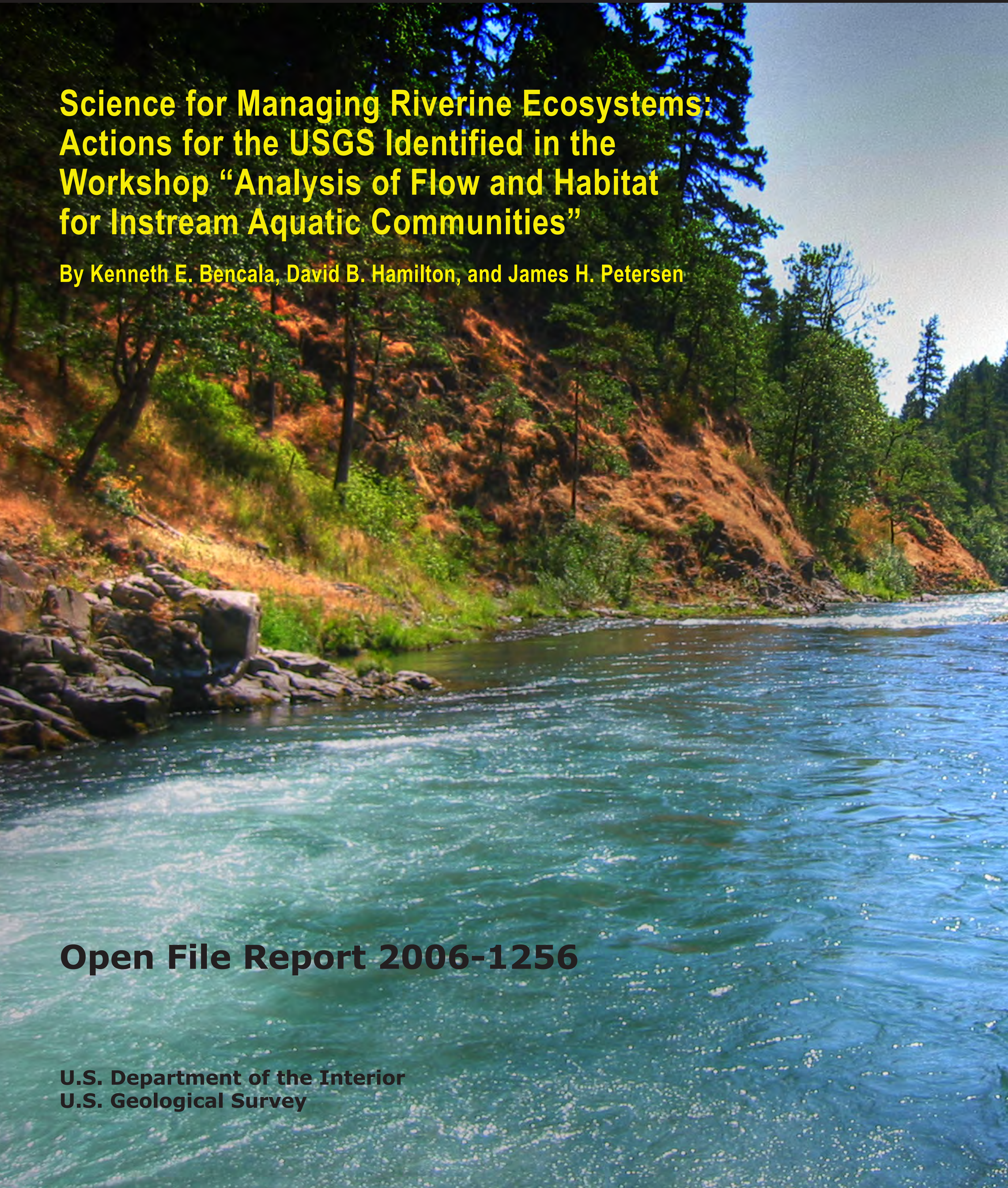
USGS
science for a changing world



Science for Managing Riverine Ecosystems: Actions for the USGS Identified in the Workshop “Analysis of Flow and Habitat for Instream Aquatic Communities”

By Kenneth E. Bencala, David B. Hamilton, and James H. Petersen

Open File Report 2006-1256

U.S. Department of the Interior
U.S. Geological Survey

Science for Managing Riverine Ecosystems: Actions for the USGS Identified in the Workshop “Analysis of Flow and Habitat for Instream Aquatic Communities”

By Kenneth E. Bencala, David B. Hamilton, and James H. Petersen

Open File Report 2006-1256

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
Dirk Kempthorne, Secretary

U.S. Geological Survey
P. Patrick Leahy, Acting Director

U.S. Geological Survey, Reston, Virginia 2006

This report may be found at::
http://pubs.usgs.gov/of/2006/1256
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth,
its natural and living resources, natural hazards, and the environment:
World Wide Web: http://www.usgs.gov
Telephone: 1-888-ASK-USGS

Suggested citation:
Bencala, K. E. , Hamilton, D. B. and Petersen, J. H., 2006, Science for Maintaining Riverine Ecosystems: Actions for the USGS Identified in the Workshop "Analysis of Flow and Habitat for Aquatic Communities": USGS Open File Report 2006-1256.

Contents

Executive Summary ... 1
Vision ... 2
Capability ... 3
Priority Actions to Undertake Now ... 4
  Introduction ... 4
    1. Synthesize the existing science of riverine ecosystem processes to produce broadly applicable conceptual models ... 4
      Action: ... 4
    2. Enhance selected ongoing instream flow projects with complementary interdisciplinary studies ... 4
      Action: ... 4
    3. Design a long-term, watershed-scale research program that will substantively reinvent riverine ecosystem science ... 5
      Action: ... 5
  Summary ... 5
Long-Term Actions ... 6
  Introduction ... 6
    1. Analyze the practice of collaboration used to establish environmental flows. ... 6
    2. Develop a conference to bring together process hydrologists, geomorphologists, social scientists, and ecologists to examine common ground, language, and understanding in environmental flows. ... 6
    3. Analyze socio-economic dimensions of instream flow protection. ... 7
    4. Develop a flow chart for environmental flow projects indicating when and how sediment transport and geomorphic processes should be taken into account, including a geomorphic classification that indicates potential for information transfer. ... 7
    5. Analyze factors that integrate riverine processes over multiple spatial scales. ... 7
    6. Incorporate geomorphic processes and sediment transport dynamics at channel and drainage-basin scales into environmental flow models and approaches. ... 7
    7. Develop modules for assessing factors affecting riverine ecosystems other than the direct effects of flow regime. ... 8
    8. Develop a set of standard habitat monitoring protocols. ... 8
    9. Promote mechanistic modeling approaches. ... 8
    10. Develop a national experimental design. ... 9
    11. Improve the scientific basis for prescribed flows. ... 9
  Summary ... 9
Appendix I. Contacts ... 10
Appendix II. Presenters, April 18, 2006 ... 11
Appendix III. Discussion Participants, April 19, 2006 ... 12
Appendix IV. Outlining Team, April 20, 2006 ... 13

Science for Managing Riverine Ecosystems: Actions for the USGS Identified in the Workshop "Analysis of Flow and Habitat for Instream Aquatic Communities"

By Kenneth E. Bencala, David B. Hamilton, James H. Petersen

Executive Summary

Federal and state agencies need improved scientific analysis to support riverine ecosystem management. The ability of the USGS to integrate geologic, hydrologic, chemical, geographic, and biological data into new tools and models provides unparalleled opportunities to translate the best riverine science into useful approaches and usable information to address issues faced by river managers. In addition to this capability to provide integrated science, the USGS has a long history of providing long-term and nationwide information about natural resources. The USGS is now in a position to advance its ability to provide the scientific support for the management of riverine ecosystems.

To address this need, the USGS held a listening session in Fort Collins, Colorado in April 2006. Goals of the workshop were to: 1) learn about the key resource issues facing DOI, other Federal, and state resource management agencies; 2) discuss new approaches and information needs for addressing these issues; and 3) outline a strategy for the USGS role in supporting riverine ecosystem management. Workshop discussions focused on key components of a USGS strategy: Communications, Synthesis, and Research.

The workshop identified 3 priority actions the USGS can initiate now to advance its capabilities to support integrated science for resource managers in partner government agencies and non-governmental organizations:

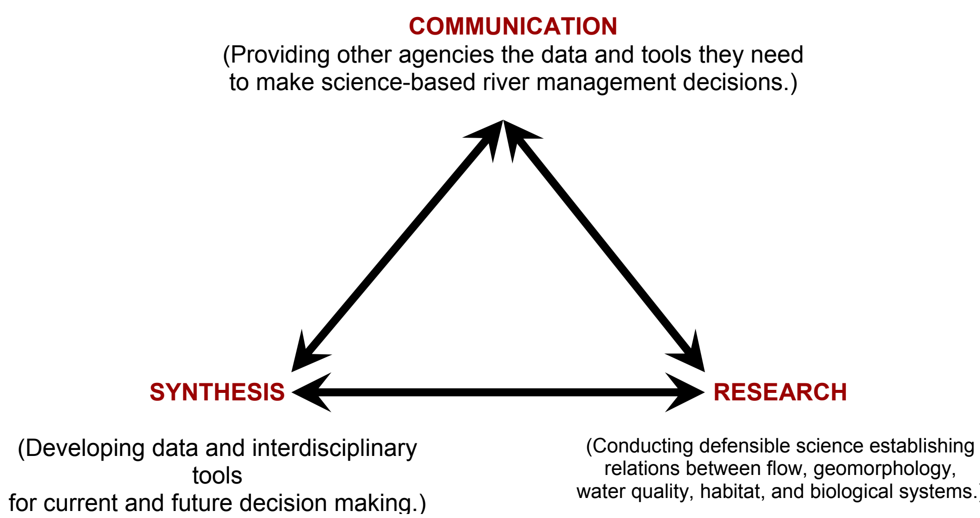
- Synthesize the existing science of riverine ecosystem processes to produce broadly applicable conceptual models
- Enhance selected ongoing instream flow projects with complementary interdisciplinary studies
- Design a long-term, watershed-scale research program that will substantively reinvent riverine ecosystem science

In addition, topical discussion groups on hydrology, geomorphology, aquatic habitat and populations, and socio-economic analysis and negotiation identified eleven important complementary actions required to advance the state of the science and to develop the tools for supporting decisions on riverine ecosystem management. These eleven actions lie within the continuum of Communications, Synthesis, and Research.

Vision

Water availability and quality, and their impact on humans, fish, and aquatic communities, are recognized as major national and international issues that will become increasingly important in the future. Riverine ecosystems and human societies are interrelated in complex and competing ways. Unintended or undesirable consequences have sometimes resulted from institutional arrangements and site-specific actions. The ability to manage riverine ecosystems wisely comes from reliable data on current and past conditions, a fundamental and integrated understanding of riverine, institutional, and economic processes, the ability to forecast the responses of rivers and aquatic communities to environmental change or human actions, and effective communication of this information to resource-managers, policy-makers, and the public. It is widely recognized that there is a significant need for a new generation of tools for managing water and riverine ecosystems. In many areas, disputes over water resources center on questions of how much water is needed to support the riverine ecosystem and the ability to confidently perform trade-off analyses. The issues encompass ground-water and surface-water hydrology, the biology of fish, birds, shellfish, and aquatic and terrestrial vegetation, and the mechanisms for resolving conflicts. Substantive progress depends on a foundation of understanding landscape change, the soils and other geologic materials on which aquatic and terrestrial communities depend, and the social contexts of water management.

Sound science for riverine ecosystem management requires a better understanding of the critical questions faced by natural resource agencies. To address this need, the USGS held a listening session in Fort Collins, Colorado in April 2006. Goals of the workshop were to: 1) learn about the key resource issues facing DOI, other Federal, and state resource management agencies; 2) discuss new approaches and information for addressing these issues; and 3) outline a strategy for the USGS role in supporting riverine ecosystem management. Workshop discussions focused on key components of a USGS strategy to address these issues: Communications, Synthesis, and Research.



These components interact with each other and should be integrated in the implementation of the USGS strategy. This document presents the actions for the USGS identified in the workshop.

Capability

As a Federal science agency, the USGS provides leadership in addressing water availability, water conservation, freshwater fisheries biology, and hydrologic hazards—all river issues. The USGS also has major capabilities for assessing water quality, wetland and riparian habitat, institutional processes, and aquatic community relationships. Unique among Federal natural resource agencies, the USGS has no regulatory function or advocacy role, but is purely a science and information agency. Other Federal agencies, states, tribes, NGOs, and the public generally value this role and often request unbiased data and evaluations from USGS.

Through its many scientific disciplines, USGS has the unique capability to integrate geologic, hydrologic, chemical, geographic, and biological information into analyses and models useful to a variety of stakeholders. The stream-gage network maintained by USGS provides the national basis for monitoring and predicting stream and river flows throughout the nation. Hydrologists and geomorphologists in USGS monitor and predict sediment loads and transport, channel migration, bottom substrates, and other characteristics of rivers forming the habitat template for biological populations. Fishery biologists and ecologists seek to understand the movements, growth, and survival of aquatic organisms in the dynamic riverine environment. Modelers from many disciplines synthesize the different types of data and processes to predict physical and biological patterns as rivers vary naturally or through the results of management actions. Specialists in institutional analysis can provide the context for use of new tools and data sources. USGS also has existing studies in a variety of watersheds throughout the nation that could be incorporated into proposed actions, thereby leveraging knowledge and costs. Current studies span a range of physiography, river flows, watershed sizes, and latitudes, thus potentially applying to all of the proposed Priority Actions – conceptual model-building, enhanced studies in existing watersheds, and design of watershed-scale ecosystem research.

In addition to our unique capacity to provide integrated science, the USGS has a distinguished history of providing long-term and nationwide information for supporting decision making. Models and decision support tools such as the Instream Flow Incremental Methodology (IFIM), which has been used by many fisheries management groups since the 1970's, were developed by scientists that are now part of USGS: this institutional knowledge provides a foundation for building a new modeling approach. Real-time streamflow and water quality monitoring, and new hydrologic tools such as Streamstats are being made available through USGS. USGS also has a unique base of expertise in the policy processes for instream flow management. All of these capabilities make USGS uniquely qualified to provide scientific support for the management of riverine ecosystems.

Priority Actions to Undertake Now

Introduction

Through the listening session, three actions emerged that USGS can undertake now to advance its capabilities to provide integrated science to resource managers in partner government agencies and non-governmental organizations. The science needs of these managers have shifted from a simple specification of flows for providing aquatic habitat to a need to better understand and predict complex ecological responses to a broad range of human-induced and natural changes to rivers. Resource management agencies face a challenge to integrate multiple societal demands for water, including the requirements of riverine ecosystems.

1. Synthesize the existing science of riverine ecosystem processes to produce broadly applicable conceptual models

Action:

A study team across the disciplines of the USGS will develop a retrospective synthesis of the expertise the agency has available to support agencies that make riverine management decisions. The synthesis will include ecological, institutional, and socio-economic perspectives. While being retrospective in documenting the existing agency expertise, the synthesis will be forward-focused in producing conceptual models of the processes underlying riverine ecosystems and how they can be assessed.

The USGS has been an active participant in developing the science supporting the decisions of the nation's resource management agencies. A retrospective synthesis of this activity will provide the information needed to construct conceptual models of the practice or riverine ecosystem science. The conceptual models will illustrate the relations among components of the ecosystem, as well as the disciplinary and institutional structures needed to enhance scientific understanding of the ecosystem.

There will be two products related to this task. Initially, a report will be prepared that sets forth the conceptual models derived through the retrospective synthesis. Second, a database will be released documenting the studies used in the synthesis. The database will serve to illustrate the state of the art of approaches to riverine ecosystem science.

2. Enhance selected ongoing instream flow projects with complementary interdisciplinary studies

Action:

Within existing USGS projects, studies will be added at existing project sites that broaden the interdisciplinary scope of the resource management focus of funding partner agencies. The immediate action is for Bureau-level and/or Regional-level funds to be committed to this effort and then for a team to develop the Request for Proposals (RFP) for such studies along with the process for implementing a bureau-wide proposal-driven funding mechanism.

The USGS has projects funded by partner agencies with specific resource management goals. As a science agency itself, part of the USGS' service to the nation can be in broadening the ecosystem perspective of our partners. Interdisciplinary complementary studies can also be viewed as the 'seeds' from which further and more comprehensive partner projects can be developed.

The short-term products of these new studies are supplements to existing projects, filling gaps in analysis and understanding. Longer-term products include the development within the USGS of experienced interdisciplinary teams, which will in-turn develop interdisciplinary tools for future decision making.

3. Design a long-term, watershed-scale research program that will substantively reinvent riverine ecosystem science

Action:

A team will begin the process of planning a USGS program of riverine ecosystem research at the watershed scale. The team will not only be from across the disciplines of the USGS, but also will include partner agencies, non-governmental organization representation from the private sector, and academic scientists. The focus of the planning work will be to specify the scope of processes that need to be studied at the watershed scale to substantively enhance the existing state of the art. Along with this strategic scientific prioritization, work will begin on identifying the institutional infrastructure appropriate to the physical scale of the science.

Many issues faced by riverine resource managers are ultimately at the watershed scale. The demands placed on water resources are now competing, if not conflicting. Future stresses engendered by climate and land-use changes will exaggerate these conflicts. In the future we can anticipate decision makers increasingly required to collaborate with a wide variety of stakeholders. The USGS should address the fundamental stresses at the watershed scale as part of this long-term, watershed-scale research program.

Initially the product of this program will be an agency planning document. When implemented the plan will be part of a changing paradigm providing defensible science in support of a new view of river ecosystem function based on understanding relations between flow, habitat, biological, and social systems.

Summary

As the USGS strives to strengthen and expand, partnerships with other agencies it must develop new scientific capabilities unique to the mission of a Federal science agency. The USGS can do this utilizing the interdisciplinary expertise within the agency. The 3 actions recommended here are priorities for the USGS in that they address partner agency needs, they can be initiated now, they will have short-term products, and they will provide the basis for long-term advances to the agency's scientific capabilities.

Long-Term Actions

Introduction

In addition to the priority actions to be taken now, topical discussion groups identified eleven important actions that can advance the state of the science and provide tools for supporting decisions on management of riverine ecosystems. These activities are described below. Although no order in priority is presented, the actions are listed approximately in the continuum of Communications, Synthesis, and Research.

1. Analyze the practice of collaboration used to establish environmental flows.

An environmental flow "is the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated." (See; Dyson, M., Bergkamp, G., Scanlon, J. (Eds), 2003, Flow - The Essentials of Environmental Flows. IUCN, Gland, Switzerland and Cambridge, UK. xiv + 118 pp.) A basic shortcoming of current knowledge is the lack of adequate information about how practitioners actually collaborate to arrive at environmental flow recommendations. For example, what are the most effective decision support tools to promote collaboration? What factors guide decision processes? What types of information help or hinder collaborators' efforts to reach a decision? A body of knowledge derived from case studies is needed to answer these questions. Case studies must follow rigorous social science study practices to document and quantify answers. To be effective, the case study literature must include a wide range of environmental flow collaborations and cover several types of decision-making scenarios (such as Federal Energy Regulatory Commission (FERC) licensing, Section 404 Clean Water Act and Section 7 endangered species consultations, state instream flow actions, and Bureau of Reclamation and Corps of Engineers operating rule negotiations).

2. Develop a conference to bring together process hydrologists, geomorphologists, social scientists, and ecologists to examine common ground, language, and understanding in environmental flows.

Delineating the links from physical processes to aquatic populations and community responses is a central challenge in environmental flow analysis. One of the obstacles to substantive progress is lack of common language and common approaches among physical and biological scientists. The purpose of this conference would be to explore the deeply held assumptions, accepted methodological approaches, and language used by physical scientists and ecologists, in an attempt to overcome these obstacles. An example of such an obstacle is the deeply held belief among physical scientists that they work in a deterministic world in which cause and effect can be established with sufficient accuracy and precision if given enough resources. In contrast, ecologists tend to believe that they work in a stochastic world, where statistical association may be achieved, but cause and effect are rarely demonstrated. This difference in approaches forces questions about the very nature of knowledge, and under what conditions scientists (and managers) can believe that they know something useful about how rivers work. Another example is the tendency of many river managers and physical scientists to work in the incremental approach to solving environmental flow problems (represented by the field of ecohydraulics), a process that implicitly assumes that science is capable of understanding complex ecosystems and managing them for specific objectives. This contrasts with the more holistic view that the science is incapable of understanding the complexity of ecosystems, so management strategies must focus on restoring the fundamental drivers of ecosystem function rather than incrementally managing pieces. This is often referred to as the ecohydrology approach. Reconciliation of these views would help identify common ground and move the science forward.

3. Analyze socio-economic dimensions of instream flow protection.

There is insufficient understanding of how incentive structures (such as market dynamics) and institutional arrangements (such as laws and policies) affect the development and implementation of instream flow protection programs and policies. Studies to develop this understanding are important and will help planners and managers be more effective as they design, implement or modify programs. Knowledge of economic and institutional arrangements may support collaboration among a broad group of stakeholders by helping stakeholders understand the connections between these arrangements and on-the-ground conditions—a vital step in decisions. In addition, socio-economic studies are needed, on a watershed scale, to forecast challenges to streams and other water bodies. These studies will focus on changing patterns of human settlement and the effects of these changes on the use and perception of water and other resources. These areas of study underpin biological and hydrological studies and guide the construction of decision support systems for environmental flows.

4. Develop a flow chart for environmental flow projects indicating when and how sediment transport and geomorphic processes should be taken into account, including a geomorphic classification that indicates potential for information transfer.

This recommendation is a practical application of one part of the research direction in the first recommendation. For some applications of environmental flow assessments, dynamic geomorphic processes can be ignored without undue consequence. An example would be a sediment-starved reach with an armored bed, downstream of a dam, where management issues relate solely to low flows that are unlikely to transport sediment. On the other hand, many river reaches are subject to the effects of sediment routing from upstream, or channel instabilities propagating from downstream. The rubric flow chart will be designed to lead a practitioner through the analysis steps that are needed to establish whether dynamic geomorphic processes can be ignored, or should be accounted in an environmental-flow project. The methodology would include a model for reach and segment scale classification of riverine systems to serve as a template for identifying geomorphically similar reaches and transferring environmental flow understanding among reaches and rivers.

5. Analyze factors that integrate riverine processes over multiple spatial scales.

USGS could develop approaches for acknowledging the broader hydro-geographic context in flow decisions. Such approaches would necessarily address factors at spatial scales larger than a reach and, as such, would place reaches in a framework of the entire watershed so the effects of distant factors could be considered. USGS may have an opportunity to expand the geographic scope of the context (climate change) and consequences (downstream) of flow decisions where other parties have a somewhat limited perspective.

6. Incorporate geomorphic processes and sediment transport dynamics at channel and drainage-basin scales into environmental flow models and approaches.

This recommendation addresses the underlying research needed to incorporate sediment routing, erosion, and deposition into environmental flow assessments. Sediment routing through drainage basins can alter sediment yields in reaches used for habitat inventories, thereby fundamentally altering the relations between hydrology and hydraulics. In some rivers, dynamic changes can take place during individual flow events as the bed is scoured and re-deposited. Sediment transport at this scale is considered a critical part of disturbance and patch dynamics, and instrumental in habitat-conditioning processes like flushing fine sediment from spawning gravels. New tools are needed to assess and model sediment transport at scales from the entire drainage basin to individual habitat elements. These are fundamental research needs in geomorphology and sediment transport processes; many of these processes are being addressed in individual research projects. A promising strategy would be to synthesize existing information to assess the state of the art in integrating dynamic geomorphology with environmental flow analysis. The importance of the issue could be assessed in one or more demonstration projects by revisiting previously modeled sites after a decade or more of geomorphic change.

7. Develop modules for assessing factors affecting riverine ecosystems other than the direct effects of flow regime.

Non-hydrologic factors such as chemical contaminants, nutrients, light and temperature, can have significant effects on aquatic ecosystems. USGS could develop modules (for example, that could be used in Instream Flow Incremental Methodology-IFIM) to address non-hydrologic factors affecting biological community. As an initial step, metrics of water sources such as the relative component of wastewater or contribution from mine drainage in each basin could be developed. Then an algorithm or conceptual framework could be developed that incorporates the hydrologic make up of the water (effluent, natural precipitation, ground water, snow melt, agricultural runoff, mine drainage) that could be used to assess the chemical contributions from all inputs.

8. Develop a set of standard habitat monitoring protocols.

USGS could develop a set of standard habitat monitoring protocols, and possibly monitoring designs, that scientists assessing instream flow can use and reference. Methods for setting instream flows, for minimum aquatic communities or for specific needs, have been around since the early 1970's, however, field protocols for measurement of habitats in streams are not standardized. This inconsistency in methods application among scientific groups has made it difficult to compare results across studies, make geographic comparisons, or build large databases. A standard set of habitat measurement protocols developed by USGS scientists should be developed and made available to all stream ecologists. Habitat measurements could then be referenced to specific protocols for better comparisons. Designs for monitoring habitat in streams over longer periods of time should also be developed and described in the scientific literature.

9. Promote mechanistic modeling approaches.

USGS should promote a more mechanistic modeling approach, which may be a list of specific aquatic community measures. Mechanistic models can be used in stream and fishery communities to better understand the influence of variable (and manageable) flows or habitats. By linking flow to the specific behaviors, physiology, or growth of fish, the impact of the physical habitat on fish will come more directly from the fish's perspective, rather than just modifying flow and habitat and assuming that fish populations will respond in a direct and positive manner. Mechanistic models can be used to examine patch relationships, life history stages of fishes, temperature responses, and other relationships. Along with mechanistic models, a list of aquatic measures or metrics might be developed to make a direct link between habitat and fish populations.

10. Develop a national experimental design.

USGS could develop a national experimental design involving several watersheds where flow, in particular, can be varied to study the response of fish and community parameters. Watersheds might be selected using an analysis or classification into flow categories and functional guilds of fish. Watersheds would hopefully have the capabilities for flow manipulation. A broad array of sampling measures would be incorporated into each watershed so comparisons could be made. Ideally, watersheds might be paired so experimental designs could use control and impact statistical designs to evaluate physical or manipulative effects. USGS might collaborate with a variety of organizations in this work, including states, tribes, the Hydro Research Foundation, and the Electric Power Research Institute. The National Fish Habitat initiative is identifying national high-priority watersheds, which might provide a starting place for watershed selection.

11. Improve the scientific basis for prescribed flows.

USGS could help establish the scientific basis linking biological responses to natural flow variability (including volume, duration, and timing) and, thus, the need for different flows to maintain ecological processes. The importance of high flow pulses for channel maintenance and floodplain connectivity is a specific issue faced across the country. The primary approach to developing the scientific information would be long term, manipulative experimental studies that demonstrate the efficacy of various prescribed flow regimes at the community level (not necessarily for a specific species). The experiments need to have specific hypotheses about the biological effects of a prescribed flow. There are opportunities to develop collaborative relations with agencies to design definitive investigations and large-scale field experiments to address critical issues that provide strong scientific basis for negotiations, such as the Colorado River flood experiment. USGS could have a role in synthesizing results and providing a more coordinated program for flow-related studies particularly at large Federal projects. This work could also be advanced by identifying and exploiting long-term monitoring efforts (e.g., FERC re-licensing). USGS could also develop a programmatic monitoring plan/national guidance that would allow results of project-level monitoring to be integrated to draw more general conclusions about hydroecology. USGS could also work with parties to develop multi-river monitoring plans that could be brought to negotiations prior to settlements. USGS could synthesize the results of existing monitoring for FERC licensing to provide a broader perspective and develop general scientific conclusions about flow and biology, working with both natural resource agencies and FERC on this issue. Current efforts are not likely to be sufficient to support this task, but could be the basis for developing an experimental flow program.

Summary

These eleven actions reflect the need for the USGS to pursue two types of integration. First, there is no question that the science for managing riverine ecosystems has moved well beyond the specification of 'minimum flow'. Syntheses of existing knowledge with new integrated research efforts are needed. Second, there is no question that the organizations the USGS looks to for partnerships have moved beyond seeking 'the answer', Communication between organizations and across the sciences now requires deliberate attention.

Appendix I. Contacts

This document was prepared by Kenneth E. Bencala, David B. Hamilton and James H. Petersen. For further discussion they may be contacted at:

Ken Bencala	kbencala@usgs.gov	650 329 4409
Dave Hamilton	dave_hamilton@usgs.gov	970 226 9383
Jim Petersen	jim_petersen@usgs.gov	509 538 2299 x236

Many individuals contributed to the Analysis of Flow and Habitat for Instream Aquatic Communities Workshop as presenters, in discussions, and in the outlining of the themes of this document. These individuals and their participation are listed on the following pages.

We specifically acknowledge, and appreciate, the work of Katie Wundrock in making the workshop's logistical arrangements.

Appendix II. Presenters, April 18, 2006

Welcome
Tom Casadevall • Central Regional Director • USGS • Denver, CO
Effectiveness of collaborations between resources managers and scientists.
Bob Deibel • National Instream Flow Coordinator • US Forest Service • Fort Collins, CO
Tools for decision support and risk assessment.
Bill Labiosa • USGS • Menlo Park, CA
Beyond physical habitat - Economics, law & policy.
Justice Gregory J. Hobbs • Colorado Supreme Court
Tools for integration of physical science in population biology.
Jim Petersen • USGS • Cook, WA
Translation of incremental changes in flow/habitat to changes in population size/viability - What new science process understanding is open for development?
Dudley Reiser • R2 Resource Consultants • Redmond, WA
Can science provide more technology?
Larry Barber • USGS • Boulder, CO
Tools for setting flow/habitat requirements.
LeRoy Poff • Colorado State University • Fort Collins, CO
Effectiveness of bringing new technology into resource management of habitat.
Ken Bovee • USGS • Fort Collins, CO

Appendix III. Discussion Participants, April 19, 2006

Name		E-mail	Agency/Organization	City	State
Charles	Ault	charles_ault@fws.gov	USFWS	Albuquerque	NM
Larry	Barber	lbbarber@usgs.gov	USGS	Boulder	CO
Ken	Bencala	kbencala@usgs.gov	USGS	Menlo Park	CA
Ken	Bovee	ken_bovee@usgs.gov	USGS	Fort Collins	CO
Dan	Brewer	dan_brewer@fws.gov	USFWS	Helena	MT
Nina	Burkardt	nina_burkardt@usgs.gov	USGS	Fort Collins	CO
Ed	Cheslak	efc3@pge.com	Pasific Gas and Electric	San Ramon	CA
Bob	Deibel	rhdeibel@fs.fed.us	USDA-FS	Fort Collins	CO
Paul	Dey	Paul.Dey@wgf.state.wy.us	WY Dept of Game and Fish	Cheyenne	WY
James	Eychaner	eychaner@usgs.gov	USGS	Sacramento	CA
Lorrie	Flint	lflint@usgs.gov	USGS	Sacramento	CA
Jim	Fogg	jim_fogg@blm.gov	BLM	Denver	CO
Travis	Haby	travis_haby@blm.gov	BLM	Denver	CO
Andy	Hamilton	andrew_hamilton@fws.gov	USFWS	Sacramento	CA
Dave	Hamilton	dave_hamilton@usgs.gov	USGS	Fort Collins	CO
Scott	Harder	harders@dnr.sc.gov	SC Dept of NR	Columbia	SC
Jim	Henriksen	jim_henriksen@usgs.gov	USGS	Fort Collins	CO
Brian	Hughes	wbhughes@usgs.gov	USGS	Atlanta	GA
Robb	Jacobson	rjacobson@usgs.gov	USGS	Columbia	MO
Joe	Klein	joe_klein@fishgame.state.ak.us	AK Dept of Fish and Game	Anchorage	AK
Chris	Konrad	cpkonrad@usgs.gov	USGS	Tacoma	WA
Bill	Labiosa	blabiosa@usgs.gov	USGS	Menlo Park	CA
Lee	Lamb	lee_lamb@usgs.gov	USGS	Fort Collins	CO
Jeff	Mabe	jamabe@usgs.gov	USGS	Austin	TX
Jonathan	Nelson	jmn@usgs.gov	USGS	Golden	CO
John	Nestler	john.m.nestler@erdc.usace.army.mil	US Army Corps of Engineers	Vicksburg	MS
Michael	Newsom	mnewsom@pn.usbr.gov	USBR	Portland	OR
Jeff	Opperman	jopperman@tnc.org	TNC	Davis	CA
Jim	Petersen	jim_petersen@usgs.gov	USGS	Cook	WA
LeRoy	Poff	poff@lamar.colostate.edu	CSU	Fort Collins	CO
Stan	Ponce	sponce@usgs.gov	USGS	Reston	VA
John	Potyondy	jpotyondy@fs.fed.us	USDA-FS	Fort Collins	CO
Bruce	Pugesek	bpugesek@usgs.gov	USGS	Bozeman	MT
Dudley	Reiser	dreiser@r2usa.com	R2 Resource Consultants	Redmond	WA
Mike	Sale	salemj@ornl.gov	Oak Ridge National Lab	Oak Ridge	TN
Robin M.	Schrock	robin_schrock@usgs.gov	USGS	Reston	VA
Rip	Shively	rip_shively@usgs.gov	USGS	Klamath Fall	OR
Laurie	Simons	laurie_simons@fws.gov	USFWS	Yreka	CA
Jim	Terrell	jim_terrell@usgs.gov	USGS	Fort Collins	CO
Lyman	Thorsteinson	lyman_thorsteinson@usgs.gov	USGS	Seattle	WA
Dennis	Woodward	woody@usgs.gov	USGS	Lakewood	CO

Appendix IV. Outlining Team, April 20, 2006

Writing Leaders -
Ken Bencala
Dave Hamilton
Jim Petersen
Team -
Larry Barber
Ken Bovee
Jim Eychaner
Lorrie Flint
Robb Jacobson
Chris Konrad
Bill Labiosa
Lee Lamb
Dennis Woodward
Headquarters Liaison -
Robin Schrock