SYSTEM INVESTMENT PLAN AS A TOOL IN ADAPTIVE MANAGEMENT

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Abstract
Environmental impact studies for water resources plans are entering a “new era” due to the need to address cumulative effects, resource and ecosystem sustainability, numerous policy and impact-related uncertainties, and the integration of economic evaluations. This paper illustrates such “new era” studies related to the on-going development of a system investment plan (SIP) to 2060 for navigation on the Ohio River. Further, the concepts of adaptive environmental management involving monitoring and feedback to continuing decision-making are described. In addition, an analysis of environmental sustainability (AES) based on the cumulative effects from past, present, and future actions along the mainstem of the Ohio River is illustrated for water quality. The key observations from this work-in-progress are: (1) the 11-step methodology of the Council on Environmental Quality provides a useful framework for conducting a comprehensive study of cumulative effects at a programmatic (plan) level; (2) the environmental sustainability (ES) of resources and ecosystems can be assessed based upon the composite consideration of the past, current, and future conditions of selected and tiered indicators; (3) adaptive management, which is derived from scientifically-based monitoring, can be a useful tool for reducing uncertainties related to actions, environmental systems, and responses to stress; (4) the outputs from the SIP can be used as inputs in the development of an adaptive management program; and (5) tiering from the current programmatic environmental impact statement (PEIS) under preparation will be required in response to future updates in the SIP and decisions related to adaptive management.

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INTRODUCTION

Environmental impact studies for water resources plans and projects promulgated by the U.S. Army Corps of Engineers are entering a "new era" due to the increasing need to address emerging issues such as cumulative effects, resource and ecosystem sustainability, and uncertainties associated with future actions and policies and related environmental impacts. To address uncertainties, adaptive management programs involving monitoring and feedback to continuing decision-making regarding resource management and mitigation measures are being utilized. Further, increased efforts are being made to integrate economic evaluations and environmental impact study findings in the selection of a specific water resources plan or project from a set of alternatives.

This paper illustrates the incorporation these emerging issues in a waterway navigation system study on the mainstem of the Ohio River. Following this introductory section, the paper contains sections on the features of the navigation study, the context for larger-scale impact studies, ecosystem and adaptive management, and the cumulative effects assessment (CEA) study that is in progress. The penultimate section includes an illustration of how cumulative effects on water quality are considered in an integrated manner relative to the environmental sustainability (ES) of the water quality resource. Final observations from this work-in-progress are in the last section.

OHIO RIVER MAINSTEM SYSTEMS STUDY

Waterway navigation facilitated by man-made structures has existed on the mainstem of the Ohio River for over 100 years. The 981-mile mainstem stretches from Pittsburgh, Pennsylvania, to Cairo, Illinois. In Pittsburgh, the Ohio River is formed at the confluence of the Allegheny and Monongahela Rivers; and at Cairo, the Ohio River flows into the Mississippi River. Mined natural resources such as coal, and manufactured products such as petrochemicals are moved up and down the mainstem via towboats and various barge configurations. As such, waterway navigation has been and continues to be a vital link in the economic structure of the six contiguous states along the river (Pennsylvania, Ohio, West Virginia, Indiana, Kentucky, and Illinois). Further, such navigation is expected to remain a central influencing factor regarding commerce and economic growth in the region.

The design features, sizes, and locations of locks and dams on the Ohio River have evolved since the "wicket dams era" of a century ago. The U.S. Army Corps of Engineers has been the lead Federal agency since the inception of the navigation system. At the current time, there are 19 "high-lift" locks and dams either on the river, under construction, or authorized. Each location is typically characterized by the presence of a main lock and a smaller auxiliary lock that is used during maintenance or rehabilitation periods for the main lock. Both locks may be used for recreational boats.

Several economic, engineering, and environmental issues are being addressed in a current study, referred to as the Ohio River Mainstem Systems Study (ORMSS), to develop a system investment plan (SIP) for navigation to the year 2060. This SIP and overall ORMSS are scheduled for completion in 2005. Economic issues are related to a range of projections of navigation traffic increases, and cost inefficiencies that occur due to barge queuing when main locks are subjected to unscheduled maintenance or repair. Engineering issues relate to designs for increased sizes of auxiliary locks at several locations, and the development of risk functions that can be used to proactively schedule major repairs at existing facilities.

The SIP will have several unique features that represent a more realistic approach for navigation system planning and management. First, it is widely recognized that "single number" projections of navigation traffic over several decades are problematic and fraught with uncertainties. The SIP being developed includes three traffic forecasts to 2060; e.g., a high growth scenario, an extrapolated scenario based on historical trends, and a low growth scenario. The high and low growth scenarios are based on a series of economic and policy assumptions. Further, the Ohio River Navigation Investment Model (ORNIM) is being used to develop numerous analyses of investment strategies based on combinations of assumptions related to navigation traffic levels, scheduling of routine lock and dam maintenance activities, and needs for major lock repairs or rehabilitation based on engineering risk analyses. As a result of anticipated uncertainties regarding navigation system needs and environmental consequences, it is recognized that the SIP will likely require adjustment on a periodic basis; e.g., every 10 to 15 years. The environmental implications of such adjustments should also be considered, as well as on-going monitoring efforts focused on navigation traffic, barge queuing, and indicators of aquatic and terrestrial ecological resources. The results of such monitoring could be used to periodically adjust navigation policies and environmental management strategies. Accordingly, these features of the SIP are compatible with the concepts of adaptive management to be described in a subsequent section.

Environmental issues are being addressed in a CEA study of the entire mainstem navigation system. This strategic-level impact study, which is scheduled for completion in 2004, provides an holistic review of the past, current, and anticipated environmental impacts from multiple actions and programs of the Corps of Engineers; other Federal, state, and local governmental agencies; and private industries and agricultural activities. The CEA study will form the technical basis for a programmatic environmental impact statement (PEIS) that will be prepared for the SIP. The PEIS is scheduled for completion in 2005.

As noted above, cumulative effects (impacts) are an emerging issue in impact studies; the definition that follows is in the Council on Environmental Quality (CEQ) National Environmental Policy Act (NEPA) Regulations *(1)*:

> "Cumulative impact" is the impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

The CEA study is in consonance with the policy of the U.S. Army Corps of Engineers relative to addressing the cumulative effects of water resources plans such as the SIP. This policy is *(2)*:

> The cumulative effects of the plan and other similar activities should be analyzed. Each proposed water resource development activity is but a piece of a large-scale program. The combined beneficial and adverse economic, environmental and social impacts of individual projects, each of which may be relatively minor, can have a significant regional or national impact. At each level of the evaluation and review process it is necessary to assess the cumulative beneficial and adverse effects of individual project impacts. Significant effects should guide the decisions.

CONTEXT FOR ENVIRONMENTAL STUDIES

In addition to CEA, two other issues are related to the context of environmental studies for the SIP. The first involves the use of ES as an "ultimate test" for determining the significance of cumulative effects. ES is identified in the recently published Environmental Operating Principles (EOPs). The second is associated with the usage of programmatic-level impact studies where water resources plans are being addressed. Both of these context issues are highlighted in this section.

Environmental Operating Principles

On March 26, 2002, General Robert Flowers, Chief of Engineers of the Corps, announced seven EOPs for Corps planning and decision-making. Three of the principles are directly related to the ORMSS and are being incorporated in the CEA study; they are *(3)*:

- Principle 1 -- Strive to achieve environmental sustainability. An environment maintained in a healthy, diverse, and sustainable condition is necessary to support life.
- Principle 2 -- Recognize the interdependence of life and the physical environment. Proactively consider environmental consequences of Corps programs and act accordingly in all appropriate circumstances.
- Principle 5 -- Seek ways and means to assess and mitigate cumulative impacts to the environment; bring systems approaches to the full life cycle of our processes and work.

The foundation principle is number 1, which relates to sustainable development and environmental sustainability. An early definition of sustainable development was that it is development that meets the needs of the present without compromising the ability of future generations to meet their own needs *(4)*. Stated differently, sustainable development involves the search for a path of economic progress that does not impair the welfare nor destroy the environmental and natural resources of future generations; thus intergenerational equity is a fundamental premise *(5)*.

The above-three principles are addressed in a recent (May, 2003) Engineering Circular (EC 1105-2-404) related to planning Civil Works projects consistent with ES considerations *(6)*. ES is defined as "a synergistic process whereby environmental and economic considerations are effectively balanced through the life cycle of project planning, design, construction, operation and maintenance to improve the quality of life for present and future generations" *(3)*. While the EC indicates that it is applicable to feasibility and general reevaluation studies initiated after May 1, 2003, the concepts of ES are already being used in the ORMSS. One relevant quotation from EC 1105-2-404 is *(6)*:

> In accord with the environmental sustainability definition, "the Corps goal is to strive to achieve the appropriate balance between the economic and environmental benefits provided by a project. Currently, Corps projects can be developed to achieve this goal through the formulation of plans that produce both national economic development benefits and national ecosystem restoration benefits. Where practical and supportable, the plan formulation should incorporate the principles of avoiding or minimizing significant adverse impacts within the guiding principle of limiting damage to the natural ecosystem. Through the incorporation of these principles, plans will likely avoid or minimize damages and be less intrusive. Thus, avoidance of disrupted natural processes is preferable, where practical, to creating new resources."

Programmatic Environmental Impact Statements

Project-level environmental impact studies have been conducted for over 30 years in many countries. Since approximately 1990, there has been increasing attention directed toward strategic-level environmental impact studies in multiple countries. Strategic-level impact studies conducted in the United States are documented via the preparation of PEISs. The PEISs prepared in the United States are focused on the environmental consequences of plans, programs, or policies of various governmental agencies. As noted above, a PEIS is under preparation for the navigation SIP for the mainstem of the Ohio River. Further, in several other locations, the Corps has completed or is also involved in the preparation of PEISs for water resources plans or programs.

Strategic-level impact studies are typically characterized by larger geographical areas and longer future time frames than used at the specific project-level. Further, due to the paucity of consistent baseline data across the larger geographical area, and the possible complete absence of impact-related data on future projects and activities in the study area, the locational and quantitative specificity of impact predictions tends to be less than for project-level studies. However, despite these differences, strategic impact studies and associated PEISs provide the opportunity to more appropriately address cumulative effects from multiple actions and activities across space and time; to delineate geographical areas, habitat types, and plant and animal species which should be afforded more protection; and to require certain impact mitigation strategies and programs for enhancing ES. Further, the planning and implementation of adaptive management programs can be integrated into PEISs. Beyond these potential benefits, the opportunity exists for introducing environmental issues and concerns at the decision level which is often driven only by traditional engineering and economic analyses, and related non-environmental policy choices.

More specifically, the PEIS for the SIP being developed via the ORMSS will address the direct, indirect, and cumulative effects of the plan itself. The SIP is expected to be an official plan prepared or approved by the Corps of Engineers which will guide or prescribe alternative means to maintain an efficient, economically viable, and environmentally compatible navigation system, and which will provide information upon which future Corps actions will be based. However, it should be noted that future environmental assessments (EAs) or EISs will be prepared, as appropriate, on specific actions included within the SIP. Such future documentation is based upon the concept of tiering. Tiering is described in Section 1502.20 of the CEQ NEPA Regulations as follows *(1)*:

> Agencies are encouraged to tier their environmental impact statements to eliminate repetitive discussions of the same issues and to focus on the actual issues ripe for decision at each level of environmental review. Whenever a broad environmental impact statement has been prepared (such as a program or policy statement) and a subsequent statement or environmental assessment is then prepared on an action included within the entire program or policy (such as a site specific action) the subsequent statement or environmental assessment need only summarize the issues discussed in the broader statement and incorporate discussions from the broader statement by reference and shall concentrate on the issues specific to the subsequent action. The subsequent document shall state where the earlier document is available. Tiering may also be appropriate for different stages of actions.

Further, and as inferred above, it will be necessary to periodically review the SIP and PEIS in order to maintain current navigation and environmental information that can inform specific project-level decision-making. Such reviews can be aided by monitoring and policy information generated by an on-going adaptive management program. Depending upon the types of modifications to the SIP, it may be necessary to issue one or more Supplemental PEISs at future dates.

ECOSYSTEM AND ADAPTIVE MANAGEMENT

Another emerging theme for strategic-level impact studies is the use of ecosystem management approaches to address larger-scale issues that may involve both policy and scientific uncertainties. Accordingly, the federal government is encouraging the implementation of ecosystem management approaches within and between federal agencies and between federal, state, and local agencies. Ecosystem (ecological) management includes the analysis of both the elements and the interrelationships involved in maintaining ecological integrity *(7)*. Such management should use a local-to-regional perspective that considers impacts at the appropriate scale within the context of the entire ecosystem. To facilitate the implementation, the Interagency Ecosystem Management Task Force was formed in the mid-1990s. The work of this Task Force and other entities and individuals has been instrumental in defining the following general principles for ecological management *(8)*:

- Common ecological management goals should be socially defined through a collaborative vision process that involves all interested participants and that incorporates ecological, economic, and social considerations.
- Given that most ecosystems and watersheds transcend conventional geopolitical boundaries, ecological management requires coordination among federal, state, tribal, and local governmental entities as well as collaboration with other interested parties.
- Ecological management policies and decisions should be based upon integrated and comprehensive scientific information that addresses multiple rather than single resources.
- Ecological management seeks to maintain and restore biodiversity and ecosystem integrity.
- Ecological management involves management at large spatial and temporal scales that correspond to ecosystems and watersheds.
- Given the finite nature of public funds and other resources, ecological management enables agencies to engage in careful targeting to select achievable solutions and to allocate resources efficiently.
- Ecological management requires an iterative, adaptive management approach to account for changing goals and values and new scientific information concerning ecological conditions.

Adaptive management refers to a relatively new concept that recognizes that scientific uncertainties and unforeseen environmental changes are inevitable when various plans, programs, or policies are implemented in particular environmental settings. Accordingly, the application of the concept in environmental management entails *(9)*:

> …"the use of carefully designed and monitored experiments, based on input from scientists, managers, and citizens, as opportunities to maintain or restore ecological resilience and to learn more about ecosystems. These actions are monitored for scientific findings to help improve understanding of how policy decisions affect ecosystems. Findings from ecosystem monitoring are then to be used to appropriately adjust management policies. Adaptive management requires that clear goals and desired outcomes be established so that progress toward desired future conditions can be assured."

Adaptive management has been applied, or is being considered for application, in environmental management efforts related to several large-scale water resources projects and programs. For example, it is included in the Comprehensive Everglades Restoration Plan in Florida, the Glen Canyon Dam in Arizona, and the Upper Mississippi River Basin navigation study in the Midwest; and it has been proposed for the Missouri River Basin ecosystem management program. Further, the concept is being incorporated in the SIP and the CEA study within the ORMSS. Recommendations for post-ORMSS activities will include periodic reviews of navigation traffic relative to the above-mentioned three growth scenarios, and adjustments in planned investments for lock extensions and maintenance and rehabilitation, as appropriate. Recommendations will also be included for monitoring of environmental indicators and adjustments of navigation traffic management and environmental policies, as appropriate.

Elements in an Adaptive Environmental Management Program

The key elements associated with an adaptive environmental management program include, but are not limited to, the following:

- The assemblage of information on the historical and current conditions of key indicators for environmental resources that are potentially subjected to impacts from a plan, program, or project; and the quantitative prediction or qualitative description of these anticipated impacts, along with impacts from other past, present, and reasonably foreseeable future actions (i.e., the cumulative effects), on the key indicators.
- A scientifically-designed monitoring program focused on measuring changes in key indicators of environmental resources subjected to potential cumulative effects.

- A strategic framework that includes periodic evaluations of the implementation of features of the SIP in view of navigation traffic levels, the monitoring data and other related policy information, and decision-making, as appropriate, relative to adapting management policies or measures for the environmental resources of concern.
- Collaborative long-term agreements between pertinent federal, state, tribal, and local environmental agencies; and a program steering committee comprised of representatives from these agencies.
- Adequate budgetary and personnel resources via the contributions from multiple entities.
- A peer group of advisors with expertise in public policy analyses, the planning and conduction of environmental monitoring and research, and environmental decision-making.

Each of these elements are currently being addressed, as appropriate, in the CEA study within the ORMSS. As suggested, a key feature of adaptive management is the planning and implementation of monitoring programs.

Monitoring Planning as a Basis for Adaptive Management

Sadler and Davies *(10)* describe three types of environmental monitoring which might be associated with the life cycle of a project or plan. These include baseline (current conditions) monitoring, effects or impact monitoring, and compliance monitoring. Baseline monitoring is the measurement of environmental variables during a representative pre-project or pre-plan period to determine existing conditions, ranges of variation, and processes of change. Effects or impact monitoring involves the measurement of environmental variables during construction and operation of one to several projects to determine changes that may have been caused, and to develop or evaluate mitigation measures. Finally, compliance monitoring takes the form of periodic sampling and/or continuous measurement of levels of waste discharge, noise, or similar emissions, to ensure that conditions are observed and standards are met. Pre-EIS monitoring includes baseline monitoring, while post-EIS monitoring encompasses effects or impact monitoring, and/or compliance monitoring. All three types of monitoring could be included in an adaptive management program for the ORMSS.

Careful planning and implementation of an environmental monitoring program is necessary for achieving the various purposes of monitoring. Three considerations are important in planning such programs in the United States. First, there is an abundance of environmental monitoring data routinely collected by various governmental agencies and the private sector. This data needs to be identified, aggregated, and interpreted since information is often compiled but never interpreted relative to the quality of the environment being monitored. Second, environmental monitoring programs are expensive to plan and implement. Every effort should be made to use or modify extant programs. Third, owing to overlapping environmental management and monitoring responsibilities of many local, state, and federal governmental agencies, it may be necessary to carefully coordinate monitoring planning with several agencies.

To illustrate the scientific considerations that may be involved in planning a monitoring program, a generic seven-step conceptual framework for developing an environmental monitoring plan for biological and ecological monitoring will be highlighted *(11)*. The framework can be adapted to the monitoring of environmental media, and socioeconomic and/or social impacts. The first step would be to define the monitoring objectives. In many monitoring schemes, the objectives are either not stated or are so complex that they become meaningless *(11)*. The second step would be to determine the locations where the monitoring will take place. The third step is to make sure the data collected is archived for future use. When monitoring extends over long periods of time, such as for the SIP and environmental resolurces, those working on the adaptive management program will change. So the need arises for methods to assure the retention of such data, which should be accessible and understandable to successive professionals. The fourth step entails various arrangements for data collection and storage. The success of a monitoring program depends not only on good planning and logistical support, but also on coordination with other related programs.

The fifth step involves the process of selecting the variables (indicators).The ideal variable and process would have a wholly ecological basis but logistical limitations (finances, time and effort) may override these considerations. Due to such logistical limitations, methods for collection of data from the field or assemblage of data from other sources should therefore be considered along with the choice of indicators. Further, composite indices can be developed from monitoring programs. For example, monitoring data can be aggregated into pertinent indices to reflect the composite quality of different environmental categories. To illustrate, several indices for the biological environment have been developed; one example is an Index of Biotic Integrity (IBI) for stream fish assemblages. An index of this type has been developed for the Ohio River.

The sixth step would involve the preliminary data gathering and baseline surveys. Ecological information from published sources or preliminary field studies should be assembled. For example, considerable ecological information exists relative to the Ohio River mainstem. To illustrate, the Ohio River Sanitation Commission (ORSANCO) has over 50 years of water quality, fish, and ecological data. Special research studies on mussels and threatened and endangered species have been conducted. Finally, the seventh step involves the analysis and presentation of the data. Considerations of who will use the data, to make recommendations, should be reviewed when the form of data presentation is selected *(11)*. For an adaptive management program, it is anticipated that the program steering committee will use the information to adapt navigation and environmental management efforts, as appropriate.

In summary, these monitoring purposes and planning elements are being utilized as the work on the adaptive environmental management program continues.

THE CEA STUDY

The CEA study within the ORMSS has been conducted based upon an 11-step methodology promulgated by the Council on Environmental Quality *(12)*. Steps 1 to 4 relate to scoping, Steps 5 to 7 to describing the affected environment, and, Steps 8 to 11 to determining the environmental consequences. The specific steps and how they were or are being fulfilled are as follows:

- Step 1 – Identify the significant cumulative effects issues associated with the proposed action and define the assessment goals. This step was based upon the identification of the typical impacts associated with the construction and operation of navigation system locks and dams, and their repair and rehabilitation and periodic maintenance activities. Public scoping meetings were held along with several meetings of a 25-person environmental review team (ERT). The membership of the ERT consisted of representatives from several federal and state agencies responsible for environmental and natural resources management, and three non-governmental organizations. The ERT has participated throughout the CEA study. The initial scoping in Step 1 provided the basis for the identification of 12 valued environmental components (VECs) of concern. The VECs included aquatic ecological resources (water and sediment quality, mussels, fish, and macroinvertebrates), riparian and floodplain ecological resources (floodplain hydrology, terrestrial habitat, wetlands, islands, and soils and geology), threatened and endangered species (fish, mussels, mammals, birds, and plants), air quality, recreational uses of the River, noise, aesthetics, human health and safety, cultural resources, transportation and traffic, land use, and socioeconomic resources (including environmental justice).
- Step 2 – Establish the geographic scope for the analysis. The scope for the majority of the identified cumulative effects issues and related VECs consisted of the mainstem of the Ohio River along with its 500-year floodplain. Due to data availability on actions, resources, and impacts, the geographic scope often focused on the mainstem and the contiguous counties in the six states along the mainstem.
- Step 3 – Establish the time frame for the analysis. The selected time frame was typically from 1920 to 2060 for most VECs. The earlier date coincides with the initiation of large-scale locks and dams on the Ohio River mainstem. The latter date reflects the economic study period for the SIP. One exception for this time frame was the inclusion of information on much earlier cultural properties for the cultural resources VEC.
- Step 4 – Identify other actions affecting the resources, ecosystems, and human communities of concern. As noted in the cumulative effects definition above, "other actions" include past, present, and reasonably foreseeable future actions (RFFAs). To facilitate these identifications and their related effects, a series of 23 RFFA matrices were developed. The 23 matrices encompassed the 12 VECs and their subcomponents as delineated in Step 1. The RFFAs, which also included similar past and present actions, were defined as:

  > Actions identified by analysis of formal plans and proposals by public and private entities that have primary (direct) or secondary (indirect) impacts on VECs associated with the Ohio River. RFFAs also include potential actions that are beyond mere speculation when incorporated in plans or documents by credible private or public entities. RFFAs may also include events forecasted by trends, probable occurrences, policies, regulations, or other credible data that may have bearing on the VECs.

  A total of 87 types of RFFAs were considered in the analyses; the types included six categories: navigation investment actions, other Corps actions, "but for" actions (those actions that would not occur "but for" the presence of the navigation system), actions by others, natural disasters, and regulatory environment. Each listed RFFA was characterized in terms of its anticipated time period of occurrence, probability of occurrence, and location on the River. The anticipated effects of each RFFA on each VEC or subcomponent were described in "smart cells" using Microsoft Excel spreadsheets. Finally, the importance (high, medium, or low) of each RFFA relative to its contribution to cumulative effects on each VEC or subcomponent was also described in “smart cells”

- Step 5 – Characterize the resources, ecosystems, and human communities identified in scoping in terms of their response to change and capacity to withstand stresses. This step was based upon aggregated historical and current information and an analysis of environmental sustainability (AES) for the 12 VECs or subcomponents noted above. The AES approach was comprised of four parts: (1) identification of “common effects” on the VEC or subcomponent thereof from the high and medium importance RFFAs as delineated in the pertinent RFFA matrix (Step 4 above); (2) selection of indicators of ES for the VEC or subcomponent thereof, and their tiered grouping, as appropriate; (3) description of the “connections” between the common effects (and related high and medium importance RFFAs) and the indicator groups; and (4) assignment of a “bottom line” category to the ES of the VEC or subcomponent, based on considering the past, present and future conditions. The ES categories were “not sustainable”, “marginally sustainable”, and “sustainable”. Specific ES definitions were developed for each VEC or subcomponent (they will be illustrated below for water quality).
- Steps 6 and 7 – Characterize the stresses affecting these resources, ecosystems, and human communities and their relation to regulatory thresholds; and define a baseline condition for the resources, ecosystems, and human communities. These two steps were addressed jointly for each VEC or subcomponent. The approach consisted of identifying historical and current laws, regulations, ordinances, and programs that contain regulatory thresholds and/or policies related to the VEC or subcomponent. Then, historical reference point and trends information, along with current conditions, were summarized for the indicators of ES for the VEC or subcomponent. Numerous information sources and extant monitoring data were reviewed for Steps 6 and 7. Further, the institutional information and environmental conditions and compliance with regulatory thresholds served as the basis for the categorization of the past and present ES for the VEC or subcomponent.
- Step 8 – Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities. This step was largely accomplished through the development of the RFFA matrices as described in Step 4. Further, peer-reviewed literature, various governmental studies and reports, and impact-study related and resource-management related books were used to more thoroughly document numerous relationships. Attention was also given to various relationships between VECs and subcomponents (e.g., what are the implications of changes in water quality on the populations of mussels in the River?).
- Step 9 – Determine the magnitude and significance of cumulative effects. Due to limited site-specific data on impacts from various actions, and to the system-wide focus of the CEA study, it has not been possible to quantitatively determine the magnitude of the historical, current and future cumulative effects on the VECs and subcomponents. Rather, a qualitative determination was made based on the AES approach described in Step 5. The significance of the cumulative effects was ascertained via compliance or noncompliance with regulatory thresholds, consideration of the connections between common effects and indicators of ES, and life cycle features of ecological resources, as appropriate. The assigned categories of ES for the past, present, and future represent the composite significance determination for the cumulative effects on each VEC or subcomponent.
- Step 10 – Modify or add alternatives to avoid, minimize, or mitigate significant cumulative effects. This step is being addressed via the identification of generic mitigation measures for many of the analyzed actions, with particular attention being given to such measures for navigation investment actions by the Corps. In addition, various regulatory programs that have facilitated, or are expected to emphasize, generic mitigation measures for numerous actions have also been identified and incorporated in the analysis. Further, measures to enhance the ES of aquatic ecological resources and riparian/floodplain ecological resources are being identified. These mitigation and enhancement measures will be grouped with the three SIP scenarios, described earlier, as appropriate, for the subsequent decision-making process.
- Step 11 – Monitor the cumulative effects of the selected alternative and adapt management. This step is being addressed in a systematic manner for each VEC and subcomponent. The key criteria that are being used to “trigger” Step 11 are the past, present, and future ES categories for the VECs and subcomponents. If the VEC or subcomponent is currently “sustainable”, and this is expected to continue into the future, only targeted additional monitoring over that currently being done may be recommended, and no specific adaptive management strategy will be developed. For VECs or subcomponents that are currently categorized as “not sustainable”, or “marginally sustainable”, specific collaborate monitoring will be

developed along with an appropriate adaptive management program. The program is expected to be based on the earlier-described elements.

CUMULATIVE EFFECTS AND ES – WATER QUALITY

To illustrate the AES approach as described in Step 5 above, the water quality subcomponent of the aquatic ecological resources VEC will be used as an example. The first part of the AES identified four common effects of multiple high and medium importance actions; they include 8 actions causing turbidity and sedimentation, 5 actions contributing to point source pollution,4 actions contributing to nonpoint source pollution, and 8 actions contributing to pollution reduction. Examples of actions from each common effects category include channel dredging/dredged material disposal and instream sand and gravel mining (turbidity and sedimentation), coal and related industries and marina operation (point source pollution), stormwater discharges and agriculture (nonpoint source pollution), and more stringent quality standards for environmental media and pollutant source control (pollution reduction).

Six indicators of ES were identified and pertinent historical and current information on them has been summarized. Regarding their relevance for ES, the following rationale is appropriate:

- measures of key water quality parameters
  - (1) dissolved oxygen – related to the total organic loading from point and nonpoint sources at specific locations along the Ohio River; can also be used as a threshold indicator since the DO standard is 5.0 to 6.5 mg/l, depending upon several conditions
  - (2) fecal coliforms – related to fecal matter contamination from humans or other animals, whether from point or nonpoint sources at specific locations along the River; can also be used as a threshold indicator since the standard is 2000 fecal coliforms/100 ml
  - (3) turbidity and total suspended solids – related to solid material which can be attributed to point and nonpoint sources at specific locations along the River; can originate from both man-made wastewater discharges and natural erosional processes; no specific numerical standards exist for the Ohio River
  - (4) nutrients such as nitrogen and phosphorus – related to the total nutrient loading from point and nonpoint sources at specific locations along the River; the nitrogen standard is 10 mg/l (for nitrite plus nitrate nitrogen); no standard has been adopted for phosphorus
- level of conformance with state and federal water quality standards, including attainment of permissible use designations – water quality standards are based on various use designations, with the level of conformance representing a composite indicator of a sustainable aquatic ecological resource
- TMDL implementation – the TMDL (total maximum daily load) program is for specific water quality parameters which may reflect an "overloaded" situation related to point and nonpoint sources at specific locations; implementation of the program reflects a coordinated effort to achieve appropriate water quality standards and promote a sustainable equatic resource
- effectiveness of specific point source control and nonpoint source control programs – such programs are focused on reducing pollutant discharges into the River, thus they promote a more sustainable aquatic ecological resource
- ability to sustain diverse, healthy populations of aquatic organisms – an aquatic system which attains water quality standards while minimizing the effects of "legacy contaminated sediments" should sustain diverse populations of various organisms; further, it should attain permissible use designations
- effectiveness of spill response, monitoring programs, and related precautionary measures – these represent both direct and indirect programs which are focused on more effective management of water and sediment quality, and thus the promotion of a sustainable aquatic ecological resource

For the purposes of this analysis, the six indicators are grouped into three tiers for the conduction of the AES. The three tiers are as follows:

- first tier – "scientific measures of quality" -- water quality parameters (DO, fecal coliform bacteria, turbidity, total suspended solids, N and P); and conformance with water quality standards
- second tier – "positive actions related to source control" -- point source control and nonpoint source control programs; TMDL implementation; and spill response, monitoring programs, and related precautionary measures
- third tier – "composite indicators of aquatic ecosystem sustainability"; this includes two measures developed from several indicators -- attainment of permissible use designations; and sustain diverse, healthy populations of aquatic organisms

Finally, the four groups of actions with common effects are connected to the indicators and tiers via simple cause-effect linkages (not included herein). For example, turbidity and sedimentation represent historical water quality concerns in the Ohio River, even with the absence of specific standards. Control programs for municipal and industrial point sources have been implemented within the last several decades, while similar programs for nonpoint sources are largely in their first decade. Increased control programs, including operational measures, are expected in the future for channel dredging/dredged material disposal, and port and marine development and operation. Implementation of a TMDL program for turbidity could occur in localized reaches of the River. Further, spill-related programs and precautionary measures are expected to reduce accidental releases. As a result of these historical, current and anticipated future source control efforts for turbidity and sedimentation, it is expected that permissible use designations will be more easily attained, thus increasing the sustainability of diverse populations of aquatic organisms.

Regarding point source pollution, of particular concern are industrial water users and dischargers who may introduce diverse chemicals and bacteria into the River. Existing point and nonpoint source control programs have already led to reductions in industrial discharges, thus increasing the possibilities for achieving conformance with water quality standards. Future source control programs may become more stringent, and TMDL requirements could be implemented for specific industrial pollutants in certain River reaches. Also, spill prevention and response programs are expected to reduce accidental point source pollution. As a result of these historical, current and possible future point source control efforts, it is anticipated that additional River reaches will attain their respective permissible use designations, and the River itself will be able to sustain more diverse populations of aquatic organisms.

Nonpoint source control programs are being currently implemented for stormwater discharges from urban areas, and for runoff waters from industrial areas. Source control programs related to floodplain sand and gravel mining, as well as agriculture, are anticipated, although the specific requirements and their possible effectiveness are largely unknown. However, when considering the background of a minimal historical emphasis on controlling nonpoint source pollution, it does appear that the current efforts, when coupled with possible future emphases, are improving and will enhance the ES of the aquatic ecosystem.

Further, several of the 8 RFFAs expected to contribute to pollution reduction in the river represent continuations of existing pollution reduction efforts. Accordingly, the sustainability of the aquatic ecosystem is expected to improve over time.

Regarding the three categories for ES of water quality, the following specific definitions were used:

- Not sustainable – the composite conditions for the selected indicators of ES for water quality do not reflect conditions that would facilitate attainment of permissible use designations in the Ohio River, nor would they sustain diverse populations of aquatic organisms in the River.
- Marginally sustainable – the composite conditions for the selected indicators of ES for water quality are such that the attainment of permissible use designations is accomplished for the majority, but not all, of the river miles in the Ohio River, and diverse populations of aquatic organisms are occurring along the majority of the River; however, the conditions of the indicators are somewhat tenuous both in location and likelihood of occurrences (in other words, the conditions are "borderline" for ES, and there are uncertainties regarding specific quantitative measures for the ES water quality for the Ohio River).
- Sustainable – the composite conditions for the selected indicators of ES for water quality are such that the attainment of permissible use designations is accomplished for essentially all of the river miles in the Ohio River, and diverse populations of aquatic organisms are occurring along the majority of the River; further, the conditions of the indicators exceed regulatory thresholds and various governmental programs are in place to control point and nonpoint pollution sources and to emphasize pollution reduction in the River.

Based upon the above-described actions and effects, the tiers of indicators, and the ES categories, the ES of the water quality of the mainstem of the Ohio River can be characterized as follows:

- In the time period prior to 1920, and continuing up to about 1950, the water quality of the Ohio River mainstem was in degraded state and thus classified as "not sustainable" due to largely untreated and uncontrolled point and nonpoint pollutant discharges from growing municipalities and various types of industries and land uses along the River.
- Due to the programs of ORSANCO (Ohio River Sanitation Commission), and the requirements of the Federal Water Pollution Control Act (and the amended Clean Water Act), the water quality of the River has shown a steady improvement in recent decades; thus it is currently in a "sustainable" category.

- Regarding the future, it is expected that water quality of the Ohio River mainstem will further improve as a result of the continuation of source control and other pollution reduction programs; thus, it will be maintained in a “sustainable” condition. However, this characterization should not bring complacency, rather, vigilant efforts are still needed to continue effective water quality monitoring and management efforts. In this regard, it may be desirable to plan and implement source monitoring programs for selected RFFAs (actions) considered to be of high importance relative to cumulative effects.

FINAL OBSERVATIONS

This paper describes a work-in-progress involving the development of a SIP for navigation on the Ohio River mainstem. Related environmental efforts include the conduction of a CEA study and the preparation of a PEIS. The CEA study includes an analysis of the cumulative effects of past, present, and future actions on the ES of pertinent VECs and subcomponents thereof. An adaptive management program, including appropriate monitoring, will be developed for those VECs and subcomponents that are determined to be “not sustainable” or “marginally sustainable” under current and/or future conditions. The key observations are:

- The 11-step CEA methodology developed by the Council on Environmental Quality provides a useful framework for conducting a comprehensive study of the cumulative effects of past, present, and future actions on key resources, ecosystems, and human communities along and within the mainstem of the Ohio River.
- Qualitative analyses of the cumulative effects of multiple actions can be considered in relation to the ES of various VECs and subcomponents thereof; and ES can be determined based on the composite consideration of selected and tiered indicators for each VEC or subcomponent thereof. If the current and anticipated future ES is “not sustainable” or “marginally sustainable”, this will serve as a “trigger” for initiating an adaptive management program.
- Adaptive management can be a useful tool for addressing the environmental consequences of uncertain policies and plans, uncertain future conditions, and inadequate scientific understanding of environmental systems and their responses to stress. The centerpiece of an adaptive management program is scientifically based monitoring focused on reducing a variety of identified uncertainties.
- The outputs of the SIP relative to navigation traffic levels, scheduling of maintenance and repairs, and timeframes for lock extensions will be used in developing the navigation-related and environmental-related monitoring systems and experiments basic to an adaptive management program.
- Future environmental documents related to the SIP and modifications of environmental management and mitigation measures will be tiered from the PEIS that is under preparation.

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