PROMOTING ENVIRONMENTAL SUSTAINABILITY VIA AN EXPERT ELICITATION PROCESS[a]

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ABSTRACT

Environmental sustainability (ES) planning was applied to the 981-mile, commercially navigable Ohio River. Navigation improvement needs were identified within the broad study along with actions to restore aquatic and riparian ecological resources to a higher state of sustainability. The actions were identified via an Expert Elicitation Process (EEP) involving aquatic and riparian/terrestrial experts knowledgeable of Ohio River resources. The received information was synthesized into goals for the selected resources (Valued Ecosystem Components – or VECs), actions or measures to attain the goals, and monitoring to evaluate conditions. Finally, 26 types of ES actions were identified and classified into three ES alternatives. These alternatives were then evaluated relative to key decision criteria, and such evaluations, based on pertinent decision criteria, were also conducted for four navigation improvement alternatives. Finally, the best combination of ES and navigation alternatives was identified. The key lessons derived from this use of EEP were that: (1) EEP can support the preliminary identification of ES measures, however, more detailed study of specific designs and cost evaluations will be necessary; (2) the method promotes collaboration between key scientists and policymakers from governmental agencies and private sectors, and such collaboration will ultimately provide the foundation for implementation of sustainability actions; and (3) an effective EEP does not occur by accident, it requires careful planning, implementation, and documentation.

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INTRODUCTION

Environmental sustainability (ES) concepts are being increasingly utilized in environmental impact studies. Such usage is occurring for studies of both direct and indirect effects from single projects, as well as studies focused on cumulative effects of multiple planned actions when coupled with similar effects from other past, present, and future actions. In some large-scale traditional infrastructure studies, attention is also being given to the delineation and analysis of ES alternatives, either singly or in combination with typical types of infrastructure plans. Ideally, the planning and analysis of both ES and traditional infrastructure alternatives should be concurrent; however, due to the relative newness of ES considerations, the formation and analysis of ES alternatives may occur sequentially rather than concurrently.

Described herein is a case study of the sequential formulation of ES alternatives and a brief discussion of their independent combined analyses with traditional infrastructure alternatives. The formulation process benefitted from use of an Expert Elicitation Process (EEP) wherein the professional knowledge, experience, and judgment of appropriate subject matter experts was utilized. The EEP involved meetings of regional resource experts to discuss and debate pertinent resource (Valued Ecosystem Components – or VECs) goals and what physical and policy measures could be used to move toward the achievement of the goals.

The included information consists of a brief description of the Ohio River Navigation Infrastructure Study and the timing of the ES emphases. Background information on the EEP and a practical eight-step method for planning, implementing, and then documenting the use of the EEP method is presented. Finally, the outputs of the method are presented, with particular emphasis given to 26 management measures for enhancing the sustainability of mussels and other aquatic and riparian VECs. The categorization of the 26 measures into three ES alternatives, and their combined analyses with four navigation-related alternatives, is then briefly described.

CASE STUDY – THE OHIO RIVER NAVIGATION INFRASTRUCTURE 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 stone, and manufactured products such as petrochemicals and metals 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 for the foreseeable future. As an example, utility coal used for electrical generation was projected to increase throughout the Ohio River system over the next 60 years under five different environmental compliance and economic scenarios. A large proportion of coal used by the electric utility industry of the region is transported via the inland navigation system.

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 Corps 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. Most locations are 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. Figure 1 displays the locks and dams on the Ohio River (Rife, et al., 2005).

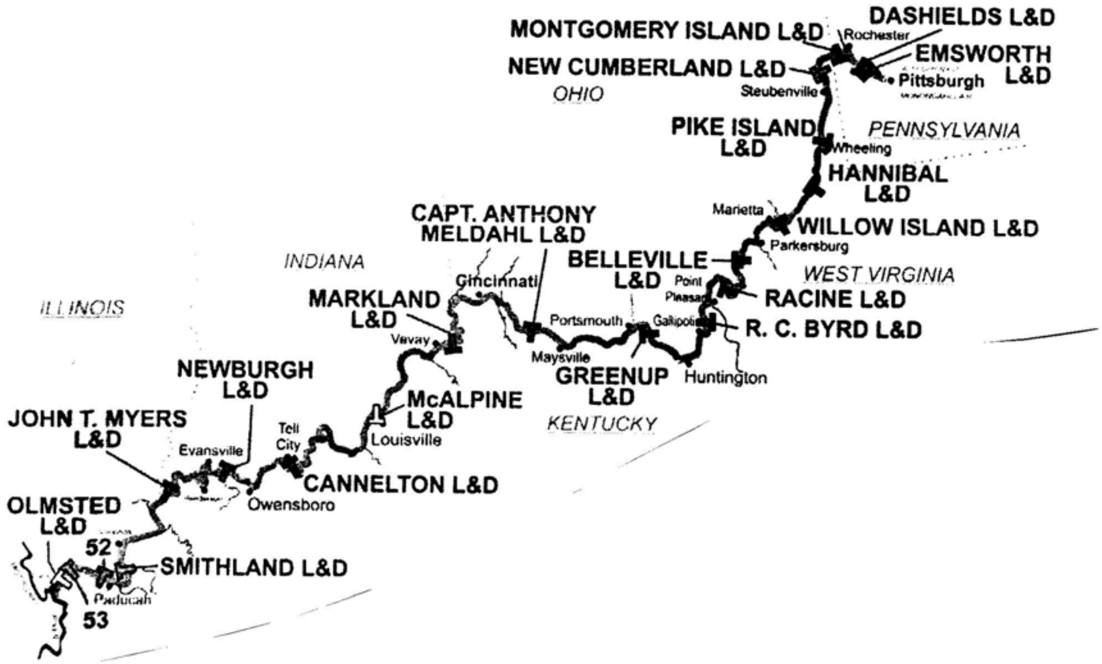
Economic, engineering, and environmental issues have been addressed in the Ohio River Mainstem Systems Study (ORMSS), to develop a System Investment Plan/Programmatic Environmental Impact Statement (SIP/PEIS) for navigation infrastructure to the year 2070. Economic issues were derived from a range of projections of navigation traffic increases, and cost inefficiencies that occur due to barge queuing when main locks are subjected to either scheduled or unscheduled maintenance or repair. Engineering issues encompassed constructing increased sizes of auxiliary locks at several locations and development of risk functions and consequences of component failures that can be used to proactively schedule major repairs, rehabilitations, and replacements at existing facilities. Environmental issues were addressed in a cumulative effects assessment (CEA) study of the entire mainstem navigation system (U.S. Army Corps of Engineers, 2006b)

Planning Objectives

The integrated ORMSS began in 1996. The initial planning objectives were two-fold (U.S. Army Corps of Engineers, 2006b, p. 6-8):

- Ensuring Future Navigability – providing appropriate maintenance to existing navigation facilities (lock, dams, and channel improvements) and providing new, improved, or replacement facilities (as justified) to ensure continued and reliable navigation for nine-foot draft vessels throughout the length of the Ohio River.

- Improving Navigation Efficiency – exploring various options to schedule and execute maintenance as well as structural options so as to maximize National Economic Development (NED) net benefits – for example, by



Note: Currently, there are 20 lock and dam sites on the Ohio River, but after completion of Olmsted L&D, tentatively scheduled for 2009, L/Ds 52 and 53 will be decommissioned.

Figure 1: The Ohio River Locks and Dams System (Rife, et al., 2005)

identifying cost-efficient measures (e.g., advance maintenance) to reduce transportation shipment costs.

Throughout planning for the CEA, it was determined that the environmental sustainability (ES) status should be included for selected Valued Ecosystem Components (VECs) being addressed. Consequently, it was also decided that ES alternatives would need to be identified and incorporated along with navigation system alternatives in the final SIP/PEIS.

To address the ES of the selected VECs, the CEA study was formulated to include sustainability for the 10 studied VECs. The VECs included three related to aquatic resources (water and sediment quality, fish, and mussels), one related to riparian/floodplain resources, and six others (air quality, health and safety involving contact recreation and fish consumption, recreation, transportation and traffic, socioeconomics, and cultural resources). The details of the analyses and findings are in the Draft PEIS (U.S. Army Corps of Engineers, 2006b, pp. 6-20 to 6-34). An important feature of the analyses involved use of generic ES definitions for each VEC. These definitions were (U.S. Army Corps of Engineers, 2006b, p. 6-21):

- Not sustainable (NS) – The composite conditions of the selected indicators (for the VEC) do not reflect conditions that can sustain the resource over the long-term.

- Marginally sustainable (MS) – The composite conditions for the selected indicators are such that the resource can be sustained for the majority of river miles in or along the Ohio mainstem, but conditions of the indicators are somewhat tenuous both in location and likelihood of occurrences.

- Sustainable (S) – The composite conditions of the selected indicators reflect sustainability for essentially all the river miles in or along the Ohio mainstem. Further, conditions of the indicators exceed regulatory thresholds and pertinent governmental programs are in place to support the resource.

The ES categories for the various VECs were determined for three time periods – past (generally 1920 to 1970), present (2003), and future (generally reflective of 2020 and beyond, possibly up to 2070). The category determinations were derived by combining the knowledge and professional judgment of the study team and an associated Interagency Working Group (IWG). The determinations were based on historical to current data and information on indicators of the VECs, along with information on past, current, and reasonably foreseeable future actions associated with the Ohio River Mainstem. Projections for future conditions also took into account trends, large-scale plans, current and anticipated environmental laws, regulatory program activities and changes, and other sources of information.

The results of the ES analyses revealed primary concerns related to the historical, current, and future conditions for both aquatic resources and riparian floodplain resources. For example, historical conditions were not sustainable (NS) for water and sediment quality, fish, mussels, and riparian/floodplain resources. Current conditions are marginally sustainable (MS) for the same four VECs. Relative to future conditions for water and sediment quality and fish, they were projected to be sustainable (S); however, for mussels and riparian/floodplain resources, the conditions were deemed to be only marginally sustainable (MS) (U.S. Army Corps of Engineers, 2006b, pp. 6-23 to 6-28).

Incorporation of Environmental Sustainability

Several important reports and guidelines were issued after 2001, and they influenced a decision to add environmental sustainability as a study objective. Included among these documents was the National Research Council (National Academies of Science) report on their review of the Upper Mississippi River/Illinois Waterway (UMR/IWW) draft navigation feasibility study (Committee to Review…, 2001). Subsequent 2003 internal guidance from Corps Headquarters to the UMR/IWW study team included incorporating environmental sustainability improvements in every alternative. Also, in 2002 the US Army Chief of Engineers issued a set of Environmental Operating Principles, and these were included in an Engineering Regulation and Circular in 2003 (U.S. Army Corps of Engineers, 2002, 2003a, and 2003b). These principles stressed achieving environmental sustainability, understanding environmental consequences, seeking balance and synergy, and assessing the cumulative effects of Corps actions and missions. As a result of this new information, a third planning objective was added to strategic focus of the ORMSS (U.S. Army Corps of Engineers, 2006b, p. 6-8):

- Enhancing Environmental Sustainability – identifying means within the authorities of the Corps of Engineers (or other agencies) to minimize degradation of environmental resources which might be caused by transportation or other development, and to improve sustainability of resources in and along the Ohio River. The Corps of Engineers Environmental Operating Principles define environmental sustainability 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.

The resultant ORMSS report integrated the findings related to the three objectives into one document. The document also served as a draft programmatic environmental impact statement (PEIS) (U.S. Army Corps of Engineers, 2006b). The final SIP/PEIS is scheduled for issuance in 2009.

To accomplish this objective, it was decided that ES alternatives should be identified for both aquatic and riparian/floodplain resources. However, schedule and budgetary constraints would not allow a comprehensive analysis and investigation of this topic. It was therefore decided that a special technique, called the Expert Elicitation Process (EEP), would be used to elicit (draw out or bring out) and summarize the professional judgment of aquatic and riparian resources experts knowledgeable about such resources associated with the Ohio River Mainstem.

BACKGROUND INFORMATION ON THE EEP

The original development of structured methods for expert-opinion elicitation was by the RAND Corporation. Two early methods, developed in the 1950s and 1960s, were the Delphi method and scenario analysis (Ayyub, 2000, p. 37). The Delphi method, which was often characterized by the use of questionnaires sent to disaggregated experts, was utilized for numerous types of applications, including environmental impact studies. Further, the method itself was often the subject of scientific and policy evaluations (Linstone and Turoff, 1975).

The EEP has evolved from earlier approaches for determining general public and expert judgments related to multi-criteria decision-making. For example, Keeney, et al. (1990) addressed surveys, indirect elicitation (inferring public values from marketplace behavior), direct elicitation (interactive meetings with individuals or groups to elicit values or dimensions), focus groups, and public involvement meetings as potential approaches. From this review, the concepts of direct elicitation and focus groups were blended to define a “public value forum.” Such a forum could consist of a workshop or a series of workshops in which selected members of the public produced a catalog of objectives that they considered relevant for evaluating policy alternatives (Keeney, et al., 1990, p. 1013).

It is of interest to note that the EEP and its precursor methods are often focused on decision-making via the use of multiple criteria for evaluation of a set of reasonable alternatives. Such methods are often referred to as multi-criteria decision-making (MCDM) multi-criteria decision analysis (MCDA), multi-attribute utility measurement (MAUM), or decision analysis (DA). In some instances, referral is also made to the analytical hierarchy process (AHP) (Kiker, et al., 2005). Examples of EEP or precursor usage involving this feature include evaluation of future energy scenarios (Keeney, et al., 1990), validation of an integrated systems model for coastal zone management (Nguyen and de Kok, 2007), management of contaminated sediments (Rogers, et al., 2004), and assessing the likelihood of rapid climate change (Arnell, et al., 2005).

The U.S. Army Corps of Engineers has used EEP for risk analysis and risk-based decision making related to the integrity of existing and planned facilities. For example, the Corps has used the EEP for quantifying the probability of failure of navigation lock components, quantifying the probability and consequences of navigation lock closure, estimating the probability of events requiring emergency gate usage at hydropower plants, quantifying the probability of failure and unsatisfactory performance of embankment dams, quantifying the probability of failure and unsatisfactory performance of multi-purpose navigation, hydropower and recreational dams, and predicting the vessel safety improvements from deep channel widening (Ayyub, 2000, pp. 14-15). Even trees and fault trees are often utilized to provide a structure for the risk-based decision making.

A recent Engineer Technical Letter (ETL 1110-2-561) has provided detailed information on the use of EEP for the performance of risk analyses of detrimental seepage and slope stability for embankment dams (U.S. Army Corps of Engineers, 2006a). Appendix E of the ETL contains detailed information relative to the elicitation of judgmental probabilities and their aggregation into an EEP output. In this case, the ETL defines expert elicitation as the formal quantification of expert opinion into judgment probabilities (U.S. Army Corps of Engineers, 2006a, p. E-1). Appendix E would also be useful for addressing probabilities of environmental consequences of planned projects.

The U.S. Nuclear Regulatory Commission has also used the EEP for probabilistic seismic hazard analysis for nuclear reactors (U.S. Nuclear Regulatory Commission, 1997).

As noted above, an EEP is often used in decision-making when risk and uncertainty needs to be addressed. However, the included experts may not necessarily feel comfortable in assigning probabilities for requested information. As a result, research has been conducted on both biases and the use of heuristics in the EEP. For example, studies of human inadequacies in assessing probabilities, and the resultant influences on decision-making, have been conducted in relation to continued EEP improvement (Kynn, 2008). Further, it is not always required that an EEP emphasize probabilities; rather, it could focus on extracting and compiling professional knowledge and judgment from included experts with other topical expertise.

PRACTICAL GUIDANCE ON THE EEP

Expert-opinion elicitation can be defined as a formal, heuristic process of obtaining information or answers to specific questions regarding pre-defined issues or problems of concern. If the EEP is utilized, it should not be seen as a substitute for rigorous analyses if data for such analyses are available and time constraints are not a factor. Rather, the EEP should be used to supplement such analyses; however, in some situations, the dearth of pertinent information may be the initiator of the selection of the EEP itself.

Key features of an EEP include initial planning led by a designated process leader, the use of experts and resource experts, and a person or group who can serve as facilitators or integrators. The following definitions are pertinent for planning and conducting an EEP (Ayyub, 2001, p. 12):

- Leader of EEP – A person or an entity having managerial and technical responsibility for organizing and executing the project (e.g., preparation of an EIS), overseeing all participants in the EEP, and intellectually utilizing the results.

- Expert – A person with related or unique experience to an issue or question of interest for the EEP.

- Resource experts – Resource experts are technical experts with detailed and deep knowledge of particular data, issue aspects, particular methodologies, or use of evaluators.

- Technical facilitator (TF) – An entity or a person responsible for structuring and facilitating the discussions and interactions of experts in the EEP; staging effective interactions among experts; ensuring equity in presented views; eliciting formal evaluations from each expert; and creating conditions for direct, non-controversial integration of expert opinions.

- Technical integrator (TI) – An entity or a person responsible for developing the composite representation of issues based on the EEP; explaining and defending composite results to other experts, peer reviewers, regulators, and policy makers; and obtaining feedback and revising composite results.

- Technical integrator and facilitator (TIF) – An entity or a person responsible for both the functions of TI and TF.

- Peer reviewers – Experts that can provide an unbiased assessment and critical review of an EEP, its technical issues, and results. It is generally recognized that peer reviewers can aid an EEP relative to quality assurance. Several means for achieving peer review are available, including participation in the EEP itself, and the review of draft written outputs from the TI.

A key feature of the EEP is the conduction of a face-to-face meeting of experts (resource experts) that is focused specifically on the issues under consideration. The meeting of the experts should be held after advanced communication with them regarding background information, objectives, list of issues, and anticipated outcomes from the meeting (Ayyub, 2001, p. 14).

To conduct the planning, facilitation, and documentation of an EEP, the following steps can be utilized (Ayyub, 2001, pp. 17-24):

Step 1 – Identify the Need for an EEP

There can be many needs which can prompt the selection of the EEP tool. Perhaps a basic need is to deal with uncertainty associated with selected technical issues in project design or evaluation, including evaluation of cumulative effects. This need may exist due to incomplete or unavailable information on one or more issues which are important in the decision making process. As a result of the careful consideration of need(s), one or more objectives to be accomplished via the EEP can be articulated. The value of the EEP itself comes from its initial intended uses as a heuristic tool, not a scientific tool, for exploring vague and unknown issues that are otherwise inaccessible. It is not a substitute for scientific, rigorous research (Ayyub, 2001, p. 18).

Step 2 -- Select the Study Leader for the EEP

The study leader could be assisted by a technical facilitator (TF) for the meeting, a technical integrator (TI) to document the meeting and its results, or a single person with both facilitator and integrator skills (TIF). In contrast, the study leader could be responsible for planning and pre-meeting communications, and for facilitation and integration. Irrespective of the extent of the responsibility, the study leader should exhibit the following attributes (Ayyub, 2001, p. 18):

- An outstanding professional reputation, and wide recognition and competence based on academic training and relevant experience;
- Strong communication skills, interpersonal skills, flexibility, impartiality, and ability to generalize and simplify;
- A large contact base of industry leaders, researchers, engineers, scientists, and decision makers; and
- An ability to build consensus based on leadership qualities.

Step 3 – Identify and Select the Scientific and Policy Issues to be Addressed by the EEP

This step is very important, and it probably should have been informally considered prior to the initiation of Step 1 above. The study leader should take the initiative in selecting the scientific and policy issues. The leader could be assisted by the staff of the study team. Once the issues have been identified, background materials for each should be assembled. Further, the key questions to be addressed for each issue should be identified along with information related to the types of responses. An introductory statement for the EEP should also be developed that includes the goals of the process and their relevance. Instructions should also be provided with guidance on expectations, answering the questions, and reporting. Following are some guidelines related to developing pertinent questions for group consideration and discussion (Ayyub, 2001, p. 22):

- Each issue can include several questions, however, each question should consist of only one sought after answer. It is a poor practice to include two questions in one.

- Questions and issue statements should not be ambiguous. Also, the use of ambiguous words should be avoided. The level of wording should be kept to a minimum. Further, it should be recognized that the choice of the words might affect the connotation of an issue, especially for different subjects.

- The use of factual questions is preferred over abstract questions. Questions that refer to concrete and specific matters result in desirable concrete and specific answers.

- Questions should be carefully structured in order to reduce biases of experts and resource experts. Questions should be asked in a neutral format, sometimes more appropriately without lead statements.

Step 4 -- Select Study-Specific EEP Experts and Resource Experts

The number to be selected will be dependent on the specific case and the delineated objective(s). The selection process could begin via the development of a list of criteria. The study leader could then solicit nominations from various agencies, stakeholder groups, and contacts with local, regional, and national subject matter experts (SMEs). Reviews of archival literature can also be useful. Examples of desirable attributes for the experts and resource experts include (Ayyub, 2001, p. 19):

- Strong relevant expertise through academic training, professional accomplishment and experiences, and peer-reviewed publications;

- Familiarity and knowledge of various aspects related to the issues of interest;

- Willingness to act as proponents or impartial evaluators;

- Availability and willingness to commit needed time and effort;

- Specific related local or regional knowledge and expertise regarding the issues of interest; willingness to effectively participate in needed debates, to prepare for discussions, and provide needed evaluations and interpretations; and

- Strong communication skills, interpersonal skills, flexibility, impartiality, and ability to generalize and simplify.

Finally, persons selected by the study leader should not be “clones” of each other. Rather, they should have a diversity of knowledge, interests, and experience.

Step 5 -- Select a Small Group of Peer Reviewers to Provide Quality Control for the EEP

Peer reviewers could participate in the EEP meeting or review the documented output, or both. An obvious key factor in selection is that the peer reviewers do not have a vested interest in the meeting objectives nor the outputs per se. Again, the study leader, with advice from the study team and others, should select the peer reviewers.

Step 6 -- Prepare Pre-Meeting Materials and Disseminate Them to the Experts, Resource Experts, and Peer Reviewers

The specific materials to be provided will be case specific. Generic examples of the types of materials include, but are not limited to, the following (Ayyub, 2001, p. 21):

- An objective statement of the study;

- A list of participating experts, integrators, facilitators, study leader, sponsors, and their brief biographical statements;

- A description of the expert-opinion elicitation process; and

- A description of the issues in the form of a list of questions with background descriptions. Each issue should be presented on a separate page with spaces for recording an expert’s judgment, any revisions and comments. Clear statements should be provided of expectations from the experts in terms of time, effort, responses, communication, and discussion style and format.

Finally, it would be desirable for the study leader, or an assistant, to personally contact individual experts for the purpose of establishing clear understanding of expectations.

Step 7 -- Conduct the Face-to-Face Meeting

The meeting should be conducted by the study leader, with possible assistance from a facilitator to record comments on “butcher block paper” and place them on nearby walls. Each topical issue should begin with a brief presentation on why it was selected and why it is relevant to the meeting. Clarifying questions can then be answered and comments recorded as noted above. Before proceeding to the next issue, the group should be asked to review the posted comments and make pertinent observations in terms of omissions, non-relevancy, factors to consider in prioritizing the results, and a possible structure for inclusion in the EEP output report (document).

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Step 8 -- Document the Outputs from the EEP Meeting

A comprehensive documentation of the EEP is essential in order to ensure acceptance and credibility of the results. The document should include complete descriptions of the steps, the initial results, revised results, and conclusions. Peer reviews could be conducted on the draft output report (document).

USE OF AN EEP TO ADDRESS ES IN THE ORMSS

As noted above, it was determined that the EEP could be used to explore the issue of sustainability needs for the aquatic and riparian/floodplain resources associated with the ORMSS. Further, it was decided that two EEP meetings would be held, with one focused on the sustainability of aquatic resources, and the other on the sustainability of riparian resources. The first meeting, with 23 participants, dealt with the former and was held on February 11, 2004. The riparian resources meeting, with 15 participants, was held on October 20, 2004. Detailed information about both meetings and their compiled outputs is available elsewhere (Swor, et al., 2005). The primary author of this paper was the study leader for both meetings.

The experts, resource experts, and peer reviewers were identified by personal knowledge and inputs from the members of the study team and the IWG. Following personal contacts with the identified persons, and upon receiving their commitments to participate, each participant was provided with the following information:

- A brief synopsis of the ORMSS, particularly with regard to the CEA and the key VECs.

- A list of constraints relative to each meeting. For example, the participants were asked to accept that the river system is highly modified and will remain so (i.e., it is not reasonable to return the river and floodplain to predevelopment conditions; however, the system is amenable to further modifications that may affect the resource either positively or negatively). Further, each participant was asked to represent the resource (aquatic or riparian). They were also asked, relative to management actions and sustainability measures, to not be concerned about who will do it, how it would be done, who will pay, and when will it happen.

- Three key questions relative to each VEC – they were: (1) what do we want the resource (VEC) to look like in the future (this is related to establishing a management goal); (2) what needs to happen (that is, what actions or measures are needed) to attain the future vision; and (3) what indicators of ES would be appropriate for the VEC?

- An indication of the anticipated products (outputs) from each meeting; they included: (1) a list of factors or actions affecting the sustainability of the VEC (either positive or negative); (2) recommendations for measuring and monitoring ES; and (3) a written summary report.

Each meeting began with a presentation by the study leader on the ORMSS, and the reasons for using an EEP for examining ES. Each of the three key questions noted above were then addressed, with a Corps employee serving as the facilitator. As the discussion of one question began to become repetitive or to pertaining less to broad based resource issues, the discussion on that question was stopped and a new question was posed until all three questions had been thoroughly discussed.

Following each of the EEP meetings, the synthesis began by determining commonalities among responses and then grouping similar responses. In analyzing and synthesizing the answers to the questions it became obvious that sometimes the ideas generated during the meeting were actually better suited to one of the other questions. In those cases, the answers were shifted to best fit the questions. In other instances, several of the answers had common themes or were re-statements of previous answers, and these were combined to form an integrated response. However, care was taken to make sure none of the ideas were omitted from the results. The results were organized and presented in a manner that allowed the participants to cross-walk between the verbatim ideas generated during the session and the categorized results. Members of the Corps study team, which included several consultants, were responsible for drafting and editing the results. The draft reports were sent to the participants for comment, and revisions then sent to peer reviewers for another round of review and revision (Swor, et al., 2005).

Illustrations of the outputs from the aquatic resources EEP meeting will be briefly highlighted. Detailed information is available elsewhere (Swor, et al., 2005). The composite goal in response to question (1) above was that the aquatic resources VEC should be “a complex and interconnected system of physical habitat features accompanied by balanced nutrient and energy cycling and minimal amounts of chemical and bacteriological contamination. These habitats would support a diverse, self-sustaining, and resilient aquatic biological community dominated by native species” (Swor, et al., 2005).

Responses to the second question on needed actions or measures were grouped into four categories: habitats, biological, policy/procedural, and communications. Further, the first three categories were divided into sub-categories. Again to illustrate, the habitat actions were divided into four groups: connectivity actions; complexity actions; nutrient balance actions; and contaminant actions. Each sub-category included specific actions. For example, connectivity actions included actions at dams (e.g., providing fish passage), riparian/floodplain actions (e.g., reconnect river with floodplain), and in-stream actions (e.g., maintenance of connection between river and embayments). The complexity actions included: in-stream actions (e.g., restoration of stable shoals), water management actions (e.g., mimic natural regimes including seasonal and extreme floods and droughts), and riparian/floodplain actions (e.g., build/restore islands).

FORMULATION AND ANALYSIS OF ES ALTERNATIVES

Based upon the actions/measures outputs from the two EEP meetings, as well as the review of identified actions associated with an authorized Ohio River ecosystem restoration program (U.S. Army Corps of Engineers, 2000), the CEA study team developed a composited list of 26 measures (actions or opportunities) for enhancing the sustainability of aquatic and riparian/floodplain resources. The initial list of measures is in Table 1 (U.S. Army Corps of Engineers, 2006b, p. 6-35). The list includes measures that address restoration of habitat variety, recovery of 'missing' habitat components, reestablishment of functions and connectivity, removal of outdated infrastructure, and means for compensating for the effects of infrastructure that must remain. It is important to note that the measures (actions) identified were focused solely on needs of aquatic and riparian resources, and that no single agency or organization has the authority or responsibility for implementing all of these actions. Rather, all interested and responsible parties must work cooperatively to undertake specific measures that would contribute to improving resource sustainability (U.S. Army Corps of Engineers, 2006b, p. 6-34).

The 26 measures were then subjected to several levels of comparative analysis. Initial attention was given to the existence of statutory authority (by the Corps or other agencies or institutions) for implementation of the specific ecosystem measures. Existing authorities for many of the measures are encompassed in several key laws under the authority of the Corps. For example, sections are included within several recent Water Resources Development Acts and the Flood Control Acts. Further, some measures could be implemented under existing Corps project authorities (U.S. Army Corps of Engineers, 2006b, pp. 8-21 to 8-23). Environmental sustainability authorities also exist within Clean Water Act features administered by the U.S. Environmental Protection Agency; the Endangered Species Act and the Fish and Wildlife Coordination Act under the purview of the U.S. Fish and Wildlife Service; multiple state agencies and state resources laws and programs; and the Ohio River Valley Sanitation Commission (ORSANCO) (U.S. Army Corps of Engineers, 2006b, pp. 8-34 to 8-39).

Table 1: Opportunities for Enhancing Aquatic and Riparian Ecosystem Sustainability (U.S. Army Corps of Engineers, 2006b, p. 6-35)

Enhance fish passage around or through dams
Dismantle unneeded federal tributary dams
Dismantle unneeded non-federal tributary dams
Increase seasonal flooding in grasslands, bottomland hardwood forests, and other habitats
Allow flows to mimic natural regimes including seasonal and extreme floods and droughts
Restore unique mainstem habitats such as canebrakes, river bluffs, and mussel beds
Protect tailwaters and provide structures to serve as refugia for fish
Create spawning shoals and other in-stream features to enhance habitat diversity in navigation pools
Identify and expand areas of submerged and emergent aquatic vegetation
Protect and manage mussel populations and their habitat on a site-specific basis
Mark critical locations to prevent mooring near mussel beds or special shoreline areas
Mark shallow mussel beds to reduce direct impacts of tow traffic
Provide the navigation industry with charts showing locations of sensitive resources and include rationale for avoiding such resources
Protect existing aquatic habitats, restore lost habitats and diminished resources
Reintroduce native fauna and expand the range and populations of native fauna from reduced levels
Control exotics, including minimization of existing populations and prevention of new introductions
Reduce bacterial contamination from combined sewer overflows
Address point and non-point sources affecting aquatic nutrient balance
Minimize catastrophic contamination events through reduction of spills, accidents, and improvement of spill response procedures
Continue remediation of CERCLA, brownfields, and other contaminated sites
Reconnect and restore streams with floodplains on the mainstem and tributaries
Protect or restore riparian habitat diversity, including islands, on the mainstem and tributaries
Maintain or restore tributary deltas and connections between rivers and embayments
Reforest lower reaches of tributaries to reduce siltation into embayments and mainstem
Restore wetlands in upper ends of embayments to reduce siltation and create fish and wildlife habitat
Conduct economic evaluation of watershed functions and benefits

Additional comparative factors which were considered for the 26 measures included their relative costs for implementation, their focus on impact prevention rather than restoration, their ease of implementation relative to time, and the level of uncertainty associated with their potential effectiveness in enhancing ES. Based upon the authorities and these comparative factors, four groups of ES measures were identified based on the following delineations (U.S. Army Corps of Engineers, 2006b, p. 8-58).

- Group A: Measures for which authority already exists and which involve minimal costs. These measures would increase awareness of key VECs, focus on impact prevention, and could be implemented relatively quickly. Group A included four measures.

- Group B: Measures for which authority already exists, but which would require some costs for planning and/or construction. These measures focus on key VECs and incorporate restoration and enhancement. Group B included 10 measures.

- Group C: Measures for which some authority already exists, but new authority may be needed for some opportunities. Planning and construction costs may be relatively high. These measures generally encompass broad descriptions of opportunity that may need refinement and the focus tends toward broader-level environmental needs. Group C included five measures.

- Group D: Measures which require new authorities or are primarily addressed through authorities of other agencies (e.g., USEPA). Planning and construction costs may be relatively high. These measures generally encompass broad descriptions of opportunity that may need refinement, and the focus tends toward broader-level environmental needs. Group D included seven measures.

Table 2 identifies the measures associated with each group. In addition, the potential environmental effects of each measure on five major VECs were identified via the development of a simple interaction matrix. To illustrate, Table 3 is the first page of a 8-page matrix (U.S. Army Corps of Engineers, 2006b, p. 8-59). The five VECs include water quality, fish, mussels, riparian resources, and water-based recreation. As can be seen, positive impacts would occur on the five VECs from each of the three listed Group A measures.

Following these analyses of the 26 measures, the study team then formulated three ES alternatives (or plans). The “minimal” ES plan, which should be included in any navigation infrastructure improvement plan, consisted of the 14 measures included in Groups A and B. The “moderate” ES plan included the 19 measures comprising Groups A, B, and C. Finally, the “maximum” ES plan included the total of 26 measures comprising Groups A through D.

Table 2: Grouping of Environmental Sustainability Measures for Aquatic and Riparian Resources

Group[a]	Measures
A – Measures for which authority already exists. Such measures would involve minimal costs, increase awareness of key VECs, focus on impact prevention, and could be implemented quickly.	• Mark critical locations to prevent mooring near mussel beds or special shoreline areas. • Mark shallow mussel beds to reduce direct impacts of tow traffic. • Provide the navigation industry with charts showing locations of sensitive resources and include rationale for avoiding such resources. • Minimize catastrophic contamination events through reduction of spills, accidents, and improvement of spill response procedures.
B – Measures for which authority already exists, but which would require some costs for planning and/or construction. Such measures focus on key VECs and incorporate restoration and enhancement.	• Allow flows to mimic natural regimes including seasonal and extreme floods and droughts. • Restore unique mainstem habitats such as canebrakes, river bluffs and mussel beds. • Protect tailwaters and provide structures to serve as refugia for fish. • Create spawning shoals and other in-stream features to enhance habitat diversity in navigation pools. • Identify and expand areas of submerged and emergent aquatic vegetation. • Protect and manage mussel populations and their habitat on a site-specific basis. • Control exotics, including minimization of existing populations and prevention of new introductions. • Protect or restore riparian habitat diversity, including islands, on the mainstem and tributaries. • Maintain or restore tributary deltas and connections between rivers and embayments. • Reforest lower reaches of tributaries to reduce siltation into embayments

	and mainstem.
C – Measures for which some authority already exists, but new authority may be needed for some opportunities. These measures generally encompass broad descriptions of opportunity that may need refinement; planning and construction costs may be relatively high. The focus tends toward broader-level environmental needs.	• Increase seasonal flooding in grasslands, bottomland hardwood forests, and other habitats. • Protect existing aquatic habitats, restore lost habitats and diminished resources. • Reintroduce native fauna and expand the range and populations of native fauna from reduced levels. • Reconnect and restore streams with floodplains on the mainstem and tributaries. • Restore wetlands in upper ends of embayments to reduce siltation and create fish and wildlife habitat.
D – Measures which require new authorities or are primarily addressed through authorities of other agencies (e.g., USEPA). Such measures may require more extensive planning and implementation costs. These measures focus on broader-level environmental needs.	• Enhance fish passage around or through dams. • Dismantle unneeded federal tributary dams. • Dismantle unneeded non-federal tributary dams. • Reduce bacterial contamination from combined sewer overflows. • Address point and non-point sources affecting aquatic nutrient balance. • Continue remediation of CERCLA, brownfields, and other contaminated sites. • Conduct economic evaluation of watershed functions and benefits.

Table 3: Potential Effects of ES Enhancement Measures on Major VECs (U.S. Army Corps of Engineers, 2006b, p. 8-59)

Opportunities for ES Enhancement	Impacts on Major VECS				
	Water Quality	**Fish**	**Mussels**	**Riparian Resources**	**Recreation**
Group A – Measures for which authority already exists. Such measures would involve minimal costs, increase awareness of key VECs, focus on impact prevention, and could be implemented quickly.					
Mark critical locations to prevent mooring near mussel beds or special shoreline areas.	+ Reduces turbidity in areas near mussel beds where vessels previously moored.	+ Enhancement of mussel habitat benefits fish and other animals that feed on mussels.	+ Helps protect mussel beds from direct damage and scouring from tows and other vessels.	+ Helps protect sensitive shoreline areas vulnerable to loss of vegetation and erosion.	+ Decreases number of potential sites on river where conflict may occur between tows and recreational vessels.
Mark shallow mussel beds to reduce direct impacts of tow traffic.	+ Similar to above action in reducing turbidity.	+ Similar to above action in enhancing mussel habitat for fish and other animals that feed on mussels.	+ Similar to above action in helping to protect mussel beds from direct damage and scouring from tows and other vessels.	+ Similar to above action in helping to protect sensitive shoreline areas vulnerable to loss of vegetation and erosion.	+ Clearly delineates areas recreational vessels should avoid.
Provide the navigation industry with charts showing locations of sensitive resources and include rationale for avoiding such resources.	+ Similar to above action in reducing turbidity.	+ Helps protect spawning areas, other fish habitat and provides education on need to protect sensitive resources.	+ Helps protect mussel beds and other benthic habitat and provides education on need to protect sensitive resources.	+ Could also include important riparian resources, including wetlands and islands; Provide education on the value & protection of such resources.	+ Clearly delineates areas recreational vessels should avoid while also providing education on the value and protection of such resources.

A final feature of the ORMSS included multi-criteria decision making in relation to four navigation infrastructure improvement plans; this was used to identify the best economic plan, also known as the National Economic Development (NED) plan. Multi-criteria decision making was also used on the three ES plans to identify the best environmental sustainability plan, also termed the National Environmental Sustainability (NES) plan. Detailed information on these evaluations, which involved one for the best combined plan (NED/NES plan), is included in Section 10 of the Draft PEIS (U.S. Army Corps of Engineers, 2006b, pp. 10-91 to 10-115).

Finally, the Draft PEIS included the following ES-related conclusions and recommendations (U.S. Army Corps of Engineers, 2006b, pp. 12-1 to 12-3). The conclusions were:

- High priority ecosystem sustainability measures are needed for the Ohio River and associated resources on a large scale. These include habitat protection and restoration, control of exotic species, reintroduction of native species, improved connectivity of habitats, and reduction of sources of degradation. These measures are needed to help improve sustainability of many resources including mussels and riparian/floodplain habitats and the species they support.

- The CEA study indicated that future navigation investments would not adversely impact long-term resource sustainability. However, mussels and riparian/floodplain resources are not expected to become fully sustainable in the future due to continued degradation from previous actions combined with the future actions identified.

The recommendations were:

- Pursue planning and implementation of measures to improve environmental sustainability in collaboration with other interests. Planning measures should include the Ohio River Basin Comprehensive Study to identify and correct sustainability problems contributed by the tributaries. Implementation measures should include adoption of all Reasonable and Prudent Measures identified during the Endangered Species Act Section 7 Consultation for on-going operation and maintenance of the Ohio River navigation system.

- Initiate preparation of the Program Implementation Plan for the Ohio River Ecosystem Restoration Program.

LESSONS LEARNED

The following lessons have been derived from the use of the EEP to promote ES considerations within the Ohio River Navigation Infrastructure Study (also referred to herein as ORMSS):

- The EEP has been previously used in both engineering design and environmental planning studies; further, it can be efficiently used for identifying and analyzing ES alternatives in situations where sustainability needs to be incorporated with infrastructure alternatives.

- While the 26 identified ES measures and their subsequent categorization and cursory analyses allowed the incorporation of ES considerations in the Corps' decision document and Programmatic EIS, it should be recognized that more detailed study of the ES will be necessary, particularly regarding detailed planning and implementation costs. In that sense, it can be stated that ES now has a place in future planning associated with the Ohio River navigation system.

- The EEP is a method which promotes collaboration between key scientists and policymakers from the Corps, other Federal and state agencies, and the private sectors. Such collaboration will ultimately provide the foundation for implementation of sustainability actions.

- An effective EEP will not occur by accident; rather, in order to achieve its purposes, it requires careful planning, implementation, and documentation.

- Outputs from an EEP can be used in several ways in CEA applied to strategic-level studies. Examples include the planning and implementation of targeted monitoring programs to determine the effectiveness of ES measures, and the provision of input in future regional planning and decisionmaking by single agencies as well as groups of agencies.

- During conduct of future site-specific studies tiered from the ORMSS, recommendations developed through the EEP should be used to formulate mitigation measures for project impacts (rather than traditional "in-kind and in-place" mitigation), environmental design features, and ecosystem restoration alternatives.

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