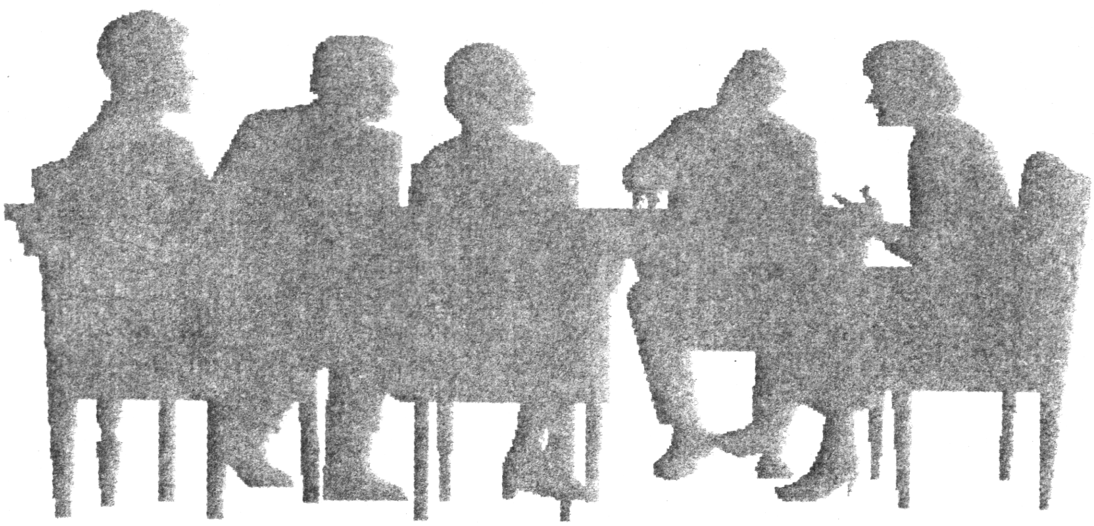
Second
Science Review Committee Report
on the Long Term Resource Monitoring Program - Environmental Management Technical Center

presented to
United States Department of the Interior
Biological Resources Division, United States Geological Survey
Environmental Management Technical Center
Onalaska, Wisconsin



December 31, 1996

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January 17, 1997

Mr. Robert Delaney
Director, Environmental Management Technical Center
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Dear Bob

I am pleased to submit to you the intended final version of the 1996 Science Review Committee Report. There are only minor changes from the draft which I sent on December 31, 1996, so I have not altered the report date. The changes are that some typographical errors have been detected and fixed, a table of contents has been added, the first two pages of the Executive Summary have been rewritten to make them more clear to readers outside EMTC and, finally, the trailing seven words of the secondary statement in Recommendation 6 have been deleted. There is no substantive significance at all to this last correction. They seemed to be expendable words, and I had to save a line of type in order to avoid a very awkward page break.

I think it is fair to say that the Committee takes some pride in the report and I hope that you, your staff, and your Management Committee will find it valuable in your management of the program. I hope that the report signals clearly the Committee's sense that this is a challenging and essential program that is moving effectively to meet its mandate, and that this will be a help to you.

Please contact me, or other members of the Committee, if you see that we can be of further help to your program.

Yours sincerely

Michael Church

Michael Church
1996 SRC Chair

cc. SRC Committee members

LTRMP/EMTC Second Science Review Committee Report

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EXECUTIVE SUMMARY

This is the report of the Science Review Committee (SRC) which visited the Environmental Technical Management Center (EMTC) on November 18-20, 1996. The Committee's charge is to review the scientific activities of the Long Term Resource Monitoring Program (LTRMP) in the Upper Mississippi River Basin (UMRB). This is an appropriate time for the review because the first 5-year trend analyses have just been completed. The Committee found that the nine recommendations of the 1990 SRC have been conscientiously implemented with a high level of success. Noteworthy achievements that support the scientific activity include the development of the Computerized Information and Analysis system (CIA), external communications, and the level of cooperative activity that has been established. Continuing attention is needed to the advice of the 1990 Committee to analyze the UMRB system over a range of space and time scales, and to thoroughly examine historical data resources.

The present SRC has reviewed the legislative mandate and the social context of the LTRMP and concludes that the primary focus must be placed on the detection of trends in the entire UMRB system. Knowledge of these trends is needed to properly inform the policy debate and management of the system. Measurements need to be made of the fluxes of water, sediments and contaminants through the entire river system in order to understand more local ecosystem processes. The current monitoring effort is focused on local physicochemical and ecological sampling within certain pools. These local observations are important for understanding the structure and function of riverine ecosystems and to establish the magnitude and pattern of local variability.

Some changes are needed in the monitoring framework in order to expand from understanding the local level to understanding the entire system. System-wide trends will be measured over periods of a decade or more. Consideration should be given to selecting new sites for study so that eventually most or all pools and reaches in the system are observed. A rotation of intensive study sites can be set up so that pools and reaches are studied intensively for 3 to 5 years, then effort is transferred to other areas. After the lapse of a decade or more, the intensive effort returns to the original study sites to determine whether or not conditions have changed. Long term trends can also be studied by comparing current observations with historical data sets. Valuable efforts are being made within the CIA program to recover information on historical land use and river configuration. Similar efforts need to be made using historical information on water quantity, quality, and aquatic ecology.

Sampling protocols and methods for the pool studies are well established. The laboratory procedures for data quality assurance, quality control and information control are particularly effective. The staff is well aware that trend analysis of the current field data will permit optimization of further sampling effort. The SRC recommends that the EMTC senior staff place a high priority on analytical activities. The SRC remains concerned that much of the field sampling appears to be focused on obtaining only a few closely related measures at any one time. For example, limnological measurements and biotic sampling appear not to be simultaneous. Strong diurnal and synoptic variability may substantially interfere with analyses made from non-coincident data. Statistical methods also deserve close scrutiny. There appears to be a deliberate effort to organize observations to meet the requirements of advanced parametric methods with stringent control requirements. However, many environmental data cannot meet parametric completeness or distribution assumptions. Historical data almost certainly will not meet such assumptions. The SRC recommends that attention be paid to non-parametric methods within the context of a "clinical" approach to sampling and analysis.

Communications are a key aspect of any mandated program. The external technical communications of the LTRMP group appear to be at a high level, but there appear to be needs for increased internal communications to optimize scientific efforts. The role of cooperating scientists from partner agencies and from regional colleges and universities is a particular strength of this program. These people expand the number of active scientists well beyond the number of the core staff, and provide important sources of background information and communication routes to the larger public. The provision of data resources from the Center via the Internet is a pioneering achievement. The SRC reminds the Center that traditional written communications remain important for the general public and for many resource managers. The SRC is concerned that the data records of the program continue to be published on paper because rapid technological change can make electronic storage media obsolete over periods of decades.

The Committee was invited to consider the prospects for continued monitoring of the UMRB beyond the current legislative mandate. The SRC recommends that the program be continued, and that any reauthorization take into account what has been learned already. In particular, processes and activities throughout the basin influence the riverine system, and the program should be authorized to study these influences. The UMRB is a large and nationally significant system which continues to change over long periods of time. Public policy decisions about the system will be shaped both within and outside traditional agencies. The EMTC staff has established an excellent information base for current and future decision making. The LTRMP provides information on physical and ecological processes at the landscape scales and, over time, will be able to provide information for regional land management. These capabilities have been achieved by effective cooperation among several federal agencies and five state partners, so that problems which span several political and administrative units may be tackled efficiently.

Following are the 16 recommendations of the current SRC. These are repeated at the end of the report with a small number of additional contextual remarks.

Strategic recommendations: the structure of the program

1. There must be increased emphasis on studies at the systemic scale and on the upstream-downstream connections that make the river system what it is. As the first step, a box-cascade model of the river system should be articulated within the guiding conceptual model and used as the basis for implementing this approach to the system.

2. A detailed quantification of inputs to the river system must be conducted to reveal the basin and watershed influence on the river, and help to identify basin problems that need to be addressed to help to maintain and improve river conditions. An increased emphasis should be placed on viewing the UMR system as a single, integrated system, which means devoting more attention to the reach, river and basin scales. This is essential and is not inconsistent with the clear intent of the legislation, even though the legislation directs primary attention to the river itself.

3. Increased emphasis must be placed on lengthening the time horizon of observations, particularly by seeking and using historical records. This is the only way in which long-term trends will be discerned in less than one or two more decades, and we doubt that either the Congress or the public will be willing to wait so long for a first assessment of changes in the UMRB.

4. To further ensure that the research conducted at EMTC will meet the mandate of the UMRB program, adapt the conceptual model to explicitly show that the impacts of management changes in the system will be evaluated in terms of multiple sets of societal goals and values, and that the scientific information necessary to achieve these evaluations will be secured. In short, incorporate social context into the conceptual model.

Operational recommendations: data collection and analysis

5. Increased attention to hydrographic, morphometric and sedimentation data is necessary to understand the river system. These characteristics drive the system yet they are receiving comparatively little attention. Model approaches can be helpful but even they are limited to available data. The association of a geomorphologist and/or sedimentation specialist with the program may be helpful in this regard.

6. There is no distinction between monitoring and data analysis; they must both be conducted to answer questions. Hence, the analysis of data should be stressed, along with the collection of data. Within the LTRMP, there should be increased and continuous analysis of data collected and comparisons with historical conditions to guide and prioritize future sampling.

   The "why" of each data collection effort must be obvious, so there needs to be a strong linkage between collection and analysis. Justifying or modifying further data collection effort in light of the results of analysis is also an opportunity to effect economies in the program.

7. It is necessary to use survey sampling and clinical statistical methods to better analyze the sampling efforts on both the spatial and temporal scales. This will help validate the approach, and help to prioritize sampling collection efforts based on input to analysis procedures. To facilitate this work, it would be desirable to associate with the program a statistician who is very familiar with clinical and survey sampling approaches using nonparametric and multivariate methods.

8. Place increased emphasis on simultaneous collection of limnological data with fish and vegetation sampling in order to facilitate analyses that will answer critical questions. Limnological sampling should include additional cations and anions, and sediment sampling.

9. Consideration should be given to a NAWQA-type approach to long-term monitoring that will sample pools intensively for 3-5 years each on a rotational basis, with an ultimate focus on systemic conditions.

A temporally staged pattern of sampling, such as this, may be the only practical way to obtain sufficient data to distinguish system-wide and local long-term trends in the face of significant short-term variability and the large geographical area.

10. The CIA/GIS/photointerpretation and remote sensing efforts appear excellent and should be continued, with additional attention to recovery of data of historical conditions. Other research can be facilitated by making additional use of the data resources provided by this program. This area of emphasis may require additional laboratory space in the Center.

Recommendations about communications

11. It is desirable to foster further in-house cooperation and sharing of resources and results. This will be essential to achieve the central goal of analyzing the status and trends of the river system in a holistic way.

12. It is desirable to further cooperative efforts with local, state and federal agencies. This is to share resources, to facilitate communication and to foster image. Include explicit consideration of what interest groups can best articulate the various goals that may be used to guide the Center's activities. Explicitly incorporate contacts with these groups into the science advisory process.

13. Volunteers may be appropriate for certain data collection activities and would be an effective way of involving the wider public directly in the program.

14. A book series of data reports (as USGS Open-File Reports or similar series) should be inaugurated, describing methods and error analyses as well as listing all the monitoring data, to provide assurance of continued accessibility of the data long after the program has ended. Consider the same approach to publishing research analyses.

Recommendations about the future

15. The Science Review Committee should meet in the next eighteen months to further evaluate the scientific efforts. This review should be held during the growing season to facilitate a limited amount of field evaluation of data collections and sites.

16. In re-authorizing this Program, Congress should consider expanding the scope of the effort to include scientific modeling of the relationships between human and natural activities in the entire UMR drainage basin as they affect the ecological status of the designated river reaches. Conditions in the river cannot be separated from conditions in the drainage basin that sustains it.

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INTRODUCTION

The Science Review Committee was convened in Onalaska, Wisconsin, on November 18-20,1996, to evaluate the quality of scientific efforts in the Long Term Resource Monitoring Program (LTRMP) of the United States Geological Survey's Environmental Management Technical Center (EMTC). Completion of the first five-year period of full monitoring activities represents, for the Center, an appropriate time to conduct such a review. Descriptive materials were provided to the SRC before the site visit was held. Additional written materials, a laboratory tour and oral presentations by Center staff were provided during the site visit. The following report and recommendations have been developed from these materials and presentations, and the scientific expertise of the SRC members.

The SRC wishes to thank the Staff of the EMTC for an informative and interesting visit. In particular, we thank Center Director Robert Delaney for hosting our visit and for his organization of the review, and all the presenters for their thorough discussions. We also thank Linda Ott and Gloria Bina-Sampson for coordinating the logistics of the visit.

The report is organized as follows. We first give a definition of the program, in which we review the mandate and discuss the context of EMTC activities. The purposes of this section are to inform "external" readers of the report and to clarify the understanding that the SRC has developed about the essential purpose and context of the program. That understanding provides the basis for our recommendations about the program. We then provide comments on current progress in the EMTC program, giving particular attention to a review of the recommendations from the 1990 SRC. The SRC's analysis and critique of the scientific work of the Center follows in two sections. In the first we define the Upper Mississippi River Basin (UMRB) as we see it, for this provides the key to how we believe the system should be studied scientifically. This leads to some "strategic" recommendations for the program. Then we review sampling and analyses of the system as conducted in the LTRMP; this section contains the kernel of our detailed recommendations. Because communications, both internal and external, are a critical element of the program, we consider communications in a separate section. The penultimate section discusses some long-term issues related to science and the management of the Upper Mississippi River basin. This discussion gives the SRC's vision for the period beyond the currently mandated program. Our recommendations for the Center are gathered together in the final section.

This report presents the independent views of the Science Review Committee. In particular, our interpretations of program mandates and objectives are our own and do not necessarily reflect the views of the United States government or of the participating state governments, nor of their agencies.

PROGRAM DEFINITION

The Long Term Resource Monitoring Program operates under direct legislative mandate. It is designed to respond to the needs of multiple public interests, it must integrate multiple scientific disciplines whilst maintaining scientific integrity, and the scientific results must be interpreted for policy makers. In order to accomplish these goals with limited resources, the LTRMP must continue to develop partnerships with other federal, state, local, and non-governmental agencies.

Legislation

The legislation providing for the LTRMP and the computerized inventory and analysis (CIA) system is Section 1103, Upper Mississippi River Plan, of the Water Resources Development Act of 1986 (P.L.99-662). The section was amended by Section 405 of the Water Resources Development Act of 1990 (P.L.101-640) to provide a 5-year extension of the Upper Mississippi River System Environmental Management Program (from 10 to 15 years). It was amended again by Section 107 of the 1992 Water Resources Development Act (P.L.102-580) to clarify the extension from 10 to 15 years, and to allow some reallocation of funds between programs. The following are relevant excerpts from the 1986 law.

(a) (2) To ensure the coordinated development and enhancement of the Upper Mississippi River System, it is hereby declared to be the intent of Congress to recognize that system as a nationally significant ecosystem and a nationally significant commercial navigation system. Congress further recognizes that the system provides a diversity of opportunities and experiences. The system shall be administered and regulated in recognition of its several purposes.

(b)(1) the terms "Upper Mississippi River system" and "system" mean those river reaches having commercial navigation channels on the Mississippi River main stem north of Cairo, Illinois; the Minnesota River, Minnesota; Black River, Wisconsin, Saint Croix River, Minnesota and Wisconsin; Illinois River and Waterway, Illinois; and Kaskaskia River, Illinois;

(2) the term "Master Plan" means the comprehensive master plan for the management of the Upper Mississippi River system, dated January 1, 1982, prepared by the Upper Mississippi River Basin Commission and submitted to Congress pursuant to Public Law 95-502;

...

(e)(1) The Secretary [of the Army], *in consultation with the Secretary of the Interior and the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, is authorized to undertake, as identified in the master plan--*

(A) a program for the planning, construction, and evaluation of measures for fish and wildlife habitat rehabilitation and enhancement;
(B) implementation of a long-term resource monitoring program; and
(C) implementation of a computerized inventory and analysis system.

These three activities can be referred to as the habitat rehabilitation and enhancement projects (HREP), the long term resource monitoring program (LTRMP), and the computerized inventory and analysis system (CIA). The legislation also provides authorization for the construction of a second lock at lock and dam 26 at Alton, Illinois and Missouri. Funding of these environmental management programs was thus connected to the funding of the lock and dam.

The presentations to the Science Review Committee revealed that the staff have interpreted the mandate for these studies to focus on "river reaches" as identified in the legislation. The operational definition of these river reaches encompasses the valley floor (floodplain) area between the rocky bluffs that are common along the Mississippi and the other major rivers. This definition and interpretation have thus excluded research on the uplands, even though upland activities contribute to the ecological changes in the river reaches.

Social Context

When Congress declared the Upper Mississippi River System to be a "nationally significant ecosystem and a nationally significant commercial navigation system," it recognized that there are multiple social goals for the management of the area, and the goals may at times be in conflict. In the abstract, natural and human resources should be managed for "the public good", but such a concept is difficult to describe in the abstract. An actual management program deals with real people, and it is useful to consider groups of people as advocates for particular social goals. The social context for the LTRMP includes federal, state, and local governments, and non-governmental business, environmental and recreational interest groups.

The US Army Corps of Engineers (COE) is an important federal agency affecting the rivers. It is responsible for the construction and maintenance of the navigation system, including locks and dams and channel maintenance, and it is traditionally responsive to the commercial navigation interests. In recent years, the Corps has become more sensitive to environmental interests, and it is responsible for funding the LTRMP and related programs. The Department of the Interior, through the US Geological Survey's Biological Resources Division, conducts the research and monitoring programs.

The state governments are direct participants in the implementation of the Upper Mississippi River Management Act of 1986. The states have participated in funding the basic monitoring and research, and also have departments for environmental management and fish and game management. Local government interests include promotion of tourism, recreation, and landscape aesthetics. Management by local governments includes planning and zoning, maintenance of waterfront and provision of access facilities, and public education.

Public recreation focussed on the river has been estimated to contribute approximately $1.2 billion of economic activity in the region each year, including fishing, boating, swimming, and hunting. Major commercial activities within the basin that influence river ecology may have advocacy groups. These include interests in navigation, agriculture, and forestry. Issues articulated by environmental groups are concerned with preserving the river and maintaining biodiversity, including prevention of extinctions or extirpations.

Scientific Requirements

Through the LTRMP and related programs, Congress recognized that scientific study of the system and of the relationships between human and natural processes in the area will be beneficial for supporting management of the area. Scientific study is based on observation and measurement, but it is not possible to measure everything everywhere. All sciences base their methods on some form of sampling. An essential scientific activity is to design a sampling program that provides knowledge of the fundamental processes and leads to prediction of all essential relationships, by the least expensive and least intrusive observations.

A fundamental constraint for observing complex systems is that processes occur at many spatial and temporal scales, which mutually influence each other. The staff of the EMTC recognize a hierarchy of spatial scales, including basin, river, reach, pool, and site. Most of the activity in the LTRMP to date has been at the pool and site levels. Some activity has characterized the reaches, but there has been virtually no activity at the levels of the river and the basin. Accordingly, time scales of interest, principally seasonal and annual, have been mainly those which characterize the major variable ecosystem elements at sites and in pools. Observing and sampling methods have been specified accordingly. But different methods are needed for observing at different scales. The implications of these observations are taken up in later sections of this report.

Policy Planning Context

The primary scientific goal should be to articulate a model of the system that is the best scientific description of the system. In mandated science, this must be done in a way that responds to the information requirements of people charged with setting public policy. Policy evaluators should look beyond current societal goals and methods of implementation, and see opportunities for substantial changes. This may lead to conflicts amongst different groups of people. When the goals articulated by different public interest groups are in conflict, it is not the role of scientists to resolve these conflicts, but it is important that they educate the public about the underlying behaviors of the system, and about the implications for system behavior of alternate policies. Therefore, the scientific activity must remain close enough to the policy and management processes to be relevant and able to inform policy and management, but also remain sufficiently distant to be objective.

An overall societal goal is to reduce unproductive conflicts (resulting, for example, in lawsuits), and focus society's resources on meeting the goals of the various public interests. This is not quite as simple as achieving the "greatest good for the greatest number"; it often means avoiding catastrophic harm to a few (for example, extinction of a species; a business failure; flooding of a city). Thus, the planning activity must consider how changes in the physical system lead to changes in the biological system which, in turn, lead to changes in elements of the social system. Such changes affect economic allocations, recreation behaviours, and perceptions of intangible values such as "a healthy ecosystem". It is not easy to define "a healthy ecosystem"[1]. Simple measures can be misleading, and if we try to manage for a set of measures that is too narrowly defined, we may find that we have made other changes in the system that are unintended.

For example, a narrowly defined view of the purpose for a management activity might be to "maximize the production of vegetation in a pool." A broader view would include educating the managers and the public to understand that maximizing vegetation doesn't necessarily maximize the biological diversity, or help preserve rare species. Or research could show that vegetation production is indeed a key indicator of fish survival. As another example, it has been observed that islands have been eroded away in the lower pools. One response is to build new islands (and include rock borders so they will not erode away). An alternative is to understand that a shift has occurred in the structure of the system, and that the erosion is part of the evolution of the system. The system may have reached a new steady-state or may be evolving differently than in the past.

Sometimes the public is surprised to return to a spot and find it different than they remembered it years before. Science teaches that there will be changes in the aquatic ecosystems of the Mississippi River Basin. The challenge is to know when these changes reflect human impacts and when they are part of natural changes. When human impacts are identified and it is decided that they are, in some sense, adverse, it must be determined whether it is possible and cost-effective to remove or reduce the causes, or to attempt directly to modify the affected resource. Effective scientific models of the system will allow better understanding of natural and forced variability and trends, and better prediction of the results of attempts to modify resources. The EMTC is well suited for this type of work, and has already accomplished notable results, particularly in documenting physical conditions and the status of plants, benthos and fishes within certain pools.

The ecosystems connected to the Mississippi River are dynamic and cyclic. They are naturally adapted to synoptically and seasonally varying weather and streamflows, and they are modified by the effect of longer term trends. When people have been flooded, the consequence of an extreme synoptic event, they regard floods as bad. But managing the ecosystem for the one goal of avoiding floods is not necessarily appropriate for other components of the ecosystem. Control of water levels by dams has reduced natural cycles of water flow and level. For species that require flooding of backwater lakes for reproduction, lack of a flood cycle may be fatally important.

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1. In particular, it is not amenable to strictly scientific definition. D. Ehrenfeld (1992) has called it a "bridging concept", one that is not operational within science, but which can nevertheless be helpful in communicating with non-scientists: "if used with care in ecology, it can enrich scientific thought with the values and judgements which make science a valid human endeavor".

Oral presentations to the SRC included observations that changes in water levels or construction of artificial islands can possibly mitigate some of the effects on aquatic plants and animals caused by construction of the lock and dam system. This leads directly to a policy issue. The conceptual plan should include explicit representation of how research on the effects of these actions can feed back into policy discussions about management of the system. As new linkages between subsystems are discovered (e.g., a linkage between upland agricultural practices and aquatic plant response), the conceptual model should be expanded to portray the linkage.

We cannot manage a system unless we have a realistic model of the system. For the UMRB, we need good models of the physical and biological processes. We must recognize that humans are part of the UMR System. A model that serves management ends well must acknowledge human activities and intentions. The LTRMP is mandated to provide scientific information for planning and management purposes. For managing the LTRMP we also need a good model of the social context within which the research program operates.

PROGRESS OF THE EMTC PROGRAM

Recommendations of the 1990 Science Review Committee

A Scientific Review Committee visited EMTC in June, 1990, when the Long Term Resource Monitoring Program for the Upper Mississippi River Basin was still being shaped. That Committee made nine recommendations designed to ensure that the program would generate front rank science as well as remaining firmly focussed on its mandated objectives. The need for scientific excellence in the Program is well summarized in the epigram of the EMTC; "providing sound science for better management". The present Committee was asked to review how well the recommendations of the 1990 committee have been implemented. In the following, the 1990 recommendations are repeated in italics.

1. *A general conceptual model of the UMRB is essential to serve as a basis for project planning, problem identification, hypothesis formulation, resource allocation, and scientific synthesis at all pertinent spatial and temporal scales.*

2. *The LTRMP research group must recognize the importance of examining and linking different spatial and temporal scales in project design, data analysis and information synthesis. A spatio-temporal perspective that recognizes the existence of multiple scales is critical to understand and manage the riverine-floodplain system.*

These two recommendations are closely connected. Their purpose was to ensure that the LTRMP recognize, incorporate and relate all environmental phenomena that impact the river and region, even though many of them operate outside the space and time scales defined in the mandate. The LTRMP research group made the development of a conceptual model a priority. It was presented in LTRMP Technical Report 93-T001 (Lubinski, 1993), and was reviewed for the present Committee. It is clear that recommendation 1 has been implemented. The model incorporates the necessary concepts to achieve recommendation 2 as well. It is not clear, however, that the implications of multiple spatial and temporal scales in the conceptual model have been fully incorporated into the monitoring and research activities of the Program (see below for further discussion).

3. *More emphasis must be placed by the project leader on achieving a holistic understanding of the UMRB by assuring that the translation of project results proceeds in a timely fashion from primary data to topical summary findings to whole project syntheses.*

Implementation of this recommendation is evident in the large number of topical reports that have been released since 1990. More fundamentally, the Annual Work Plan has in each year been a substantial document which reviews and synthesizes progress as the basis for defining the new year's work. Of greatest significance, however, is the current production of a series of 5-year trend reports, summarizing the analysis of data recorded during the first 5-year field phase of the project. This suite of activities indicates the dedication of the Center to carrying out this recommendation. We remind the Center Director, however, that the trend reports must in turn form the basis for a "state of the system" report in order to complete the cycle of monitoring, statistical analysis and synthesis, and to provide a report which will be most directly useful to the larger community along the Upper Mississippi River.

4. *The LTRMP must place a high priority on integrating its personnel and its finding with the broader scientific community, including; 1) structuring research in the context of extant scientific literature, 2) publishing the findings in peer reviewed literature, 3) participating in national meetings of scientific societies, and 4) developing a modest program of competitive extramural support for collaborative research.*

The purposes of this recommendation were to ensure that LTRMP staff are in command of the most current scientific concepts and methods, and to obtain authority for the scientific results through peer review and acceptance. The recommendation has been followed conscientiously. In particular, a substantial number of reports have been delivered at scientific and management conferences. The Center notably organised a major international meeting "Sustaining the ecological integrity of large floodplain rivers", held at Lacrosse, Wisconsin, in July, 1994. Papers from the meeting have been published as volume 11 of the international journal *Regulated Rivers: Research and Management*. The recommendation that EMTC scientists publish information more generally in scientific journals also appears to have been followed; 51% of recent report production is either technical reports or journal reprints. The Center has not established a competitive grants program. This decision follows the advice of the Management Review Committee, which observed that adjudication of applications would add a substantial administrative burden. Instead, cooperation and contract arrangements have been vigorously pursued with members of regional colleges and universities, and with state agencies. A substantial portion of the published technical reports (including the reprint series) derive from such collaborations. Consequently, the spirit of the recommendation, to connect the program firmly to professional environmental science activities, appears to have been fully met.

5. *LTRMP leadership must develop a logical and objective rationale for prioritization of project resource allocation among competing subprojects. This rationale must be derived from the general conceptual model that guides the entire project.*

It is clear that a conscious attempt has been made to effect this recommendation, and it clearly is at the forefront of the senior members' minds as resources, in general, become more precious. The degree to which the attempt has been successful is reflected in the balance of activities in the current program, about which comments are made throughout this report.

6. *There is a need for a coherent long-range information management plan to guide the CRIC* [= CIA] *program.*

7. *The great importance of retrospective data must be recognized, and procedures developed for systematic review in order to incorporate relevant data into the information base of the project.*

Recommendation 7 is a particular aspect of recommendation 6. The long-range information management plan, extending from the information control associated with sample data acquisition through provisions to deliver information to customers, is arguably the single most impressive feature of the current Center. Recommendation 6 certainly has been achieved. The information system contains provision for covering recommendation 7. Some retrospective data sets have been recovered and analyzed (cf., for example, Report 95-T001, "Analysis of Water Level Management on the Upper Mississippi River (1980-1990) (Wlosinski and Hill, 1995a); Wlosinski and Hill, 1995b). It appeared to the Science Review Committee, however, that there remains a lack of consensus amongst the scientific staff about the priority to be assigned to recovery of retrospective data. We suppose that this is closely related to the relative lack of emphasis given to varying time scales in the conceptual model. We address this matter further below.

8. *Staff size and expertise must be expanded to address additional research needs implied by the general conceptual model and to exploit more adequately the relevant bodies of techniques and methodologies.*

This recommendation has certainly been met insofar as staff numbers are concerned. Only two of the present scientific staff were on site at the time of the 1990 Scientific Review. We were somewhat surprised, however, to discover that all of the senior scientific staff are by training ecologists. Whilst ecology undeniably constitutes the central scientific discipline within the project, it is not obvious that all the methodologies and relevant bodies of technique that must be considered are best covered by this complement. On the other hand, it presumably minimizes problems of internal technical culture and communication, which is a significant concern in a large project. It remains important, though, to incorporate all available environmental information into analyses of the state of the UMRB, consequently that the project make use of physical perspectives as well as ecological ones.

9. *Contingency plans must include provision for scientific study of short-term and extreme events in order to increase scientific understanding of the river system.*

This recommendation has been carried out largely by maintaining some flexibility in the observing programs of the field stations. It apparently has been met. The Center was able to conduct significant special observations during the flood of 1993.

As an overall comment, we should say that the Center has made an impressive attempt to meet the recommendations of the 1990 Scientific Review Committee, and nearly all have been achieved with complete success.

The Center

The practical functions of the Environmental Technical Management Center are overall administration of the LTRM and CIA programs, including coordination of activities with other agency partners; planning and supervising program activities; coordination of the field station programs within LTRMP; central laboratory functions and QA/QC activities related to LTRMP monitoring; providing space and facilities for the Onalaska field station (pool 8); participation in planning and monitoring HREP projects; collection, archiving and distribution of all relevant data within the CIA initiative; conduct of scientific studies within the program, including contracting and cooperative activities; and periodic reporting of program achievements and activities to various agencies and public organizations, and to the regional public at large.

Amongst these activities, the SRC was pleased to learn that the scientific program has advanced to the point that the first status-and-trend reports are being completed, and was particularly impressed to hear the report of activities related to data and information distribution. The automated system of sample information control is both efficient and effective for data recovery. The Center appears to be pioneering effective use of the Internet to distribute data sets, air photographic images, and map products to all interested parties. This is both effective communication and effective public relations. The level of cooperative research activity is also praiseworthy: there are now many more scientists associated with this program than just those in the Center or in the principal cooperating agencies. Many of them, in regional colleges and universities, are also valuable sources of background information and significant communicators of the program's achievements.

EMTC has been located in its own building since early in the program. At this stage, although basic personnel housing seems to be adequate, it is apparent that space for sample treatment, data reduction and archiving is inadequate. In particular, the chemical and biological laboratories, and the photointerpretation/remote sensing/GIS laboratories are undesirably crowded. Indeed, the building appears not to be ideally configured or equipped for some of the laboratory activities (in respect of services, air conditioning, and traffic flow, for example). Physical space problems are of interest to the SRC insofar as they may influence the quality of work.

An important feature of the organization of the Center and of the Upper Mississippi River Basin Program is that they represent a legislatively mandated multi-agency effort to improve the long-range management of a significant region of the United States, defined by its proper physical and ecological boundaries rather than according to administrative or political divisions. Whilst the Center is managed through an individual agency (now the Biological Resources Division of the United States Geological Survey), the program incorporates the efforts of several federal agencies (amongst which the United States Army Corps of Engineers is prominent both because it shares the formal mandate to conduct the program and because of its major support of the program) and five state governments, and receives advice from a wide range of stakeholder groups along the river. In both organization and geographical focus, the program conducted through the Center is an important demonstration of how regional government responsibilities which transgress administrative boundaries might effectively be discharged in the future.

Status of the Program

Although the Upper Mississippi River Basin Program was established in 1986, the first significant funds were received in 1988. Monitoring programs were mainly established in the period 1989-1992. The 1990 Scientific Review Committee urged that continuing analysis of monitoring data be initiated as soon as was practical, and the Management Review Committee further emphasized the need to conduct statistical trend analyses of temporal data in order to evaluate the effectiveness of sampling programs and to identify changes that may be occurring in the river.

The majority of monitoring effort has been organized through the six field stations and expended on measuring physicochemical and biological parameters in a number of pools, with seasonal to annual resolution. The purposes are to identify major functional features of the ecosystem and the controlling physical conditions, and to detect trends in the occurrence and condition of significant elements of the riverine ecosystem. At present, Center scientists are just completing the first sequence of status-and-trend reports, incorporating five years' data. Within the five-year period, many of the scientific staff members were recruited and they have reviewed and improved many of the original sampling protocols. Both for operational reasons, then, and because five years is a very short period on the time scale of the river, no definitive conclusions about trends can be expected from the current review. It nevertheless is important because it will establish the first statement of current conditions in the river, and of our understanding of the structure and function of the system. The data will also be amenable to analyses to identify and eliminate redundancies in data collection, and identify significant gaps, as the Management Review Committee intended.

The monitoring program provides the basic data for scientific studies of the river system. At this stage, then, substantial attention should begin to be focussed on scientific studies of system function and process in the River. It was clear to the SRC that a major question presently faced by the scientific and senior administrative staff is the proper distribution of effort between continued monitoring and scientific analysis. The problem is made difficult by the shrinking real resources to support the program. Appraisal of the data collected to date is a high priority task in order to optimize further monitoring activity. Aspects of this issue will appear throughout the report and recommendations appropriate for a Scientific Review are given at the end.

Another key aspect of the Center's program is the archiving and distribution of the data and information gathered. This function appears to be well organized and adequately supported at present, except that incorporation of data of both contemporary and historical land conditions in the river valley appear to be proceeding more slowly than desirable (because the task is labour-intensive and consequently very expensive). The resources given to this activity must be reviewed in light of the larger strain on resources, but its basic importance should not be doubted.

Within the legislative mandate, and the interpretation placed by the staff on the conceptual model of the UMRB, the program has made major progress since 1990 and is currently well positioned in relation to its goals. Major technical problems related to sampling, data handling and communication have been efficiently overcome. The first five-year period of data collection is complete. The staff is poised to commence major analysis activities.

DEFINING THE SYSTEM

Although management activities along the river are often local in character (as represented, for example, by the decision to expand locking capacity at a specific dam; by the construction of artificial islands in a particular pool; by the establishment of a wildlife refuge in a designated area), the overall social goals are primarily systemic. Therefore policy development and planning start at the systemic level (cf. the enabling legislation) and are later extended to more local levels in order to define specific management actions. A program of scientific studies that supports these activities well must similarly be constructed to study and characterize issues all the way from the systemic to the local.

In comparison with the range of scales implicit in the policy and planning process, and well defined in the conceptual model of the system, most of the scientific studies that were presented to the SRC are now strongly centered on spatial scales that are pool-sized or smaller and, as such, are relatively local. They seem to contain the implicit assumption that scientific conclusions gained from pool-centered studies can eventually be extrapolated to the UMR system as a whole. But it is not clear that this is so. Whilst it is plain that system-wide effects must contain within them the sum of all more local processes, it is not always practical to integrate up to system-level response from locally conceived observations. Sampling constraints may defy such an effort, or useful precision may irretrievably be lost. Certain emergent phenomena -- particularly ones that depend upon spatial or temporal patterns of events at particular scales -- may not be detected at all.

The SRC encourages the staff to approach scientific issues more systemically and less locally; from the outset to frame scientific questions at a more systemic scale, in the expectation of reaching system-wide conclusions from which pool-centered conclusions can be interpolated. Interpolation is generally a safer strategy than extrapolation because consistency in interpretation at the primary systemic scale is thereby assured. Pool *observations* will, of course, remain important, because we can not make measurements everywhere, *but the measurements must clearly be seen as observation points of the system and interpreted as such.*

Scales and the River

Any geographic region must be interpreted in terms of a continuum of spatial scales from large areas to small areas. There is also a continuum of observational tools such as satellite remote sensing, aerial photography (for mapping), low flying aerial video (to observe but not map resource condition), boat transects for sampling water quality, vegetation, and fish, sediment samples (including counts of organisms), laboratory analyses (analyzing a few grams of soil or a few milliliters of water), and microscopic observations. Spatial scales range from the whole basin to proportions of molecules in a sample.

Similarly there is a continuum of temporal scales. Examples of processes, ranked from long to short observational periods, include geologic processes (uplift of mountains and erosional development of the river basin, advance and retreat of glaciers, deposition of glacial materials, and deposition of loess), development of soils and ecosystems on the post-glacial landscape, agricultural development following European settlement, with the attendent soil erosion and redeposition, navigation on the river, leading to construction of locks and dams, management of the lock and dam system, dredging and dredge spoil disposition, other uses of the river, major floods (e.g. of decadal frequency), introduction of exotic species, seasonal life cycles, diurnal activity cycles, and the momentary rate of photosynthesis and resulting dissolved oxygen concentration in the water in response to the presence or absence of shading. A variety of observational methods are needed to understand processes, and the implications of them for land management, across these time scales.

So much is made explicit in the conceptual model of the UMRB adopted for the LTRMP, but it is not well reflected in the scientific program. In particular, large-scale and long-term processes that characterize the physical system, that determine secular trends in ecosystems, and that dominate policy considerations, have thus far received rather slight attention in comparison with the smaller-scale and shorter-term processes that characterize the functional aspects of the ecosystem.

Furthermore, the feature that distinguishes river systems most markedly from other ecosystems is the overwhelming importance of fluxes. Site-specific studies of physical and biotic conditions at fixed localities can lead to inadvertant neglect of these fluxes, and hence minimize the understanding that is gained of them. In particular, one loses the upstream-downstream "connectedness" that makes river systems what they are. To properly encompass the lotic nature of the system, the staff should add, to the intensive studies now being conducted on conditions and processes *within* pools, more emphasis on inputs *to* pools and outputs *from* pools. We understand that such an effort is underway in respect of sediment movements through one pool. It is also evident in cooperative reports from the Illinois State Water Survey (e.g., Bhowmik and Demissie, 1989; Bhowmik, 1993; Bhowmik and Clark, 1993), so this may be more a matter of refocussing thoughts than of redesigning programs. But the effort must become a system-scale one.

Physical Components

The main impediment that the SRC sees to being able to consider the UMR system as a whole, or to consider the fluxes within it, is the lack of an overall physical system framework of measurement and modeling, even though it is implicit in the conceptual model. Rivers are well known to be physically driven systems. Explicit development of the physical framework should be given high priority because it is the context within which all the other studies/factors must operate, and the systemic context within which they are best understood. We encourage the EMTC staff to begin to think of the system as the sum of its parts. The concept is well summarized in a box-cascade model.

The comprehensive budget approach (the box-cascade model) would necessarily begin with water. The water budget is an absolute prerequisite as it is the forcing function to the load budgets of other quantities like nutrients, sediments, and contaminants, and to more sophisticated considerations like energy flow through the UMR system. Use of regional hydrometric and hydrometeorological data can facilitate analyses. These are available on CD-ROM and can be incorporated without the necessity of independent data collection.

Among the most urgent measurement requirements are accurate bathymetric data. Bathymetric maps are still lacking for most of the pools. Without basic bathymetric/volumetric data, one cannot calculate even the simplest fluxes (e.g., water) on a system-wide basis, nor the throughput and residence times of less conservative variables such as sediment, carbon, and nutrients.

One of the ultimate goals of the program (and an exemplification of the box-cascade model approach) should be a comprehensive sediment budget for the entire UMR. Sediment is perceived as one of *the* major environmental issues in the UMR by resource managers and river stakeholders alike. However, a comprehensive sediment budget for the entire system cannot be constructed from models of Newtonian fluid forces on sediment particles. While such models are valid in the study of specific problems in local contexts, their results cannot be extrapolated upward more than one order of spatial magnitude without losing precision and approaching chaos. A pool-by-pool compilation of inputs, outputs, and storage in pool-scale segments is needed, which can be linked together as a cascade to pinpoint major sources, fluxes, and sinks for the system as a whole. Thence many other phenomena associated with sediment transfers (erosion, siltation, transfer and storage of metal contaminants, for example) may be systemically described and explained. In this way, long-range trends may be discerned in conditions that drive pool and sub-pool scale ecosystems.

Defining Trends: Water Quality

Trends should be investigated at the time scales at which changes in principal parameters are likely to be discernible. A key connection between the physical processes that drive the UMR system and the responses of organisms and habitats is provided by water quality. A time scale of importance to water quality is the 30-year scale of change that has been detected in the streamflow records of the UMR (figure 1) and other river systems of North America. Knox (1983, 1984, 1985) has pointed out that, in the UMR, the magnitude of the 2-percent probability flood was only about 2,000 m^3/s for one 29-year period (1920-49), whereas it was greater than 3,000 m^3/s during other periods of approximately the same length (1867-95 and 1950-80). Knox related these differences in flood magnitude and frequency to differences in the prevailing patterns of atmospheric circulation, which was mainly meridional before 1895 and after 1950, and mainly zonal between 1895 and 1950. Given this scale of hydrologic periodicity, and given that the large water-holding capacity of the UMR provides a lot of temporal damping of hydrologic responses, the time spans over which significant changes in water quality parameters are likely to be discernible are decadal or longer. In consequence, this is a key time scale for analyzing trends in many ecological characteristics of interest.

The water quality monitoring program of the LTRMP has been ongoing for long enough to define the present-day variabilities around the mean values that have prevailed during the last half-dozen years. While these records have captured an extreme of high water and a period of infrequently recurring low water (and thereby contain the raw material of event histories), significant long term trends are unlikely

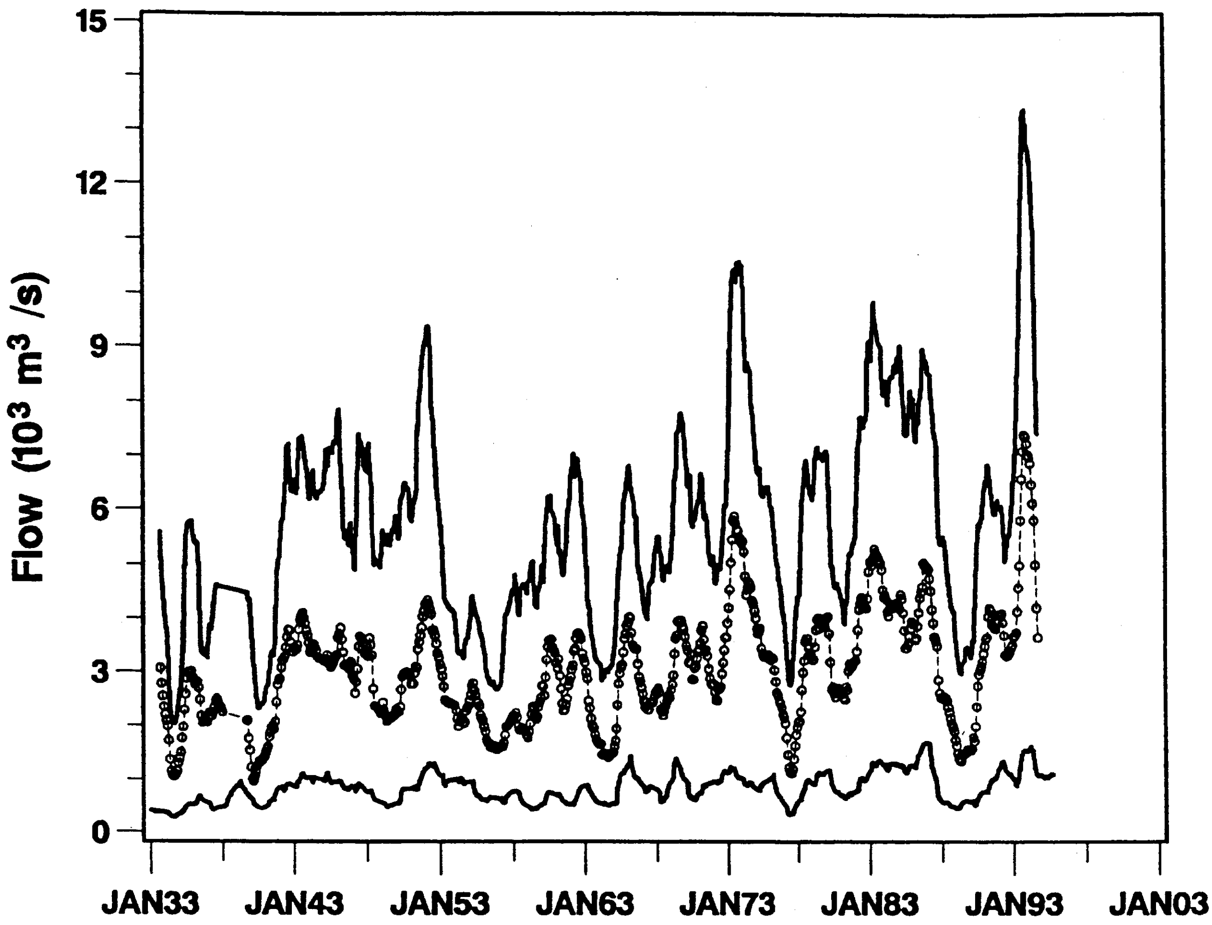

Figure 1. Long term flow records on the Upper Mississippi River. Stations are (in order of increasing flow) Winona, Minnesota; Alton, Illinois; Thebes, Illinois (from a presentation to the SRC by D.M.Soballe).

to be discernible through the scatter of short term variability until the data collection programs are continued for another 10 to 20 years.

In light of the long time spans that will be necessary to establish water quality trends of any significance, consideration should be given to adopting a National Water Quality Assessment (NAWQA) type approach to long term monitoring. The basic design of the USGS's NAWQA program involves the intensive collection of data in a river basin of logistically manageable size for a long enough period (three years, usually) to establish significant values of the means and variances of water quality parameters that may be subject to extreme variability on seasonal or longer time scales. After the intensive three year program is completed, sampling in the river basin is suspended for a period of nine to twelve years (during which time, three or four other river basins are being sampled in three year programs). If all goes as planned, after nine to twelve years, the original river basin will be the subject of another three year intensive program of sampling that will allow for the establishment of new mean values of water-quality. Subsequent value can be compared with those measured nine to twelve years previously to see whether they have been decreasing with time, increasing with time, or remaining stable.

If the monitoring function of LTRMP is to continue into the indefinite future, a NAWQA-type approach deserves serious consideration. Indeed, it appears that an approach of this general type will be essential if the system is to be adequately studied within the looming budgetary cnstraints. The kind of attention that has been paid so far to Pools 4, 8, 13, and 26 can be applied, on a rotational basis, to other pools. After one full rotation cycle has been completed, the originally studied pools can be reworked, and water quality trends can be demonstrated for the time scales at which their characteristics are most likely to be discernible.

The design of a specific long-term monitoring program must consider all the significant scales of variability within the system in order to avoid unfortunate aliasing of observations. It furthermore must seek to capture exceptional events that may be of "system setting" significance. The monitoring data set now contains the raw material for two event histories -- one of a spectacularly high discharge (especially at Cape Girardeau and Pool 26, progressively less so in Pools 13, 8, and 4) and one of infrequent low discharge. What lessons can be drawn from the occurrence of these two events within a few years that will inform our knowledge of the way the system functions? What are their implications for long-term monitoring designed to detect secular trends in ecosystem function?

Critical Ecological Components

In a presentation to the SRC, a staff scientist characterized important limnological scales of the UMRB in terms of the river as aquatic habitat, with scales of order 10^0 to 10^3 m and 10^0 to 10^2 h; and the river as conveyor and processor, with scales of order 10^3 to 10^6 m and 10^2 to 10^4 h. It was also noted that the emphasis of LTRMP efforts was firmly placed on the former. The SRC has argued above that the longer term scales are those at which significant trends in the system will be detected. It follows that information must be amassed that reveals ecological variability at these scales. This focus is indeed evident in some of the ecological studies; cf. TR 95-T003, "Modification to the Upper Mississippi

River and their effects on floodplain forests" (Yao and Nelson, 1995). It is perhaps natural to consider forests on the larger and longer time scales, since they happen to be consistent with the cycle of forest succession. The effort within the CIA program to document historical land use changes is also consistent with these longer time scales. Means must be found to compile information about other aspects of ecosystems -- particularly the aquatic ecosystems -- at similar scales. These are the scales of landscape ecology, and a landscape ecology approach would be consistent with a focus upon systemic behavior in the UMRB. *But this is not an argument to de-emphasize the shorter-term studies*. They remain essential to define ecosystem structure and function and to establish the scales of variability within which field observations of the contemporary ecosystems are made. This knowledge will be essential when it is time to establish contemporary secular trends in the system, as well as to provide some context for historical observations.

Turning to the field observations, the SRC notes that subsurface physical and chemical attributes of the water column are critical to production and preferences of fish stocks, as well as to estimating anthropogenic influences on, and expectations from, aquatic systems. Such structural features as logs, root wads, boulders, ledges, and the like for the needs of juvenile and adult fishes, and inundated wetland (terrestrial understory and herbaceous vegetation) or nearshore aquatic vascular plants for early life stages, are usually associated with sustained high yields of fish stocks. Variations in water quality such as suspended matter, dissolved solids, major cations and anions (especially plant nutrients), alkalinity, pH, dissolved oxygen, and other characteristics are often related to variations in fish communities on short and long term scales. Moreover, those water quality characteristics often figure prominently in spontaneous or seasonal movements and preferences of fishes and their food web organisms. If short term changes in those ecological components are not adequately described, then long term trends will not be understood. Thus, *variations in physicochemical attributes of the water column should be monitored concurrently with biotic monitoring*. Although it may not be possible to measure all physicochemical characteristics of the column during fish sampling efforts, it should be possible to measure some important "volatile" habitat features. For example, depth, number of logs, boulders, cover, bank slope, and *in situ* water quality variables such as temperature, dissolved oxygen, pH, specific conductance, and Secchi disc depth can be collected before shocking, setting nets, seining, or trawling. Those features may be monitored by the limnological crews as well. Statistical models can be derived to describe possible associations between variations in fish stocks and *in situ* habitat attributes with the more complete list of physicochemical characteristics monitored on a different time scale by the limnology crews.

SAMPLING AND ANALYSIS

Systemic Versus Local Measurement

The foregoing section presents arguments that substantially greater attention should be paid to systemic trends in space and time as an appropriate basis for policy and planning considerations. Nonetheless, sampling remains a local activity. This introduces some significant constraints into the design of the sampling program. Trends with respect to spatial differences (latitude-longitude, or habitat-subhabitat type) should always be described with regard to the inexorable changes that occur with time at each station selected (randomly or otherwise) to be monitored. If the monitoring crew collects data in any one location through time, changes in that place (second-to-second, hourly, daily, monthly or yearly) will occur and be detected insofar as sampling frequency permits. If another crew collects data in another part of the same reach with the same frequency, many, if not most, physicochemical or biological features may appear to be be different at least in part because they are out of phase temporally with nearby data collections. This is because of a different proximity to the channel, time-of-travel of the water, flushing rate, or position with respect to fetch and wind-drift. Inasmuch as those attributes vary with geographic position or habitat type, temporal pattern variations will be prevalent and can be confused with definitive spatial variations.

Thus, it is incumbent upon the monitoring teams to adequately describe all temporal variations at each site. To obtain information at a site which is to be of value for describing systemic trends, it remains necessary to sample sufficiently intensively to understand purely local variability, so that system analyses may be appropriately adjusted. For example, we know that lentic waters change quite dramatically overnight, and that diel features vary with pulses in phytoplankton as much as they vary at mid-day, each day throughout the entire month. Those water quality changes can be expected to be associated with short term or spontaneous movements of the nekton and even some less mobile food-web organisms. It remains therefore to characterize all the variability on a diel scale, as well as other temporal and spatial scales before real, underlying trends may be discerned..

There are variations to be expected in short-term pattern variability from reach to reach. The river reach monitored near Lake City, Minnesota, and that near LaCrosse, Wisconsin, may be expected to change more rapidly than the reach at Alton, Illinois, and less rapidly than the river-run at Cape Girardeau, Missouri. These differences are more due to flushing rate and local bathymetry than because of latitudinal differences. Since the USGS is monitoring the water discharges of the Upper Mississippi River systemically from month-to-month, and year-to-year, it is incumbent upon the LTRMP monitoring crews to adequately describe short term changes (even diel monitoring) that occur each season (and all seasons) in each habitat type in each River reach. This can be done randomly, so long as local short term variations are described for each habitat type (i.e., channel, open lake or pool, back-water lake or pool, vegetation bed, and unvegetated shoreline).

Sampling

Presentations made to the SRC made clear that the sampling protocols originally established for the LTRMP proved in many cases to be relatively inefficient. Consequently, substantial effort was given after 1990 to redesigning sampling programs to improve their effectiveness. The current sampling protocols appear to be good ones with respect to each of the individual variables that is regularly monitored. It is not clear, however, that sufficient attention has been paid to coordinating the various measurements to ensure that the structure of the system can be effectively diagnosed. It was noted that boat sampling often is optimized for collection of a limited number of variables related to one resource. This approach may allow the collection of more data from additional sites. However, limnological sampling was often separated from sampling of, say, fishes. Given the occurrence of short-term variability as discussed above, this makes it very difficult to collate variables that can be used to determine why a fish was present in one location and not in another.

Some abiotic monitoring should be accomplished concurrently whenever biota are collected in the field. Every shocking, net-setting, seining or other sampling event should have associated with it *in situ* Hydrolab and Secchi disc (or *in situ* PAR light measuring device) observations. The limnology crew boat(s) should make every effort to accompany the fishing crew at least once each season. If this is not possible, perhaps the fishing crew can take the water grabs and place them on ice for shipping to the Onalaska lab the next day. We believe this approximates the approach some USGS field stations take.

Some individual sampling procedures still raise concern. Benthic sampling appears to be non-standard, the consequence apparently of attempts to reduce labor. The benthic invertebrate community should be sampled and analyzed using accepted standardized protocols (Standard Methods, APHA Manual). The benthic invertebrate system is an extremely important and complex community that has intrinsic value to the overall health of the Mississippi River. Benthic invertebrates are important in food webs and as biological monitors of high and low levels of pollutants; harmful substances that quickly precipitate, or that nekton can avoid, often have measurable and sometimes immediate effects on bottom organisms. If they do not alert us to cryptic or low-level harmful substances by disappearing, they may concentrate or magnify the substance so that we can detect the perturbation in the river. The opportunity afforded by long-term monitoring to gain insight into the reasons for the apparent significant reduction in our native North American benthic fauna (and the "ripple" effects throughout indigenous food webs) should not be lost. Benthic invertebrates need to be monitored and, to ensure comparability of collections in the long term, they must be monitored according to standard practices.

The expansion or contraction of vascular, submerged aquatic vegetation (SAV) beds in the UMR have effects on food webs tantamount to the building or loss of littoral zones. The "edges" procreated by building rip-rap islands and by growth of "islands" of SAV have similar functions insofar as they serve as nurseries for early life stages of fishes and their foods. Efforts to quantify changes in the SAV beds may be possible through aerial photointerpretation, analysis of remotely sensed data, or interpretation of video data, supported by ground truth information. Quadrat samplers (grids or rings) placed among the beds are commonly used to quantify SAV and their changes. Coupled with limnological observations, grid sampling can be used to examine cause and effect questions regarding SAV changes.

Analysis: Statistical Tests

At this stage of the LTRMP, it is necessary to make a detailed analysis of the data collected thus far. Many topical analyses have been conducted and the important first trend analysis is in good order, but the SRC has gained the impression that analyses of results have remained a secondary objective in comparison with continued data collection. Rigorous analyses help to point to efficiencies in the sampling design and data collection, and form the heart of empirical investigations. Analysis can determine whether the appropriate emphasis has been made and will reveal the appropriate intensity of sampling. A minimalist approach to data analyses can harm the effort to maximize data collection within the available resources. We expect that an increased proportion of the effort of the senior scientific staff should henceforth be given to analyses of the data in order to develop both substantive scientific results and to provide the basis for further adjustments of the sampling program.

In evaluating the monitoring efforts thus far, it is important to note that a low-flow event has been captured in the 1988 data collection, and a high-flow event was captured in the 1993 data. These differences can help guide the sampling effort as they represent two extremes of the range of flow conditions that can be encountered. Clearly, if a given variable in a given pool shows little change from the 1988 event to the 1993 event, the appropriate sampling protocols and level of effort for its collection need to be reevaluated.

The use of a range of statistical approaches and tests can greatly improve the analysis of data. In particular, attention should be paid to nonparametric tests. Nonparametric tests are often the most appropriate for analysis of data collections in the "wild." Nonparametric assumptions are very appropriate to the data commonly acquired, including acceptance of unequal and limited sampling sizes, non-normal distributions, and categorical variables. Nonparametric approaches can facilitate analyses, and provide a wealth of analytical results from the on-going monitoring efforts. Tests or approaches such as MANOVA, Mann-Whitney U, Kruskal-Wallis, and nonparametric correlations such as Spearman-rho and Kendall Tau-B should be primary methods for analyses. They will often form the only feasible basis for dealing statistically with retrospective data. Altogether, the context for much of the statistical work in the program will be very similar to that of biomedical clinical statistics, with a heavy emphasis upon survey sampling methods and imperfect control. There exists a rich literature in these areas which should be consulted.

After five years of monitoring, it should be possible to examine the data gathered by the separate investigative teams in a more holistic manner. Many times several variables are important, or several variables are greatly influenced by some forcing variable. The combination of multiple variables may hold the key to the analysis. Accordingly, multivariate statistical analyses are vital for analyses of natural or "wild" systems. Appropriate methods include clustering, principal components analysis (PCA), canonical analyses, maximum likelihood categorization, and the more familiar step-wise regression analyses. These approaches are necessary for complete evaluation of data sets.

For example, multivariate analyses would help to link presence/absence of fishes to vegetation and limnological conditions. Fish sampling data and limnological data, insofar as they were collected in similar time-scales in the same river reaches (i.e., throughout the summer low-water periods), can be subdivided according to habitat type and blocked on time. This may make it necessary that the water quality information be culled, but there should be sufficient abiotic data juxtaposed in time and space to perform multivariate analyses (cf. sampling recommendations above). MANOVA (split-plot design) can be used to check for possible differences in water column profiles and in nutrients (cations and anions) among habitat types. Wind speed vectors can be included in the models as co-variates to examine wind effects on in situ hydrochemistry (or nutrient) variables. Similarly, MANOVA can be used to determine whether the mean catch-per-unit-effort of fish stocks, relative abundances, diversity indices, (or other population or community attributes) have varied significantly with geographic region or river reach. Furthermore, the test should disclose whether one particular habitat type is significantly different from another habitat, or all the other habitat types, with respect to its stock(s) or fish(es). After the MANOVA test is performed, Tukey's Studentized Range Test or Least Squares Means can be run to determine which, if any, reach or habitat type is significantly different with respect to either the biotic or abiotic features measured. Those tests can be run using the Proc GLM procedures for the Statistical Analysis System. The Fortran program, Canonical Community Ordination (CANOCO) analyses or other canonical analysis procedures can be used to describe which physicochemical attributes are useful in explaining reasons for the variations witnessed in the biota on either time (year-to-year) or space (reach or habitat) scales. This discussion emphasizes why simultaneous collection of biotic and abiotic observations is desirable.

Finally, The SRC wishes to emphasize that some attempt must be made to examine the historical fish collection efforts by the Illinois Natural History Survey and State Fish and Wildlife biologists. The relative lack of attention being given to recovery and assimilation of the historical record was perhaps the most disturbing finding of the review. No doubt limitations of the historical data, including ignorance of some of the collection protocols, will have to be taken into consideration. Data transformations, and/or nonparametric tests will usually be required. But, if only community-level, or very conservative statements can be supported by the nonparametric time-series analyses, nevertheless, the effort should be made and may, in view of the time scale for regional systemic change, yield the best available indicators of secular trends until another decade or two of monitoring has elapsed.

COMMUNICATION AND COOPERATION

LTRMP must place a high priority on coordinating its personnel and findings within the operation and with a variety of larger "publics" including the parent organization (USGS), cooperating partners (COE and the state partners), governmental and resource management organizations at a variety of levels, and with an interested public-at-large. This coordination requires a good communication system. Much effort has been devoted to these goals, and more should be encouraged in the future. EMTC has done an impressive job of developing an information management plan and a sophisticated electronic communication system which provides the basis for communication and coordination. Because of the diversity of consumers, the SRC urges the EMTC to continue to support both written and electronic means to disseminate information.

Technical communication

Priorities for future scientific work at LTRMP must emphasize synthesis of data and information from the various ecosystem components. To judge by the presentations made to the SRC, it appears that there has not been a great deal of information sharing between component specialists at this time and specialists from one component may have difficulty obtaining and assimilating information from specialists in another component. This is somewhat understandable because of the volume of the data being generated; the sophisticated technologies for storing, retrieving, and analyzing data; the different "languages" of science and computer technologies; and everyone's busy schedule. It appears that much of the information generated is technical and needs sophisticated approaches to access. However, if the goal of synthesis is to be achieved all staff need to be able to access, download, and analyze all the electronic data. For synthesis between components to occur, there needs to be both formal and informal communication systems to facilitate the sharing of information and ideas.

In comparison, external technical communication via technical reports, conferences and conference papers, Internet access and personal peer contacts appears to be quite satisfactory.

Public Communication

There is a great need as well for more “pedestrian” approaches to communication. Many of the publics that have use for the information may not have the knowledge and skills needed to access and interpret the data. These publics have a great need for information they can apply to resource management issues, and they form a broad base of support for EMTC. As an introduction to EMTC activities, the information bulletin "River Almanac" appears to provide a good synopsis of pertinent information for river managers, scientists, and an interested public.

Some communication suggestions include having a "single point" of contact for persons desiring information. Then that person can direct the inquiry to the proper location. Workshops for local government officials to inform them of the information assets at EMTC and how to access them are also recommended. The 1990 SRC recommended that EMTC staff participate in national scientific meetings. For communication, it is equally if not more important that staff participate in regional and local meetings. As budgets tighten, resource managers are less likely to travel to national conferences. Conferences are often efficient means of presenting information to an audience that is not in close contact with national or international information sources. The Mississippi River Research Consortium meetings were mentioned as a good venue for presenting information to audiences directly involved with river management.

It was somewhat difficult to directly determine the amount of information provided by EMTC to resource managers. It appears that the closer the partner, the closer the access to information. County land conservation committees, local planning and zoning authorities, extension offices, and other groups have uses for information. Even close partners such as refuge managers and departments of natural resources personnel can use an annual update of new findings in verbal form, if it is not otherwise provided. More information also needs to be provided to refuge managers on how to access information assets. Held in conjunction with workshops for local officials, a joint conference could provide good opportunities for cross communications.

The equipment needed to electronically store, analyze, and transmit information is sophisticated and expensive. However, many of the recommendations we make are basic. Writing, editing, public contact, and public relations greatly enhance communications and build public support for the EMTC and its activities. A sound basis has been established for this effort, but it remains to conduct more of these activities as appropriate.

Cooperative activities

The legislative mandate of the program makes it immediately a cooperative one. It is directed through the cooperation of two federal agencies and five state governments. Collaboration with COE scientists and engineers, an important requirement for the program to be a success, appears to be routine and productive. The recent administrative reorganization of EMTC into the United States Geological Survey makes directly available the advice and experience of one of the most distinguished research units within the US government. The strengths of the Survey, moreover, are greatest in those areas where the program has thus far been relatively less active; characterization of the regional physical and hydrological system. The experience of the Survey should be entrained in whatever ways are possible and advantageous to the EMTC.

The state partners in the UMRB program have fish, game and environmental agencies with good regional knowledge and substantial interest in ongoing monitoring of biotic resources, particularly fish and game animals, to support their main responsibilities. EMTC should investigate the possibility to coordinate more of its monitoring activities with the needs and interests of the state agencies in order to effect economies in the operation of the field stations. It is possible that some of the field stations may be of sufficient interest to the states for them to take over operation, or that state surveys in other reaches of the river may serve to significantly expand the spatial data coverage. If such arrangements are possible, an important responsibility of the Center will be to examine sampling methods and data reduction protocols to ensure that common and mutually acceptable standards are established and maintained.

The 1990 SRC report suggested that a variety of other persons, including university faculty, students, and intergovernmental loan personnel, be utilized to strengthen the science program at the Center. The EMTC's publication list, and the record of student and sabbatical visitors, indicate that this initiative has been vigorously and successfully pursued. This not only strengthens the program but is also an effective communication device. It is possible that the real long-term strength of the EMTC program resides in the degree to which cooperating scientists -- including students -- in regional institutions can be drawn into it. Future budget constraints may force greater reliance upon such cooperators. The initiative should be continued and expanded. In addition, the EMTC should consider expanding its use of volunteers. Not only can volunteers collect data useful to the program (for example, presence/absence monitoring for Zebra mussels comes to mind), but these efforts also form additional opportunities for effective communication.

Archives

Although electronic data storage is rapid and efficiently handles large volumes of information, it remains unclear how long-lived electronic data are. As hardware and software change, data can be rendered inaccessible. This is not desirable for a long term database. Making data available in printed copy in accessible locations is still recommended as a long-term assurance of easy access. The USGS has a long tradition of maintaining long-term datasets. It is recommended that the guidelines of this parent organization be followed for archiving hard copy data, and for data dissemination. Printing data reports in small editions and distributing them to libraries will increase the likelihood of their use in future activities when historical data are needed to assess time-based changes or trends.

A data report will contain three main components:

1. A description of the sampling and analytical methods (including references to pertinent literature) so complete that it can be used in by future investigators to repeat measurements and produce comparative data and define long term trends;
2. A complete listing of data;
3. A thoughtful and thorough discussion of errors, so that any differences between existing and future results may be judged. Both sampling and analytical errors should be evaluated to facilitate later analysis of the data. Many groups make use of Quality Assurance/Quality Control (QA/QC) procedures to both guide the data collection and to standardize the analysis and reporting of results. QA/QC procedures should be discussed in the description of methods, or elsewhere.

A VISION BEYOND 2002

Public attitudes and preferences concerning environmental policy are rapidly evolving. This section of our report is the SRC's look beyond the currently mandated Upper Mississippi River Basin Long Term Resource Monitoring Program. Our vision is not constrained by past law, policy, or bureaucratic structure or direction, nor is it constrained by the narrow charge to focus on the river and its flood plain. In fact it appears desirable that Congressional re-authorization should change in significant ways the scope and importance of scientific efforts in the Upper Mississippi River System.

Rapid changes in public policy are reflected in Secretary Babbitt's address to the conference "Science, Sustainability, and the Mississippi River System: North America's Largest River" in 1994:

"Science needs to come together. We need to see it whole. We need to be looking at the entire river basin. We need to understand that the water in this river system is really a living indicator of everything that is happening in the entire watershed . . . "

Secretary Babbitt's remark reflects a change in how public environmental policies are being defined -- away from narrow questions such as balancing river transportation with fish and wildlife uses and toward policy (and scientific) problems being defined by the larger public, the ultimate stakeholders, and then implemented by governmental or quasi-governmental entities. Current examples of this new approach are found in attempts to solve environmental controversies over competing views of ecological resources in the Pacific Northwest, the operation of the Glen Canyon Reservoir (Lake Powell), and how to protect the wetlands of South Florida. The Upper Mississippi River Basin shares many policy features with the three examples mentioned.

Establishing Trends in Physical, Chemical, and Biological Parameters

Scientific information is and will continue to be important in the newer approaches to solving environmental problems but, regardless of the public policy question being considered, it is essential to keep in mind that establishing any meaningful chemical or biological trends will require decades. Strong synoptic and seasonal variability in the system, as well as cyclic trends in climate, will mask true secular trends that may exist. Such a situation should not discourage pursuit of establishing trends, but there must be a recognition that the effort will require a sustained commitment of financial and intellectual resources. This is one reason why historical data, although fraught with many analytical problems, are an excellent source of information to indicate long term trends.

Another challenging task will be to closely link the parameters monitored to evolving policy needs. This is not easy in a rapidly evolving public policy environment. Our recommendations, if implemented, should help focus efforts on providing the scientific information that will be useful in decision making activities.

Evolving Public Policy

Ecological policy is evolving away from being set by technocrats operating in government or other organizational positions (usually in close alliance with local congressional representatives) toward a "democratization" of policy development. Consequently, environmental policy in the United States is undergoing rapid shifts, especially over the past decade. Secretary Babbitt points out that the Upper Mississippi River Watershed is a "...national resource..." as are the old growth forests of the Pacific Northwest, Grand Canyon, and the wetlands of South Florida. There are many stakeholders both within and without the Upper Mississippi River Basin who do not have an organized bureaucracy to advocate for them. The environmental policy issues in the Upper Mississippi River Basin are far more complicated than simply a question of balancing river modifications and fish and wildlife mitigation, even though those factors will remain important.

These developments are typical of all major environmental problems, not just those in the Upper Mississippi River Basin. Organizations such as the Environmental Management Technical Center (EMTC) are ideally situated to play an essential role in the "new political environment" if they can become the honest brokers of technical information which serves to allow us to understand the issues and work toward viable management of them.

Adaptive Environmental Assessment (AEA)

To help elicit emerging and important public policy priorities from a disjointed and fractured public debate, the approaches used in AEA and in "futures analysis" are promising. The basic ideas are conceptually sound and are implicit in the purpose of EMTC, but have some practical problems that need to be considered. To be most useful for defining post-2002 options, the exercise should not be constrained by current law or policy. Specifically the focus should be on determining options for the entire *watershed*, not simply the river and river corridor.

One problem with Adaptive Environmental Assessment (AEA) or futures analysis is either not involving all the relevant stakeholders or not honoring the commitments from all. The most difficult stakeholders are those not formally represented by a governmental or nongovernmental organization. Specifically, a likely policy argument will be whether the taxpayers should continue to subsidize a transportation "project" when all the societal costs, especially ecological ones, are not clearly recognized. Another important policy question that will be raised is whether agricultural subsidies should continue, especially considering that the larger society bears the additional cost of undesired ecological changes elsewhere in the watershed.

Another problem to which to be sensitive is that the exercise is merely a means to achieving consensus on policy objectives. The debate is less over how accurate are the predictions, but over *what* is important to predict. It is very easy to fall into the analytical trap in Adaptive Environmental Assessment of using the modeling tools available rather than modeling what is really important from a policy standpoint.

Role of Scientific Information in Resolving Policy Issues

Scientific information can and should play an crucial role in resolving ecological policy problems in the upper Mississippi River watershed. The challenge is for organizations like EMTC to recognize the major policy questions, assemble the needed scientific information, and provide it to everyone in ways that it can be used, all the while maintaining policy neutrality.

For EMTC, these considerations will entail devising means to monitor and assess the effects of policy initiatives that have been implemented, and inventing means to analyze the probable effects of policy proposals, without becoming partisans of any policy. For LTRMP, it means maintaining the flexibility to collect new types of information as they appear to become relevant to policy evaluation.

It will be important for the Environmental Management Technical Center to continue to be independent of stakeholder, management, and policy positions, but to produce data and analyses that are scientifically sound and policy relevant. Achievement of these goals, which are the intent of the governing legislation, should assure the usefulness and continuation of the important program that the Center conducts.

RECOMMENDATIONS

The following recommendations arise from our review of the EMTC activities. Most of the recommendations are more detailed and more specific than those of the 1990 SRC. That is because we are this time reviewing an operational program that is in many significant respects a successful one. The recommendations are directed more toward "fine-tuning" than to setting operational desiderata. Nonetheless, the first four recommendations address structural issues which the SRC considers still to require review and adjustment if the program is to achieve its fundamental goal of providing a scientific description of the Upper Mississippi River that can serve as the basis for policy formulation and planning to manage the system, as the enabling legislation requires. Some of the recommendations are couched in general terms: related details have been discussed in the foregoing text.

Strategic recommendations: the structure of the program

1. There must be increased emphasis on studies at the systemic scale and on the upstream-downstream connections that make the river system what it is. As the first step, a box-cascade model of the river system should be articulated within the guiding conceptual model and used as the basis for implementing this approach to the system.

2. A detailed quantification of inputs to the river system must be conducted to reveal the basin and watershed influence on the river, and help to identify basin problems that need to be addressed to help to maintain and improve river conditions. An increased emphasis should be placed on viewing the UMR system as a single, integrated system, which means devoting more attention to the reach, river and basin scales. This is essential and is not inconsistent with the clear intent of the legislation, even though the legislation directs primary attention to the river itself.

3. Increased emphasis must be placed on lengthening the time horizon of observations, particularly by seeking and using historical records. This is the only way in which long-term trends will be discerned in less than one or two more decades, and we doubt that either the Congress or the public will be willing to wait so long for a first assessment of changes in the UMRB.

4. To further ensure that the research conducted at EMTC will meet the mandate of the UMRB program, adapt the conceptual model to explicitly show that the impacts of management changes in the system will be evaluated in terms of multiple sets of societal goals and values, and that the scientific information necessary to achieve these evaluations will be secured. In short, incorporate social context into the conceptual model.

Operational recommendations: data collection and analysis

5. Increased attention to hydrographic, morphometric and sedimentation data is necessary to understand the river system. These characteristics drive the system yet they are receiving comparatively little attention. Model approaches can be helpful but even they are limited to available data. The association of a geomorphologist and/or sedimentation specialist with the program may be helpful in this regard.

6. There is no distinction between monitoring and data analysis; they must both be conducted to answer questions. Hence, the analysis of data should be stressed, along with the collection of data. Within the LTRMP, there should be increased and continuous analysis of data collected and comparisons with historical conditions to guide and prioritize future sampling.

   The "why" of each data collection effort must be obvious, so there needs to be a strong linkage between collection and analysis. Justifying or modifying further data collection effort in light of the results of analysis is also an opportunity to effect economies in the program.

7. It is necessary to use survey sampling and clinical statistical methods to better analyze the sampling efforts on both the spatial and temporal scales. This will help validate the approach, and help to prioritize sampling collection efforts based on input to analysis procedures. To facilitate this work, it would be desirable to associate with the program a statistician who is very familiar with clinical and survey sampling approaches using nonparametric and multivariate methods.

8. Place increased emphasis on simultaneous collection of limnological data with fish and vegetation sampling in order to facilitate analyses that will answer critical questions. Limnological sampling should include additional cations and anions, and sediment sampling.

9. Consideration should be given to a NAWQA-type approach to long-term monitoring that will sample pools intensively for 3-5 years each on a rotational basis, with an ultimate focus on systemic conditions.

   A temporally staged pattern of sampling, such as this, may be the only practical way to obtain sufficient data to distinguish system-wide and local long-term trends in the face of significant short-term variability and the large geographical area.

10. The CIA/GIS/photointerpretation and remote sensing efforts appear excellent and should be continued, with additional attention to recovery of data of historical conditions. Other research can be facilitated by making additional use of the data resources provided by this program. This area of emphasis may require additional laboratory space in the Center.

Recommendations about communications

11. It is desirable to foster further in-house cooperation and sharing of resources and results. This will be essential to achieve the central goal of analyzing the status and trends of the river system in a holistic way.

12. It is desirable to further cooperative efforts with local, state and federal agencies. This is to share resources, to facilitate communication and to foster image. Include explicit consideration of what interest groups can best articulate the various goals that may be used to guide the Center's activities. Explicitly incorporate contacts with these groups into the science advisory process.

13. Volunteers may be appropriate for certain data collection activities and would be an effective way of involving the wider public directly in the program.

14. A book series of data reports (as USGS Open-File Reports or similar series) should be inaugurated, describing methods and error analyses as well as listing all the monitoring data, to provide assurance of continued accessibility of the data long after the program has ended. Consider the same approach to publishing research analyses.

Recommendations about the future

15. The Science Review Committee should meet in the next eighteen months to further evaluate the scientific efforts. This review should be held during the growing season to facilitate a limited amount of field evaluation of data collections and sites.

16. In re-authorizing this Program, Congress should consider expanding the scope of the effort to include scientific modeling of the relationships between human and natural activities in the entire UMR drainage basin as they affect the ecological status of the designated river reaches. Conditions in the river cannot be separated from conditions in the drainage basin that sustains it.

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