulating the hydrology and sediment dynamics at a 100 meter resolution in the pool. At this spatial resolution, the model is extremely slow for somewhat reliable results (on the order of 10 minutes per simulation year). One option suggested was to use higher powered hydraulic models, the results of which could then be plugged into the pool-scale model. The debate remains largely open, with no selection of preference made at the workshop.

A number of modifications were suggested for each of the submodels. These include:

- compiling data and building better representations of sediment transport in the tributaries;
- developing a model of sediment-landform building;
- economic assessments for potential structural modifications (e.g., construction and operating costs of changes to dikes, levees, and channels);
- developing a water quality model;
- developing stage-area relationships for habitat and vegetation responses;
- compiling data on recreational and navigational demands;
- developing composite dredging cost curves;
- connecting pool models together to evaluate cumulative effects;
- adding remaining pools to the river system model (i.e., Pools 11-26); and
- refining vegetation models with other factors such as flooding and water stresses, nutrients, and temperature.

Workshop participants suggested modifying the user interface to permit comparisons among various output maps. One suggestion was to have the option for simultaneous display of three maps, where two of the maps would represent results under different scenarios and the third would highlight differences and similarities between the other two maps. Other suggestions were to have an automatic pause at the end of a year of simulation, and to have supplemental files that could be accessed to explain aspects of model code, functional relationships, or parameters. Another suggestion was to have the ability to export graphics or data files for use in other applications.

Model Assessment

A recurrent theme in the January 1997 workshop was the need to critically evaluate or assess the submodels. One example was the stated need for sensitivity analysis of the sediment components of the pool and system models. Participants also highlighted the need for the vegetation submodel to be evaluated by people who are knowledgeable about long term dynamics and to be tested by compiling and comparing model output with historical time series data on vegetative cover. Similar statements were made about the habitat and navigation submodels. Several workshop participants said they planned to work individually and with other colleagues to assess various aspects of the model. A group mailing list has been established by the U.S. Geological Survey's Environmental Management Technical Center to facilitate communication among model users:
umrs-aea@emtc.nbs.gov

Scenario Development

Workshop participants identified a range of scenarios that they would like to explore using the UMR AEA simulation model. They emphasized the importance of exploring a full range of alternatives, noting that the computer model permits low-risk, low-cost experimentation because it does not require commitments to any alterations in the physical world.

The scenarios described below represent general categories of management alternatives identified by participants. In all of these scenarios, a suite of indicators would be examined. These indicators might include changes in pool volume, time required to reach sediment equilibrium, vegetation changes, habitat suitability plots, economic flood damage reductions, dredging costs, recreational boating, and fishing. Using the model to explore any specific scenarios would involve manipulating a few key inputs while holding a large number of other variables constant.

- Basin scale modifications of land use affecting input of nutrients and sediments — would attempt to determine how surrounding land use practices would affect aspects of water quality and sediment patterns in the river.

- Pool drawdowns — water level manipulation to restore more natural variation in water levels through seasonal changes in stage height. Potential manipulations include a summer drawdown to dry out sediments and promote plant growth, and a fall increase in water levels to flood low-lying areas so fish and waterfowl have access to new plant growth.

- Reduction of flood impacts — would attempt to use a variety of floodplain management regulations and physical structures to moderate flood impacts to developed areas.

- Extremes — could remove all river regulatory structures to examine restoration options, or could significantly increase river regulation to support increased channel depth.

- Physical modifications — variations include increasing spatial diversity by island construction; adding, removing, or notching training structures and levees; dredging channels deeper; partitioning pools into more management units; and creating nutrient and sediment trapping structures.

- Improved shipping efficiency — could include modifications to tows and barges, alternative lock schedules, and larger locks.

FUTURE WORK AND NEXT STEPS, *Phase II*

As described earlier, the AEA project for the Upper Mississippi River has two objectives. Considerable progress has been made in the first objective - i.e., developing an integrated science-based understanding of the river as a natural system. Computer simulation models at both a pool and river system scale have been developed and reviewed by participants representing a wide range of perspectives and expertise. Participants in the January 1997 workshop recommended that the UMR AEA go forward to the scenario exploration phase after some additional modifications to the model are completed. Phase I, the scoping of the problem and model development, is now complete.

The next steps in the AEA process will explore alternative ways of reconciling the competing demands made of the Upper Mississippi (Figure 7). Development of restoration options must be articulated and explored. As testing of the river system and pool models proceeds, understanding will grow. The process must balance precision with relevance — i.e., the river system is far too complex to capture entirely on any computer, so we must confine ourselves to attempting to model the most important factors in the key river processes and uses. The goal of scenario building is sustainability. Sustainability is multi-faceted and each individual has a unique weighting that he or she assigns to various ecological, economic, and social issues. AEA attempts to provide truly open access to information and devices to use information. All vested interests are asked to contribute.

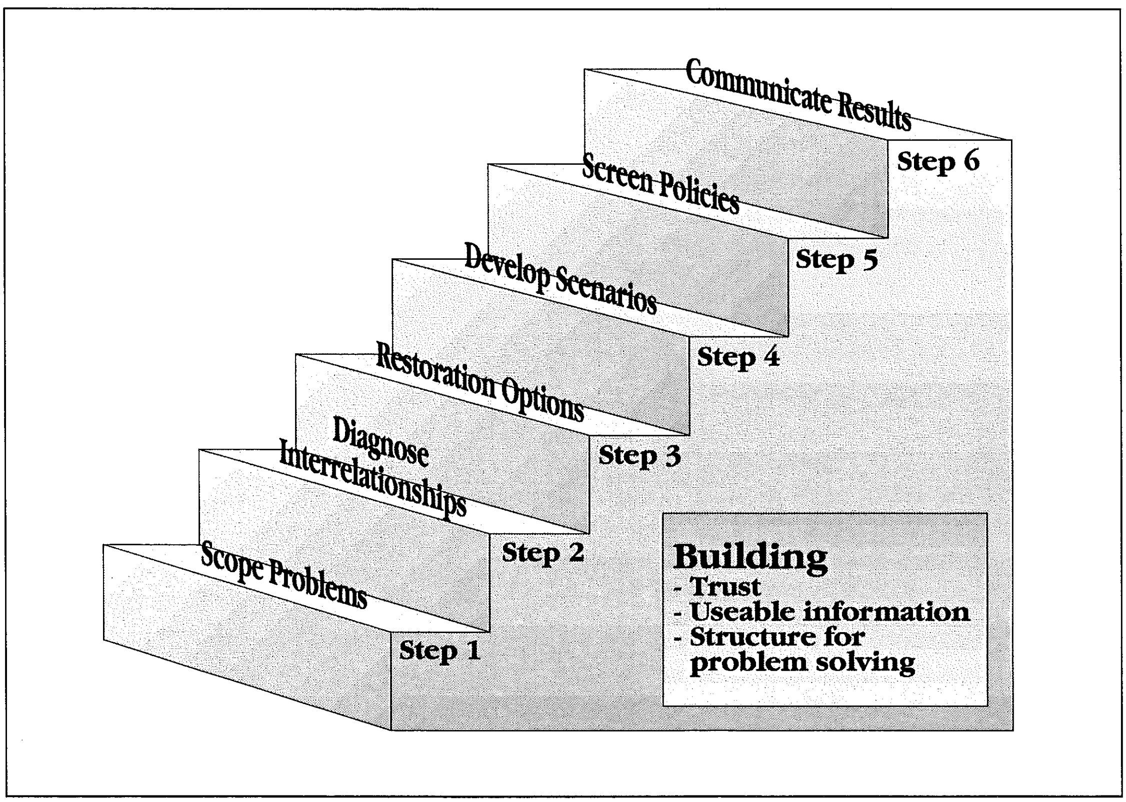
In Phase II, the AEA process focuses on learning that sharpens distinctions and builds clarity as it begins to probe for flexibility and irreversibilities. Alternative ways of solving the river puzzle are examined. Participants will identify policy and management options that achieve social, economic, and ecological goals. In the end, no single solution will emerge. Instead, several composite solutions drawn from a variety of ideas are recognized, but the real product consists of shared insights and understanding.

The Phase II workshops will help build relationships and dialogue that span methods, disciplines, and institutions. Scenario development is a tool for helping the river community take the long view in a world of considerable uncertainty, building deep and realistic confidence based on insight into possible outcomes of our choices. Key steps in Phase II will include:

- identification of central economic, ecological, and social issues or decisions we face in the foreseeable future on the UMR;
- identification of key regional factors influencing the success or failure of these decisions or issues;
- identification of national and international driving trends that could influence key regional factors;
- ranking key factors and driving trends on degree of importance and uncertainty;
- selecting sound reasons for how key economic, ecological, and social variables and interrelationships will change in the future;
- elaborating on scenarios; and
- exploring implications of alternative scenarios, including vulnerabilities and robustness of scenarios.

Figure 7

Steps in the Process—Adaptive Environmental Assessment



Attachment 1

Additional Reports Related to
UMR AEA Phase I

Adaptive Environmental Assessment, December 5-7, 1995 Scoping Workshop Evaluation Summary

Upper Mississippi River Basin Adaptive Environmental Assessment and Management, Workshop 1 Report, February 1996

User's Guide to the Adaptive Environmental Assessment Models Developed for the Upper Mississippi River, January 1997

Adaptive Environmental Assessment, January 15-17, 1997 Workshop Evaluation Summary

(Note: Copies of these reports are available from the Upper Mississippi River Basin Association, 415 Hamm Building, 408 St. Peter Street, St. Paul, MN 55102, 612-224-2880.)

Attachment 2

UMR AEA Workshop 1 Participants
December 5-7, 1995

Allen Anderson
Harvest States Cooperative

Phil Baumel
Iowa State University
Department of Economics

Ron Benjamin
Wisconsin Department of Natural Resources

Adele Binning
Science Museum of Minnesota

Greg Cope
National Biological Service
Upper Mississippi Science Center

Mike Davis
Minnesota Department of Natural Resources

Barry Drazkowski
National Biological Service
Environmental Management Technical Center

Jon Duyvejonck
Upper Mississippi River Conservation

Jim Eckblad
Luther College
Department of Biology

Jonathan Ela
Sierra Club
Midwest Office

Susen Fagrelius
Susen Fagrelius & Associates

Jim Fisher
Upper Mississippi River National Wildlife and Fish Refuge

Bill Franz
U.S. Environmental Protection Agency, Region 5

Calvin Fremling

Bob Gaugush
National Biological Service
Environmental Management Technical Center

Mike Griffin
Iowa Department of Natural Resources

Lance Gunderson
University of Florida

Jon Hendrickson
U.S. Army Corps of Engineers
St. Paul District

Barry Johnson
National Biological Service
Upper Mississippi Science Center

Steve Johnson
Minnesota Department of Natural Resources
Division of Waters

Dennis King
Chesapeake Biological Laboratory
University of Maryland

Vern Knapp
Illinois State Water Survey
Sediment and Wetland Studies Office

Jim Knox
University of Wisconsin-Madison

Josh Korman
Ecometric Research, Inc.

Dan Krumholz
U.S. Army Corps of Engineers
St. Paul District

Richard Lambert
Minnesota Department of Transportation
Ports and Waterways

Tom Lange
Missouri Department of Natural Resources

Jerry Leenheer
U.S. Geological Survey

Steve Light
Minnesota Department of Natural Resources
Office of Planning

Sandra Martin
U.S. Army Corps of Engineers
Waterways Experiment Station

Dave McConville
Resource Studies Center
St. Mary's University

Dan McGuiness
Minnesota-Wisconsin Boundary Area Commission

Curt Meeder
U.S. Army Corps of Engineers
St. Paul District

Terry Moe
Wisconsin Department of Natural Resources

Barbara Naramore
Upper Mississippi River Basin Association

Ron Nargang
Minnesota Department of Natural Resources

Dennis Neffendorf
Natural Resources Conservation Service

Garry Peterson
University of Florida

Marc Schultz
University of Wisconsin Extension
La Crosse County

Richard Sparks
Illinois Department of Natural Resources
Illinois Natural History Survey

Holly Stoerker
Upper Mississippi River Basin Association

Norm Stucky
Missouri Department of Conservation

Don Sweeney
U.S. Army Corps of Engineers
St. Louis District

Pam Thiel
U.S. Fish and Wildlife Service
La Crosse Fishery Resources Office

Stan Trimble
University of California Los Angeles
Department of Geography

Carl Walters
University of British Columbia

Gary Wege
U.S. Fish and Wildlife Service
Twin Cities Ecological Services Field Office

Keith Wendt
Minnesota Department of Natural Resources
Office of Planning

Attachment 3

UMR AEA Workshop 2 Participants

January 15-17, 1997

Terry Becker
Riverway Barge and Towing

Ron Benjamin
Wisconsin Department of Natural Resources

Adele Binning
Science Museum of Minnesota

Mike Davis
Minnesota Department of Natural Resources

Barry Drazkowski
Resource Studies Center
St. Mary's University

Jon Duyvejonck
Upper Mississippi River Conservation Committee

Jim Eckblad
Luther College
Department of Biology

Jonathan Ela
Sierra Club
Midwest Office

Susen Fagrelius
Susen Fagrelius & Associates

Jim Fisher
Upper Mississippi River National Wildlife and Fish Refuge

Cal Fremling

Bob Gaugush
U.S. Geological Survey
Environmental Management Technical Center

Mike Griffin
Iowa Department of Natural Resources

Lance Gunderson
University of Florida

Dudley Hanson
U.S. Army Corps of Engineers
Rock Island District

Jon Hendrickson
U.S. Army Corps of Engineers
St. Paul District

Barry Johnson
U.S. Geological Survey
Upper Mississippi Science Center

Scot Johnson
Minnesota Department of Natural Resources
Division of Waters

Josh Korman
Ecometric Research, Inc.

Carl Korschgen
U.S. Geological Survey

Dan Krumholz
U.S. Army Corps of Engineers
St. Paul District

Dick Lambert
Minnesota Department of Transportation
Ports and Waterways

Jerry Leenheer
U.S. Geological Survey

Steve Light
Minnesota Department of Natural Resources
Office of Planning

Ken Lubinski
U.S. Geological Survey
Environmental Management Technical Center

Dave McConville
Resource Studies Center
St. Mary's University

Dan McGuiness
Minnesota-Wisconsin Boundary Area Commission

Sandra Martin
U.S. Army Corps of Engineers
Waterways Experiment Station

Curt Meeder
U.S. Army Corps of Engineers
St. Paul District

Terry Moe
Wisconsin Department of Natural Resources

Barbara Naramore
Upper Mississippi River Basin Association

Lee Nelson
Upper River Services, Inc.

Kent Pehler
Brennan Marine

Bernie Schonhoff
Iowa Department of Natural Resources

Marc Schultz
University of Wisconsin Extension
La Crosse County

Richard Sparks
Illinois Department of Natural Resources
Illinois Natural History Survey

Holly Stoerker
Upper Mississippi River Basin Association

Norm Stucky
Missouri Department of Conservation

Pam Thiel
U.S. Fish and Wildlife Service
La Crosse Fishery Resources Office

Stan Trimble
University of California Los Angeles
Department of Geography

Carl Walters
University of British Columbia

John Wetzel
Wisconsin Department of Natural Resources

QH 104.5 .M5 U66 1997

Upper Mississippi River
adaptive environmental

DATE	ISSUED TO

For further information, contact:
Upper Mississippi River Basin Association
415 Hamm Building
408 St. Peter Street
St. Paul, MN 55102
Telephone: 612-224-2880
or contact:
Steve Light
Minnesota Department of Natural Resources
Office of Planning
500 Lafayette Road
St. Paul, MN 55155
Telephone: 612-296-9228