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Environmental Flows in Water Resources Policies, Plans, and Projects

Case Studies

Rafik Hirji and Richard Davis

April 2009

Sustainable Development Vice Presidency

THE WORLD BANK ENVIRONMENT DEPARTMENT

Environmental Flows in Water Resources Policies, Plans, and Projects

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Foreword

Investments in infrastructure provide opportunities for economic growth and poverty alleviation. Many developing nations face the major development challenge of providing the infrastructure to meet the growing demand for water for domestic consumption, agriculture, energy and industry and to buffer against the vulnerabilities to floods and droughts. Climate change is likely to heavily impact water supply and demand and worsen extreme events. Adaptation to climate variability and climate change may require a suite of solutions including investments in water resources management policies, plans and institutions, demand management, conservation and protection of watersheds, lakes, wetlands and aquifers as well as rehabilitation, upgrading and construction of new on-stream and off-stream abstractions, small and large dams, and interbasin transfers as well as conjunctive use of surface and ground water. The global food crisis has refocused attention on improving agriculture, including investment in irrigation infrastructure among other actions in developing nations, while the global energy crisis has drawn attention to accelerating investments in energy production, including hydropower development. The current global financial and economic crisis is adding weight to the argument for increasing investments in infrastructure in the water, transport, and energy and other sectors in both developed and developing nations both as a solution to and buffer against the uncertainties associated with the economic downturn. In all cases, SDN's challenge will be how and at what pace to increase infrastructure investments while maintaining the necessary measures required for economic, social and environmental sustainability.

The World Bank's 2003 Water Resources Sector Strategy calls for investing in "high risk" infrastructure projects (such as dams) in an environmentally and socially responsible manner. It calls for a new business model for developing high risk water infrastructure that takes full account of both upstream and downstream environmental and social impacts of the infrastructure in a timely, predictable, and cost effective manner. Apart from reducing uncertainties associated with project decision making and financing, this socially and environmentally responsible approach will help sustain ecosystem services on which many poor people in developing countries rely. The formation of the Sustainable Development Network in 2007 has further elevated environmental responsibility as a core element of the World Bank's work.

The World Bank's own analysis and the far-reaching report of the World Commission of Dams have both shown that dam developments have not always been planned, designed or operated satisfactorily. Even though dams generate considerable benefits in aggregate, these benefits have not always been shared equitably. Dams have often been developed without adequate consideration for either the environment or the people downstream of the dam who rely on local ecosystem based services.

The World Bank's knowledge and experience in addressing impacts upstream of dams has advanced considerably over recent decades. However, its experience in addressing the downstream impacts of water resources infrastructure, although growing, remains limited.

Environmental flow work within the Bank has been shaped by the evolving global knowledge, practice and implementation of environmental flows. The Bank has also contributed to this growing international experience particularly through its support for the Lesotho Highland Water Project, the restoration of the downstream parts of the Tarim River, and the restoration of the Northern Aral Sea and the Senegal River basin. It has also supported environmental flow initiatives in Central Asia, China, Ecuador, India, Mexico, Mekong River, Moldova and Ukraine, Tajikistan, and Tanzania, and has produced knowledge products and support material including a series of technical notes on environmental flows.

This report further contributes to international knowledge about environmental flows and sustainable development. It focuses on the integration of environmental water allocation into integrated water resources management (IWRM) and so fills a major gap in knowledge on IWRM. It also contributes to broadening our understanding of benefit sharing from risky infrastructure development. This report is an output of an important collaboration between the Bank's Environment Department and Energy, Transport and Water Department to promote and mainstream sustainable development.

James Warren Evans
Director
Environment Department

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Acronyms

ANC	African National Congress (South Africa)
ASBP	Aral Sea Basin Program
BC	British Columbia (Canada)
BBM	Building block methodology
BWP	Berg Water Project (South Africa)
CC	Consultative committee (Canada)
CDA	Chilika Development Authority (Orissa, India)
CCT	City of Cape Town (South Africa)
CIS	Common implementation strategy (EU)
CMAs	Catchment management agencies (South Africa)
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DANIDA	Danish International Development Agency
DWAF	Department of Water Affairs and Forestry (South Africa)
IWMI	International Water Management Institute
DEP	Department of Environmental Protection (Florida, U.S.A.)
DFO	Department of Fisheries and Oceans (Canada)
DRIFT	Downstream Response to Imposed Flow Transformation
EA	Environmental assessment
EF	Environmental flows
EFA	Environmental flow assessment
EFI	European Fish Index
EIA	Environmental impact assessment
EMC	Environmental monitoring committee
EMP	Environmental management plan
ESW	Economic and Sector Work (World Bank)
EU	European Union
FAME	Fish-based assessment for European rivers
GEF	Global Environment Facility
GEP	Good ecological potential (EU)
GES	Good ecological status (EU)
HES	High ecological status (EU)
HMWB	Heavily modified water bodies (EU)
IBFM	Integrated basin flow management
ICWC	Interstate Commission for Water Coordination

IFR	Instream flow requirements
IWRM	Integrated water resources management
ISP	Internal strategic perspective (South Africa)
KNP	Kruger National Park (South Africa)
KNPRRP	Kruger National Park Rivers Research Programme (South Africa)
KST	Kihansi spray toad (Tanzania)
LAS	Large Aral Sea
LHWP	Lesotho Highlands Water Project
LHDA	Lesotho Highlands Development Authority
LKEMP	Lower Kihansi Environmental Management Project (Tanzania)
LKHP	Lower Kihansi Hydropower Project (Tanzania)
MDBC	Murray Darling Basin Commission (Australia)
MFLs	Minimum flows and levels (Florida, U.S.A.)
MRC	Mekong River Commission
MTAC	Multisectoral Technical Advisory Committee (Tanzania)
NAS	Northern Aral Sea
NAWAPO	National Water Policy (Tanzania)
NCC	National Competition Council (Australia)
NGO	Nongovernmental organization
NSW	New South Wales (Australia)
NWA	National Water Act (Republic of South Africa)
NWC	National Water Commission (Australia)
NWI	National Water Initiative (Australia)
NWRCS	National Water Resources Classification System (South Africa)
NYM	Nyumba ya Mungu regulating reservoir (Tanzania)
OMVS	L'Organisation pour la Mise en Valeur du Fleuve Sénégal (Senegal)
OWRCP	Orissa Water Resources Consolidation Project (Orissa, India)
PAD	Project Appraisal Document (World Bank)
PASIE	Plan d'Atténuation et de suivi des Impacts sur l'Environnement (Senegal)
RBWO	Rufiji Basin Water Office (Tanzania)
RFOs	River flow objectives
ROP	Resource operations plan (Australia)
RSA	Republic of South Africa
RWRA	Rapid water resources assessment
SANParks	South Africa National Parks
SDN	Sustainable Development Network (World Bank)
SEA	Strategic environmental assessment
SFN	Stl'atl'imx First Nation (Canada)
STAR	Stream and River Typologies Project (EU)
TANESCO	Tanzania National Electricity Supply Company
TAP	Technical advisory panel
TBMB	Tarim Basin Management Bureau (China)

TBWRC	Tarim Basin Water Resources Commission (China)
TCTA	Trans Caledon Tunnel Authority (South Africa)
TNC	The Nature Conservancy
TRC	Tarim River Committee (China)
TRMB	Tarim River Management Bureau (China)
TTL	Task team leader (World Bank)
UNEP	United Nations Environment Programme
UK	United Kingdom
UNDP	United Nations Development Programme
WCD	World Commission on Dams
WCWSS	Western Cape Water Supply System (South Africa)
WCSA	Western Cape Systems Analysis (South Africa)
WFD	Water Framework Directive (EU)
WMA	Water management area (South Africa)
WMDs	Water management districts (Florida, U.S.A.)
WRB	Water resources bureau (China)
WRP	Water resources plan (Australia)
WRVs	Water resource values (Florida, U.S.A.)
WSP	Water sharing plans (Australia)
WUA	Water user association
WUP	Water Utilization Project
WUP	Water use plan (Canada)
WWF	Worldwide Fund for Nature
XUAR	Xinjiang Uygur Autonomous Region (China)
YRBC	Yellow River Basin Commission(China)

Note: All dollars are U.S. dollars; all tons are metric tons.

Summary

Environmental flows are really about the equitable distribution of and access to water and services provided by aquatic ecosystems. They refer to the quality, quantity, and timing of water flows required to maintain the components, functions, processes, and resilience of aquatic ecosystems that provide goods and services to people.

Environmental flows are central to supporting sustainable development, sharing benefits, and addressing poverty alleviation. Yet allocating water for environmental uses remains a highly contested process. Investments in water resources infrastructure, especially dams for storage, flood control, or regulation, have been essential for economic development (including hydropower generation, food security and irrigation, industrial and urban water supply, and flood and drought mitigation), but, when they are improperly planned, designed, or operated, they can cause problems for downstream ecosystems and communities because of their impact on the volume, pattern, and quality of flow. While aquatic life depends on both the quantity and quality of water, changes in flows are of particular concern because they govern so many ecosystem processes. Consequently, changes in flow have led to a diminution of the downstream ecosystem services that many of the poorest communities rely on for their livelihoods. In order to achieve sustainable development, downstream impacts will require more attention by all parties, as countries—through both public and private sector investments—expand their infrastructure in many sectors, especially dams for various purposes.

Climate change is projected to affect the supply of and demand for water resources; in turn, these changes will have an impact on water for the environment. Sea-level rise will cause saltwater intrusion and affect estuarine processes that rely on freshwater environmental flows. In some nations, adaptation to climate change is likely to involve more investment in dams and reservoirs to buffer against increased variability in rainfall and runoff. This will further affect downstream ecosystems, unless the impacts are properly assessed and managed.

The overall goal of this report and the accompanying report summarizing the findings and recommendations, both based on the economic and sector work (ESW), is to *advance the understanding and integration in operational terms of environmental water allocation into integrated water resources management.* The specific objectives of the two reports are the following:

- Document the changing understanding of environmental flows, both by water resources practitioners and by environmental experts within the Bank and in borrowing countries
- Draw lessons from experience in implementing environmental flows by the Bank, other international development organizations with experience in this area, and a small number of developed and developing countries
- Develop an analytical framework to support more effective integration of environmental flow considerations for informing and guiding (a) the planning, design, and operations decision

making of water resources infrastructure projects; (b) the legal, policy, institutional, and capacity development related to environmental flows; and (c) restoration programs
- Provide recommendations for improvements in technical guidance to better incorporate environmental flow considerations into the preparation and implementation of lending operations.

Environmental Flows: Science, Decision Making, and Development Assistance

The provision of flows, including volumes and timings, to maintain downstream aquatic ecosystems and provide services to dependent communities has been recognized in developed countries for more than two decades and is increasingly being adopted in developing countries. These services include the following:

- Clean drinking water
- Groundwater recharge
- Food sources such as fish and invertebrates
- Opportunities for harvesting fuelwood, grazing, and cropping on riverine corridors and floodplains
- Biodiversity conservation (including protection of natural habitats, protected areas, and national parks)
- Flood protection
- Navigation routes
- Removal of wastes through biogeochemical processes
- Recreational opportunities
- Cultural, aesthetic, and religious benefits.

But the impacts of development on communities downstream are often diffuse, long term, poorly understood, and inadequately addressed.

Assigning water between environmental flows and consumptive and nonconsumptive purposes is a social, not just a technical, decision. However, to achieve equitable and sustainable outcomes, these decisions should be informed by scientific information and analysis. The causes of changes in river flow can also be broader than just the abstraction or storage of water and the regulation of flow by infrastructure; upstream land use changes due to forestry, agriculture, and urbanization can also significantly affect flows. The impacts of environmental flow can extend beyond rivers to groundwater, estuaries, and even coastal areas.

Many methods, from the very simple to the very complex, exist for estimating environmental flow requirements. The process for estimating environmental flow requirements is also referred to as environmental flow assessment (EFA). There is an extensive body of experience for the main EFA techniques.

The Entry Points for Bank Involvement

The Bank has four entry points through which to support countries seeking to integrate environmental flows into their decision making: (1) water resources policy, legislation, and institutional reforms;[1] (2) river basin and watershed planning and management;[2] (3) investments in new infrastructure; and (4) rehabilitation or reoperation of existing infrastructure. Consistent with its commitment to sustainable development, the Bank should support measures to promote the integration of environmental flows at an early stage in the decision-making process through dialogue on water resources policy, river basin planning, and programs that entail major changes in land use. The World Bank already has supported some projects with successful environmental flow components and outcomes.

[1] The word "policy" is used throughout much of the report to include legislation supporting the policy.
[2] Different countries use different terminology: river basins, catchments, and watersheds. Generally river basins are larger than catchments and watersheds. In this report we use the term basin to refer to basins, catchments, and watersheds generically unless a particular catchment or watershed is being discussed.

Environmental Flows, Integrated Water Resources Management, and Environmental Assessment

EFAs are an intrinsic part of integrated water resources management. Although it is desirable for EFAs to be integrated into strategic environmental assessments (SEAs) for policy, plan, program, or sectorwide lending, and into environmental impact assessments (EIAs) for project-level investments, the practice of SEA and EIA has yet to mature to the point at which it can effectively integrate EFA. As a consequence, most EFAs have been undertaken separately either in conjunction with or after the EIAs have been completed.

Bank Adoption of Environmental Flows

An analysis of select dam projects found that, until the mid-1990s, Bank support for environmental and social work was heavily focused on evaluating and addressing the upstream impacts of dams. By the mid-1990s, these assessments had expanded to include downstream environmental and social issues with about equal frequency, underscoring the evolving concern about downstream impacts. An analysis of country water resources assistance strategies, however, showed mixed results concerning the inclusion of environmental flows, with only some countries incorporating them into their planning. There is a limited perception of the need to include environmental flows within the water policies of developing countries, but a good understanding of the importance of environmental flows in catchment-scale water resources planning. The Bank-Netherlands Water Partnership Program has catalyzed some notable achievements in introducing environmental flows into infrastructure planning, design, and operations in dam rehabilitation and reoperation projects.

International Development Organizations and NGOs

Various international development organizations and nongovernmental organizations (NGOs) have been supporting environmental flow assessments at both the project and basin levels, conducting training courses, and providing information and support material. The Bank has partnered with some of these organizations to produce analytical material on the incorporation of environmental flows into infrastructure development and reoperations.

Environmental Flow Implementation Case Studies

Seventeen case studies were selected for an in-depth analysis to identify the lessons from incorporating environmental flows into water resources policy, basin and catchment plans, new infrastructure projects, and the rehabilitation and reoperation of existing infrastructure. The analysis included eight case studies that were supported by the World Bank.

The assessment criteria included factors that influenced the case study's success, as well as the institutional drivers that initiated and supported the introduction of environmental flows.

Inclusion of Environmental Flows in Water Resources Policies

An analysis of five policy case studies found that the inclusion of environmental flows in policy should provide for the following:

- Legal standing for environmental water allocations
- Inclusion of environmental water provisions in basin water resources plans
- Assessment of all relevant parts of the water cycle when undertaking EFAs
- A method or methods for setting environmental objectives in basin plans
- Attention to both recovery of overallocated systems and protection of unstressed systems
- Clear requirements for stakeholder involvement
- An independent authority to audit implementation
- A mechanism for turning value-laden terms into operational procedures.

Inclusion of Environmental Flows in Basin and Catchment Plans

Several lessons emerged from the analysis of four basin and catchment water resources plans:

- Recognition of environmental flows in water resources policy and legislation provides important backing for including environmental flows in basin or catchment plans.
- There is a need to demonstrate the benefits from environmental water allocations after plans are implemented.
- The term "environmental flows" can be counterproductive if not explained at an early stage.
- Participatory methods need to be tailored to suit stakeholder capacity.
- A range of EFA techniques are needed to suit different circumstances.
- Ecological monitoring is essential to provide information for adaptive management.

Inclusion of Environmental Flows in Infrastructure Projects

Four new dams and four restoration projects were reviewed for lessons in assessing and implementing environmental flows:

- Engineering improvements usually have to be combined with reoperations to provide the volume of water needed for major ecosystem restoration.
- Inclusion of environmental flows in water resources policy simplifies the application of EFAs at the project level.
- Environmental outcomes need to be linked closely to social and economic outcomes.
- EFAs should be conducted for all components of the hydrological cycle.
- Traditionally trained water resources professionals can find it difficult to grasp environmental flow concepts.
- Water resources plans provide benchmarks for water allocations during project assessments.
- Active monitoring is needed to enforce flow allocation decisions and undertake adaptive management.
- It is important to present information in terms that are comprehensible to decision makers.
- Economic studies can support arguments for downstream water allocations.
- EFAs are yet to be fully mainstreamed into EIAs.
- The cost of conducting EFAs constitutes a small fraction of project costs.
- EIAs have not always or adequately identified issues associated with downstream water provisions.

Mainstreaming Implications

The science underpinning EFAs has advanced considerably. There are now many more methods for estimating environmental flow requirements, and more information is available on the ecological response to different flow regimes. There is also growing experience in integrating information from across a range of physical, ecological, and socioeconomic disciplines. In addition, a wide variety of EFA methods have been developed, backed by considerable field experience, to suit a variety of levels of environmental risk, time and budget constraints, and levels of data and skills. The Bank's support for the Lesotho Highlands Water Project has contributed to the development of a method known as Downstream Response to Imposed Flow Transformation (DRIFT), which systematically addresses the downstream biophysical and socioeconomic impacts. There is also a growing body of experience in implementing environmental flows, including monitoring and adaptation of management procedures.

Mainstreaming Achievements

Developed countries, including parts of the United States, Australia, New Zealand, and the countries of the European Union, together with South Africa, have accepted the need to develop and implement catchment

water resources plans that include environmental flows. There is general public acceptance of the importance of maintaining healthy aquatic environments in these countries. In these countries, where environmental flows have now been mainstreamed into water resources planning, there is an acceptance that the concept of environmental flows should be extended to groundwater as well as to estuaries and even near-shore regions.

Support for Developing Countries

International development organizations, NGOs, and research organizations have been active in providing support in developing countries through assistance with EFA and implementation, training programs, and provision of support material and Internet resources. The Bank has collaborated with diverse development partners. The Bank's major contribution to global good practice has been its restoration of the degraded Tarim basin and Northern Aral Sea, its assistance with the provision of flood flows in the Senegal basin, its support for the pioneering work on the Lesotho Highlands Water Project, and its growing influence in introducing environmental flows into government water policies. In these cases, provision of environmental flows has restored (or retained) ecosystems with demonstrable benefits to downstream populations; in the Tarim basin case, there were also significant benefits to the upstream irrigation communities.

Challenges

Both the Bank and environmental flows practitioners face many challenges:

- Overcoming the misperceptions arising from the term "environmental flows"
- Developing methods for systematically linking biophysical and socioeconomic impacts
- Incorporating the whole water cycle (surface, groundwater, and estuaries) into the assessments
- Applying EFAs to land use activities that intercept and exacerbate overland flows
- Including climate change in the assessments
- Integrating environmental flow assessments into strategic, sectoral, and project EAs
- Understanding the circumstances in which benefit sharing is a viable approach.

Framework for Expanded Bank Engagement with Environmental Flows

The analysis points to a four-part framework for improving the Bank's use of environmental flows.

First, efforts are needed to strengthen Bank capacity in assessing and overseeing environmental flows:

- Promote the development of a common understanding across the water and environmental communities about the concepts, methods, and good practices related to environmental flows, including the need to incorporate EFAs into environmental assessment at both project (EIAs) and strategic (SEAs) levels.
- Build the Bank's in-house capacity in EFA by broadening the pool of ecologists, social scientists, and environmental and water specialists trained in EFA.

Second, efforts are needed to strengthen environmental flow assessments in lending operations through training, support materials, and access to international experts:

- Disseminate existing guidance material concerning the use of EFAs in program and project settings and conduct training for Bank and borrower country staff on this emerging issue
- Identify settings, approaches, and methods for the select application of EFAs in the preparation and implementation of project-level feasibility studies and as part of the planning and supervisory process
- Provide support for hydrological monitoring networks and hydrological modeling to provide the basic information for undertaking EFAs

- Prepare an update of the EA sourcebook concerning the use of EFAs in SEAs and EIAs
- Prepare a technical note that defines a methodology for addressing downstream social impacts of water resources infrastructure projects
- Test the application of EFAs to include infrastructure other than dams that can affect river flows, as well as other activities, such as investments in large-scale land use change and watershed management, and their effects on downstream flows and ecosystem services
- Broaden the concept of environmental flows for appropriate pilot projects to include all affected downstream ecosystems, including groundwater systems, lakes, estuaries, and coastal regions
- Develop support material for Bank staff and counterparts in borrowing countries, such as case studies, training material, technical notes, and analyses of effectiveness.

Third, efforts are needed to promote the integration of environmental flows into policies and plans through dialogue, instruments such as country water resources assistance strategy (CWRAS), country assistance strategy (CAS), country environmental assessments, and development policy lending, and support material for Bank staff:

- Promote basin or catchment plans that include environmental flow allocations, where relevant, through country dialogue
- Use CASs and CWRASs to promote Bank assistance with basin or catchment planning and water policy reform so that the benefits of environmental water allocations for poverty alleviation and the achievement of the Millennium Development Goals are integrated into country assistance
- Incorporate environmental water needs into Bank SEAs such as country environmental assessments and sectoral environmental assessments
- Test the use of EFAs in a small sample of sectoral adjustment lending operations, including where the sectoral changes will lead to large-scale land use conversion
- Promote the harmonization of sectoral policies with the concept of environmental flows in developing countries and the understanding of sectoral institutions about the importance of considering the impact of their policies on downstream communities
- Develop support material for Bank staff on the inclusion of environmental flows into basin and catchment planning and into water resources policy and legislative reforms
- Draw lessons from developed countries, which have experience with incorporating environmental flows in catchment planning.

Fourth, efforts are needed to expand collaborative partnerships:

- Expand collaboration with NGOs (International Union for the Conservation of Nature, Worldwide Fund for Nature, The Nature Conservancy, Natural Heritage Institute, and others), research organizations, and international organizations (United Nations Environment Programme, Ramsar Secretariat, International Water Management Institute, and United Nations Education, Scientific, and Cultural Organization) to take advantage of their experience in conducting EFAs and building environmental flow capacity in developing countries
- Strengthen collaborative relationships with industry associations, such as International Hydropower Association and private sector financing, to extend their recognition of environmental flows as desirable hydrological outcomes to include the social and economic outcomes that result from the ecosystem services delivered by the downstream flows
- Integrate lessons from this analysis into—and coordinate the activities outlined above with—the ongoing initiative of the World Bank's Sustainable Development Network and Energy, Transport, and

Water Department for enhancing benefits to local communities from hydropower projects.

Adoption of this framework will improve the Bank's ability to implement its strategy of increasing investment in water resources infrastructure, while reducing the risk of detrimental environmental impacts that threaten the livelihoods of downstream communities.

I Case Study Criteria

Selection of Case Studies

Case Study Characteristics

The policy and basin case studies were selected to provide a diversity of institutional settings, geographic regions (Figure A.1), and levels of economic development (Table A.1). The infrastructure project case studies were selected for their diversity of geographic regions, sectoral purposes, and whether they involved new infrastructure, rehabilitation, or re-operation of existing infrastructure. Only one example of each type was taken from a given country, even though countries such as Australia, for example, have a number of catchment-scale water plans with environmental flow components, and there are numerous examples of project-level environmental flow assessments in European countries and the United States. Five policy-level, four catchment/basin plan-level, and eight project-level case studies were selected. Policy, catchment/basin, and project-level case studies were selected from South Africa—because of its experience in environmental flows—and Tanzania, a country currently developing expertise in environmental flows.

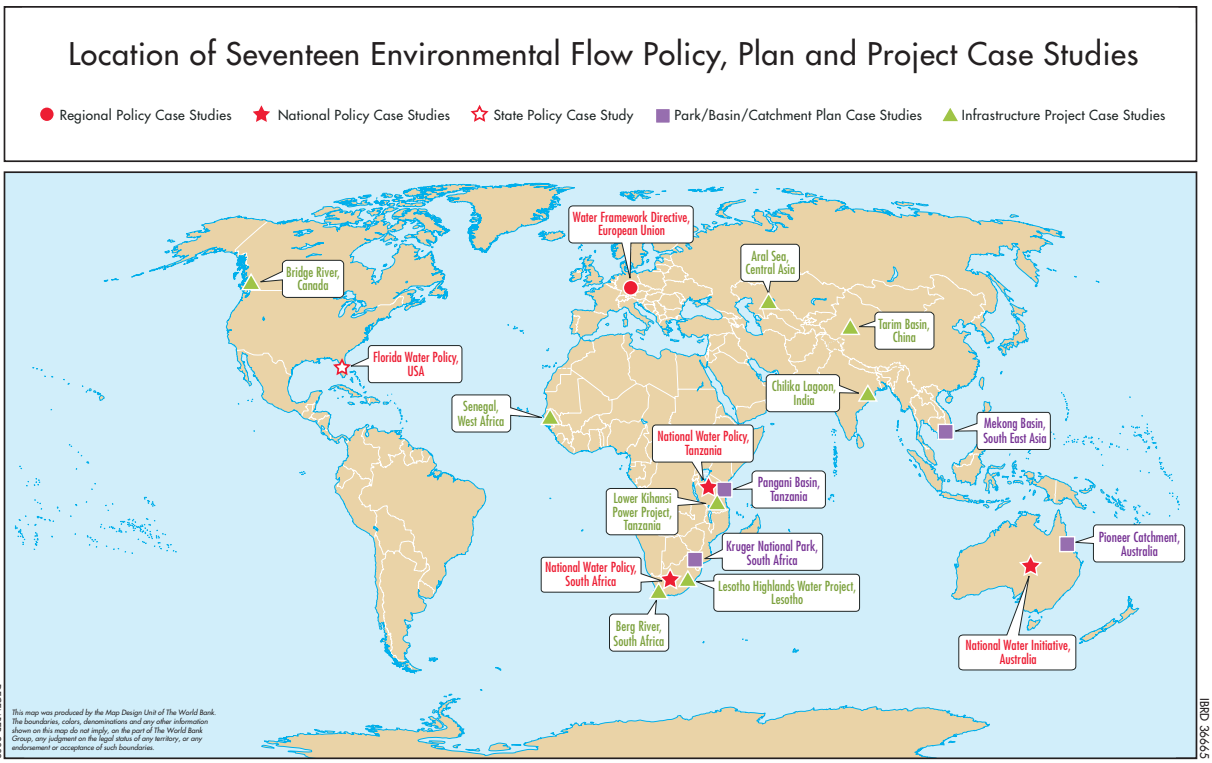
In order to draw on the best available experience, the selection of case studies included both World-Bank-supported and non-World-Bank cases. Bank-funded case studies were used where there was good documentation in English and staff members were available for interview. Overall, eight of the 17 case studies were supported by the Bank. Figure A.1 shows the locations of the case studies, and Table A.1 describes the characteristics of the case studies.

South Africa, Australia, Florida (United States), and the European Union (EU) were selected for the policy case studies, because these represent the settings where environmental flows have been introduced through water policies. In these locations, the policies have now been implemented for a number of years and thus offer good opportunities for learning lessons. Australia and the EU also provide opportunities to learn from environmental flow provisions in cross-border and transboundary policy settings respectively. The Tanzanian water policy case study provides an example where environmental flows were required in the national water policy of a developing country.

Four catchment- or basin-level water planning studies that included EFAs were selected for case studies. They included one from a developed country—Australia—and three from developing countries and regions—South Africa, Tanzania, and the Mekong region. Finally, eight single and multipurpose projects covering a diversity of sectors—hydropower generation, irrigation, inter-basin water transfer, water supply, and ecosystem restoration—were selected for project-level case studies. All but one were in developing countries, and all but two were supported by World Bank funding.

The project-level case studies include EFAs conducted as part of the development of a new dam (Berg River Dam, South Africa; and Mohale Dam as part of the LHWP in Lesotho), replacement of old infrastructure (Naraj Barrage, Mahanadi River, India; and irrigation canals in Tarim basin, China), reconstruction/modification of existing infrastructure (Berg Strait dyke, Aral Sea; Lower Kihansi, Tanzania; and Katse Dam as part of the Lesotho Highlands Water Project in Lesotho), and re-operations for existing infrastructure (Bridge River, Canada;

Figure A.1. Location of Case Studies



Manantali Dam, Senegal basin; dams on Syr Darya River, Aral Sea basin; and Tarim basin, China). Some of the lessons for the rehabilitation and re-operation case studies differ from those for the new infrastructure.

Introducing EFAs into cross-border and transboundary rivers and groundwater systems is particularly difficult because of the inherent complexity of dealing with multijurisdictional issues. There needs to be agreement between the countries of the basin on the allocation of water for environmental purposes before environmental water allocations can be made. Six of the case studies—two policy-level, one catchment-level, and three project-level—provide examples of cross-border or transboundary EFAs.

The case studies were developed from both documentation and interviews. Documentation was initially obtained from published sources, including the archives in the case of the Bank-led case studies, and unpublished materials and reports. Interviews were then arranged with the project team leaders who were available, and with other team members where the team leader was not available. The interviews were either in person or by telephone. The interviews particularly focused on the motivations for the study and its subsequent influence, since this information was seldom documented. Additional documentation was collected during these interviews. The draft case studies were sent to team leaders for checking before being finalized. For non-Bank case studies, principals involved in the case studies were contacted and either interviewed or requested to provide information by e-mail. These case studies were sent to the principals for checking before being finalized.

Table A.1. Characteristics of Case Studies

Case Study	Country/ Region	GNI per capita (US$)*	Institutional Setting	Sector	Purpose	Date Completed
Policy						
National Water Initiative	Australia	$35,990	Federation of States	Multisectoral		1994; revised 2004
Water Framework Directive	European Union	$4,089–$89,571	Union of countries	Multisectoral		2000
Florida Water Policy	USA	$44,970 (USA)	State government within federal system	Multisectoral		1972; subsequent amendments
National Water Policy	South Africa	$5,390	Unitary government	Multisectoral		1997
National Water Policy	Tanzania	$350	Unitary government	Multisectoral		2002
Catchment and Basin Plans						
Kruger National Park	South Africa	$5,390	National (with transboundary component)	Environment, agriculture, biodiversity	Planning and operations	On-going
Mekong Basin	South East Asia	$480–$2,990	Transboundary	Multisectoral	Planning	On-going
Pangani Basin	Tanzania	$350	National and Transboundary	Multisectoral but environment-focused	Planning	On-going
Pioneer Catchment	Australia	$35,990	National	Multisectoral	Planning	2002
Infrastructure Projects						
Aral Sea	Central Asia	$260–$5,060	Transboundary	Environmental Restoration	Re-operations and restoration. Dyke upgrading	GEF project 2003; World Bank project still active
Berg River	South Africa	$5,390	Catchment	Water supply	New dam	In progress
Bridge River	Canada	$36,170	Sub-catchment	Hydropower	Re-operations	2001
Chilika Lagoon	India	$820	Sub-catchment	Irrigation Flood control	Restoration and re-operations	2004
Lesotho Highlands Water Project	Lesotho	$1,030	Transboundary	Inter-basin transfer (water supply)	Reconstruction of outlet structure in old dam, and new dam	2006
Lower Kihansi Power Project	Tanzania	$350	Sub-catchment	Hydropower	Reconstruction of outlet structure in new dam	In progress
Senegal	West Africa	$750	Transboundary	Multi-purpose	Reoperation and restoration	Regional Hydropower Development Project completed 2005
Tarim Basin	China	$2,010	Sub-basin	Irrigation	Irrigation canal reconstruction and re-operations	2005

Note: *GDP per capita is from World Bank Doing Business 2008 site, accessible at: http://www.doingbusiness.org/ExploreEconomies/EconomyCharacteristics.aspx

Case Study Assessment

Good Practice Criteria

Good practice criteria for including environmental aspects in water resources policy, legislation, plans, institutions, and infrastructure investments are listed in Appendix A of the recent World Bank ESW on Strategic Environmental Assessment and Integrated Water Resources Management (World Bank, forthcoming). The criteria used here to assess the environmental flows case studies were developed from these EIA and SEA criteria, since environmental flow assessments are a special type of EA. These criteria have similarities to those proposed by Lamb (1995) to assess the effectiveness of management programs for in-stream flows in the United States (Box A.1), although the latter are focused on the implementation of institutional programs rather than EFAs and so are less relevant here.

The following good practice assessment criteria were used for the policy, plan, and project case studies here, largely

Box A.1. Assessment Criteria for In-Stream Flow Programs in the United States

A number of U.S. states introduced instream flow programs, but there was little information on how well the programs worked. There were a number of reasons why these programs had not been evaluated; one was the lack of evaluation criteria. To remedy this deficiency, Lamb proposed five criteria: (1) public confidence—a good program was one that enjoys public confidence that the program will work; (2) certainty—if the in-stream water use is guaranteed for a long period, the program can be judged to be successful; (3) proper administration—this criterion covers a number of factors, including setting of goals and measurement criteria, systematic implementation process, and appropriate authorization; (4) expense—a measure of the budgetary expense, but not including measurement of the benefits of the program; and (5) outcomes—both the extent of stream protection and the quality of the protection.

Source: Lamb (1995).

based on the criteria used in the ESW on Strategic Environmental Assessment and Integrated Water Resources Management (World Bank, forthcoming):

- environmental allocations (recognized and required as part of water allocation planning)
- a mechanism to identify environmental objectives in water planning
- comprehensiveness (including all components of the water cycle, national and transboundary concerns, and the linkage of environmental flows to social and economic outcomes)
- the detail with which provisions assess and implement EFAs, and the handling of overallocated systems
- policy provisions to encourage stakeholder participation n formulating environmental flow requirements and in the making and implementation of decisions
- the use of reliable data, high-quality science, and recognized methods for assessing environmental water needs
- monitoring, reporting, and auditing requirements

Catchment or basin plans were assessed for the extent to which:

- the legitimacy of environmental flows was recognized when the plan was being formulated and implemented
- stakeholders with an interest in environmental flow outcomes were engaged in the planning
- recognized methods and reliable data were used in the planning
- there was integration between environmental impacts and the consequent social and economic impacts of water allocation decisions
- the EFA methods were cost-effective
- the EFA influenced the allocation of water for environmental purposes within (and beyond) the plan

Project-level case studies were assessed for the extent to which:

- environmental flow considerations were recognized as being legitimate during the conduct and implementation of the EFA
- stakeholders were encouraged to participate in the EFA and their requirements were taken account of
- recognized methods and reliable data were used in the EFA
- there was integration between environmental impacts and the consequent social and economic impacts of water allocation decisions
- the EFA was conducted in a cost-effective way and its recommendations were cost effective, taking account of the overall project costs
- the EFA was influential in including downstream environmental considerations into the final project deign and operations

While most of the criteria relate to the conduct of the EFA itself, the effectiveness of a case study requires a

judgment about its subsequent influence. This is difficult for a number of reasons. Some case studies have yet to be fully completed and it is difficult to assess their effectiveness at this stage. In addition, there are a number of cases that might have been judged to have had little influence in their early stages, but subsequently were very influential. For example, the early definitions of IFRs in the rivers flowing through the Kruger National Park were not implemented for a number of reasons, and so would have been assessed as having little influence. However, they subsequently formed the basis of the Reserve determinations of those rivers, and the experience gained in carrying out the IFRs had a significant influence on the subsequent South African Water Policy.

Institutional Drivers

The basin/catchment and project-level case studies were analyzed to identify the drivers that initiated and sustained them (Box A.2). The six drivers describe the mechanisms that can initiate an EFA and maintain the momentum for its completion. They are based on drivers originally identified for project-level EIAs (Ortolano, Jenkins, and Abracosa 1987) and have been modified here to incorporate the additional drivers that can lead to the inclusion of environmental flows in water policy and basin planning.

However, the drivers that lead to the inclusion of environmental flows into water resources policies

Box A.2. Drivers for Environmental Flows

The classification of drivers in this assessment is drawn from the six types of institutional drivers identified by Ortolano, Jenkins, and Abracosa (1987) for environmental impact assessments.

Judicial drivers. The courts have a formal role in ensuring that government agencies implement EFA provisions in the relevant legislation. Judicial drivers are widely used in the United States, where the judiciary has a constitutionally sanctioned role in reviewing government procedures.

*Procedural drivers***.** Legislation, regulations, and guidelines provide formal drivers over the procedures to be followed when EFAs are conducted for basin water allocation plans or project impact assessments. However, procedural drivers are seldom effective without the availability of other drivers such as evaluative or professional drivers. By themselves, they can lead to well-written EFAs that are ignored. These drivers also include external agreements such as international conventions and regional agreements.

Evaluative drivers. Evaluative drivers exist when there is an institution responsible for assessing the quality of implementation of policy requirements, or plan- or project-level EFAs. These independent assessors may have the power to return catchment or basin plans or EFAs for revision; may be able to fine lack of compliance with policy requirements; or may rely on publicity to generate effective implementation of policy.

Instrumental drivers. The requirements of international development partners provide an additional driver for EFAs. Many development partners have formal requirements for EFAs as part of the due diligence attached to loans. There can also be informal instrumental drivers operating where the development partner advocates environmental flow considerations when supporting water policy reforms. Instrumental drivers can play a central role in developing countries, where legislative and evaluative drivers are absent.

Professional drivers. The considered judgment of planners, professional associations, and other professionals undertaking policy development, catchment/basin plans, or project developments can act as a powerful driver for EFAs. Professionals can be influenced by international developments in EFA or, more broadly, in environmental sustainability.

Public drivers. These drivers rely on informed public citizens, community-based organizations, and nongovernmental organizations who are motivated and confident enough to make their views about environmental equity known to government. They may be more relevant in developed countries, which have a tradition of active public engagement in the decisions of government, but may also be important in developing countries. A stimulus is often provided by local, national, or international NGOs, who make an assessment and then inform the public.

Source: Modified from Ortolano, Jenkins, and Abracosa 1987.

differ from the ones that operate for plans and projects. Environmental flow provisions are included in policy when the policies themselves are being revised, and so the policy drivers need to include both those that lead to the policy reforms as well as those that operate specifically to include environmental flows into the new policies. Three types of policy reform drivers were apparent in the case studies and four drivers operated for environmental flow provisions (Box A.3).

The case studies are reviewed for both their inclusion of environmental flow considerations into policies, plans, and projects and the subsequent implementation of environmental flow provisions (where there is sufficient information on implementation).

Box A.3. Drivers for Water Resource Policy Reform and Inclusion of Environmental Flows

Policy Reform

*Convening***.** In a federal system—such as the EU, the United States, or Australia—the federal government can use its influence to convene and lead policy reforms even when the responsibility for the policy implementation lies at a subsidiary level. This convening power is sometimes supplemented with financial assistance from the federal level to help the subsidiary levels of government implement the policy reforms.

Singularity. A singular event—such as a drought—can precipitate policy reforms if it is clear that the current water policy is inadequate to handle the event. While such events act as triggers for reform, there is often a backlog of issues—including provision of water for the environment—that need to be incorporated into the new policy beyond the particular deficiency that triggered the reform.

Public. Public pressure, because of perceived deficiencies in water resources management, can act as a powerful stimulus for reform**.**

Environmental Flow Inclusion

*Institutional***.** Water managers and other professionals within government can support the inclusion of environmental flow provisions in policy because they are aware of the benefits that these flows confer on downstream environments and communities.

*Evaluative***.** A specific organization can be identified in the policy with the oversight of environmental flow provisions to ensure they are implemented. The organization is typically at least partially independent of government since it is overseeing the performance of government agencies. This driver acts to implement the environmental flow provisions rather than to introduce them into policy.

Public. Where the public is concerned about the decline in downstream environments because of water abstractions and other developments, they can exert considerable pressure for environmental flow provisions to be included in policy reforms.

Scientific Professional. Scientific organizations and individual scientists can use their standing in government and in the community to highlight the issues arising from disruptions to downstream flows and to propose policy provisions to help restore downstream environments.

International Developments. The proclamations from major international conventions, such as the 1992 Rio Summit, can exert considerable influence on the content of new policies.

II. Policy Case Studies

Case Study 1. Australian water reform

Background

Australia is a federation where, until recently, the commonwealth government has had only a coordinating, convening, and funding role in water resources management. The responsibility for water resources management has resided with the six state and two territory governments. Recently, the commonwealth government approved legislation— the Water Act 2007—that establishes a commonwealth government agency that has responsibility for planning water use in the Murray Darling Basin, the basin with the highest population and most heavily used water resources.

The southeastern part of the country, where most of the population is concentrated, experienced a severe drought in the early 1980s. This sensitized both urban and rural populations to the overallocation of water entitlements that had occurred in some catchments, particularly in the Murray-Darling Basin. By the early 1990s, it was apparent that the environmental health of the continent's water resources—its rivers, aquifers, estuaries, and wetlands—was deteriorating (National Land and Water Resources Audit 2001; Australian State of the Environment Committee 2001). In 1994 the Council of Australian Governments (COAG)—heads of the federal, state, and territory governments—agreed to undertake major reforms of water resources management, including (a) separation of water service delivery, water resources management, and regulatory functions; (b) pricing water at its full cost; (c) separation of land and water titles; (d) a market for water trading; (e) privatization and corporatization of institutions; (f) re-use of urban wastewater; (g) improved education and consultation procedures; and (h) allocation of water for environmental benefit. The COAG Water Reform Framework was to be fully implemented by the year 2001. This date was subsequently extended to 2005 for certain components of the reforms, including water allocations and trading.

Providing water for environmental benefit was central to the reforms (Agriculture and Resource Management Council of Australia and New Zealand and Australian and New Zealand Environment and Conservation Council 1996). All governments committed to determining the environmental water requirements for all river systems and groundwater basins using the best available scientific information. For overallocated or stressed systems, governments agreed to provide environmental water allocations that would restore the health of these systems. The COAG agreement and the 12 principles for the provision of water for ecosystems (Box 1.1) provide a coherent and unified (although not uniform) framework for water resources management across the country.

The COAG agreement was amended in 1996 to strengthen the groundwater and stormwater management components, and further extended in 1999. Even so, the timetable to complete the COAG reforms by 2001 proved overly ambitious. In addition, a number of environmental assessments (Australia State of the Environment Committee 2001; National Land and Water Resources Audit 2002) made it clear that the state of the nation's water resources was not improving. Consequently, in June 2004, the federal, state, and

Box 1.1 ARMCANZ/ANZECC National Principles for the Provision of Water for Ecosystems

Principle 1. River regulation and/or consumptive use should be recognized as potentially impacting on ecological values.

Principle 2. Provision of water for ecosystems should be on the basis of the best scientific information available on the water regimes necessary to sustain the ecological values of water-dependent ecosystems.

Principle 3. Environmental water provisions should be legally recognized.

Principle 4. In systems where there are existing users, provision of water for ecosystems should go as far as possible to meet the water regime necessary to sustain the ecological values of aquatic ecosystems while recognizing the existing rights of other water users.

Principle 5. Where environmental water requirements cannot be met due to existing uses, action (including reallocation) should be taken to meet environmental needs.

Principle 6. Further allocation of water for any use should only be on the basis that natural ecological processes and biodiversity are sustained (that is, ecological values are sustained).

Principle 7. Accountabilities in all aspects of management of environmental water should be transparent and clearly defined.

Principle 8. Environmental water provisions should be responsive to monitoring and improvements in understanding of environmental water requirements.

Principle 9. All water uses should be managed in a manner that recognizes ecological values.

Principle 10. Appropriate demand management and water pricing strategies should be used to assist in sustaining ecological values of water resources.

Principle 11. Strategic and applied research to improve understanding of environmenta water requirements is essential.

Principle 12. All relevant environmental, social, and economic stakeholders will be involved in water allocation planning and decision making on environmental water provisions.

territory governments (except Tasmania and Western Australia)[1] signed a further agreement, the National Water Initiative (NWI), to accelerate the water reform process.

The National Competition Policy of April 1995 was an agreement between the commonwealth, state, and territory governments to advance a nationally coordinated approach to microeconomic reform across a number of sectors, in return for a series of national competition tranche payments based upon the effective implementation of the reform agenda. These microeconomic reforms included the 1994 COAG water reform agenda. Bringing the water reforms within the National Competition Policy had a number of consequences. In particular, the state and territory treasuries now paid attention to the water reforms because of the linkage between progress and tranche payments. There was pressure on the water management authorities from their own treasuries to formally meet the terms of the agreement (although they were less interested in achieving the substance of the reforms). Unlike the 1994 agreement, the National Water Initiative of 2004 did not link compliance with the flow of financial resources.

The NWI provided a more thorough blueprint for water reform than did the 1994 agreement, and

[1] Tasmania signed the agreement in 2005 and Western Australia signed the agreement in April 2006.

highlighted a number of areas where the reforms were lagging, including provisions for environmental flows where improved environmental outcomes were to be achieved through:

- expansion of permanent trade in water, bringing about more cost-effective and flexible recovery of water to achieve environmental outcomes
- more sophisticated, transparent, and comprehensive catchment-level water planning dealing with key issues such as the interception of water[2], the interaction between surface and groundwater systems, and the provision of water to meet specific environmental outcomes
- a commitment to return water to overallocated systems as quickly as possible, in consultation with affected stakeholders

The National Water Commission (NWC) was established to drive the NWI agenda.

The COAG and NWI agreements had significant implications for environmental flows. They required state and territory governments to:

- recognize water for the environment as a legitimate use, on the same legal footing as consumptive water
- draw up water allocation plans for catchments and groundwater areas that provided for environmental flows
- implement mechanisms that returned water to the environment in surface and groundwater systems that were overallocated from a sustainability point of view
- establish water markets where environmental allocations could be traded
- develop new, or amend existing, legislation to provide for the above requirements

As part of the agreements, each jurisdiction was required to introduce legislation and programs to implement the reforms.

The National Competition Council (NCC) prepared assessments of progress with the COAG agreement in 1999, 2001, 2002, 2003, 2004, and a sixth and final assessment in 2005.

The NWC issued the first biennial assessment of progress with the NWI in late 2007. Although some components of the NWI—water accounting, water pricing, water trading, and water entitlements—were progressing well, environmental water allocation aspects were less satisfactory. A number of states and territories were not meeting NWI requirements to return overallocated systems to environmentally sustainable levels of extraction. It was very difficult to define the NWI concept of sustainable levels of extraction. Although states had generally made good progress in rolling out catchment-level water allocation plans, the scientific underpinning of these plans, especially the links between water and the environment, were weak. In addition, management of water for the environment was judged to be weak. Thus, environmental water managers, with authority and funding to trade and manage water on behalf of the environment, had either not been established or had been given inadequate authority and resources. In addition, most states did not have adequate institutions for auditing environmental outcomes.

Because of the lack of progress in returning overallocated systems to environmentally sustainable levels of water extraction, in early 2007 the federal government announced a major $10 billion program—the National Plan for Water Security—to acquire water for the environment through a mixture of irrigation water use efficiency improvements and outright purchases of water entitlements. This program has subsequently been increased to $12.9 billion through the Water for the Future program.

[2] Interception refers to the (usually unlicensed) extraction of water before it reaches watercourses, primarily through commercial forestry activities, groundwater extraction, and small farm dams.

Drivers

The COAG and NWI agreements were the formal drivers of the water reforms, including the increased prominence of environmental water. However, these formal drivers were underlain by other influences. There was widespread public concern about the deteriorating state of Australia's water resources, and politicians at the state and national levels were sensitive to these concerns. Scientifically credible studies on the state of the aquatic environment provided legitimacy to these concerns; these studies had been commissioned by governments seeking factual advice. In addition, government officials at the state and federal levels recognized the importance of reforming water resources management and added their active support to the reform program. Through these multiple influences, the strength of concern was strong enough and enduring enough to lead to the two rounds of national water reforms over 13 years, together with other reforms to water management, both within the Murray Darling Basin (MDBC 2004; Independent Audit Group 1996) and nationally (Council of Australian Governments 2007; Australian Government 2007).

Since 2003, many parts of Australia have undergone the most severe drought in over 100 years. Many irrigation districts in the Murray Darling Basin are receiving only minimal water allocations. Urban areas, including six of the country's eight capital cities, are on water restrictions. These water shortages have heightened public awareness of the need to ensure that the country's water resources are managed carefully and given support to the water reforms.

The financial and convening authority of the federal government was also an important driver. The initial COAG agreement relied on implementation by the state governments, initially with oversight from a high-level steering group and then with periodic assessments by the NCC—an institution without specific expertise in water management. Within a few years it was clear that some components of the reforms, including provision of environmental flows, were proceeding at too relaxed a pace, partly because there was no institution charged with actively driving the reforms. Consequently, the National Water Commission was established as part of the NWI, specifically to drive the water reforms.

Assessment

Recognition. Environmental flows were a central component of the 1994 COAG agreement: "States would give priority to formally determining allocations or entitlements to water, including allocations for the environment as a legitimate user of water" and subsequently the NWI. The National Principles (Box 1.1) were developed through negotiation between all Australian governments specifically to provide a framework for incorporating environmental considerations into water planning.

Both the COAG agreement and the 2004 NWI agreement explicitly recognized that water for environmental purposes provided public benefit outcomes and that it underpinned the sustainability of other water uses. A central plank of both agreements was returning water to rivers that were overallocated in order to ensure their environmental sustainability.

While neither agreement assigned an explicit priority to water for the environment, the NWI implies that water for the environment should have a high priority by stating that consumptive water uses must be restricted to "environmentally sustainable levels of extraction." This requirement is echoed in state-level legislation. In New South Wales, the Water Management Act (2002) requires that water abstraction must (a) protect the water source and its dependent ecosystems, and (b) protect basic landholder rights. This implicitly assigns environmental water equal priority with landholder rights. However, determining the environmentally sustainable levels of extraction has proven to be very difficult in practice, partly because there is a lack of agreement about the meaning of the term and partly because there is a lack

Box 1.2. Interpreting Environmentally Sustainable Levels of Extraction

In a 2005 self-assessment, the Australian state and territory governments identified only three out of 340 surface water management areas and 19 out of 367 groundwater management units as being overallocated. These estimates are significantly lower than the estimates of overallocation in the preceding 2000 *Australian Water Resources Assessment*, which identified 26 percent of Australia's river basins and 34 percent of Australia's groundwater management units as approaching or being beyond sustainable extraction limits. It is unlikely that this decrease resulted from improved management; rather it arose from changes to definitions of sustainable yield and level of development between the two assessment reports.

The National Water Commission then applied a nationally consistent set of measures of stress on surface and groundwater systems in an independent assessment of 51 representative water management areas. This assessment still relied on self-assessments of sustainable yield by the state and territory governments. The analysis found that:

- Three out of the 51 water management areas had a consumptive use greater than sustainable yield.
- Seventeen water management areas had a high level of consumptive use as a proportion of inflows.
- Eleven water management areas had a high level of consumptive use as a proportion of the total water resource.
- Two groundwater management areas had a consumptive use greater than the total annual inflow.

While this independent assessment was based on data for just 2004–05, it indicates that the 2005 self-assessment by the states significantly underestimated the level of overallocation. State and territory governments need to agree on a consistent set of definitions and assessment procedures before the environmental sustainability of the country's water resources can be properly determined.

Source: National Water Commission (2007).

of reliable scientific evidence linking river flows and groundwater levels to ecosystem services and human benefits (Box 1.2).

Three out of the 51 water management areas had a consumptive use greater than sustainable yield.

Under the NWI, environmental water entitlements must be given statutory recognition and be accorded at least the same degree of security as water access entitlements for consumptive uses. Water allocation plans also must have a statutory basis. These requirements have now been implemented in all states through new or amended water legislation and, in principle, environmental water entitlements have equal statutory recognition to other entitlements.

Both the COAG and the NWI agreements pay little attention to the effects of dams and other water resources infrastructure on downstream flows[3]. This is partly because few dams are being built in Australia, and partly because environmental policies and legislation, rather than water resources policies and legislation, provide the primary protection for environmental flows below infrastructure such as dams.

Comprehensiveness. The COAG agreement initially focused on surface freshwater systems (rivers, wetlands, floodplains); groundwater systems were not properly incorporated until 1996. Groundwater management subsequently became a centerpiece of the NWI —including provision of water for groundwater-dependent ecosystems—when it became clear that restrictions on surface water abstractions in the Murray Darling Basin were shifting demand to groundwater abstractions. The measurement of connectivity between surface and groundwater has become a priority in recent years. However, groundwater has yet to be fully integrated into water allocation plans, even though there are groundwater management provisions in some plans.

The provision of water to sustain ecosystem services in estuaries has received little attention in the COAG and NWI agreements. Even so, a number of the catchment-

[3] The COAG agreement requires that assessments have to be undertaken and the environmental requirements of rivers have to be met before water is harvested for irrigation, rural water supply or for dam construction. The NWI agreement treats dams as either mechanisms to hold environmental water entitlements or as part of interception of surface flows (i.e., as small-farm dams).

level water allocation plans include provisions for ensuring flows to estuaries.

The Murray Darling Basin and the Great Artesian Basin are the major cross-border water resources in Australia. The former is subject to separate agreements, which are formally recognized in the NWI agreement. However, there is no explicit mention of the Great Artesian Basin or other cross-border water bodies in the NHI.

Both the COAG and NWI agreements include both water flow and water quality aspects. For example, the NSW Water Management Act 2002 requires environmental objectives for both water quality and river flow, and envisages "water sharing plans" (WSP) that include water quality aspects and source protection and rehabilitation. This requirement has been implemented in the WSP for the regulated Lachlan River system in New South Wales as a set of rules for a water quality allocation that may be used for any water quality issue.

The NWI agreement provides for a wide range of influences on water availability, specifically identifying forestry plantations, but also allowing for other influences such as farm dams, groundwater pumping, and bushfires. The NWI requires water resource accounts that include the effects of climate change and also requires that the effects of climate change are included in water allocation plans. The NSW legislation allows the minister to modify a WSP to reduce water entitlements as a result of climate change, but does not include climate change as an influence to be included in a WSP.

Environmental water mechanisms. Legally enforceable catchment-level water allocation plans with specific environmental water allocations are at the heart of the COAG and NWI agreements. These plans have been slow to be developed because of the requirements for stakeholder consultations, the difficulty of establishing environmental water allocations, and the time required to collate best available scientific knowledge in each catchment. Nevertheless, water allocation plans have now been approved for about 150 of Australia's major surface and groundwater systems. For example, 36 WSPs had been gazetted in New South Wales by 2006, covering 80 percent of surface and groundwater use in the state. A further 10 WSPs are yet to be completed, and 28 surface water plans and 5 groundwater plans for less stressed systems (termed macro plans) are being developed to cover most of the remaining waterbodies.

The NWI requires state and territory governments to establish "environmental and other public benefit outcomes" for their water allocation plans. All governments have legislated for these outcomes. For example, the New South Wales government has developed "interim river flow objectives" (RFOs) for each catchment in New South Wales.

Returning water to overallocated rivers and groundwater systems has proven to be one of the more difficult components of the reforms. Both state and federal governments have mounted well-funded programs, using subsidies and outright purchases of water, but the amount of water returned to environmental use has been limited. In addition to the recent Water for the Future Program, some state governments have implemented programs to buy back water entitlements on selected overallocated rivers, and the Murray Darling Basin Commission is midway through a $500 million water recovery program.[4] Nevertheless, there has been public disquiet about the environmental benefits from this returned water, and opposition from irrigators who fear that remaining irrigation enterprises will be rendered unviable as irrigation properties are taken out of production.

The NWI accepts that environmental water can be provided through both a rules basis (such as cease-to-pump rules during low flow periods) or as an access

[4] The Living Murray Initiative requires that 500 Gl of water will be returned to environmental purposes by 2009; to date, 328 Gl has been recovered.

entitlement (environmental water entitlements held in a headwater storage). Registers of environmental water entitlements and a reporting system for rule-based environmental water are being developed.

The COAG and NWI agreements emphasize the use of economic instruments, including market mechanisms, for maximizing environmental water allocations. The NWI envisages that environmental water entitlements will be traded on the market in the same way as consumptive water entitlements. Although water markets have operated successfully for some years, they have yet to be actively used for buying and selling environmental water entitlements. However, off-market mechanisms, such as tenders, have been used successfully in NSW and Victoria for purchasing entitlements for water.

The NWI envisaged that environmental water managers would be appointed to manage environmental entitlements, including trading on the water market. Few such managers have been appointed and there is only limited legislative, financial, and technical support for them.

Participation. The National Principles (Box 1.1) make it clear that all relevant stakeholders must be involved in all decisions on environmental water provisions. On the other hand, the NWI commits jurisdictions to include consultations with all stakeholders on quite specific issues—devising pathways for returning overdrawn water systems to environmentally sustainable extraction levels, and when water plans are reviewed—but makes no mention of involvement on other issues such as the initial preparation of water plans.

The NWI requires states and territories to provide information to all relevant stakeholders on specific topics, including the sustainability of water use, and the science underpinning the identification and implementation of environmental and other public benefit outcomes.

Environmental representatives have played an important role in water allocation planning in all states, in some cases being represented on the decision-making committees. In spite of some disputed decisions about the adequacy of environmental water allocations (leading to a court challenge in one NSW catchment), environmental views have generally been represented in decisions.

Review and Enforcement. Progress with implementing the 1994 COAG agreement was monitored annually by the National Competition Council between 1999 and 2004. From then, the NWC assessed progress of initially the COAG agreement and subsequently the NWI. The 1999–2005 assessments included sanctions; the NCC and NWC could recommend that the federal government withhold payments to state governments where the latter had not met the requirements of the COAG agreement. For example, $28m was withheld from NSW in 2004 for inadequate scientific backing for environmental flow allocations and for lack of transparency in determining these allocations; half these funds were paid in 2006 and the remainder returned in 2007 because of progress with these aspects of the reforms. The NWC biennial assessments, commencing in 2007, are not backed by these financial penalties. However, the federal government has recently decided to reinstate payments to state and territory governments that meet achievement criteria in areas of reform, including water resources management.

The NCC and NWC assessments of the COAG reforms provided a uniform policy assessment framework across multiple jurisdictions, and the public nature of the assessment by an independent commission served to maintain impetus for implementing the agreement. While there is no firm evidence available, anecdotal information strongly suggests that linking water reforms to financial payments in the 1994 COAG agreement was an effective motivator of change.

Data and science. The National Principles (Principle 2, Box 1.1) and the NWI both explicitly require that best

available science is used in establishing environmental water requirements. The 2004 NCC assessment report (National Competition Council 2004) required that a holistic approach be employed, and defined this as (a) a multidisciplinary approach; (b) all components of the water system; (c) data that are comprehensive, relevant, current, and subject to quality control; (d) the entire water regime (that is, variability, duration, magnitude, frequency, and timing); (e) human use constraints; (f) peer review; and (g) ongoing monitoring.

All states have now introduced such multidisciplinary, holistic techniques for environmental water assessment, some more rapidly than others. Some states (such as Queensland) have undertaken scientific field studies to support catchment-level environmental water assessments (Case study 8); others have relied on collation of existing knowledge. Few assessments are peer-reviewed, and the monitoring of environmental outcomes is patchy. The use of non-holistic or poorly defined environmental assessment techniques in some states was criticized by both the NCC and the NWC assessments (which led to the financial sanctions resulting in the withholding of funds for one state government) and may have been a factor in the subsequent adoption of more defensible holistic techniques in Tasmania and NSW.

Monitoring and Reporting. The NWI requires that robust monitoring systems are introduced for assessing compliance in overallocated surface and groundwater systems; less stressed systems require monitoring to record progress toward full allocation. National frameworks for environmental water accounting and river and wetland health are still being developed. Some states have introduced monitoring of outcomes from environmental flows—for example, NSW has an integrated Monitoring of Environmental Flows program—but progress is slow in this area, partly because the definition of environmentally sustainable levels of extraction and hence environmental targets remains ill-defined.

Lessons

1. Even in a complex federal system, it is possible to make substantial progress toward water reform, including provisions for environmental water, if there are strong, mutually reinforcing drivers.
2. Widespread concern about environmental degradation and overallocation of water resources recognized in the 1990s was one of the principal drivers for water reform. Regular, public assessments of environmental health by independent authorities served to maintain the impetus for the reforms, ultimately leading to a new round of more comprehensive reforms in 2004 when it was clear that environmental health was not improving.
3. The public nature of the reviews of progress in implementing the water policy was an important driver for maintaining impetus. It is probable that the financial sanctions contained in the COAG reforms were effective motivators for change.
4. The initial focus on surface water management led to potential environmental problems, as demand quickly shifted to groundwater and interception of overland flows. The whole water cycle needs to be included in the reforms.
5. Institutional aspects of environmental water management—making laws and regulations, restructuring institutions—have largely progressed satisfactorily, but actually providing the environmental water has proven more difficult. Water allocation plans have taken much longer to produce than anticipated; the recovery of environmental water in overallocated systems has been slow, contentious, and expensive; states have been slow to establish environmental water managers; and the framework for monitoring of environmental outcomes has been slow to establish.
6. Scientifically credible information has played an important role in supporting the reforms, establishing the initial extent of environmental degradation, assessing environmental water requirements in catchment plans, and monitoring progress with improvements.

7. Couching a central part of the reforms in terms of "environmentally sustainable levels of abstraction" placed pressure on environmental science. To date, it has not been possible to reach agreement across the states on the interpretation of this concept. This has proven to be the major impediment to the environmental aspects of the reforms and a stumbling block to wider reforms, since they rely on priority assignment of water to environmental sustainability.
8. Non-market economic instruments have been successfully used to source environmental water in stressed river systems. However, market-based instruments have yet to prove effective for acquiring environmental entitlements because parts of the institutional framework—environmental water managers, legal provisions in some states—have yet to be established.

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Case Study 2. European Union Water Framework Directive

Background

The European Union (EU) currently includes 27 member states with other countries, such as Turkey, waiting to join over the next decade. Climate and water resources vary considerably across the continent. Southern Europe is dominated by a Mediterranean climate with hot dry summers and mild wet winter. Water demand is primarily for irrigated agriculture and domestic supply, with major increases in population along the coast during the summer. In Northern Europe, precipitation is more evenly spread throughout the year and water use is primarily for domestic supply and industry. High population densities produce localized water stress. For example, the Thames basin in southeast England receives around 650 mm of precipitation, but houses over 10 million people, yielding less than 1,000 m^3 per person per year, the international standard for water stress.

In general, European states have strong institutions with well-qualified technical staff. Water-related issues and policies vary across the continent. Rivers in Central and Eastern Europe suffered significant pollution during the 20th century due to discharges from heavy industry, but many restoration projects are in place to return these rivers to good quality. Northern European countries have tended to have tight controls over pollution of the aquatic environment, as well as provisions for environmental flow allocations, due partly to more plentiful water resources in these regions. In the southern part of the EU, countries receive limited rainfall and experience high seasonal water demands. Spain has over 1,200 large dams and its natural waters are highly regulated. Along with most other Mediterranean countries, however, it has relatively weak environmental flow requirements.

The Water Directive Framework

The European Water Framework Directive (WFD) (Council of European Communities 2000) came into force on December 22, 2000. This major legislative initiative is intended to resolve the piecemeal approach to European water legislation that had developed since 1975, largely because water-related issues— such as pollution, nature conservation and drinking water standards—had been handled through separate sectors. Directives dealing with these issues were sometimes inconsistent. The WFD was intended to bring a unifying framework to these separate water-related directives. Whereas previous Europe-wide directives had been implemented through different legislation in the various European member states, the WFD required national legislation to be put in place to complement the directive, with competent agencies selected to implement it.

The Water Framework Directive has two classification systems: (1) ecological status, which is an integrated system using biological and physico-chemical parameters and has five classes (Figure 2.1); and (2) a chemical classification, which is an assessment of compliance with standards for "priority hazardous substances," which has two classes (pass or fail). The final status is defined as the lesser of the chemical and ecological status and is assessed in terms of the extent of deviation from undisturbed reference conditions.

Figure 2.1 Status options for water bodies in the WFD

The primary means of setting reference conditions is by identifying similar water bodies that are undisturbed, with similarity being assessed by classifying and typing sites according to selected physical variables, from a combination of mapped (catchment area, slope, geology) and site-specific (water width, depth) data.

Deviation from ecological reference conditions in any body of water is measured primarily through assessment of three elements of the aquatic ecosystem: (1) fish (taxonomic composition and age structure); (2) invertebrates (taxonomic composition and the mixture of sensitive and non-sensitive species); and (3) macrophytes and algae (taxonomic composition and abundance).

Under the WFD, all EU member states agreed to achieve the objective of at least "good ecological status" (GES) in all bodies of surface water and groundwater by 2015, and also to prevent deterioration in the status of water bodies. Pristine sites are classified as "high ecological status" (HES), and must be maintained at this status level. Only in the case of HES is the river flow regime a primary quality element and must be close to natural, along with the biology of the river. For water bodies classified as "moderate," "poor," or "bad," measures must be implemented, such as improving water quality or removing structures, to remedy the causes of failure to meet GES. Environmental flows are seen as part of the measures needed to restore many rivers to GES or maintain those already at GES.

The WFD does not specify the measures needed to restore or maintain GES, as these will be case-specific. Each country is left to define environmental standards, such as maximum abstraction rates or releases from dams, since these are related to river type and will vary according to reference conditions in different countries. Furthermore, the WFD does not specify how water may be retrieved from licensees in overabstracted basins. Nevertheless, a "common implementation strategy" (CIS) has been established by the European Commission to achieve some consistency of approach.[5] The water directors from government departments meet every six months to comment on and/or agree on the recommendations of the CIS Working Groups. Pan-European research projects have been established to allow scientists to work together.

The WFD allows limited exceptions to achieving GES. In particular, an alternate objective of at least "good ecological potential" (GEP) can be applied where water bodies are designated as "heavily modified"

[5] CIS guidance documents are available at http://forum.europa.eu.int.

(HMWB) or artificial because of constraints imposed by physical modifications to the water body, such as dams. A HMWB is designated if (1) the water body is likely to fail to achieve GES because of substantial physical modification for the benefit to society (such as flood protection or navigation); and (2) the beneficial functions would be significantly compromised by restoration measures required to achieve GES, and there is no other technically feasible and cost-effective way to deliver that function. For example, a dam that is no longer economic should be removed or operated in a way that will achieve GES. Designation of a water body as HMWB is thus ultimately an economic judgment.

Drivers

Harmonization of legislation, policies, and practices was a major driver for the establishment and development of the European Union. Since the 1970s, EU-wide directives have been drawn up that require member states to change their national legislation in line with a common European goal. The EU has many international rivers, and it is within the spirit of the EU that guidance is issued to promote transboundary basin management.

Until the WFD was initiated, water issues were covered under many separate EU directives and sectoral policies covering, for example, drinking water, bathing water, flood protection, and river pollution. A key turning point occurred in 1988, when those responsible for management of ecosystems proposed an ecological directive on the basis that the ecosystem was the best indicator for sustainable development. The idea was supported by sectors such as domestic water providers, who felt that their water treatments costs were increased because of degraded surface and groundwater.

Many NGOs supported the introduction of the WFD because it recognized the importance of natural ecosystem functions that provide services to humans. Some ecological advocates supported the concept of reference conditions that were broadly natural. Furthermore, some environmental protection agencies support the WFD because they saw it as an opportunity to strengthen their roles in environmental protection. Even some water abstractors have viewed it as a way of "greening" their credentials.

However, the use of natural conditions as the benchmark for river restoration means that some cherished characteristics of rivers are under threat. For example, chalk streams, which are one of the most highly prized river ecosystems in the United Kingdom, are the result of centuries of river management. The WFD states that these should be returned to more natural conditions, which may be less biodiverse and less attractive to local people. The WFD's focus on ecological outcomes rather than social objectives may thus be less acceptable to local stakeholders.

Assessment

Recognition. The WFD is concerned with river protection and river restoration and is not focused on environmental flows specifically. Consequently, hydrological modification is not used to assess ecological status, except for HES. Thus, even if the flow regime is significantly altered in a water body downstream of an impoundment or abstraction, unless the biology is impacted, it could be rated as GES.

Even though the WFD only explicitly requires environmental flows in relation to maintenance of HES, appropriate flows are still accepted as a basic requirement of a healthy river. The flow regime is included as a supporting quality element for GES and other lower status levels. This recognizes that GES is unlikely to be reached in a water body with significantly altered flows, as this will result in changes to the river ecosystem through modification of physical habitat and alterations in erosion and sediment supply rates. Consequently, restoring a more natural flow regime may well be a necessary measure in a river that fails GES, and so environmental standards have to be set for abstractions and for releases from impoundments as part of river management to restore or maintain GES.

In addition, there is currently uncertainty as to whether existing tools for assessment of biological quality elements are adequate for provisional designation of HMWBs. While there is no provision within the WFD for surrogates to be used when biological assessment is not possible, there is an acceptance within the UK that alteration to the river flow regime can be used for an initial classification in these circumstances (Acreman 2007). However, the final classification must be based on biological data.

Each country reports to the European Union on progress with implementation of the WFD and can be fined for lack of compliance. This is a powerful lever for action by some countries that see noncompliance as politically damaging. Other countries appear less concerned. Some countries are finding it difficult to implement the directive, but none has yet been fined because major deadlines for WFD have not been reached.

Comprehensiveness. A key element of the WFD is the development of river basin management plans. Many European states are already managing water resources at the basin level, and so anticipate a smooth transition to WFD implementation. This includes existing transboundary river basin initiatives, such as those for the Rhine and Danube. Each river basin must show the current and objective status for each water body and a set of measures to achieve at least GES by 2015. However, the WFD does not explicitly identify a priority water allocation for the environment; it merely states that water bodies must achieve at least GES by whatever measures are necessary.

The WFD is comprehensive in its definition of water bodies, which include rivers, lakes, canals, reservoirs, groundwater, and transitional water (estuaries and deltas). Wetlands are not explicitly referred to as such since, under the Ramsar Convention, all water bodies are wetlands. However, wetlands associated with water bodies are included within the definition; for example, floodplains are included as part of the adjacent lake or river water body. Wetlands fed by aquifers are referred to as "groundwater-dependent terrestrial ecosystems."

The WFD explicitly links water quantity with water quality and stream morphology as elements that support the biology of aquatic ecosystems.

It is increasingly recognized that climate change will have a significant impact on the aquatic environment in Europe. In particular, there is current debate about how reference conditions will alter under climate change, and thus change the targets for management of water bodies. However, the WFD currently does not address climate change explicitly.

Data and science. Major problems have arisen in trying to implement the WFD because of the need to interpret the practical meaning of general concepts. The definitions of reference sites, GES, and GEP have been particularly difficult, and there is not yet agreement across Europe on these terms.

The CIS for the WFD is producing guidance on some of these interpretations, but interpreting other terms raises fundamental ecological issues that cannot readily be resolved. For example, if reference conditions for certain river types (such as lowland rivers, which are almost all heavily developed in Europe) do not exist, how can ecological objectives be defined for these river types? Another major issue is whether significant hydrological alteration alone can be grounds for declaring that a water body is not in good status. Some argue that the WFD is a biological directive and thus decisions need to be made using biological data; others argue that biological data are often lacking so decisions need to be made on other grounds, such as hydrological alteration. In reality, this is an integrating directive because the standards for all physico-chemical and biological quality elements have to pass the standards to achieve GES. In addition, there is a lack of consistent tools and data across Europe to measure the degree of alteration of a water body from reference conditions. Pan-European projects have been set up to address

some of these issues. In the meantime, implementation has proceeded on a practical basis because the arguments have not been resolved and deadlines are approaching.

Successful implementation of such major legislation needs to be flexible to allow for issues not considered when the legislation was originally established. A good example is that reference conditions are becoming a moving target due to climate change. This complication was not considered seriously 20 years ago.

The tools and data for water management differ between countries and, in many cases, between provinces within countries. For example, some countries use detailed physical habitat models, such as PHABSIM, to define ecologically acceptable flows, whereas other use expert-based judgment or rules of thumb. In France, the environmental flows from dams must be a minimum of 1/40th of the mean annual flow for existing schemes and 1/10th of the mean annual flow for new schemes. These differences cause problems when flow requirements need to be established for transboundary rivers and for EU-wide assessments of the ecological status of water bodies.

The UK is leading Europe in the development of methods for establishing the environmental flow needed to achieve GES. The WFD 48 project (Acreman and others 2005) focused on setting standards for water resources, such as the maximum abstraction levels that would maintain GES. This work only covered river types found in the UK. The project produced two main outputs: (1) a means of classifying river water body ecosystem types based on the characteristics of the river basin draining to them; and (2) the production of look-up tables for each river type, specifying the maximum abstraction allowable at different flows. The maximum levels of abstraction ranged from 7.5 to 35 percent of the natural flow, depending on river type and flow rate. No other countries have produced new methods or look-up tables explicitly for WFD implementation, although several countries (including Norway, Sweden, and Slovenia) are starting the process and have invited UK experts to present their experiences in start-up workshops.

An additional project was set up, called WFD 82 to provide best practice guidance for setting flow releases from impoundments. It employed the building block method (BBM) (Tharme and King 1998), which was developed in South Africa (case study 3), for identifying the elements of the flow regime needed to achieve either GES or GEP in river ecosystems. Full application of BBM requires site-specific data. However, the WFD 82 project produced some generic data sets of flow requirements for different species that could be used in rapid assessment of flow releases from reservoirs without the need to collect site data. The recommendations of this work are currently being tested on a set of water bodies with reservoirs across the UK.

The WFD thus faces some major challenges in its goal to harmonize water management across Europe. The EU has funded various research projects to support implementation of the WFD, primarily on methods for predicting reference conditions in water bodies. The fish-based assessment method for European rivers (FAME) (Schmutz 2004) is a good example. FAME supported development of the European Fish Index (EFI), which used environmental variables (altitude, distance from source, catchment area, slope, wetted width, air temperature, presence/absence of lake upstream) to predict what fish species could be expected to be present in reference conditions. Rivers are then classified into five levels of degradation based on deviation of observed fish species and abundance from those predicted by the model. The Stream and River Typologies Project (STAR) developed a similar procedure for predicting macro-invertebrate community reference conditions (Sandin and Verdonschot 2006). In some cases, these methods can suggest the causes of the degradation and suggest measures that can be implemented. In other cases, separate studies are required to identify causes of failure to achieve GES.

Participation. The WFD recognizes the importance of developing effective mechanisms to support public and stakeholder participation and encourages involvement in river basin decision-making processes. However, the role of stakeholders in decision making is not explicit; certainly, there is no defined role in environmental flow assessment within the WFD.

Reviews of participation in five European countries (Portugal, Greece, the Netherlands, the United Kingdom, and Spain) that encompass a range of different political and institutional contexts have concluded that there is little real opportunity for the active involvement and collaboration of the interested parties (Videira, Antunes, Santos, and Lobo 2006). Instead, the engagement, although called participation, is largely an information dissemination exercise for government departments or implementing agencies, with an opportunity to comment. However, some stakeholder participation occurs in the development of visions for river basin management plans or for specific activities, such as environmental impact assessment and development of measures where water bodies fail to achieve GES. This limitation on stakeholder participation is partly because the WFD moves decision making to an objectives-based approach, where the target status of the water body is fixed in advance (at least GES), and away from scenario-based decision making, where options are presented and stakeholders can influence the selection of the most appropriate scenario.

The experience in Europe with catchment-based stakeholder participation has not always been positive (Box 2.1). In the past, local negotiations led to different water allocations in different river basins. This was seen to be un-equitable at national scale. Negotiations were often dominated by a few vocal water users, which led to bias, and sometimes only key stakeholders were invited to meetings, giving rise to conspiracy theories and distrust of the outcomes. In other cases, interaction with stakeholders was counterproductive because the stakeholders were promised participation, but were merely being consulted with little prospect that their views would be acted upon, and thus became frustrated.

Implementation. EU member states are required to identify a competent authority to implement the WFD. Many of these authorities have already had experience in balancing the needs of water users and the environment and developing decisions that reflected the different needs of different water bodies. The WFD removes much of this flexibility, as it specifies a homogenous ecological status target that must be achieved.

The ownership of water is not addressed in the WFD; it just requires water bodies to be in at least good status. Operating rules for most reservoirs have been agreed between the dam owners (water or hydropower companies) and these have to be revised to include environmental flows. In many cases, especially major dams, the owners are required to provide river flow data to prove that they are operating the dam within the agreement. The competent agencies (mainly environment protection agencies) are then responsible for monitoring all the relevant quality elements needed for the ecological classification, including the biology and physico-chemical quality elements that provide the test of whether the water body is at GES. This is likely to require adaptive management, since the precise environmental flows required to achieve GES are not known. Releases and abstraction allowances may need to be altered as understanding grows through monitoring programs. Monitoring for the WFD will also have to be integrated with other needs, such as conservation of designated habitats and species and management of invasive species.

Many river basins are overabstracted because of weak license agreements or even lack of licenses. The major issue for the future is implementing the environmental flows needed to achieve GES in these overabstracted rivers. Some of the approaches being tested in trials are:

- Users are asked to give up some abstraction to increase their "green" credentials or in exchange for priority attention in seeking alternative water sources.

Box 2.1 Wetlands and Environmental Flows in Spain

The Upper Guadiana Basin is located on the Central Spanish Plateau, covering an area of 16,130 km^2. Development of the region since 1972 has been achieved through expanding irrigated agriculture. The intensive use of groundwater, especially during long periods of low rainfall, has caused a dramatic decline in groundwater levels and led to the degradation of important groundwater-fed wetlands, such as Las Tablas de Damiel.

In 1994, the La Mancha Occidental aquifer was declared "definitively overexploited" because of unsustainable use. This designation implied restrictions on groundwater withdrawals, a ban on drilling new wells, and the development of a participatory process with irrigation communities. The Guadiana River Basin Authority was established as an independent body to manage the river and aquifers and allocate water between the various stakeholders, including the environment. In addition, the Spanish 1985 Water Code required the authority to prepare a water plan indicating the water available to each groundwater-licensed user in aquifers declared as "overexploited."

Before the declaration, about 16,000 wells had been drilled; following the declaration, farmers have probably drilled about 8,000 to 9,000 additional illegal wells. It is also estimated that there are in total about 20,000 to 40,000 illegal wells with unknown abstractions. NGOs are not strong in the basin, and most environmental issues have been raised by academics or government representatives.

Hydrological models showed that pumping rates above two-thirds of the maximum historical rate (400 m^3/yr) were unsustainable. By 1998, the abstraction rate was 600 Mm^3/yr of water per year. When faced with having to reduce abstraction, the farmers took out a legal case against the authority, which effectively stalled the whole water management process.

The process for managing overexploited water resources created considerable mistrust between the different stakeholder groups, and the legislation proved to be inadequate when faced with this level of overabstraction. All the water users and officers of national and regional government were invited to a workshop in May 1998. The goal was to move from confrontation to collaboration, in order to achieve sustainable development by finding a balance between environmental flows to the wetlands and allowing groundwater abstraction for agriculture. This goal was ambitious and parts of the meeting were confrontational.

Several further meetings with stakeholders have been held with a high level of participation. These meetings show the interest by stakeholders in trying to solve the problems through dialogue and by developing a trusting environment. This has been an important step in collaborating to find a solution. While the participatory process required under the legislation is under way, the other required actions—restrictions on current withdrawals and bans on new bores—have not been implemented, primarily due to insufficient manpower in the Guadiana River Basin Authority.

*Sources:*Acreman and de la Hera 2007; Bromley and others 2001.

- Farmers are increasingly investing in efficient technology or on-farm storage of water during floods for use during dry periods. To encourage this, licensing authorities may agree to higher total abstractions if water is taken during floods, because more water is available. In addition, publicity campaigns, free advice, and water metering with sliding tariffs have all proved successful.
- Licenses are granted for short time periods, after which they can be revoked or reduced; this gives water users time to adjust and find new sources or implement demand management.
- Some users own licenses they do not exploit. Under new laws, licenses may be tradable, either loaned or sold to other water users. Market mechanisms for this have not yet been established.
- In most EU countries, water tariffs are set administratively. In some cases, water suppliers can increase charges to customers to offset costs of new infrastructure required to reduce abstractions from overabstracted water bodies. This has been successfully applied in several cases. For example, restoration of the River Kennet in the UK, impacted by water abstractions, was funded by increases in the component within the water supply costs related to environmental issues.
- In some cases, the only solution to implementing environmental flows to achieve GES will be compulsory purchase of licenses from water users

by the state; that is, provision of compensation payments for lost resource use.

However, these approaches to reducing water abstractions from overallocated systems are still being tested in trials, and there are few experiences in the EU from which lessons can be drawn.

Lessons

1. Overcoming the major variations in legislation, customer law and civil rights, assessment techniques, and data availability to achieve a uniform water management framework within the EU requires investment in major R&D programs costing many millions of dollars. Establishing a consistent environmental flow policy across such a diverse region is expensive and time consuming.
2. For the legislation to be effective, many technical concepts need to be clearly defined and procedures need to be defined for implementing these concepts. The problems arise partly because scientists do not agree on some biological, ecological, or hydrological issues, and partly because the implications of implementing the directive will create political problems.
3. A tool-kit of environmental flow procedures is needed to implement the legislation, so that assessments can be conducted for different issues and river types. Look-up tables provide a simple means of setting environmental flow requirements, but are inflexible and uncertain at any individual site. Techniques, such as BBM, combine explicit knowledge of the hydrological and ecological system to provide a site specific solution, but are costly to employ.
4. Stakeholder participation is a key requirement if true community involvement is to be achieved. This is particularly important when water users may have to give up some rights, as experienced in Spain. The WFD is weak on specifying participative requirements. Consultation under the guise of true participation can create ill-feeling and can be counterproductive.
5. The implementation of an externally defined objective, such as GES, ignores and discards much of the local experience that river management authorities have accumulated in meeting the needs of water users and the environment for different water bodies with different characteristics.
6. Recovering water in overabstracted river basins remains the most difficult obstacle to implementing environmental flows. Various methods are being tried, but recovering water is likely to remain contentious and will require political commitment.

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Case Study 3. South Africa National Water Policy and Legislation

Background

Until the election of the democratic government in 1994, South Africa's water law was based on the riparian rights principle. Being based on the ownership of property, this favored a selective portion of the population. Legal access to water was thus biased in favor of the interests of the dominant white population. The advent of a democratically elected government in 1994 provided opportunities for a new constitution. As part of that, the government implemented an overhaul of the policies, laws, and institutions governing water management.[6]

The White Paper, National Water Act, and National Water Resource Strategy

The new South African constitution of 1996 laid the foundation for an overhaul of water policy by guaranteeing access to "sufficient water" for all citizens and the right to an environment that is "not harmful to their health or well-being," as well as the right to have the environment protected for the benefit of present and future generations. The subsequent White Paper on Water Policy (Department of Water Affairs and Forestry 1997) included these principles by stating that water for meeting basic human needs and maintaining environmental sustainability would be guaranteed as a right.

This new approach to water management was encoded in the 1998 National Water Act (NWA). The previous Water Act of 1956 had emphasized riparian ownership and commercially based control of water, and did not deal adequately with issues of environment, equity, and downstream water requirements for human or ecosystem needs. The NWA is based on 28 fundamental principles and objectives,[7] which included three principles that were relevant to provision of water for the environment:

- There shall be no ownership of water, only a right (for environmental and basic human needs) or an authorization for its use (Principle 3).
- The quantity, quality, and reliability of water required to maintain the ecological functions on which humans depend shall be reserved so that human use of water does not individually

[6] Apart from redressing the manifest inequities, there were other reasons for overhauling South Africa's water policy. South Africa is already classified as water-stressed, with just 1,200 m^3 of available freshwater per person per annum, and is predicted to be water-scarce by 2025. The growth of the economy was making demands for water in the industrial and urban heartland, which was far from the areas of highest rainfall. It was increasingly expensive to build more water storage to meet these demands. Agriculture and forestry were economically important and provided a living for millions of people in the rural areas. Agriculture accounted for about half the nation's water use, and its use of water needed to be made more efficient if water was to be shared among all sectors. Water was also important for South Africa's extensive mining industry; at the same time, mining was a source of water pollution that degraded the resource for other users. There was also obvious degradation of the aquatic environment in many parts of the country where water resources have been polluted, or where changes in flow regimes have affected aquatic ecosystems. Consequently, the focus of water planning and management had to shift from development of the water resource to improving water use efficiency, including conservation and reuse, protection of water sources, and maintenance of aquatic environments.

[7] Fundamental Principles and Objectives for a New Water Law for South Africa, 1996.

or cumulatively compromise the long term sustainability of aquatic and associated ecosystems (Principle 9).

- The water required to meet the basic human needs …. and the needs of the environment shall be identified as "The Reserve" and shall enjoy priority of use by right. The use of water for all other purposes shall be subject to authorization (Principle 10).

The 1997 White Paper and the 1998 legislation are the fundamental statements of water policy in South Africa and, as such, cover a variety of topics related to the objectives and mechanisms for water planning and management. They are consistent with the South African Bill of Rights, which gives all South Africans the right to an environment that is "not harmful to their health or well-being," as well as the right to have the environment protected for the benefit of present and future generations.

It is difficult to strike a balance between, on the one hand, the fundamental changes needed if previously disadvantaged groups are to obtain access to water and, on the other, the certainty needed for productive water-dependent economic activities to continue. Consequently, the policy places considerable emphasis on participatory approaches to implementing its provisions (Department of Water Affairs and Forestry 2005). According to the NWA, any decision in water resource management requires two participatory processes (Burt and Neves 2006):

1. Relevant stakeholders and water users must be consulted on every step, from establishment to implementation.
2. Before anything can be legally formalized, it must appear in the Government Gazette, inviting written comment from the public.

The NWA thus requires participation in important decisions such as the establishment of catchment management agencies, classification of a particular water body, establishing the reserve, and developing a water resource management plan. DWAF has developed its own policy guidelines for participation (Department of Water Affairs and Forestry 2001).

There are a number of provisions in the policy and the legislation that are relevant to environmental flows. Principle 7 of the policy states that management of waters is "to achieve optimum, long term, environmentally sustainable social and economic benefit for society from their use." The prominence given to environmental water requirements in the policy, and subsequently in the NWA, was influenced by a recognition from a number of quarters—including the Southern African Society of Aquatic Scientists (Palmer 1999), DWAF, and Water Resources Commission—that there was a need to provide quantitative estimates of environmental water requirements. The role played by aquatic scientists and natural resource managers is noteworthy. They took advantage of the opportunity provided by the water reforms to ensure that both long-term sustainability and more immediate equity issues were incorporated in the new water policy and legislation. This sense of building expertise and influence and then seizing the opportunity offered by the water reforms is well described in a recent paper (Biggs, Breen, and Palmer, in press).

The provision of water for basic human needs and for environmental functions (the basic human needs and ecological reserves) are the only recognized rights to water; all other water uses require entitlements that will be recognized only if they are beneficial in the public interest.

The basic human needs reserve is a core obligation—it is immediately effective—for drinking and hygiene purposes. In principle, it is met using a specific quantity of water, such as the 25l/person/day specified in the Reconstruction and Development Programme, the development manifesto of the ANC government. On the other hand, the act allows for the ecological

reserve to be phased in over time. The decision on how much water will be allocated to the environment is location-specific and depends on the environmental class of the water body. The water requirements of the ecological reserve—both quantity and quality—are determined from a scientific assessment of the water needed to achieve ecological sustainability. In many cases, this requirement cannot be met if all the current water rights are exercised. In these cases, the decision makers (DWAF at present and ultimately the CMAs) try to meet the ecological reserve through adjustments to water management rules; where this is not possible, a decision has to be made on the water allocation that best meets all requirements. These decisions on overallocated systems are yet to be made in South Africa, but will come to the fore during the formulation of water resources plans by CMAs.

As van Wyk and others (2006) point out, the ecological reserve is commonly regarded as being in direct competition with the needs of humans, resulting in varying interpretations of the meaning and purpose of the ecological reserve. They propose that the reserve should be regarded as contributing to human water needs by sustaining the ecosystem functions that support human uses, rather than being seen as in competition with human needs. While the concept of ecosystem goods and services is theoretically attractive, the actual delivery of many of these ecosystem benefits is either long term (when many needs are immediate) or indirect (and hence not always obvious). It requires strong scientific backing, as well as political support, for these concepts to be put into practice.

The objectives for water use are embedded in a National Water Resources Classification System (NWRCS) that is to be applied to all surface and groundwater resources throughout South Africa. The NWRCS is a set of guidelines and procedures for determining the desired characteristics of a water resource (Department of Water Affairs and Forestry 2006). The NWA leaves it up to the minister to determine the classification system to be used, following a period of public consultation. The classification system is being progressively implemented.

South Africa has been a leader in developing environmental flow techniques for determining the quantity and quality of water needed to provide a given level of habitat protection (Box 3.1). The development and use of these techniques pre-dates the water policy and legislation, and provides the country with internationally recognized technical expertise to determine environmental water requirements.

Some water resources may be already unacceptably degraded as a result of overexploitation; in these cases, the policy states that management will rehabilitate the resource to an acceptable state over a long enough period to allow water users to adjust their activities.

The policy and the NWA also deal with activities that reduce the quantity of water reaching streams and thus impact on downstream human and ecological processes. Commercial forestry is specifically identified in the NWA as a stream flow reduction activity, although the minister has the power to declare other land uses as stream flow reducing activities. One of the drivers for controlling these land uses is their effect on the downstream aquatic environment.

The policy and the act require catchment management agencies (CMAs) to be progressively established throughout South Africa, giving priority to the most stressed catchments. The CMAs are to be locally responsible for water management in each catchment, with each CMA being governed by a board. The functions of the CMA include the preparation of a catchment strategy, which includes the water resources classification in the catchment (an ecological, economic, and social exercise to identify the management level for each part of a river system), the requirements for the reserve, and water allocation plans. Nineteen water management areas (WMAs) were declared in 1999; the National

Box 3.1. Development of Environmental Flow Methods in South Africa

The early environmental flow allocations were simple hydrological ratios, starting with 1 percent of allocations to be assigned to the environment in the 1970s, later increased to 10 to 15 percent, until there was a realization that simple ratios were insufficient and that environmental flows needed to be based on the water requirements of aquatic ecosystems. Various research projects were undertaken supported by the Water Research Commission and the DWAF, including the trial of the IFIM method in the Olifants River (Western Cape). Overall, IFIM was not suited to the objective of maintaining South African river ecosystems in a healthy condition. The first workshop on "Ecological Flow Requirements for South African Rivers" was held in 1989 following these studies.

South Africa subsequently became a pioneer in the development of holistic techniques, which considered the water requirements of the complete ecosystem, including the source area, river channel, riparian zone, floodplain, groundwater, wetlands, and estuary. South Africa opted for these methods because they are quicker, more consultative methods based more on expert opinion rather than intensive data collection. In addition, they are more suited to the capacity and financial resources available, as well as to situations where there was a greater dependence on natural-resource based livelihoods. Holistic methods were groundbreaking, not only because they integrated consideration of all components of the flow regime, but also because they required the cooperation of aquatic scientists, hydrologists, and managers. The earliest and at that time most widely used holistic technique in South Africa, the building block methodology (BBM), was first introduced in a workshop at the Lephalala River in 1992.

BBM-based methods have been applied systematically to major water resource projects in 14 rivers throughout South Africa and in the Logan River in Australia. Following a workshop on the Sabie-Sand rivers, the DWAF determined that the BBM could meet the legal requirements for quantifying environmental water requirements. As a result, the BBM was formally endorsed by the DWAF and is accepted by other water management and conservation organizations.

The BBM is a prescriptive approach for developing a flow regime that maintains a river in a predetermined condition. However, the habitat flow stressor response (HFSR) method, developed using the BBM as a basis, has largely supplanted the BBM. The HFSR has been applied to about 10 large reserve studies during the last five years. An integrated framework method, SPATSIM, was used for many of the major E-flow assessments (Hughes 2004). The DRIFT method, developed during the Lesotho Highlands Water Project (Case Study 14), has also been approved and has now been used in about two reserve studies.

Sources: King, Tharme, and de Villiers 2000; Liphadzi 2007; D. Louw (pers. comm.)

Water Resource Strategy (Department of Water Affairs and Forestry 2004a) provides the sequence for establishing CMAs in these areas. To date, six CMAs—Inkomati, Mvoti-Mzimkulu, Gouritz, Olifants-Doorn, Thukela, and Usutu to Mhlathuze CMAs—have been established. Their catchment strategies have yet to be produced.

The National Water Resource Strategy required under the NWA has now been completed (Department of Water Affairs and Forestry 2004b). Although it does not describe the classification system, because that has to be established by regulation after public consultation, it does propose that the reserve consist of three classes—natural, moderately used/impacted, and heavily used/impacted. It also proposes that, for a particular system, the determination of the classification of a resource, the associated reserve, and resource quality objectives will usually be undertaken as an integrated exercise once the final resource classification system is established.

Since being passed in 1997 and 1998, the water policy and legislation have been slowly but progressively implemented and have sought to overcome a number of significant impediments. First, the new water policy requires a fundamental shift in approach from water allocations being based on prior riparian rights (usually held by the white minority), to one based on negotiation over equitable and efficient sharing of the resource. This transition has proven to be difficult, with opposition from groups who previously had extensive access to water resources. Secondly, there has been a reluctance (until recently) to transfer responsibility for operational management from DWAF to the CMAs because of concerns within sections of DWAF and the wider water resources community about the capacity of new agencies to

manage effectively. Thirdly, the ecological reserve has proven to be particularly difficult to implement in catchments where the available water has been fully allocated.[8] Reserving water for the environment in these catchments will mean reducing current entitlements, finding additional sources, or introducing efficiency gains, with the saved water being assigned to the environment. Fourthly, the strong emphasis on participatory approaches to all stages of decision making has been onerous to implement because of the limited experience in such approaches among both institutional staff and stakeholders (Lotz-Sisitka and Burt 2006). Finally, some marginalized stakeholder groups find difficulty in seeing that a functioning aquatic environment can provide ecosystem services that are as important as the use of the water for purposes such as irrigation and household supply. Water that is allocated to the environment is seen as water that is lost to these stakeholders.

In the meantime, the minister is authorized under the act to make a preliminary determination of the water resource classification and the social and ecological reserve. This power has been used since 2001 to make some preliminary determinations of the ecological reserve. Low confidence estimates of the reserve have been produced for all South African quaternary catchments for the National Water Resource Strategy. The methodology used for the determination of the preliminary water resource class and ecological reserve was established in 1999 (Department of Water Affairs and Forestry 1999). These estimates are based on a very limited understanding of the functioning of ecosystems or habitat requirements. DWAF has subsequently produced an internal strategic perspective (ISP) for each WMA to assist in their management prior to the establishment of the CMAs. These include updated estimates of the reserves, based on testing the impacts of various flow scenarios on ecological responses and on other water users. An optimized flow scenario is then selected that maximizes ecological outcomes and minimizes impacts on other water users.

Drivers

The transition from apartheid to a democratic regime and the consequent need to redress inequities in the access to and allocation of South Africa's water was the key driver for the reform of water management. While the apartheid government had recognized the issue of environmental flows for, at least, key ecosystems, it took the now government to embrace the concept wholeheartedly and incorporate it into policy and legislation.

There were a number of drivers for including an environmental water reserve within the new policy. Firstly, it ensured that the basic human needs reserve was sustainable in the long term, particularly for those on subsistence incomes who were highly dependent on the resource. Secondly, it was part of a wider set of components of the water reforms, designed to redress the degraded state of a number of the country's water resources. Thirdly, it was a response to a number of international developments that emphasized the importance of maintaining the aquatic environment because of the ecological services provided by the environment.[9] Finally, it was driven by a need to be a good neighbor with countries with which South Africa shared water resources, which, in turn, was driven by the higher level political changes following the end of apartheid.

In addition, a number of professional societies, such as the Southern African Society of Aquatic Scientists, worked with officials from the DWAF to provide the foundations for environmentally sustainable water

[8] The reserve has not yet been implemented in catchments that are not overallcoated.

[9] The White Paper lists these as: the UN Conference on the Human Environment (Stockholm, 1972); the International Drinking Water Supply and Sanitation Decade launch (Mar del Plata, 1977); the World Conference on Water and the Environment (Dublin, 1992); the UNCED Earth Summit – Agenda 21 (Rio de Janeiro, 1992); the Drinking Water and Environmental Sanitation Conference on the Implementation of Agenda 21 (Noordwijk, Meeting of Ministers, 1994); the Global Water Partnership meeting (Stockholm, 1996); and the First World Water Forum of the World Water Council (Marrakesh, 1997).

resources development and management in the policy and the NWA because they recognized the links between maintaining aquatic ecosystems and poverty reduction and equality (Biggs, Breen, and Palmer, in press). The unity and organization displayed by the South African aquatic science community was a key factor in including environmental flows in the policy and demonstrating that there were techniques available for putting the policy into practice.

Assessment

Recognition. The need for maintaining environmental flows, including the setting of water objectives through the classification system and the provision of an environmental reserve, is a central part of the water policy and its supporting legislation and strategy. The policy is recognized internationally as setting a benchmark for incorporating environmental water considerations into national water policy. The policy discusses the concept of environmental sustainability at length, recognizing that the concept includes the provision of ecological services that support beneficial uses of water, while maintaining enough resilience in the system to allow recovery from shocks.

The ecological reserve is assigned an equal first priority with the basic human needs reserve in the policy and the act. These quantities have to be established before any other water use permits are allocated (although there are temporary water allocation mechanisms available until the new catchment strategies are established).

Although the environmental water focus in the policy is on the establishment of the ecological reserve and its inclusion in the catchment strategies, the policy also includes provisions for protecting the environment as part of project-level developments. Developments "require an assessment of the possible impacts of a proposed project, and the design of measures to reduce negative impacts and enhance positive impacts." However, it does not specifically identify environmental flows within this broader environmental impact requirement because the reserve was seen as being for the benefit of people rather than the environment.

The environmental water provisions of the policy—including the establishment of the classification system, the reserve, the formation of CMAs, and their authorization to produce water allocation plans—are contained in the National Water Act 1998. Thus, the environmental water provisions of the policy are backed by legislative authority.

The minister has used the provisions of the act to establish an interim classification system and environmental reserve while the CMAs are being declared. A program has been commenced to improve the calculation of the reserve (Department of Water Affairs and Forestry 2004a).

Comprehensiveness. The policy is very comprehensive, with provisions for managing all the main stages of the water cycle, including the interception of overland flow (streamflow reduction activities). At this stage, only commercial forestry (which is specified in the Act) has been declared a streamflow reduction activity, but dryland sugarcane is being considered (Warren 2000). The ecological reserve applies to both surface and groundwater; the reserved water is available to support ecosystem functioning rivers, wetlands, and estuaries.

The policy is intended to take account of the impact of human activities on climate, rainfall, and evaporation, but the issue of climate change is not mentioned in the policy, and the legislation does not include it as one of the considerations to be taken into account when strategies and plans are being drawn up. However, the National Water Resources Strategy sees climate change as one of the two factors (the other is land use change) that can affect water availability and argues that "it is prudent to anticipate the possibility of climate change and to take this into consideration in the development of catchment management strategies."

Transboundary obligations are given prominent recognition in the policy; in fact, transboundary water allocations rank third in priority after the social and ecological reserves, although environmental flows are not explicitly included in these obligations to neighboring countries.

The policy requires that environmental considerations are integrated with social and economic considerations when catchment strategies and water allocation plans are developed. It states: "The process of balancing social and economic benefits as well as of determining environmental objectives should involve those affected, or their representatives, in weighing up the options on an informed basis." Under the act, the catchment management strategy must include the water resource classification (which is based on environmental and social objectives), the requirements of the reserve, and the water allocation plan. The latter, in turn, must be based on a range of considerations, including the requirements of the reserve and past social inequalities.

Environmental water determination. While South Africa's National Water Policy and NWA provide the legislative and policy framework for water allocations, they do not provide detailed strategies and approaches to promote equity, sustainability and efficiency in water use, or a process to roll this out across the country (Department of Water Affairs and Forestry 2005). Thus, the policy does not prescribe a particular mechanism for establishing the water requirements of the ecological reserve. Nor does it or the act or the National Water Resource Strategy provide details on how the ecological reserve is to be determined, apart from requirements for consistency with the water resource classification and formal stakeholder consultation in the act. To help operationalize the reserve, DWAF has developed four levels for determining environmental water needs—desktop, rapid, intermediate, or comprehensive. The desktop and rapid determinations are largely based on applications of the BBM to determine instream flow requirements (King and Tharme 1994). The rapid determination also includes low confidence hydraulic modeling and some limited data collection. The intermediate and comprehensive determinations—which can be based on the BBM, DRIFT, or HFSR methods—involve specific local data collection and hydraulic modeling.[10]

While the policy, the act, and the National Water Resource Strategy place considerable emphasis on the ecological reserve, they do not specify the mechanisms for implementing the reserve. The implication of designating the reserve as a right with all other uses being conditional implies that the conditions on these licenses act as the mechanism for achieving the social and ecological reserve. There is no mention in the policy of holding water in reservoirs in regulated systems for environmental purposes.

The policy recognizes that some systems may already be degraded and may need "restoration to a healthy state." The act assigns the CMA (or the minister) the power to undertake compulsory licensing within a specific geographic area that is, or is soon likely to be, under "water stress." After specified consultation procedures, the CMA or minister can issue water allocations that bring the water resource back to sustainable levels. The National Water Resource Strategy amplifies these circumstances, and describes a gradual return of the water resource to an acceptable level of health. The strategy contains preliminary estimates of the total volumes required for the reserve in each WMA; these estimates indicate that about half the WMAs are, in principle, already overallocated (the reserve cannot be met from local yield and interbasin transfers), although, in practice, not all water licenses are currently exercised. Putting the provisions for recovery to sustainability into practice means reducing someone's allocation of water and will always be difficult. Given the slow formation of CMAs and the lack of water resource plans, these requirements have yet to be tested in practice.

[10] Pers comm., D. Louw, March 2008.

While the policy recognizes the efficiency of economic instruments, including market-based ones, for controlling water use, it does not advocate their immediate use because of the cost associated with markets and the possibility of windfall profits for people who have inherited water allocations under an unjust system. Instead, regulatory means are proposed as the mechanism for allocating water to environmental and other purposes.

In spite of the slow rollout of water allocation plans under the act, South Africa has acquired considerable experience in undertaking site-specific EFAs over many years (Case Studies 11, 14). There is thus a pool of scientific knowledge and scientific capacity, together with a range of assessment techniques that can be applied to the production of these plans and catchment strategies when the mechanisms are in place.

Participation. The policy, legislation, and strategy[11] were developed as a result of widespread consultation among political leaders, officials, water user groups, and citizens in the post-apartheid era, beginning with the distribution of the booklet on water rights for public comment. A Water Law Review Panel produced a set of principles for a new water law, taking into account the comments from the public, and these principles were then further refined through public consultation, with special attention to including the views of the rural poor and the disadvantaged. Other interest groups such as agriculture, industry, mines, municipal users, and environmental groups were encouraged to arrange their own meetings to discuss the principles. National government departments and both provincial and local spheres of government were also consulted.

The act includes extensive provisions for consultation during the implementation of the provisions of the policy. For example, the formation of the governing board of a CMA is a complex process. The minister has to appoint an advisory committee, which recommends relevant organizations in each catchment to serve on the board following consultations within the catchment. For example, the Advisory Committee for the Inkomati WMA proposed that there be 14 seats on the governing board, with one representing conservation interests (Burt, du Toit, Neves, and Pollard 2006). The minister then asks these organizations to nominate members who he can accept or reject. The minister can also appoint additional board members to achieve a balanced representation of interests.

While the extensive consultation requirements have been introduced to help overcome previous inequities, they have proven to be time-consuming to implement because of misconceptions about the role of the reserve, fears about loss of access to water by those with licenses, and a limited capacity among the country's poor to engage in the consultative processes. The limited acceptance by the poor of environmental flows implies that, despite these consultative efforts, it is difficult to introduce the idea that a healthy environment bestows sufficient long-term benefits to outweigh the short-term gains from additional water for consumption.

Data and science. The policy and legislation do not mention the use of best available scientific information and methods in establishing and implementing environmental water provisions. Although not required in law, the National Water Resource Strategy does state that resource directed measures—that is, the classification and the reserve—should be "technically sound, scientifically credible, practical and affordable."

Even though high-quality scientific approaches are not required in the policy or legislation, South Africa has, in fact, been a world leader in developing methods for assessing environmental water needs using best available scientific information and integrating it with social and economic information (see Case Studies 7, 8, 14).

[11] Appendix F of the Water Resource Strategy lists the extensive consultations carried out.

The policy emphasizes the need to improve monitoring and to ensure that water resources are managed and protected on the basis of sound scientific and technical information and understanding. The act states that one of the entities to be monitored is health of aquatic ecosystems. An Ecological Reserve Monitoring Program is being developed but is not yet implemented. Hence, it is too soon to assess whether these monitoring requirements are being implemented effectively.

Lessons

1. A progressive policy and legislation, a strong scientific knowledge base and capacity, and a wide commitment and energy for change, are important but are not necessarily sufficient to bring about fundamental redistribution of water resources, including allocations for environmental purpose. There also needs to be widespread social support for the change, and this has been difficult to generate in the polarized world of water in South Africa.
2. Scientists can play a key role in introducing innovative ideas such as an ecological reserve if they are well-organized and able to seize opportunities when there are major water reforms under way.
3. It is difficult to introduce an ecological reserve in catchments where the water resource was already fully allocated under the old riparian doctrine. This usually means reducing the allocations to water users who have held entitlements for long periods.
4. Introducing the ecological reserve has proven to be difficult because there is little acceptance that the reserve is intended to provide the goods and services on which poorer segments of society depend. There is a perception among some poorer communities that allocations of water to the environment frustrate their opportunity for access to water resources, which they had previously been denied under the apartheid regime. But it has also been easier to explain to the poorer and rural communities than to established farmers the benefits of the ecological reserve, because of their more direct dependence on the ecosystem services provided by the reserve.
5. The extensive consultation requirements in the policy and legislation have proven to be time consuming to implement and, because of the requirements in the legislation, this has slowed down the production of catchment strategies and the determination of the ecological reserve.
6. The policy and the legislation do not require that best available scientific knowledge is included in the determination of environmental water requirements. While this has not prevented cutting-edge scientific approaches being used in the EFAs that have been carried out to date, it may prove to be a limitation when the catchment strategies are being rolled out and difficult decisions have to be made between water for the environment and water for consumption.

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Case Study 4. Tanzania National Water Policy

Background

Until the early 1990s, water supply planning and management in Tanzania was based on administrative regions and was focused on provision of urban and rural water supply, while irrigation and energy planning were carried out at the national level. At the end of the Water and Sanitation Decade, water supply targets were far from being met and even investments in urban and rural supplies were facing serious problems related to the sustainability of those supplies. At the same time, there were growing conflicts over access to and utilization of the water resource in some of the more heavily used river basins. A review of the water sector in 1993–94 revealed that more emphasis needed to be placed on (a) full involvement of beneficiaries, (b) involvement of the private sector, (c) a strengthened legal and institutional framework, and (d) the management of the basic water resource.

Through the 1990s, a series of well-publicized water management conflicts between hydropower and other uses of water—including irrigation, environment, and livestock—underscored the need to improve the management of the country's water resources (Box 4.1). These examples and subsequent analysis illustrate how the country's economic performance is both vulnerable to climate variability and closely linked to good water resources management (World Bank 2006).[12]

The government of Tanzania (GoT) responded to these issues with parallel reforms that were loosely linked in the water resources sector and water related subsectors. The first track focused on the management of water resources through a phased approach initiated by the Department of Water Resources in the Ministry of Water, Energy and Minerals:

- Phase 1: Rapid Water Resources Assessment (reconnaissance-level study in 1995)
- Phase 2: Management Actions of Specific Basins (supported from 1997; ongoing)
- Phase 3: Implement Policy, Interventions and Programs sector-wide (ongoing)

The second track involved development and policy reforms in the various water-using sectors—rural and urban water supply, irrigation, and hydropower development. In addition, the GOT formulated an environmental policy (1996) and implemented a series of water-related environmental management projects in all the three Great Lakes and in the Lower Kihansi Gorge.

A rapid water resources assessment (RWRA), undertaken in mid-1994 by the government with support from DANIDA and the World Bank, identified major inadequacies in intersectoral coordination of water use and management, growing

[12] Among the components of the Tanzanian economy, both the largest sector (agriculture) and the fastest growing sectors (tourism and mining)—as well as traditional sectors such as energy, industry, and livestock—are heavily reliant on access to sufficient water of good quality, and individual livelihoods and social well-being depend on well-managed water resources. Given the strong links between water and the national economy and the livelihoods of Tanzanians, the targets in the Tanzanian National Strategy for Growth and Reduction of Poverty (NSGRP) are not likely to be achieved if the management of water resources and the environment is not improved.

Box 4.1 Tanzania Water Management Conflicts

Mtera Crisis: Hydropower and Irrigation
The Mtera Dam on the Great Ruaha River is the main structure regulating the two hydropower plants on the Rufiji River, which generate nearly 50 percent of the nation's electricity. The Mtera reservoir reached full capacity in 1990, after which the water levels declined, with serious consequences for hydroelectric generation. The consequent reduction in generation caused severe load shedding and rationing of electricity nationwide during 1991–93.

The causes of the decline in reservoir level were strongly disputed. The generating authority, TANESCO, blamed uncontrolled and expanding upstream abstractions for irrigation, while the farmers blamed the low rainfall conditions at the time. Others claimed that poor operations of the reservoirs were the problem. Technical studies were conducted to determine the real causes of low storage levels and inflows. They concluded that the primary cause of the low reservoir levels was reduced rainfall and inflow into the dam, precipitated by uncontrolled and expanding irrigation as well as increased demand for electricity, resulting in *ad hoc* responses leading to poor operations at Mtera Dam.

Usangu Plains: Irrigation, Livestock, and Environment
The drying of the Great Ruaha River since 1993 also resulted in intense competition between irrigators and pastoralists for water, particularly during the dry season, in the Usangu Plains upstream of the Mtera reservoir. Farmers believed that increasing numbers of cattle were placing greater demands on water and forage during the dry season. The gradual expansion of areas under irrigation by farmers decreased land that was previously available for grazing and the availability of water for livestock.

The Great Ruaha River originates in the Kipengere Mountains and flows through the Ruaha National Park—an important wildlife-based tourism site—and into the Mtera Dam, that regulates the river for power production at Kidatu. The regular drying of the river during the dry seasons caused the wildlife to move away from the river, affecting the income from tourists. Wetlands on the Usangu Plain have also been affected. The western wetland has almost disappeared and the eastern wetland—which is important for grazing, game animals, and fishing during the wet season—has shrunk substantially.

Pangani Falls Hydropower Station: Hydropower and Irrigation
When the Pangani Falls hydropower station (68MW) was nearing completion in the early 1990s, it was found that inflows into the Nyumba ya Mungu (NYM) regulating reservoir were much lower than predicted because of an increase in the number of uncontrolled upstream abstractions for irrigation. NORAD, the main funder of the power station, had asked the government to put measures in place to manage the water resources before construction commenced. For this reason, the Pangani Basin Water Office was established in 1991. Following the regulation of the river by NYM, the productive fishery in the Kirua Swamp collapsed because the annual flooding of the wetland ceased (IUCN 2007). Decreased flows into the Pangani estuary have also increased saltwater intrusion.

Lower Kihansi Hydropower Plant: Hydropower and Environment
The Lower Kihansi hydroelectric plant (LKHP) was constructed on the Kihansi River at the 900 m Kihansi Falls during the mid-1990s (Case Study 16). Although the project EIA had concluded that there were no significant environmental issues, it did not consider impacts downstream of the proposed dam. Subsequent ecological monitoring studies conducted during project construction in 1996 found an endemic toad, the Kihansi spray toad (KST), in a rare wetland system in the Kihansi Gorge located downstream from the dam. The toad was dependent on the spray created from the water falls. Operation of the underground hydroelectric plant would abstract over 90 percent of the annual river flow and consequently would drastically reduce the spray in the gorge, adversely impacting the spray wetland.

Once discovered, temporary measures were taken to safeguard the ecosystem. The flow required to maintain the ecosystem was not known. The decision to generate power from diverting nearly 90 percent of the total flow had been assumed in the economics of the project. As a consequence, the process of granting a water right for generating power and setting aside water for ecosystem needs was highly contested, largely because at that time there was no policy that recognized the environment as a legitimate user of water and because of the substantial costs from reduced hydropower production. Following extensive scientific studies, a final water right for the hydroelectric plant was granted in June 2004. It stipulates an environmental flow requirement of 1.5–2.0 m^3/s to be coupled with other mitigation measures to ensure the conservation of the Kihansi Gorge as stipulated in the environmental management plan, including a specially designed and constructed sprinkler system to generate artificial spray in the gorge wetlands and captive breeding of KST in U.S. zoos for safekeeping (an insurance against ecosystem collapse).

conflicts between different uses of water (including water for environment), limited representation of stakeholders in decision making, insufficient incentives for efficient water use, increasing pollution, and limited hydrologic and water use data on which rational allocation decisions could be based in most river and lake basins. The RWRA identified four out of the nine basins as priority basins. Of these four, the Pangani and Rufiji basins, which generated most of the nation's hydropower, faced severe water use conflicts; the Lake Victoria Basin—important for fishery exports, trade, and navigation—faced degradation of the lake ecosystems; and the unregulated Ruvu Basin faced water shortages affecting the city of Dar es Salaam, the economic hub of the country,

As part of the reforms, a new National Water Policy[13] (NAWAPO) was passed in 2002, containing provisions for improved management of water resources and urban and rural water supply. Improvements to both surface water and groundwater management are included in the policy. It places important emphasis on environmental water management, including provisions for environmental flows, maintenance of water quality, and protection of surface and groundwater sources. The environmental flow provisions of the policy are grounded on economic, livelihood, and biodiversity values. The nation's largest and best-known protected areas, national parks, and game reserves—such as the Serengeti, Lake Manyara, Ruaha and Sadani National Parks, and the Selous Game Reserve—are all based on water-dependent ecosystems. They not only have very high biodiversity value, but are also high foreign-income generators and revenue providers for the national economy. Although it was largely driven by local concerns and initiated locally, the policy was, in part, influenced by the 1997 South Africa White Paper on Water Policy (Department of Water Affairs and Forestry 1997), including its environmental water provisions (Case Study 3). Thus, like the South African policy, the Tanzanian policy:

- recognized the importance of ensuring that ecosystem services are maintained through environmental water provisions
- assigned the environment second priority for water allocation following basic human needs
- required a national water resource classification scheme to be developed
- required public participation in establishing environmental water allocations
- recognized that best available scientific information should be applied to establishing environmental water requirements
- required an EIA process for large-scale water infrastructure development projects

Tanzania took a pragmatic and empirical approach to establishing its river and lake basin water offices, starting with some of the priority basins identified prior to and during the RWRA. Three years after NAWAPO had passed, it had established seven offices.[14] Even though all basin boards have been formally established, not all of them are operationally effective yet. Their level of effectiveness varies; nonetheless, this proactive approach has allowed the staff to radjust to their new roles, understand basin issues, and to gain experience through learning in new and complex procedures such as determining environmental flows (Case Study 9).

South Africa's experience and expertise have also been influential at an operational level in environmental water allocation. The South African DRIFT method has been adapted for the pilot EFA in the Pangani basin (Case Study 8), and an older South African method, the building block methodology, is being used in other basins. The design of the Tanzanian environmental flows capacity building program was influenced by

[13] The development of this policy, which includes water resources, urban water and rural water components, was supported through the World Bank River Basin Management and Smallholder Irrigation Improvement project.
[14] The Pangani and Rufiji River Basin offices had already been formed in 1991 and 1993 respectively.

South African and UK consultants (Acreman and King 2007). Nevertheless, Tanzania's experience differs from South Africa's in the speed with which it has implemented its water policy and the associated environmental water provisions. Nine river and lake basin organizations have now been formally established (although they have serious capacity limitations and many are yet to be operational), and several environmental flow initiatives are under way or have advanced in anticipation of (river basin) water resources management plans:

- The environmental water requirements of the Lower Kihansi hydropower plant, stipulated as part of the final water right, was negotiated on the basis of economics, national priority concerns, ecological studies, mitigation measures, and experimental flow release studies.
- Short-term training in EFA has been provided to University of Dar es Salaam under the LKEMP project.
- A study tour has been organized to South African institutions.
- A pilot basin-wide EFA, with capacity building components, is being conducted in the Pangani Basin with support from IUCN and other agencies (Case Study 8).
- EFAs are being implemented on the Mara River catchment (with WWF/GLOWS support) and the Wami-Ruvu Basin (USAID/GLOWS support).
- Preliminary environmental flows have been recommended for the Ruvu River estuary under the preliminary EIA for the proposed Kidunda Dam. These recommendations may be revisited through additional studies as part of the EIA.
- A broad stakeholder forum for an EFA has been recently initiated in the Ruaha Basin (with DANIDA/WWF support).

Nevertheless, Tanzania needs to put considerable effort into building its internal capacity to undertake and implement EFAs and apply them in river basin planning and project developments.

Complementary reforms in the environmental sector include the passage of Environment Management Act, 2004, which mandates an EIA for any application for a water abstraction permit and a strategic environmental assessment for any hydropower or major water project (World Bank, forthcoming). The recent wetlands strategy has included provisions for environmental flows, the draft irrigation policy is consistent with the provisions of NAWAPO, and a number of ministries (Agriculture, and Natural Resources and Tourism) are engaging in activities to support environmental flow provisions. However, other ministries that depend on water resources are yet to fully recognize and integrate the importance of supporting the broader water management reforms, including the provision of environmental flows. This is most noticeable in the case of the Ministry of Mining and Energy, which does not include water management or environmental flow provisions in its energy policy, even though hydropower provides 60 to 70 percent of the electricity generated nationally.

Drivers

NAWAPO was initiated by the Tanzanian government because of the clear policy failure of previous attempts to provide urban and rural water supply without adequate attention to protecting the water resource base and address the pronounced water use conflicts. Although funding for NAWAPO preparation was supported by donor agencies, the policy development process was largely driven locally and was highly consultative. There was a combination of local and external factors that may have contributed to the policy and its requirements for environmental flows. The RWRA, which initiated the water reforms including the new policy, was a result of rising local awareness of water resources issues and management limitations that became evident during the nationwide drought and water crises in the Pangani and Rufiji basins. Although some of these issues—the drying of the Great Ruaha River, the desiccation of the Kirua

Swamp in the Pangani Basin, and the Lower Kihansi challenge—arose because of a neglect of environmental water requirements, it is notable that the RWRA was not primarily driven by, nor centered around, environmental issues.

An additional driver was the awareness of Tanzanian water resource professionals of the emerging international consensus on responding to water resources challenges and the inclusion of environmental considerations in this consensus.[15] Environmental components were included in the new water resources policy because of the range of environmental issues in the country. The South African policy and law (Case Study 3) provided a model to learn from and guidance on how to respond to these issues.

Public concerns were not a strong motivator for the inclusion of environmental water considerations in the new policy, although some of the issues that had an environmental component (such as the loss of tourism in the Ruaha National Park as a result of the drying up of the Great Ruaha River) did raise local public and political concern.

Although the policy itself was primarily motivated by forces from within Tanzania, the implementation of the environmental flow provisions of the policy included a strong external influence. Multilateral and bilateral funding agencies and international NGOs have supported environmental flow assessments in Tanzania because (a) the country had a suitable policy framework, (b) some river basin offices welcomed initiatives to undertake EFAs, and (c) the donors were seeking suitable locations to implement their own EFA programs. The Lower Kihansi environmental flow work, although part of an emergency response, was central to the granting of the final water right for the hydropower plant. Implementation of environmental flows has yet to be rolled out and driven systematically by the Ministry of Water and Irrigation as part of its water policy implementation process and to meet the legal requirements for river basin plans under the soon-to-be-enacted Water Resources Bill.

Assessment

Recognition. The policy has a solid basis in sustainability. It recognizes that "environmental flows and levels are necessary for riparian biodiversity, wetland systems, and freshwater-seawater balance in deltas and estuaries." The reasons for maintaining these aquatic environments include both protection of biodiversity (including rare and endangered species) and the provision of ecological goods and services such as flood control, sediment retention, nutrient recycling, and microclimate stabilization.

The policy requires that integrated, multisectoral river basin plans are drawn up. After basic human needs, it assigns second priority to water for the environment in these plans. Development of both surface and groundwater resources must conform to these plans. In particular, large water schemes—dams, large rainfall harvesting schemes, water intakes, groundwater abstraction, and interbasin water transfers—will be subject to a permit and an Environmental Impact Assessment (EIA). The Tanzanian Environmental Management Act (2004) has provisions to support this policy.

In spite of these clear provisions in the policy and the draft legislation, there are varying levels of understanding of the importance of environmental water allocations within Tanzanian institutions. As a result of the experiences of the Lower Kihansi hydropower plant, and the Mtera and the Pangani Falls hydropower plant crises, there is now a good appreciation within the Ministry of Water and Irrigation regarding the importance of integrating

[15] The Dublin Principles were issued in 1992. In 1993, the World Bank issued its Water Resources Management Policy calling for a more holistic approach to the management of water resources.

environmental concerns into water resources management. The EFA study in the Pangani Basin (Case Study 8) and proposed EFA studies in other basins are being managed by the basin water offices rather than the environment institutions. It is important that other institutions (including the National Environment Management Council, the Division of Environment and sectoral Ministries) become more familiar with the environmental flow provisions in NAWAPO and develop their capacities to help implement these provisions.

Comprehensiveness. The policy clearly recognizes the importance of managing the whole terrestrial water cycle from the watershed to the ocean. However, the environmental water components of the policy are written in terms of surface water—wetlands, rivers, floodplains, estuaries, and coastal zones—and, in spite of the importance of groundwater for parts of the country, make only a single mention of the role of groundwater in sustaining some ecosystems. However, the physical sustainability of groundwater—for example, by protecting recharge areas—is well-recognized in the policy. The effect of activities in the watershed that intercept runoff before it reaches streams are only considered in terms of erosion and sedimentation of water storage facilities. Nevertheless, the policy provides a comprehensive justification for providing water for the environment, including recognition of the links between water quantity and quality and the role that environmental water plays in providing economic and social benefits.

The policy recognizes the need for cooperative management of transboundary water resources, and makes specific mention of transboundary environmental management issues such as water pollution, biodiversity conservation, wetlands and catchments degradation, fisheries management, and water hyacinth control.

Environmental water status. The policy advocates providing water for the environment, while the National Water Sector Development Strategy specifies the mechanisms for implementing it. The implementation strategy for the water policy (Ministry of Water and Livestock Development 2004) specifically requires that environmental flow requirements be determined for all major rivers. The draft legislation makes provision for a water reserve, which is to be declared by the minister for each water resource that has been classified according to a water resource classification scheme. But neither the policy nor the draft legislation establish mechanisms for acquiring water for either basic human needs or the environment in circumstances where the water is already overused.

Nevertheless, in spite of the lack of legislative backing and the limited knowledge about water-ecological relationships in Tanzania, the government has progressed with EFAs in four basins with assistance from external partners.[16] These EFAs will be fed into the water resources plans that will be developed by the basin water boards when the legislation is passed. However, because the EFAs are being supported by different external agencies, the approaches and techniques are likely to differ between basins. There is a need for coordination so that a well-considered set of EFA methods and approaches are adopted across Tanzania to meet different financial and time and legal requirements.

Participation. The policy contains some general provisions concerning participation in water planning ("Planning shall involve all stakeholders and will be intersectoral in character")but there are no specific requirements regarding stakeholder participation in water allocation planning or environmental water determination. The draft legislation has some provisions for stakeholder involvement in planning and the minister has powers to establish regulations, including

[16] The EFA in the Pangani Basin is supported by IUCN; the proposed EFAs in the Mara River catchment and the Wami-Ruvu basin are supported by WWF and the USAID GLOWS program; and the proposed EFA in the Ruaha Basin will receive DANIDA and WWF support.

regulations for preparing water resource management plans and the involvement of persons with "a clear interest in water resources." Overall, there is not the requirement for extensive stakeholder participation that is found in the South African policy and legislation. In part, this could be because the Tanzanian policy did not emerge from a constitutional review process designed to fundamentally address a history of racial discrimination and economic and social marginalisation, as occurred in the case of South Africa (Case Study 3).

The draft legislation contains some provisions for participatory planning. The basin water boards, which draw up the basin water resources management plans, are required to consist of representatives from the water sectors and other key sectors (including the environment), local government, NGOs, women, and catchment committees. The catchment committees comprise private sector, WUA, local government, women, and NGO representatives. There are thus opportunities for environmental representation on the boards overseeing the plans through sectoral representation. However, the draft legislation does not have any specific requirements for stakeholder participation when basin water resources management plans are being developed. Nevertheless, the experience to date has been that water management has been participatory. The RBMSIIP supported the establishment of selected water user associations to provide a framework for stakeholder participation in irrigation water management in the Rufiji and Pangani basins, and the Pangani EFA study has included extensive participation by stakeholders. Since the Pangani EFA is being used as a training opportunity for water resources staff, it can be expected that subsequent EFAs will be more participatory.

Data and science. The policy has a clear emphasis on the use of scientific information. It notes that "water for the environment shall be determined on the best scientific information available considering both the temporal and spatial water requirements to maintain the health and viability of riverine and estuary ecosystems," and "water resources assessment will be done on the basis of sound scientific and technical information and understanding." The EFA being conducted in the Pangani River Basin has fulfilled this requirement, with the assessment being based on a detailed scientific analysis of the water requirements of organisms in the freshwater and estuarine parts of the river. The other EFAs being proposed will also include strong scientific investigative programs in accordance with the policy.

The policy also recognizes the need to rehabilitate and expand the data collection network and improve data analysis and storage if well-rounded decisions are to be made. Data collection and analysis should be at the regional (basin) level, since that is where decisions are to be made, and dissemination and storage should be at the national level. The policy also sees research, data collection, and information dissemination as one of the opportunities for improving cooperation in the management of transboundary water bodies. The policy advocates that there should be public access for all to the data.

In accordance with the policy, some river flow gauging stations were rehabilitated and augmented in the Pangani and Rufiji basins as part of the River Basin Management and Smallholder Irrigation Improvement Project (World Bank 2004) between 1997 and 2003. Additional funds and technical assistance for improving the data collection infrastructure and monitoring, enforcement and compliance activities in all nine Tanzanian river and lake basins under the Water Sector Support Project (World Bank 2007) were approved in January 2007, and implementation of this is under way. However, this monitoring infrastructure will need to be maintained and the data will need to be processed and analyzed by the government over the long term for this monitoring to be effective. Skills and capacity for interpreting the data will also need to be developed to get the best out of this investment. These critical factors will determine the sustainability of the WSSP investment.

Lessons

1. The crisis brought about by inadequate water supply planning and enforcement in the early 1990s led to water reforms throughout the remainder of the decade. Although the environment was part of, but not a major sector in this crisis, environmental water needs became increasingly more pronounced once the reform program commenced, in part due to the problems with providing water to Ruaha National Park and the international publicity given to the Lower Kihansi Gorge issue (Case Study 16). The lesson is that sometimes a crisis can precipitate positive action, even if environmental-flow-related issues are not central components of the crisis, they can be incorporated into the crisis response mechanism.
2. It is not necessary to wait for supporting legislation; progress can be made in institutionalizing EFAs and water resource management plans and building experience in EFA if there is sufficient political and administrative will, resources, and technical support.
3. Support from NGOs and international agencies can be valuable in supporting EFA studies, but the timing and structure of these EFAs should be determined by the government's implementation strategy rather than by relying on the initiative of basin water offices or the objectives of external development partners. The separate EFA initiatives need to be reviewed so that lessons are learned for broader, more cost-effective applications.
4. There are mutually supporting environmental requirements in the NAWAPO (and the draft water resources bill) and in the 2004 Environmental Management Act. This policy harmonization provides for a coordinated approach across institutions when the environmental flow provisions are being implemented.
5. The level of understanding of environmental flows varies considerably at policy and operational levels across ministries. The Water Resources Department exhibits the greatest understanding and has taken the lead in implementing environmental flows, rather than the environment agencies. The environmental agencies played a prominent role alongside the Rufiji Basin Water Office (RBWO) in defining and enforcing the environmental flows for the Lower Kihansi Hydropower Project. The ministry responsible for hydropower has, however, not embraced the environmental flow provisions in its 2003 energy policy, in spite of being at the center of the controversies in the early 1990s and 2000s that highlighted the importance of allocating water to the environment. Such sectorally focused, engineering-based institutions find it difficult to internalize environmental and social issues such as environmental water provisions.
6. Despite the importance of groundwater for urban water supply and in the semi-arid parts of Tanzania, the environmental sustainability of groundwater systems is inadequately reflected in the policy.

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Case Study 5. Florida Water Management Policy

Background

Within the United States, state governments have responsibility for water resources management. Unlike some other federated systems—such as the European Union and Australia—there is little national coordination of this management, so that different water management approaches have developed within regions within the country. These approaches, however, are still subject to national legislation that affects water, such as the 1969 National Environmental Policy Act and the 1972 Clean Water Act.

Florida, particularly southern Florida, has experienced rapid growth since the 1940s as a result of urban and industrial development, the expansion of recreation and tourism facilities, and agriculture. Unlike many rapidly developing areas of the United States, Florida as a whole has extensive water resources. The northern part of the state contains the largest collection of springs in the United States. However, there are serious spatial and temporal distribution problems. Seasonal fluctuations result in large quantities of water when demand is low, and less water in winter months when demand is high. In addition, the available water is frequently in the interior of the state, not on the coast where the demand is greatest.

A system of aquifers supplies 90 percent of the state's urban water uses and half its agricultural needs. South Florida's development also depends on draining surface water from places it is not needed through hundreds of kilometers of canals, dikes, and levees. Developing this flood-control and drainage system has damaged thousands of acres of wetlands, fish and bird hatcheries, and waterways. Consequently, there are now programs to restore some of these damaged aquatic ecosystems and to protect remaining ecosystems.

While water management policies have contributed to the development that has fueled the state's population growth, they have also taxed its seemingly abundant water supply. Florida's water-dependent environment needs large quantities of freshwater for its sustained health. The interior of south Florida is largely agricultural, with additional water demands; the coastal regions require water for urban and industrial development. In recent years choices have had to be made regarding assigning water to further economic growth, environmental protection, and maintaining an adequate, safe water supply.

Florida water policy

Florida has incorporated the water resources policy statement from the 1972 Water Resources Act and its subsequent amendments into Chapter 373.016 of the Florida statutes. The policy statement has, as two of its aims, the conservation of surface and groundwater resources and the preservation of natural resources, fish, and wildlife. Given the issues confronting the state, including the spatial disjunction between sources and the demand for water, the policy emphasizes that water sharing between different regions of the state only be undertaken after all local sources of water have been utilized, including desalinization, conservation, reuse, and aquifer storage and recovery.

The 1972 legislation created six water management districts (WMDs), later reduced to five, with territories defined by watersheds rather than political boundaries. The WMDs are responsible for water supply, flood protection, water quality, and natural systems as well as considerable policy-making authority. The Florida Department of Environmental Protection is responsible for protecting the quality of Florida's drinking water, rivers, lakes, and wetlands. The department establishes the technical basis for setting the state's water quality standards, conducts monitoring programs, and coordinates water management across the state. However, planning and management is the responsibility of the WMDs. One commentator claims that the resulting two-tiered structure has created inefficient, decentralized water resource planning and development agencies with little statewide coordination (Fletcher 2002).

Each WMD is controlled by a board with nine members (13 in the case of the SouthWest Florida WMD-SWFWMD) chosen for their residency and technical qualifications, including hydrology and environmental science. Each WMD develops a district water management plan that defines the district's role in water resource management and provides comprehensive long-term direction. Under the 1972 act, these plans must establish minimum flows for surface water and minimum levels (MFLs) for surface water and groundwater. MFLs act as minimum requirements beyond which significant harm will occur to water resources or ecosystems (Box 5.1). A subsequent review of the act required that MFLs be based on best available information, and that recovery or prevention strategies be developed for any water body where the MFLs were not currently being met or where they were likely to be exceeded within 20 years.

Each WMD also has to submit to the department a priority list for the establishment of MFLs within the district. The process of setting the MFLs can be subject to independent scientific review at the discretion of the district or at the request of a stakeholder or the department, and the WMD and department must give weight to the independent review when making a final decision on the MFL. The WMDs also provide the department with an annual report on progress with their water management plans.

Apart from MFLs, the districts can also control water abstractions by declaring water reservations, where permits for water abstraction can be subject to quantity and timing constraints. However, all existing permits at the time the reservation is declared are exempt from the restrictions.

The WMDs also establish "caution areas," where they believe that there are existing water resource problems or where problems may develop in the next 20 years. This allows permitted quantities of water consumed to

Box 5.1 Minimum Flows and Levels

The Florida Water Resources Act defines MFLs as:

373.042. Minimum flows and levels

1. Within each section, or the water management district as a whole, the department or the governing board shall establish the following:

    a. Minimum flow for all surface watercourses in the area. The minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.

    b. Minimum water level. The minimum water level shall be the level of groundwater in an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area.

be gradually reduced. If water sources and conservation efforts will not meet future needs, a regional water-supply plan is prepared that provides water for all existing and predicted uses and natural systems. (Regional water supply plans have now been developed for all parts of Florida and, in some cases, are in their second, third, or fourth iteration.) However, the WMDs have found themselves in a difficult position when preparing these development plans because they are responsible for the contradictory tasks of both preserving the environmental values of water resources and meeting increases in water demand. In addition, the lack of statewide coordination and strong grassroots political support for "local sources first" means that there are institutional barriers to moving water from the water-rich parts of the state to where there is excess demand.

At the state level, the Water Policy Office of the DEP prepares Florida's Water Plan, which is the DEP's principal planning tool for long-term protection of Florida's water resources. The plan is intended to help DEP focus on the highest water resource protection priorities, organize its own water management responsibilities, and build water management partnerships. DEP is also required to produce an annual progress report, based on the reports from the districts and its own activities, with performance measures against the plan's objectives.

The Water Resources Implementation Rule 62–40 provides guidance on implementing the state and district plans. It includes requirements for establishing goals and objectives, implementing the MFLs, and reporting and monitoring. For example, it states that MFLs should recognize the natural fluctuations in flows and levels that contribute to ecosystem functioning, and that MFLs should be expressed in a way that defines a hydrologic regime. This provision has ensured that MFLs, in spite of their name, are not implemented as simple minimum flow requirements but as minimum flows that are sensitive to hydrologic conditions.

Drivers

The legislation was passed because of the need to manage both the rapid growth in demand for water and the need to protect important ecosystems, some—such as the Everglades—of international significance. The severe drought of 1970–71 had demonstrated that the existing water resource management arrangements were inadequate and that reforms were needed. Representative stakeholder groups also played an important role; urban development, agriculture, industry, and environmental interests were all represented by organized groups who ensured that the legislation protected their interests as far as possible. These same groups have remained active in promoting changes and improvements since the legislation was first passed.

Assessment

Recognition. The protection of natural ecosystems through environmental flows (and groundwater levels) was central to the 1972 legislation and the implementation rule, making this an early inclusion of environmental flow requirements in legislation. Despite this, no significant progress was made by the districts to set MFLs for nearly 20 years after the 1972 act. It was not until a series of lawsuits and subsequent legislation in the mid-1990s that the districts began to set MFLs. The MFLs and the water reservations are intended to protect water-dependent ecosystems. In the 1972 act, there was recognition of 10 water resource values (WRVs),[17] which are effectively ecosystem goods and services. The maintenance of minimum flows for surface water systems is intended to protect both the water resource and the ecology of the area, but the maintenance of minimum levels in groundwater systems is linked only to protection of

[17] These WRVs include recreation; fish and wildlife habitat and passage of fish; estuarine resources; transfer of detrital material; maintenance of freshwater storage and supply; aesthetic and scenic attributes; filtration/absorption of pollutants; sediment loads; water quality; and navigation.

the water resource and not to groundwater-dependent ecosystems. In spite of this limitation in the wording, where minimum levels have been set for aquifers, the levels were chosen to protect connected ecosystems such as springs, wetlands, and lakes.

There is an implicit first priority accorded to the provision of water for ecosystem protection in the wording of the MFLs (Box 1). However, the link between issuing water abstraction permits and the MFLs is not explicit in either the legislation or the implementation rule. Wade and Tucker (1996) state that, when the act was first drafted, it was intended that MFLs were to be protected in the permitting process, but that this was not carried through into the act. Under Part II of the act, remaining within MFLs is not one of the conditions for issuing permits, although the implementation rule requires that established MFLs shall be protected during the issuance of permits under parts II and IV of the act. Nevertheless, there are opportunities to make this linkage stronger. Water reservations are the tool for implementing MFLs when issuing water use permits. However, there is little political will to establish water reservations, and thus MFLs are not considered when issuing new permits.

However, the priority accorded to MFLs is illustrated by the requirement in the implementation rule that MFLs shall be protected during water shortages, except when the drought is so severe that such protection would compromise public health and safety.

MFLs apply to infrastructure projects as well as to district plans. The implementation rule states that "Established minimum flows and levels shall be protected during the construction and operation of water resource projects."

Comprehensiveness. The legislation is very clear on the need to protect both surface and groundwater sources, floodplains, and wetlands. It recognizes that uplands, wetlands, and other surface waters provide ecosystem functions, which include (a) providing cover and refuge; (b) breeding, nesting, denning, and nursery areas; (c) corridors for wildlife movement; (d) food chain support; and (e) natural water storage, natural flow attenuation, and water quality improvements.

However, it does not include the need to account for the impacts of climate change on either the availability of water or shifts in patterns of water demand. Nevertheless, some districts, notably SWFWMD, are incorporating long-term climate variability in setting MFLs.

The legislation also includes provisions for inter-district water transfers. While such transfers are discouraged in favor of utilizing the intra-district water resources, they are permitted subject to conditions. These include consideration of the costs and benefits and the environmental impacts on both the supplying and receiving areas. The legislation also includes a compact among Florida, Georgia, and Alabama for the management of the transboundary Apalachicola-Chattahoochee-Flint River Basin. However, the compact is more concerned with equitable apportionment of the basin waters among the three states and does not mention environmental management. The compact broke down in 2003 with Florida refusing to agree to an allocation formula that only gave minimum flows for the Apalachicola River, whose freshwater flows into the Apalachicola Bay (Melville 2005). The case will be heard in the Supreme Court; it seems that Florida will have to be on the side of sound ecological management in order to advocate its position.

Environmental water mechanisms. The legislation states that goals, objectives, and strategies for water management are to be contained in the implementation rule, which, in turn, defines the "protection of the functions of entire ecological systems" as one of the objectives of water resource planning. The state water plan describes a hierarchy of goals, objectives, and strategies for water management in Florida and the performance measures used in measuring progress. For natural systems, it describes four goals and two objectives:

- Maintain the integrity and functions of water resources and related natural systems.
- Restore degraded water resources and related natural systems to a naturally functioning condition.

The two legislated mechanisms for maintaining and restoring natural ecosystems—MFLs and water reservations—are instruments for controlling abstractions of water by consumptive users to ensure that water is left in the systems. The legislation does not provide for legally secure environmental water reserves to be held in storages for release for downstream environmental benefit because Florida has very few impoundments on its rivers. The legislation and the implementation rule are designed around regulatory measures to achieve environmental outcomes; there are no provisions for introducing economic instruments to improve water use efficiency and the redistribution of water to the environment.

The legislation has provisions for returning water to overallocated or potentially overallocated systems; that is, those where MFLs have been exceeded or are likely to be exceeded. In these systems, recovery and prevention strategies are required to describe how the MFLs will be achieved through development of additional water supplies and implementation of conservation and other efficiency measures. The legislation and implementation rule do not allow for reducing or returning water permits in order to meet MFLs. The performance measures in the Department of Environmental Protection (DEP) annual progress reports do not report on progress toward MFLs for systems that are overallocated, and so the success of these measures is difficult to determine. At present, there is only one water body, the upper Peace River, designated as overallocated, and one, the Loxahatchee River, as potentially overallocated. Both are in the very early stages of recovery or prevention strategy implementation.

Participation. The boards of the WMDs are appointed by the governor of Florida and are selected on their residency and technical skills; the latter include agriculture, the development industry, local government, government-owned or privately owned water utilities, law, civil engineering, environmental science, hydrology, accounting, or financial businesses.

The implementation rule requires adequate opportunity for participation by the public and governments, the measure of which is public workshops with advance notice at least 90 days before plan acceptance or amendment by the WMD board. The legislation also requires that the WMD board hold a public hearing at least 30 days in advance of completing the development or revision of the district water management plan. While these provisions ensure that stakeholders can comment after the plan is drafted, they do not promote full engagement in the development of the plan. However, some districts, notably SWFMD, go well beyond the legislative requirements for public/stakeholder engagement in developing their regional water supply plans.

The legislation also requires WMDs to develop an information program for the legislature, media, and the general public, although it does not mention environmental information specifically.

Data and science. The legislation requires that the "best available information" is used when calculating MFLs for a water body. As noted above, this includes recognition of the natural fluctuations in flows and levels. While, in principle, it is desirable to use best available information, it has raised some problems in practice (Wade and Tucker 1996). Because it is technically difficult to determine all the ecologically related functions that the water flows and levels support, some managers interpret the "best available information" phrase to mean that extensive research programs need to be completed before MFL determinations can be made. They are concerned that the MFLs need to be legally defensible against charges of not being "best available," particularly in areas where water is contested. In some cases, the slow progress in establishing MFLs for 20 to 25 years

after the 1972 act was passed can be attributed to this conservative interpretation. Since 1992, the districts have established MFLs for 237 separate water bodies, most of these since 1997. Another 114 are scheduled to be adopted over the next two years, so this requirement need not be an impediment to developing protective measures based on high-quality science if there is political will to establish these measures.

A related difficulty with determining MFLs is interpreting the criterion "significantly harmful" in the definition of MFLs. The implementation rule provides some factors to be included in the determination, but stops short of providing a decision rule. This has proven to be a significant practical impediment to uniformity across the state. However, districts have been quite conservative in their interpretation of "significant harm," preferring to err on the side of maintaining instream flows near natural conditions.

Nevertheless, methods for determining water withdrawal procedures that are consistent with the MFL requirements have been developed and applied. The Southwest Florida WMD has adopted a percentage-of-flow method (typically 10 percent with a cutoff to protect low flows) for deciding on the impacts of water withdrawals on its un-impounded rivers. This method provides protection to the fresh and estuarine portions of these rivers, where the responses of key characteristics to flows are frequently nonlinear (Flannery, Peebles, and Montgomery 2002).

The legislation allows for independent scientific review of the process by which MFLs are established. However, the review is not an intrinsic part of the process—it has to be requested. Even so, most districts are being proactive with respect to peer review of MFLs. SouthWest Florida and St John's River WMDs convene peer-review panels for all MFLs and are responsive to the findings of those peer reviews.

*Reporting and Monitoring.*Under the legislation, both DEP and the districts are required to provide annual progress reports. The 2003 DEP annual report, the latest available, shows that 97 percent and 28 percent of established MFLs were being maintained in the St Johns River and South West Florida WMDs, and that 70 percent and 22 percent of new MFLs were established on schedule in these districts. One district, the North West Florida Water Management District, has yet to set a single MFL, despite having most of the state's most ecologically important rivers and estuaries. The report does not comment on the reasons for the shortfall in these and other performance measures, nor does it recommend remedial actions.

These reports focus on hydrologic outcomes; there is no requirement for measuring ecological outcomes from the MFLs and water reservations activities.

Lessons

1. It took a crisis in the form of a severe drought to trigger the development of legislation that provided a framework for equitable water allocation. The heightened environmental awareness of the population meant that the legislation incorporated the need for environmental water allocations.
2. While devolving planning and management responsibility to districts, such as river basins, has many benefits, it can also impede the resolution of transboundary issues such as inter-district water transfers. State agencies need to retain sufficient authority to coordinate actions and make decisions on transboundary issues.
3. Restoring overallocated systems to sustainable flows and levels is inherently difficult. It seems unlikely that this can be achieved through just water conservation and development of additional water sources (which may add further stress to other water bodies). Policies to restore these systems would be stronger if there was clear authority for districts to revoke or buy back water abstraction permits on an equitable basis.
4. The policy is proactive in that it requires that potentially stressed waterbodies be identified

up to 20 years in advance, providing time for precautionary actions to be implemented.

5. The focus on setting MFLs for stressed and potentially stressed water bodies means that more pristine systems are sometimes allowed to degrade substantially before any attention is paid to them. This means that degradation may occur before protections are put in place.
6. Merely defining MFLs is not sufficient unless a clear link is established between MFLs and limits on the issuing of water abstraction permits. Although there are mechanisms available, such as declaring water reservations (which then require the consideration of MFLs), invoking these mechanisms requires political will.
7. Implementing MFLs is difficult if there is no defined procedure for quantifying value-laden terms such as "significantly harmful." Establishing an MFL is a social, not a scientific, decision and the policy or its associated rules should describe the mechanism to determine the MFL.
8. In cases where there is a likelihood of litigation over establishing limits to water abstraction permits (through mechanisms such as MFLs), legislative requirements for "best available information" may actually impede progress toward establishing sustainable limits on water abstraction. Conversely, these same requirements have resulted in some of the best science and most sound approaches for protecting instream flows in the United States.

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III. Basin/Catchment Plan Case Studies

Case Study 6.
Kruger National Park and Catchments

Background

The Kruger National Park (19,633 km²) is famed for both its biodiversity and its record of early human settlement, from San rock paintings to archaeological sites with evidence of early hominids. It is an important tourist destination and source of foreign income for South Africa.

The Sabie Game Reserve, the precursor of the park, was proclaimed in 1898. In 1926, the Kruger National Park (KNP) was formed from the merging of the Sabie and Shingwedzi Game Reserves under the National Parks Act. More recently, the KNP has been joined with Mozambique's Limpopo National Park and Zimbabwe's Gonarezhou National Park into the Greater Limpopo Transfrontier Park.

The KNP is located in the northeast of South Africa, abutting Mozambique to the east and Zimbabwe to the north. The park is a long strip about 60 km wide and 350 km long, running in a north-south direction. It straddles three major basins—the Levuvhu in the north, the Letaba/Olifants in the middle, and the Incomati in the south. The Incomati River empties into Maputo Bay in Mozambique (Box 6.1), while the Olifants and Letaba Rivers join together on the ark boundary before flowing into the Limpopo River, which reaches the Indian Ocean to the north of Maputo. The main rivers passing across KNP are (from north to south) Levuvhu, Shingwedzi, Letaba, Olifants, the undeveloped Uanetse, Sabie-Sand, and the (highly developed) Crocodile Rivers. The northern region of the park is mostly arid and flat, although there are local areas with higher rainfall. The central region of the park is grassland plain, stretching west to the Lebombo Mountains, which form the boundary with Mozambique. The southern region of the park has higher rainfall and is more densely vegetated.

Box 6.1 Transboundary Water Management

The Incomati Basin is transboundary with Mozambique and Swaziland. The Incomati River dried up in 1982 under drought conditions, leading to widespread public awareness within all three countries about the demands being placed on the river. Impoundments and abstractions had reduced the freshwater and sediments flowing into the estuary, which has changed the flow regime. These changes had detrimentally affected the estuarine ecosystem and shrimp and fish production. It was apparent that plans in all three countries for dams would exacerbate the situation in the lower rivers of the basin, and there was a need for agreed minimum flows. After considerable negotiation, base flow at the border between South Africa and Mozambique was set at 2m³/s in 1991 to satisfy water demands from the border down to the confluence with the Sabie River.

However, within a few years, Mozambique claimed that South Africa and Swaziland were not adhering to the agreement. The Joint Incomati Basin Study (JIBS) was initiated to provide a better factual basis on which the waters of the basin could be assessed and shared. An agreement—the Tripartite Interim Agreement on the Projection and Sustainable Utilization of the Water Resources of the Incomati and Maputo Watercourses—was signed by the three countries during the World Summit on Sustainable Development in 2002 in Johannesburg. Instream flow targets are included in the agreement, although these were not obtained through a rigorous process.

Source: Nkomo and van der Zaag 2003.

The rivers rise in the high veldt to the west of the park. These rivers are heavily utilized and suffer from water depletion and pollution from urban runoff, industry, and mining. These rivers already have a number of impoundments to provide water for irrigation and urban use power generation, and the construction of dams is continuing. The Injaka Dam was completed on the Marite tributary of the Sabie River in 2002, and the De Hoop Dam is planned for the Steelpoort River, a tributary of the Olifants River. Dam developments also are under way downstream of the park. Mozambique is planning to raise the walls of two major dams—the Massingir and Corumana dams. These projects will flood environmentally important gorges on the Olifant and Sabie rivers within the park.

Meeting water demand is the key issue in the catchments feeding the park (Department of Water Affairs and Forestry 2004a). This demand arises from multiple sources, including (a) a huge demand for additional water-use licenses by emerging black farmers; (b) rapid population growth in parts of the Inkomati and Olifants basins, including urban and semi-urban development; (c) international obligations to Mozambique to provide minimum flows at the border from rivers of the Inkomati Basin; and (d) social water requirements (beyond the basic human needs reserve), which place water demands on the rivers above the park, particularly those in the Inkomati and Olifants basins.

Water quality is an issue in some of the catchments. Water quality in the Inkomati is threatened by the presence of coal mines and large coal reserves. There are salinity, eutrophication, toxicity, and sediment problems in areas of the Olifants Basin and, in the Lower Olifants sub-area, water quality is influenced by discharges from the mining complex around Phalaborwa in the Ga-Selati River. The water quality of the groundwater resources in the Steelpoort area of the basin is under threat from mining and agricultural activity.

Adequate, good quality flows in these rivers are vital to the ecological integrity and biodiversity of the park. The threat to these rivers was made clear by the 1992 drought, the worst in recorded history (Newenham and Chavalala 2003), when many of the rivers ceased to run. The drought also pointed to the inequities of the then-water law. In the Sand subcatchment of the Sabie River, the main agricultural concerns continued to water crops, while water had to be trucked in to poorer communities for domestic consumption. A single water-use sector could stop the flow of the river with impunity (Pollard and Walker 2000).

Water abstraction for irrigation, coupled with a drought, has caused the Olifants River to cease flowing at least twice since 2000. The Levuvhu and Letaba rivers already commonly stop flowing in the dry season because of upstream water demands. With large-scale infrastructure planned for the Olifants River, especially new mining operations in the Dilokong corridor, the Sabie River is the last remaining perennial river in KNP,[18] but it too faces increasing demands, primarily from irrigation developments. The Inyaka Dam in the Mariti River, a tributary of the Sabie River, was recently completed. This dam makes provision for maintaining environmental water requirements in the Sabie River and therefore in the park, as well as rural domestic water requirements in the local region and some irrigation expansion. A considerable amount of water (25 million cubic meters per annum) is also earmarked to be transferred to the stressed adjacent Sand River catchment for domestic water requirements, freeing up some of the flow of the Sand River for environmental water requirements. If properly managed, the environmental integrity of the Sabie River can thus be safeguarded for the foreseeable future.

Because of the growing stress on the rivers within the park during the drought of the 1980s, South African National Parks (SANParks) needed to know the flows needed to maintain the park's biodiversity. In 1988,

[18] The Waterwheel (January/February 2007). Pretoria: Water Research Commission.

it initiated a comprehensive multidisciplinary and multi-institutional research program, the Kruger National Park Rivers Research Programme (KNPRRP), to investigate the rivers of the park, in particular the polluted Olifants River, the severely degraded and once-perennial Letaba and Levuvhu rivers, and the ecologically important Sabie River (Du Toit, Rogers, and Biggs 2003). The KNPRRP has been implemented through three phases, with successive phases broadening their coverage from scientific knowledge, to predictive capabilities that supported management, to capacity building for implementing decisions.

The KNPRRP addressed a wide diversity of topics (Breen and others 1998), including (a) better predictions of physical processes; (b) better predictions of biological processes and responses; (c) integration of physical and biological understanding; (d) addressing problems of scale; and (e) methods for determining management objectives.

Most of the initial research was undertaken on the Sabie River, which is a small but ecologically significant river with importance for the tourism industry (Sudlow 2004). Where the information was available, these studies provided the baseline information for assessments of instream flow requirements (IFR) of rivers in the park and more widely throughout South Africa. The last phase of the program has specifically focused on broadening the base of understanding to include stakeholder groups (Breen and others 2000).

The KNPRRP successfully raised awareness of the vulnerable condition of rivers in the park and provided researchers with a factual basis for establishing in-stream flow requirements for rivers in the park.

The Building Block Methodology and KNP

The building block methodology (BBM) (King and Louw 1998) was first introduced into the KNP at a workshop for the Lephalala River in February 1992 and further developed in a series of water resource development projects (King, Tharme, and de Villiers 2000). It was designed to provide a rapid first estimate of the IFR for rivers in the park, which were subject to considerable hydrological stress (Box 6.2). The method was subsequently adopted by DWAF for

Box 6.2 Instream Flow Requirements and the Building Block Methodology

The Building Block Methodology (BBM) was developed specifically to provide a relatively rapid, scientifically reliable method for determining instream flow requirements (IFR). The first workshop on the development of an environmental flows method was held in 1987 (Ferrar 1989). The BBM was initially applied to rivers within South Africa where dams were being considered, including in the KNP. It has subsequently been used to determine the ecological reserve as required in the 1998 National Water Act.

The method is based on three main assumptions: (1) riverine biota can cope with naturally variable flow conditions, but atypical flow conditions constitute a disturbance and could cause fundamental changes; (2) management of the most important components of the natural flow regime will contribute to the maintenance of natural biota and ecosystem functions; and (3) flows that most strongly influence channel geomorphology should be included in the managed flow regime.

The BBM approach involves the following sequence:

- Current and historical geomorphology, water chemistry, and biotic data are collected.
- This information is presented at an IFR workshop together with descriptions of the virgin and present daily flow regimes. The workshop is attended by specialists in relevant disciplines.
- Habitat availability, together with the sediment-moving capacity of various flows, form the basis for a recommended modified flow regime *built* in monthly *blocks* of water. Each volume of water is characterized with a description of the biological, hydraulic, or geomorphological function it serves.

Hydrological modeling research provides techniques to translate IFR recommendations into reservoir release operating rules for both low flows and flood events.

Source: Palmer 1999.

determining IFRs, although other methods and more advanced developments of the BBM methodology have subsequently been approved as well.

The method was applied to all the rivers within the park and IFRs were developed for these rivers (Mackay, King, and Louw 1999). For example, the maintenance flow ecological water requirement for the Sabie River within KNP was determined to be an annual average flow of 291.2 million m^3/yr.

SANParks required these IFRs to provide evidence for the flows needed to maintain the park's biodiversity. However, it had little influence over activities that were producing the stresses outside the park boundaries, and was reliant on DWAF to implement the IFRs. DWAF could not initially provide these environmental flows because many of the rivers were already fully allocated (or even overallocated) and there was no mechanism to recover water for environmental purposes. There was also a lack of understanding in some parts of DWAF about the importance of environmental flows (Gyedu-Ababio 2005). The sections within DWAF that had estimated the water requirements of the reserve had no responsibility for implementing the reserve and consequently these environmental water requirements were not put into effect.

More recently, the "internal strategic perspectives" (ISP) produced by DWAF contained low confidence estimates of the ecological reserves for all catchments in South Africa. Where better information is available, such as for some of the rivers within the park, the ISPs contain higher confidence estimates of the reserve.[19] Unfortunately, the delay in implementing the reserve has meant that it is now more difficult to acquire the water for the environment than it would have been if the IFRs had been implemented.

It is clear that it will not be possible to meet many of the preliminary ecological reserve requirements for the park's rivers, given the current level of development, international water obligations, and the requirements of the basic human needs reserve. Thus, in the Inkomati Basin, the implementation of the ecological reserve is likely to have a serious impact on the availability of water for irrigation and afforestation, and in the case of the Komati River, power stations also, and the reserve needs to be implemented gradually (Department of Water Affairs and Forestry 2004b). The situation is especially serious in the Crocodile River region, where there is potential for economic growth, and yet where the reserve cannot be met even now, given existing water licenses. In the Sand River catchment, there are presently insufficient water resources for domestic use and irrigation requirements let alone for the ecological reserve, and in the Letaba catchment almost all flow is abstracted during drought and very little is left to meet the significant ecological requirements of the park.

The progressive implementation of the 1998 Water Act has provided the means to determine the ecological reserve for the park's rivers. Catchment strategies, which are required under the Water Act (Case Study 4), will include determinations of the ecological reserve and the water allocation plans needed to achieve these environmental flows. The strategies will be developed once the CMAs are established. The Inkomati CMA was the first to be established under the National Water Resources Strategy (Department of Water Affairs and Forestry 2004a) because of the level of stress in that basin, including in the basin rivers that flow through the southern part of the park. However, even after plans have been developed and accepted by the minister, it will require considerable political and institutional willpower for water to be returned to safeguard essential ecological functions.

The reserves for the rivers flowing through the park are being determined at present, with different levels of confidence for different rivers. Thus, high confidence

[19] The Kruger National park is included within the Inkomati, Olifants, and Levuvhu/Letaba WMA Internal Strategic Perspectives, published in 2004 by Department of Water Affairs and Forestry, Pretoria, South Africa.

environmental water requirements have been finalized for the Letaba River (Pulles, Howard, and de Lange Inc. 2006) and Komati River (AfriDev 2006) and an ecological reserve monitoring program is being formulated in the Letaba River. This monitoring program will be applied to other rivers flowing through Kruger National Park. High confidence reserve studies are also being undertaken on the Sabie/Sand and Crocodile systems to complement and improve the previous IFR studies. Operating rules have been developed for the Olifants River and are being modified to reflect current developments in the catchment, and rules are also being developed for the Luvuvhu and Letaba rivers (Thomas Geyedu-Ababio, pers. comm., January 2008). Unlike the IFR studies, these new reserve determinations include implementation mechanisms and methodologies.

Drivers

The drought of the early 1990s was the principal driver for the establishment of IFRs for the park's rivers. The drought highlighted the vulnerability of the rivers to upstream developments, including land use changes (such as increased forestry plantations in the upper catchments and increased human settlement) and the development of dams upstream and downstream of the park. The upstream developments within South Africa had reduced flows in the rivers to the point where only one major river, the Sabie, remained perennial. The downstream proposals to raise the dam walls on the Massingir and the Corumana dams in Mozambique acted as an additional driver, because these proposals would cause additional loss of riverine habitat by flooding gorges on the Olifants and Sabie rivers.[20]

SANParks was deeply concerned about the potential loss of biodiversity from these developments, given that maintenance of biodiversity was the major objective of SANParks. Loss of this diversity would not only be an issue in its own right, but it would lead to reductions in tourism, especially international visitors, and economic losses to the surrounding region.

The concern of NGOs about the threats to the park's biodiversity from these developments acted as an additional driver for action. There was also professional pressure from leading South African researchers who were concerned about the impacts of the upstream development on the park.

The requirements under the 1998 Water Act subsequently provided a legislative driver for establishing the ecological reserve within the park's rivers. The recent establishment of the Inkomati CMA provides an institutional mechanism for bringing about the water reallocation needed to meet the reserve requirements.

Assessment

Recognition. SANParks clearly understood from an early stage the need to maintain river flows to provide the basic ecosystem functions that supported the park's biodiversity and tourism industry. They supported research under the KNPRRP to provide the factual basis for the initial establishment of IFRs for the park's rivers. The South African Water Research Commission also recognized the need to establish environmental flows in the park and funded much of the biophysical research carried out during the 1990s in the park, as well as the development of planning and management. There was also strong support from sections of the DWAF, where there was recognition of the need for environmental flows.

Other parts of DWAF were slower to accept the need to conserve the park's river flows. The DWAF had traditionally focused on the development of the country's water resources and has taken time to adjust to its new role under the National Water Act

[20] The raising of the Massingir Dam wall has gone ahead and the water has backed up and flooded the gorge within the park.

of custodian and coordinator of the country's water resources, with many of the operational responsibilities (including planning) transferring to the CMAs. Consequently, there have been different opinions within DWAF about the importance of the reserve. While the water reform staff in the Sub-Directorate of Environmental Studies, together with some other parts of the department, have been actively involved in assessing the environmental reserve within the catchments feeding into the park, the concept of the reserve is still not fully accepted by all staff within the department.

Many holders of riparian water licenses in the catchments above the park, including both traditional irrigators and more recent black entrepreneurs, have had trouble accepting the primacy of the ecological reserve and its implicit restrictions on water abstractions. There is a concern within DWAF that these groups would mount legal challenges to any attempt to implement the reserve, and that it would be better to wait until the compulsory licensing system is introduced under the Water Act before attempting to recover water for the environment.

Participation. The first IFRs within the park were estimated through use of the BBM method. This method is essentially a technical exercise (Box 2) with limited stakeholder engagement, apart from SANParks itself. This reflects the focus of the IFR process on establishing just the environmental water needs and not extending to a wider assessment of stakeholder requirements for water. Nevertheless, it was recognized that an EFA cannot be a purely scientific process because these flows also provide some of the ecological goods and services on which local people rely.[21] The estimations of the ecological reserve through the ISPs and the more recent high-confidence determinations of the reserve for the Letaba and Komati catchments (Pulles Howard & de Lange Inc. 2006) include considerations of the needs of other water users as well as operational constraints. However, these studies did not involve other stakeholders directly in the assessment of the different flow scenarios; rather, the impacts of the different scenarios on other water users were incorporated into the reserve determinations.

Given the years of disenfranchisement, the capacity of local stakeholders needs to be developed so that they can engage productively in the water allocation planning process. Ensuring that local views and aspirations are incorporated will be especially important in the overallocated WMAs, where some difficult decisions will need to be made on access to water. Phase III of the KNPRRP contributed to a common vision for the Sabie and Olifants rivers, although the changing management environment with the formation of catchment management committees and CMAs partially eclipsed these efforts. Similarly, efforts to enhance river forums were undercut by the new management structure, which absorbed the attention of the stakeholders (Breen and others 2000). Nevertheless, the KNPRRP activities will contribute to participative management in the longer run.

Other activities include a pilot study in the Crocodile River system to test two methods for capturing local perceptions and priorities for management. One of the underlying reasons for the study is to ascertain how stakeholders understand sustainability, with a special focus on environmental flows and compliance with the ecological reserve.[22]

Assessment Technique and Data. Over the last decade, the Kruger National Park has been central to the development of expertise in South Africa in the

[21] Subsequent comprehensive determinations of the reserve, such as that undertaken in 2004 in the Thukela River catchment of the Kwazulu/Natal province, pioneered the incorporation of stakeholder involvement, user needs, and social aspects such as goods and services into EWR methodology.

[22] "An exploration of the value of understanding stakeholder mental models for management of water resources in the Crocodile Catchment, Mpumalanga South Africa. Preliminary Findings of the Mental Models Working Group." Report provided by S. Pollard, February 2008.

determination of environmental flows. The initial BBM exercises on the Luvuvhu and Letaba covered the whole catchment and were not done as part of the KNPRRP, which focused on the Sabie River. Kruger National Park specialists were involved in these exercises, and this contact led to the IFR on the Sabie in partnership with the KNPRRP. The BBM method was initially used to establish the IFRs of the park's rivers. This technique is an internationally recognized method and was the first technique accepted by DWAF for determining the environmental water requirements under the Water Act (MacKay, King, and Louw 1999).

More recently, the flow stressor response (FSR) method (O'Keefe and Hughes 2004) has been used for the determination of the reserve for low-flow conditions within the rivers of the park. This method is designed to guide the evaluation of the ecological consequences of modified low-flow regimes using an index of flow-related stress. It can be used within holistic methods, such as BBM and DRIFT (Case Study 14); thus, in the case of the reserve for the Letaba catchment, FSR was used for the low flows and a combination of DRIFT and BBM were used for the high flows (Pulles Howard & de Lange Inc. 2006). The method is independent of the level of biological knowledge, although the amount of knowledge will affect the level of confidence that can be placed in the recommendations.

The BBM assessments of the park's rivers were underpinned by the data collected during the KNPRRP. The early establishment of this program was a far-sighted decision. A formal scientific assessment of the BBM method in August 1996 between those developing the BBM and those carrying out the KNPRRP research on the Sabie River concluded that, while the BBM could not directly use the full range of available scientific data, it could access it indirectly through the knowledge of scientists engaging in BBM workshops (MacKay, King, and Louw 1999). The high-confidence assessments also drew on the information gathered during the KNPRRP.

The Ecological Reserve Monitoring Program is still being established, and it is too early to assess its progress.

Integration. The BBM method and the subsequent FSR method are primarily environmental assessment methods that do not integrate the social and economic issues with environmental water requirements. Basic social needs for water are identified through the basic human needs reserve.

Cost Effective. The cost of undertaking the determination of the ecological reserve for the rivers of the park is not available. However, an economic study is presently under way as part of the reserve determination in the Sabie and Crocodile rivers to estimate the value of the ecosystem goods and services under the different flow scenarios.

Influential. The application of environmental flows procedures in the park as a result of the concern about water security has been influential in establishing the ecological reserve for the rivers of the KNP. Although the application of the BBM method within the park did not, at the time, result in environmental flows, the development of these IFRs helped spread awareness about the importance of environmental flows and formed the basis of the subsequent reserve determinations. The determination of the IFRs also provided confidence that there were procedures for assessing environmental water requirements, and this contributed to the inclusion of the ecological reserve into the South African national water policy and legislation.

Lessons

1. Even though there was no policy or legislation in the early 1990s that legitimized environmental flows, the concern of park officials for quantifying the flow needs of rivers in KNP ultimately contributed to both national legislation and to the implementation of the reserve for the rivers flowing through the park.

2. The early quantifications of environmental water requirements (IFRs) were not acted upon because they were not backed by legislative requirements or implementation mechanisms. They were accepted for planning purposes by the Planning Division of DWAF, which had asked for them, but were not widely accepted within the department. Nevertheless, they formed the basis for subsequent reserve determinations in the rivers of the park.
3. The KRRP was undertaken independently of the development of the BBM methodology. It was a visionary decision because it helped provide the scientific basis and credibility for the subsequent BBM applications.
4. Developing an ecological monitoring program is an important part of implementing environmental flows.
5. Where stakeholders did not have a history of engagement in decisions, their capacity needed to be built up through specific capacity building activities, including development of a common vision, establishment of local objectives and involvement in monitoring activities.

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Case Study 7. Mekong River Basin

Background[23]

The Mekong River is a vital resource that shapes the social, economic, cultural and ecological functions of the six countries through which it flows—China, Myanmar, Peoples Democratic Republic of Lao (Lao PDR), Thailand, Cambodia, and Vietnam. With a total catchment area of about 795,000km^2 and about 4,800km long, it is one of the largest rivers in the world. Similar to other tropical river systems, the Mekong River has large fluctuations in seasonal discharge. It experiences very low flows during the dry season, yet floods extensively during the rainy season. The most important event of this wet season is the annual flooding of the Tonle Sap in Cambodia, Southeast Asia's largest natural freshwater lake (Box 7.1). During this period, the lake expands to five times its dry-season size, allowing fish to move into the wetlands to feed and breed, creating one of the most productive, diverse, and biologically rich freshwater ecosystems in the world.

The river provides livelihoods to people in the basin, primarily through fisheries and irrigation. Wild fisheries are the major source of low-cost and high-quality protein, and a major source of employment and income in rural areas. Wetlands that are vital for maintaining the fisheries depend on the cycle of dry-season low flows and wet-season floods to sustain the ecological systems. Rice, the major agriculture product, also depends on flood recession agriculture.

[23] This section is drawn from World Bank 2000 and World Bank 2006.

Box 7.1 The Tonle Sap Ecosystem

Tonle Sap, a large shallow lake in the center of the Cambodian plain, is a unique lake-river system. During most of the year, the lake drains into the Mekong River through the Tonle Sap River. This flow provides a substantial part of the dry-season flow in this part of the basin and helps to control salinity intrusion in the delta and conserve mangrove forests. These dry-season flows also allow the cultivation of a second rice crop in the Mekong Delta.

During the wet season, the Tonle Sap River reverses its flow and fills the lake from the Mekong River to cover an area up to 1.6 million ha. The lake basin contains extensive wetlands and flooded forests that are critical to the lower basin fishery and other biodiversity resources. The periodic flooding that carries sediment-rich water from the Mekong River to the lake, combined with the area's high biodiversity, are the main reasons for the development of this unique and rich ecosystem.

The lake is an important source of fish for the Cambodian population, providing about 138,000 tons annually, while fish migration from the Tonle Sap to the Mekong River represents a crucial re-stocking source for the river. The lake and its floodplain provide a refuge for a wide variety of birds, including a number of breeding colonies of large water birds. Approximately 350,000 hectares of the lake's floodplain are cultivated. Much of the cultivated crop is rice (450,000 tons p.a.), along with mungbeans, melons, and a variety of other vegetables. Finally, Tonle Sap and the associated cultural heritage of the Angkor complex are central to Cambodia's national identity.

Source: ILEC 2005.

The Mekong riparian countries have different economic and social development goals, some of which depend on maintaining existing flows, while others require changes to the flow regime. Cambodia plans on increased irrigation and agriculture, yet must also maintain existing freshwater flows to support wild fisheries and for transit. Lao PDR intends to develop its enormous hydropower potential for export, yet must also maintain flows for transport and capture fisheries. Thailand has ambitious plans for irrigation and agro-processing development in the poor regions within the basin, along with river diversions to northeast Thailand and an inter-basin transfer to the Chao Phraya River, which drains central Thailand through Bangkok. Vietnam is concerned about flood protection maintenance of existing river flows for its agricultural areas, and maintaining flows in the dry season for rice production and salinity control in the Mekong Delta to protect agricultural land and prevent domestic water supply problems. China looks to the Mekong River to provide hydropower to support its extensive plans for economic growth.

There are other important environmental issues in the basin. Severe deforestation in Thailand was contributing to increased flash floods in the rainy season. Increased abstraction for irrigation in Vietnam and the upstream dam projects could together exacerbate salinization of the Mekong by affecting its flow. The Mekong River's aquatic ecosystems also support a globally significant level of biodiversity. The Mekong floodplain ecosystem, which comprises an extensive network of wetlands, flooded forests, and estuaries, is dependent on the annual flood regime to provide nutrients and floodwaters to support over 1,200 fish species, including the giant Mekong River catfish, the largest freshwater fish in the world. Many Mekong fish species are highly migratory through the basin's river network, which makes them very susceptible to changes in flow regimes and barriers.

In 1995, Lao PDR, Cambodia, Thailand and Vietnam—the downstream countries in the Mekong Basin—ratified an agreement[24] that created the Mekong River Commission and set out provisions for improving water resources management in the Mekong River Basin. The agreement identifies the need to develop the basin for the benefit of all four countries while protecting the environment and ecological balance. Specifically, the agreement identifies the need to utilize water resources reasonably and equitably, and to develop guidelines to manage the river flows. The four countries are the full members of the MRC; Myanmar and China have observer status to the MRC and are active members of discussions on regional economic development of the Mekong River.

Institutionally, the MRC comprises a Council (a ministerial level body for policy direction), the MRC Joint Committee (which implements the decisions of the Council), and the MRC Secretariat (which provides technical and administrative capacity). In addition, each country has its own National Mekong Committee, which acts as the conduit for cooperation between the MRC Secretariat and their counterparts in the basin countries. The agreement established a comprehensive institutional framework to address sustainable use of the river, not only to meet the needs of the four MRC riparian nations but also for informing and guiding future upstream developments in China. The agreement sets out general principles and procedures, including the protection of the environment and ecological balance of the basin. It does not set specific water allocations for the four countries, but requires that mutually acceptable minimum monthly natural flow during the dry season, natural reverse flows to the Tonle Sap during the wet season, and maximum daily peak flows during the flood season be identified and agreed on.

However, there is an active pursuit of national interests by the lower Mekong countries and the upper riparian country that poses a challenge to the expectations set

[24] "Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin Water and Related Resources." *http://www.mrcmekong.org/agreement_95/agreement_95.htm*

forth in the agreement. China's existing dams and plans to construct further dams[25] and the Laos PDR's recently approved Nam Theun 2 project and further plans for hydropower dams have brought public attention to the need for coordinated development of the Mekong. Active planning by Thailand to pursue water diversion from the Mekong, together with Vietnam's steps toward further dam construction, signal the intentions of these countries to move ahead with development projects, possibly irrespective of regional considerations.

This unilateralism is partly fueled by a perception by some outside observers that the MRC is a regulatory agency imposing rules, instead of (as stated in the Mekong Agreement and the MRC's Strategic Plan) a river basin organization facilitating mutually beneficial and optimal development. MRC itself has not yet fully acquired the regional credibility—or all of the expertise, organizational capacity, or analytical tools—to facilitate inter-country negotiations, despite good progress in the past seven years to put basic cooperative frameworks and a decision-support system together. In addition, the MRC has no authority and limited ability to enforce agreements. Compliance with basin scale plans, including rules for the maintenance of flows, is by consensus and through recognition of mutual benefits.

The Water Utilization Project

The World Bank was the implementing agency for the Global Environment Facility (GEF) Water Utilization Project (WUP), which provided assistance to the MRC to implement some provisions of the agreement (World Bank 2000). The project is due to reach completion in 2008. The outputs include the participatory development of basin-wide hydrological modeling capability, which was agreed by all member countries to allow predictions of the consequences of various development proposals on downstream flows. The project also supports a process to negotiate and agree on five sets of procedures (initially entitled "rules") on (1) data and information sharing, (2) water use monitoring, (3) prior notification and consultation, (4) acceptable minimum flows, and (5) water quality in the Mekong River Basin.

An environmental flows approach was developed and applied as the technical basis for determining acceptable minimum flows in support of the procedures enabling Article 6 of the Mekong Agreement, which requires (1) that dry-season flows should be "not less than the acceptable minimum monthly natural flows during each month of the dry season," and (2) wet-season flows should "enable the acceptable natural reverse flow of the Tonle Sap to take place." The WUP aimed to establish interim flow procedures[26] by July 2004. In addition, the project supported strengthening of various institutional (regional and national) capacity for the implementation of the procedures for water utilization, undertaking basin management functions, coordination with upper riparians and donor agencies, supervision and monitoring of the implementation of the project, and financial and procurement management.

While the MRC had agreed in principle, under the WUP, to provide for flows that would sustain the health of the river system, they lacked the technical expertise to determine those flows. The World Bank, through the BNWPP Environmental Flows Window, and under the WUP helped develop a three-phase work plan to a work program jointly developed and implemented by the MRC's WUP and Environment Program (EP) entitled Integrated Basin Flow Management (IBFM). IBFM is the MRC's custom-made environmental flows assessment approach to provide information to Mekong basin countries so that more informed trade-offs can be made between development and social and environmental impacts. IBFM activities were agreed and implemented under the guidance of a technical committee representing each of the MRC countries.

[25] About 16 percent of the Mekong's flow comes from China.
[26] Procedures for Maintenance of Flows on the Mainstream (PMFM)—one of five sets of procedures agreed to be drafted and approved by the MRC Council under the WUP.

The three IBFM phases can be summarized as follows:

1. An initial phase designed to describe the present-day flow regime of the Mekong basin, make this information readily available, and propose flows based on these as a first step in agreeing acceptable minimum flows.
2. A rapid, yet comprehensive, environmental flows assessment encompassing not only the biophysical, but also the social and economic aspects of possible infrastructure development, based on available data and information with an international recognized panel of experts paired with riparian specialists.
3. Ongoing comprehensive flows assessment based on continuing field work, acquisition of data and information, and broad stakeholder participation.

In the first phase, the hydrologic and hydraulic models, being developed under the WUP, were used to describe the present-day flow regime of the Mekong based on historical data. This work resulted in the preparation of a widely distributed publication providing essential information on the origin and distribution of river flows in the basin (Mekong River Commission Secretariat 2005). The first draft—*Technical Guidelines for Implementation of the PMFM*—was also developed under this phase. These guidelines were initially developed to meet the July 2004 WUP deadline for a flow plan for the basin, but were not approved.

These flow rules were one of four rules produced from the WUP. Three have been enacted by all four member states; that is, the rule on notification of the riparian neighbors in case of interventions in the water system, and rules on standardizing and sharing of data. However, the rule concerning the minimum acceptable dry-season flow was only accepted as a nonbinding guideline in February 2006, because of concerns that development plans would be restricted too much by flows aimed to maintain the present river condition.

In a second phase in 2005, a range of development scenarios, initially generated under a study by the World Bank (World Bank 2004) and later refined under the MRC's Basin Development Program (BDP), were used to describe a possible range in the general level of basin development from present day to the greatest potential level of development over the next two to three decades. The MRC hydrological models, developed under the WUP, were used to describe the resulting flow regime in a manner that could be readily understood by the multidisciplinary expert team. Each flow regime was assessed in terms of its ecological, social, and economic implications based on current best available knowledge. This phase was conducted as a desk study supplemented with limited fieldwork, using an expert panel of specialists from the lower Mekong basin countries and international specialists. This phase was completed by the end of 2005.

Some of its findings include:

1. The Tonle Sap is highly vulnerable to potential flow changes. The high-development scenario has the potential to permanently flood more than 50 percent of the flooded forests that circle its dry-season extent, thereby drastically reducing what is thought to be the main food source for the fishery.
2. The expected benefits of controlling salt intrusion in the Mekong Delta from higher HEP-generated low flows in the dry season would be extremely modest because the extra water flowing down the Mekong would retard draining of the Tonle Sap, and so very little extra water would arrive in the delta.
3. The study also illustrated the shift in beneficial uses of the Mekong's waters by country that would occur as development progressed. Dam building countries would increase their proportion of benefits, while those relying on the natural resources of the river would decrease theirs.
4. The initial economic valuation of beneficial uses, although considered to be only a first approximation, provided indications of the magnitude and direction of change and is considered to be a useful basis to start the discussion of trade-offs between sectors and

between regions as the MRC seeks to guide future development activities in the basin.

5. Additional aspects of the flow regime should be considered beyond the two nominated in Article 6 of the Mekong Agreement. They include (a) vegetation in protected areas in southern Lao and northern Cambodia; (b) bank erosion between Vientiane and Pakse; and (c) maintenance of deep pool habitats for the highly productive and important Mekong fisheries.

This phase was carried out over eight months using available knowledge and data, and so confidence levels are low. Nevertheless, it has indicated the need to combine development with protection of important ecosystems.

The third IBFM phase commenced in 2006 and was originally scheduled for completion in 2008. It was intended as a comprehensive holistic flow assessment based on a targeted research program of both riverine ecology and socioeconomic factors. In this phase, the "Mekong method" of flow assessment, based on the DRIFT method (Case Study 14), is intended to provide higher confidence scenarios of the linked flow, biophysical, social, and economic implications of development. The Mekong method is designed to be highly participatory. This phase of IBFM is intended to include a comprehensive consultation process, although there are considerable difficulties in developing this process across the diversity of governance structures within the basin. Phase 3 was halted in 2007 for a number of reasons, including funding limitations. It may start up again in a different form under the MRC's new Basin Development Plan.

Scenarios developed by the MRC will be assessed for their costs and benefits over the next 20 to 30 years for different stakeholders. The scenarios show the implications of different development paths to inform decision making, but it is unlikely that a specific scenario will be selected as providing the optimal development path.

The IBFM was seen in some quarters as anti-development because it was seen to be focused on maintaining the natural flow regime (Johnston 2007). This undermined its credibility with some development advocates, even though it is intended to provide an objective and scientific framework enabling the best "triple bottom line" outcomes—economic, social, and environmental returns—from water resources development. These concerns have impeded the implementation of the third phase of the program to the point where a number of reports on environmental water needs have not been published and consultations with stakeholder groups have not proceeded.

Drivers

A number of pressures drove the development of an environmental flows program in the Mekong River.

While all basin countries had economic development plans that used the water of the Mekong River, China's ambitious plans for dams was seen by the downstream countries to pose a particular threat to their use of the river's water. The downstream countries were concerned that China's development plans did not limit their use of the Mekong for development. Vietnam and Cambodia, in particular, were concerned about disruptions to their fishing activities, which are important sources of protein for their people. Lao PDR had a particular reason to support an environmental flow assessment—they were keen to establish an agreed envelope within which they could develop dams to export electricity and generate foreign income.

However, environmental flow concerns were not dominant issues for any of the countries, even those downstream within the basin. The requirement of development partners for environmental flow assessments was the primary driver in this case. The World Bank and GEF supported the development of flow rules through project funding. Bilateral assistance agencies also promoted environmental flow assessments.

NGOs were specifically concerned that changes in the flow regimes as a result of upstream dams would inhibit the functioning of the Tonle Sap ecosystem. Reductions in wet-season flows could limit the quantity of reverse flows into the Tonle Sap, abstractions of water for irrigation and other off-stream purposes could reduce the extent of flooding, and barriers across the river could limit the upstream migration of fish. Higher dry-season flows from upstream dams would retard drainage of the Tonle Sap in the dry season.

Environmental Flow Assessment

Recognition. Environmental flows as a scientific and objective basis for flows assessment is central to the Mekong Agreement. Article 6 requires that mutually acceptable minimum monthly natural flow along the main stem of the Mekong River be maintained during each month of the dry season, and that wet-season flows be great enough to provide for the reversal of flows into the Tonle Sap. Nevertheless, the MRC was attracted to the environmental flow approach, but only if implemented in a broad and holistic manner to cover all in-stream and on-stream water uses, including those essential to protect the ecological conditions on which some populations relied.

While the concept of a holistic environmental flows approach is accepted in principle by the lower Mekong countries, there remains considerable tension and misunderstanding both between countries and within countries over its application in support of the Mekong Agreement. This is because:

1. The enabling, rather than the restrictive or regulatory, aspects of the flow procedures and guidelines as intended by the Mekong Agreement are not yet well-understood by all parties.
2. The IBFM approach and the results based on environmental flows assessments were necessarily complex due to their multidisciplinary nature, and therefore difficult to communicate and agree in a multinational context.
3. Because of time pressures under the WUP, there was a need to agree on flow values in a short period of time without adequate understanding by all parties.

Participation. The first two phases of the IBFM were conducted as technical exercises with limited stakeholder input. The third phase has been designed to be participatory, with special attention to subsistence users who are generally most at risk from hydrological and ecological change since they are heavily reliant on natural systems. However, comprehensive stakeholder participation in a new, multinational institution such as the MRC is complex and still in its infancy. This lack of experience is complicated by the different approaches of the Mekong basin countries toward stakeholder input to major decisions. For example, the most articulate NGOs are found in Thailand, while there is very different stakeholder representation from government and party structures in Lao PDR and Vietnam (World Bank 2006). Thus, stakeholder participation may be expected to be implemented in quite different ways in each of the countries.

Consultations on environmental water requirements were held with government agencies, local and international NGOs, and academics during 2006 and further consultations were planned with provincial agencies and local communities during 2007 (Guttman 2006). However, these latter consultations have now been delayed because of concerns within the MRC that they may lead to undue weight being given to the requirements of traditional water users rather than to development proposals. As a consequence, one NGO (Dore 2006) has complained that "public engagement to this point has been practically nonexistent. Moreover, it has been a struggle to get the reports into the public domain."

Assessment Technique and Data. IBFM occurred in three phases spanning the period of 2004–09. The first phase of the IBFM was essentially a hydrological assessment. The outcomes of this work were a publication on the

hydrology of the Basin (Mekong River Commission 2005) and the initial technical guidelines describing this hydrology in relation to the provisions of Article 6 of the Mekong Agreement. These outputs provided an important contribution to the understanding of flows in the Mekong Basin and the basis for further analysis of flow components.

The second phase went beyond hydrology by assessing the individual environmental, economic, and social benefits and costs of a number of possible future flow regimes. Due mainly to time limitations imposed by the WUP, it was essentially a demonstration run, and was limited to a desk study using already available information supplemented by limited field work. It was carried out by a multidisciplinary team of specialists in environmental flow impact assessment, hydrology, hydraulic and hydrodynamic modeling, geomorphology, water quality, botany, aquatic invertebrates, fisheries, herpetology, ornithology, sociology, and economics. It represents a major achievement in that the methodology was agreed with the member countries at different levels of development and applied over a large river basin at an early stage of infrastructure development.

The third phase, based on the DRIFT procedure, is designed to overcome both the methodological and data limitations of the second phase. The expert panel approach will be replaced by verifiable modeled predictions, and the limited data of the second phase will be augmented by a specially designed, 4-year biophysical and socioeconomic research plan based on the outcomes of the first two phases. The additional research includes hydraulic modeling of selected river reaches, sediment transport modeling, studies of river bank stability and erosion, the dynamics of deep pools, studies of fish, the increased inundation of SiPanDone (a proposed Ramsar site within Lao PDR), and better information on the how the river functions and of its importance in the lives of its people. Almost all of this work remains to be done; the development and calibration of the physical models within the MRC is the most advanced.

These three phases represent a graduated response to implementing an environmental flows approach in cases where there is very limited expertise, data, and time. The first phase met the need for some immediate flows to provide interim protection while more detailed assessments were being carried out. The second phase allowed the existing data and knowledge to be explored so that a targeted research plan could be drawn up and also helped increase local awareness and capacity for EFAs. The third phase, based on field data and stakeholder objectives will, if it proceeds, provide a more defensible set of environmental flow assessments designed to provide sound information to decision makers on possible trade-offs in moving forward with infrastructure development.

Integration. The IBFM is holistic in that it requires the understanding of the interaction between changes in flows within the basin as a result of human activities and the resulting environmental impacts and social and economic benefits and costs. Because of the need to integrate the analysis of water and ecological resources, water quantity and quality, and transboundary issues and concerns, the knowledge base and modeling package of the WUP project incorporated components to allow the direct assessment of transboundary impacts on ecological, social, and economic resources and conditions. This integration of environmental issues with social and economic development was central to the acceptability of the IBFM program. The term "environmental" in describing environmental flows as applied at the MRC generated much misunderstanding. It was viewed by some to be restrictive and limiting of future development, rather than facilitating and enabling better and objective decision making about future development.

Influential. The EFA was technically proficient and well-designed. It produced several important outputs, but has fallen short of influencing the operations of the countries in the basin. The now widely distributed description of the hydrology of the basin was produced

under phase 1 and, under phase 2, the initial assessment indicating there is room for future development if attention was paid to the impacts of changes in flow on downstream water users. The new Basin Development Plan, which started in 2008, is based on the results of the IBFM.

The third phase has been restricted in its stakeholder consultations and production of technical reports because of misunderstanding by some countries and individuals who believe that environmental flow rules will restrict development. Even if it is completed, it is not certain that the MRC has sufficient standing with the governments of the basin to lead to the results being implemented in basin planning and management operations.

Nevertheless, these EFAs have helped widen the understanding within the MRC and, to a lesser extent, within the basin countries of the importance of retaining sufficient flows in the river to maintain vital ecosystem functions.

Lessons

1. The term "environmental flows" can be misunderstood to mean the protection of the environment at the expense of development and human needs. This can bias development agencies and the private sector against the concept to the point where the EFA is ineffective.
2. Technically thorough and scientifically credible EFAs are not sufficient to bring about decisions and implementation of flows for truly sustainable development if there is not strong political and senior managerial support. This is especially true for transboundary rivers, where there is a need for trust among the riparian countries, along with technical competence and a mandate for decision by the transboundary authority.
3. The Mekong Agreement included the maintenance of just two components of the flow regime—minimum dry-season flows and sufficient wet-season flows to reverse flows into Tonle Sap. The subsequent analyses showed that this was too simplistic and that a wider range of flow components needed to be considered in the full third phase analysis. For example, the establishment of a minimum dry-season flow may be too simplistic—upstream developments that increase dry-season flows may be just as environmentally disruptive as development that reduce dry-season flows.
4. The integration of environmental issues with social and economic development was central to the acceptability of the IBFM program; an analysis that was focused just on environmental outcomes would not have been accepted.
5. A broadly based environmental flows assessment using participatory methods in the member countries is highly complex and difficult to communicate in a multinational context. Adequate time and mechanisms are required to communicate and enable understanding of the enabling aspects of the approach, and ownership and mutual benefits by all participants.
6. A phased approach can be effective in establishing EFAs when there is limited expertise and few data available. Interim flow management assessments can be developed and established while skills are developed and data needs are identified and met.
7. Developing a stakeholder consultation process, including the production of information in multiple languages, in transboundary river basins where there are major differences in government attitudes toward inclusion and generally a low level of education is extremely difficult and slow. Technical studies, with only limited stakeholder engagement, may be a sensible interim step while a properly inclusive study is developed.

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Case Study 8. Pangani Basin Environmental Flow Assessment

Background

The Tanzanian Water Utilization and Control Act (1981) proposed devolution of management responsibility to the river- and lake-basin level. The 2002 National Water Policy (Policy Case Study 4) reinforced that requirement. Among other things, it requires that basin-level water resource management plans be developed taking into account "land use-water-environmental linkages." The bill implementing the recommendations in the policy is expected to be passed by the Tanzanian Parliament in 2008. The bill confirms that water resources management plans should be developed at national, basin, catchment, and subcatchment levels and that environmental concerns should be incorporated into the plans.

Tanzania has nine river and lake basins. The first river basin office established in the early 1990s, the Pangani River Basin Office, with support from NORAD was further strengthened during the World Bank-funded River Basin Management and Smallholder Irrigation Improvement project because of the severe water use conflicts facing this river basin (Box 8.1). More recently, the PBWO has received technical assistance from a multiagency program (elaborated below), including for a pioneering basin-wide environmental flow assessment (EFA). This case study describes the conduct of the Pangani basin EFA, which will contribute to the water resource management plan for the Pangani Basin.

The Case Study Description

The Pangani River has two main tributaries; the Kikuletwa rises on the slopes of Mount Meru, and the Ruvu rises on the eastern slopes of Mt. Kilimanjaro. These rivers join at the Nyumba ya Mungu (NYM) reservoir. About 90 percent of the flow of the Pangani River originates from the slopes of the two mountains. Springs in the Kilimanjaro region are an additional source of water. Some of the basin's larger springs contribute as much as 20 m^3/s to the NYM inflows. This proportion becomes vital during the dry season, when rainfall contributions diminish. A small part of the basin (about 5 percent) is transboundary, where the Lumi River flows into Kenya before returning to

Box 8.1 Water Use Conflicts in the Pangani Basin

When the Pangani Falls hydropower station (68MW) was nearing completion in the early 1990s, it was found that inflows into the Nyumba ya Mungu (NYM) regulating reservoir were much lower than predicted because of significantly increased uncontrolled upstream abstractions for irrigation. NORAD, the funder of the power station, asked the government to take strong action to better manage water resources in the Pangani basins. As a result, the government initiated actions to establish the Pangani Basin Water Office. Following the regulation of the river by NYM, a large portion of the largest wetland in the basin—the Kirua swamp—dried up, with loss of fisheries and recessional agriculture. Flows into the estuary have also been affected, but the environmental consequences are not known.

Source: IUCN 2003.

Lake Jipe in Tanzania. Currently there is a dialogue project that promotes cross border cooperation in the management of this ecosystem.[27]

The largest use of water in the basin is for smallholder irrigation, although electricity generation in the lower part of the river is of national importance and contributes nearly 17 percent of the total electricity generated nationally. Fishing and urban and industrial demands are important additional uses of the basin's water. Important wetlands in the basin include Lakes Jipe and Chala and the NYM reservoir, all of which support fisheries. The basin contains wetlands, notably the Kirua swamps to the south of NYM reservoir, although little is known about their biodiversity or their hydrological contributions (IUCN 2003). The Mkomazi Game Reserve, a protected area, is located within the basin.

Principal concerns are the loss of river flow from uncontrolled irrigation and urban demands and the consequent likelihood of conflict between water users. In particular, these upstream water demands have reduced the quantity of water available for the downstream hydropower generation. Flows into Lake Jipe have been reduced, partly because of overabstractions for irrigation in Kenya. Fisheries in the NYM reservoir are under considerable stress due to overfishing, and large portions of the Kirua swamp have dried up as a result of the regulation of water flows issuing from the NYM dam. In addition, reduced inflows plus increased nutrient loads into Lake Jipe have encouraged excessive Typha growth, which restricts fishing and access for stock watering. There has also been a drastic decline in estuary condition and fishery.

Although the water resource management planning required under the bill is yet to commence, the government of Tanzania is conducting a pilot EFA in the Pangani Basin under the direction of the Pangani Basin Water Office and with support from the IUCN Water and Nature Initiative through a grant from the government of the Netherlands, as well as the Global Environment Facility through UNDP. IUCN has selected this basin as one of the 10 demonstration sites for its global Water and Nature Initiative, which has the goal of integrating an ecosystem approach into catchment policies, planning, and management. The EFA is used to explain the ecological and social outcomes of different ways of allocating water. A particular scenario represents a chosen trade-off between resource protection and development. The flow regime within that scenario is the environmental flow needed for ecosystem maintenance. To date, eleven development scenarios have been tested. This information, and the tool, will be used subsequently when the Pangani Basin water resources management plan is developed to help illustrate the implications for the environment of different flow scenarios.

The study is using the downstream response to imposed flow transformation (DRIFT) method (see Case Study 14), modified to suit the limited data, funds, and technical capacity available in the Pangani Basin. The team undertaking the assessment comprises staff from a number of basin water offices, the National Environment Management Council, the Ministry of Water, and academics from the University of Dar es Salaam and other institutions. The team is led by South African consultants. An important objective of this effort is also to strengthen the capacity of local staff in EFA in Tanzania.

The EFA is currently well-advanced, with the river, estuary, and social baseline situation assessments completed. The ecological, social, and economic effects of the eleven flow scenarios have also been completed. Tanzanian water resources and environment professionals have been trained in undertaking EFAs, and stakeholder groups—the basin board, staff of relevant ministries, water user groups, local government officials, policy makers—have been kept informed of

[27] The dialogue is being financially supported by InWent, an international NGO.

progress with the EFA so that they will be ready to interpret results when they are available.

The activity has a budget of about $500,000 and will take between 2 and 3 years to complete (mid-2005 to late 2008).

Drivers

The study resulted from a conjunction of an existing policy requirement, an impending legislative driver—the Water Resources bill—and the opportunity for financial and technical support by an international NGO. IUCN, as part of its Water and Nature Initiative, was looking to undertake a demonstration EFA study in a basin where there was considerable pressure on water and environmental resources, biodiversity and ecosystem goods and services were threatened, people and institutions were willing to act, and there was a capacity to support the implementation of an EFA. The government of Tanzania was keen to support the project, given that it was seeking to build its capacity for undertaking EFAs as part of its basin-level water resources planning.

There was also strong institutional support from the PBWO for the EFA, given the need to include environmental water allocations in the proposed basin-scale water resource plans.

Assessment

Recognition. Environmental flows are recognized as an important part of the river basin planning process in both the National Water Policy and the draft legislation. The Ministry of Water supported the development of an EFA in the Pangani Basin, even before a water resource management plan process was commenced, in an attempt to develop an e-flows methodology for use in other Tanzanian river and lake basins. Both the water management agency (Ministry of Water and Irrigation) and the environment management agency (National Environment Management Council) are supporting the study and have provided staff to join the study team to develop skills in EFA. As a consequence of this EFA, there is growing understanding among the various water-using sectors in the basin about environmental flows.

Although there are some transboundary aspects to flow management in the Pangani Basin, the scope of the pilot EFA is confined to the Pangani River and its main tributaries within Tanzania and does not extend to the transboundary part of the basin.

Participation. The NAWAPO calls for participation of stakeholders in decision making, planning, management, and implementation of water resources plans. The modified DRIFT methodology developed in the Pangani Basin is participatory. Major stakeholder groups (including members and staff from the basin board, ministries, water user groups, local government, policy makers, and the environment sector) have been consulted to identify their dependence on river flows. They have provided input to the scenarios to be tested, and the services and goods they receive from the river have been valued through a specific activity. Consultations were carried out during the social economic studies at two levels within five socioeconomic zones. Focus groups were conducted with old people, village leaders, smallholder irrigators, and extension officers in the area. River health assessment included consultation with residents on ecological information such as fish catches and types.

Subcatchment forums are being established across the basin, starting with the Kikuletwa Subcatchment Forum.[28] These forums will provide opportunities for on-going local participation in water resources decision making (Pangani Basin Water Office 2007).

Environmental objectives. The modified DRIFT is exploratory with the objective of assessing the

[28] This work is supported with funds from the Netherlands Development Organization (SNV).

environmental effects of different scenarios based on possible changes in both water supply (climate change and catchment management) and water demand (allocation options, irrigation and hydropower development, efficiency, population growth). By October 2008, eleven flow scenarios are planned to be evaluated. It is anticipated that the outputs of the EFA work will strongly inform the environmental objectives and outcomes in the final river basin plan required under the upcoming Water Resources Act and guided by the national policy that assigns environmental objectives second priority after basic human needs.

Assessment technique. The DRIFT method is holistic in that it includes many components of the aquatic ecosystem. In the case of the Pangani Basin, this means that the environmental water requirements of rivers, lakes, swamps, and estuaries are included in the assessment. Although the important role of groundwater in the upper basin has not been specifically included, the springs in the Kikuletwa River have been taken into consideration as they strongly affect surface water flow in that river.

The assessment relies on site-specific hydrological, environmental, social and economic data collected in the basin over two years. A simple hydrological systems model, WEAP, based on available data from gauging stations and from water use, is used to predict the flow regimes under the different scenarios and the ecological responses to these flows. A river and estuarine health assessment has been conducted, once during the dry season and once during the wet season, to provide the baseline conditions for the river. A socioeconomic situation assessment was also undertaken to determine the type and extent of use made of the aquatic ecosystems by people living in the catchment. The application was designed and organized by recognized international experts from South Africa, who led a team of Tanzanian water managers and academics.

In addition, a number of specialized scientific reports from experts outside of the team have been completed to provide information for the assessment. They include studies on macroeconomic issues, hydroelectric power generation modeling, climate change, hydraulic modeling, fisheries in the basin, fish and invertebrate life histories, and vegetation.

Integration. DRIFT was specifically designed to integrate environmental outcomes with their social and economic impacts and so is well-suited to developing countries where there is a high dependence on environmental goods and services from rivers. Each scenario assessed during the EFA allocates a different priority to each use (such as hydropower generation, agriculture, and urban and industrial water). The scenarios are not limited to environmental considerations. However, the integration of environmental water needs with other demands for water use in the basin can only occur properly during a planning exercise when all stakeholders can be fully involved. This is best undertaken after the relevant legislation is passed so that the basin water office has a mandate to require the participation of these institutions and communities and make decisions about water allocations.

Cost Effectiveness. The project has a budget of $500,000 over 3 years—a high cost if the EFA is a model of what is to be carried out in the country's other eight river and lake basins. However, there are a number of factors that may have inflated the cost of this assessment, such as the training component to build Tanzanian capacity for carrying out EFAs, and the establishment costs for the country's first EFA, including the development of the modified DRIFT method. Although the cost is substantial, EFAs are still only a small percentage of total development costs for a basin such as the Pangani. They provide a factual basis for making water allocation decisions that share the basin's water equitably.

The project has yet to be completed and so its achievement of objectives within the limits of available information, time, resources, and methodology and its influence on the final river basin plans cannot be assessed yet.

Reporting. To date, the project has produced various draft reports from specialist studies and reports on the hydrological nature of the basin, basin delineation, scenario selection, river health, estuary health, and socioeconomic assessments for the Pangani Basin (IUCN 2007), as well as a summary of all these that synthesizes understanding of the basin. A scenario report is completed in draft form showing the options and trade-offs involved for a range of development and climate change scenarios. The report that provides the river and estuarine health assessment has been summarized in an easily understood "state-of-the-basin" report.

Influential. Given that the EFA study is yet to be completed, and the basin planning exercise has yet to be carried out, it is too early to assess whether this study has influenced the provision of water for environmental benefit or not. However, it has helped develop capacity within Tanzania for conducting EFAs and has helped raise awareness within environmental and water resource agencies of the importance of providing environmental flows.

Staff trained under the Pangani EFA are now being used both in the recently commenced EFA for the Wami River and in the proposed EFA for the Ruaha Basin. However, since these recent EFAs are being supported by other NGOs, they may follow different EFA methods and procedures. While this is not a reflection of this specific EFA project, it illustrates that the influence of the project has been limited at national coordination levels. It is important for a critical review to be conducted of these different methods so that Tanzania benefits by identifying a small number of methods that are both suited to the different circumstances across its river and lake basins and are cost-effective for a nation that faces enormous budgetary constraints.

Lessons

1. The National Water Policy and proposed legislation provide a firm foundation for conducting the EFA, legitimizing the assignment of staff from both water and environment agencies to the study team.
2. There needs to be firm direction at the national level when conducting donor-funded trials of EFA in a developing country, to ensure that the locations chosen and the methods used suit the needs of the country. At present, there are no guidelines or regulations in place in this case to guide the design of these EFA projects. The Pangani EFA work is expected to provide important input into the future river basin planning process and will be an important learning model for informing future EFA work in Tanzania.
3. EFA projects in developing countries can provide opportunities to develop technical skills for undertaking further EFAs (including for project developments) within the country. The Pangani EFA is specifically designed to build these skills across government institutions at the national and basin levels, as well as academic institutions. They are now being utilized in two further EFA studies.
4. The method employed for the EFA in a data-poor developing country needs to balance the cost of implementation with the need to produce environmental flow recommendations that are based on data and defensible. In this case, the experience of the international consultants allowed them to devise a procedure that included the major requirements while limiting the cost. The applicability of DRIFT to less-well-funded basins is yet to be determined.

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Case Study 9. Pioneer Catchment

Background

Under the 1994 Council of Australian Governments (COAG) and subsequent National Water Initiative (NWI) agreements, state and federal governments of Australia agreed on wide-ranging reforms to Australia's water management, including the development of water allocation plans for all Australian catchments and major groundwater systems. The water allocation plans were to include provisions for environmental water.

Under the Water Act 2000, the state of Queensland has drawn up a state-wide water allocation plan and has adopted a 2-level approach within each of its 35 catchments—a Water Resources Plan (WRP) specifying the objectives for meeting the social, environmental, and economic needs of the catchment, and a resource operations plan (ROP) providing the details of how water resources will be managed from day to day to meet these objectives. A monitoring strategy for assessing the ecological outcomes of flow management has also been developed and implemented. These catchment plans are subsidiary legislation under the Water Act and so their provisions carry the force of law.

As of April 2008, Queensland has completed 18 WRPs, and has four more in preparation; it has completed nine ROPs and 10 are being drafted. The Pioneer WRP was approved in December 2002 and the ROP was approved in June 2005.

Case Study Description

The Pioneer planning area (encompassing the Pioneer River, Sandy Creek and Bakers Creek) is a small area, about 2,200 km^2, on the northeast coast of Queensland. Sugarcane is the predominant form of agriculture (although there are other horticultural activities), as well as cattle grazing. Mackay is the major town. Apart from an estuarine wetland, there are no significant wetlands in the area. Four endangered and three 'of concern' ecosystems, 18 rare or threatened plant taxa, some macroinvertebrate and fish species, and two mammals (the water mouse and the Irrawaddy dolphin) occur within the study area. Eungella National Park occupies a small part of the northwest of the Pioneer catchment, and Mt Kinchant Conservation Park covers about half of the Sandy Creek catchment in the southeast of the study area. There are two dams, Teemburra and Kinchant, in the planning area. Mirani, Marian, and Dumbleton Rocks weirs control flows and levels within the Pioneer River. The Teemburra Dam and downstream flow regulators were completed for irirgation useage about 3 years before the study was carried out, and the water licenses were still being taken up as the dam filled. The Pioneer River is not overallocated and the study area is not regarded as being under stress.

The environmental flows study assessed the potential environmental impacts of increased water abstractions in the Pioneer catchment. Environmental water requirements were assessed by a panel of experts through an environmental conditions study (Technical

Advisory Panel 2001a) and an environmental flows report (Technical Advisory Panel 2001b). The former assessed the current environmental conditions, the likely conditions if all present water entitlements were utilized, and the key knowledge gaps. Specialist reports were produced on geomorphology, hydrology, habitat, water quality, aquatic vegetation, riparian vegetation, macroinvertebrates, fish, other vertebrates, estuarine, and marine environments. The flow regime under current and full water abstraction entitlements was modeled with the IQQM model (Technical Advisory Panel 2001c). The environmental flows report quantifies the associations between changes in the flow regime of the waterways and their geomorphological and ecological impacts.

This environmental assessment was then used to inform the decisions in the WRP about water allocation between environmental and various consumptive uses.

Drivers

Two procedural instruments—the 1994 COAG agreement and the Queensland Water Act 2000—acted as the primary drivers for the WRP. The NWI was signed two years after the Pionner catchment WRP was completed and so was not an influence in the conduct of the WRP. Oversight by the National Competition Council (NCC), and subsequently the National Water Commission (NWC), of progress with the water reforms, including the production of water allocation plans, acted as a realistic evaluative driver for the Pioneer WRP.

Professional drivers were also important. While professional associations were not specifically involved, water managers and aquatic scientists throughout Australia were concerned about the state of the country's water resources. There was a widespread acceptance of the need to ensure that environmental services were maintained through environmental water delivered through water allocation plans.

Although not as prominent as other drivers, public opinion was one of the forces behind the inclusion of environmental concerns into these catchment plans. In the early 1990s, there had been widespread public dismay over the degradation of the waterways in the southeast of Australia, especially the Snowy River and the Murray Darling Basin, leading to the COAG agreement. Ten years earlier, a federal government had been defeated largely on environmental issues and politicians were sensitive to public opinions about the environment. This public interest in environmental water issues was maintained throughout the 1990s as shown by the public engagement in water allocation planning.

The Water Act 2000 requires the minister to report annually on the progress of implementing the plan and the results of monitoring for ecological outcomes. These public reports provide a driver for putting the environmental water provisions into practice.

Assessment

Recognition. The Water Act 2000 requires that water resource plans (WRPs) include environmental flows by requiring the minister to consider the "duration, frequency, size and timing of water flows necessary to support natural ecosystems" when developing these plans. However, the act does not state a priority to be accorded to environmental water allocations. Thus, the need to assess environmental flow requirements was inherently part of the preparation of the plan, and a technical advisory panel (TAP) was appointed to carry out the environmental flows assessment at an early stage.

By the time the Pioneer Valley WRP was being produced, sectoral departments were accepting the concept and implementation of environmental flows and there was no significant institutional opposition. The major sectoral institutions (Department of Primary Industry and Fisheries, Environmental Protection Agency, National Parks and Wildlife Service,

Pioneer Valley Water Board) had input into the plan formulation.

Participation. The catchment planning exercise was led by the Queensland Department of Natural Resources and Mines (now Department of Natural Resources and Water), and involved other relevant departments, stakeholders, and interest groups. The planning process was highly participatory, with submissions being sought from the general public when the intention to prepare the plan was first announced and again on release of the draft WRP and ROP. A number of information sessions and meetings were also held with various interest groups in the plan area to allow face-to-face feedback. A separate Community Reference Panel, containing environmental representatives, was formed. It reported directly to the minister.

However, the work of the TAP in assessing the effect of different flow scenarios on the aquatic environment was treated as a technical scientific exercise that did not require stakeholder input. The scenarios were established by the lead department with stakeholder input through the Community Advisory Panel. The TAP's reports were publicly available on the internet and were available for comment during the public consultation phase of the planning. The TAP's reports provide extensive detail on how environmental sustainability was assessed from both fieldwork, existing data and information, and from comparision with comparable rivers in other catchments. The reports were not independently peer reviewed.

A total of 226 submissions on the ROP were received by an independent referral panel formed by the chief executive of the department. The panel considered the submissions and made recommendations to the chief executive on each submission. This process was transparent with a public report being produced (Department of Natural Resources and Water 2005) detailing each submission, the recommendation of the referral panel, and the chief executive's decision with reasons.

Environmental Objectives. The WRP states both the general outcomes sought in the plan and eight specific environmental outcomes:

- to maintain habitats of native plants and animals in watercourses, lakes and springs
- to maintain riparian systems and their functions influencing the riverine ecosystems
- to maintain and favor native plants and animals associated with watercourses, lakes, and springs and riparian zones
- to provide wet-season flow to benefit native plants and animals in estuaries
- to maintain long-term water quality suitable for riverine and estuarine ecosystems
- to maintain existing geomorphic features and processes
- to maintain the capability of one part of the river system to be connected to another through the flow of water (a) throughout the watercourse network, and (b) within the riparian zone, floodplain and watercourses, lakes and springs
- to maintain ecosystem food chains, their balance and the movement of carbon energy

Although these objectives solely deal with fresh and estuarine surface waters, the plan also includes provisions for maintaining ecosystems that are groundwater-dependent and have been subsequently addressed separately.

Assessment technique and data. The environmental flows assessment method used in the plan development—the "benchmark" method (Brizga and others 2002)—is regarded as comprising best practice. It is holistic in that it considers contributions from all stages of the hydrograph and their role in sustaining the major organisms and habitats in the river system. The assessment covered freshwater and estuarine systems, including river pools and wetlands, and groundwater.

The benchmark method relied upon a mixture of data collected during field assessments of the river system,

together with data on the responses of biota to flow conditions in comparable rivers in the region. The flow regime under the two development scenarios was modeled using a daily flow calibrated for the catchment.

The technical advisory panel that undertook the EFA comprised eight professionals with scientific backgrounds in hydrology, geomorphology, and various speciality fields within aquatic ecology. The panel commenced work two years before the decisions were made and so was able to report in time to influence the development of the WRP.

The ecological outcomes of the WRP are monitored through the Environmental Flows Assessment Program (EFAP). Rather than monitoring general parameters, the EFAP process identifies specific ecological assets in each catchment that have critical links to flow. It then develops conceptual and numerical models of the links between the relevant elements of the critical flows and the ecological assets that are to be protected.

Integration. Only two scenarios were assessed in the environmental study—(1) the current water abstraction, and (2) the level of abstraction if all licenses were utilized following the completion of the Teemburra Dam. While, on the surface, this is quite a limited selection of scenarios, it does represent the outer limits of the range of likely levels of water abstraction and so was approriate in this catchment. The scenarios did not include the impacts of climate change on the water resources of the catchment. The EFA was restricted to assessing the environmental aspects of the flow allocation rules and did not include the social and economic aspects. However, the environmental, social, and economic aspects were considered together when the water allocation decisions were made during the WRP preparation.

Cost effectiveness. The cost of conducting the EFA and WRP is not available. However, there are indications that the program is regarded as cost-effective. The procedure has subsequently been used in other Queensland surface water catchments where a WRP has been drawn up. Environmental flow studies have increased in effort through the EFAP and the appointment of regional biologists.

Reporting. The Environmental Conditions Report and the Environmental Flows Report, together with the hydrological modeling reports, provide an extensive and transparent base of scientifically credible information on which to make decisions. These reports are understandable by non-technical people, with the key information contained in maps and diagrams illustrating the predicted impacts of the development scenarios on key organism groups in each river reach and estuary.

While the ROP specifies quite clearly the environmental water requirements—such as minimum flows at different seasons of the year at strategic locations—the way in which these operating rules were derived from the environmental water study, and the extent to which the environmental assets would be protected using these rules, is not clear. This is being addressed through EFAP and annual reporting requirements.

Studies are being undertaken to fill some of the key knowledge gaps so that a better information base is available when the plans are revised in 10 years.

The ROP requires ecological monitoring and assessments that will be used to establish whether the ecological assets with critical links to flow in the catchment are protected with the environmental flow regime in the WRP and ROP. This monitoring program was developed separately using a risk assessment approach (Cottingham and others 2004). The implementation of the ROP and WRP are reported annually by the minister responsible for water. The latest report (Department of Natural Resources and Water 2007) for 2006–07 identifies five priority ecological assets (four fish and one amphibian species) for monitoring because they are at greatest risk from

water development activities. The ecological monitoring strategy will be presented for public consultation within the next year.

Influence. The minister is required to take notice of the study when making his final water allocation decision. In that formal respect, it was influential. The environmental reports, including the EFA, were a significant input to the decision-making process. However, the recommended environmental flows were only partly included in the WRP because of stakeholder and public feedback on future possible allocations.

Lessons

1. This case study illustrates how multiple drivers operate at different time scales and different levels of visibility. Thus, the formal procedural drivers of intergovernment agreements and legislation were actually driven, in turn, by public pressure and, to a lesser extent, by professional recognition that action needed to be taken on environmental water management.
2. The Water Act 2000 legitimized the inclusion of environmental flows in the WRP.
3. While the EFA was a competent, focused and well-reported activity in its own right and there was a legal requirement for the minister to consideer its findings when drawing up the WRP and ROP, and the flow management rules in the ROP are clear, there is no easily discernible link between these rules and the environmental outcomes identified in the WRP.
4. The EFA does not need to be participatory to provide acceptable input to the plannning process. However, the EFA feeds into a highly participatory planning and decision-making process and this may compensate for the absence of stakeholder input to the EFA.
5. The monitoring and public reporting requirements of the Water Act provide drivers that promote the environmental outcomes of the WRP.

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IV. Project Case Studies

Case Study 10. Restoration of the Northern Aral Sea

Background

The Aral Sea is situated in Central Asia. Its catchment lies in seven countries—Tajikistan, Afghanistan, Uzbekistan, Turkmenistan, Kazakhstan, Islamic Republic of Iran, and the Kyrgyz Republic—with two, Kazakhstan and Uzbekistan, bordering the lake. The Amu Darya and the Syr Darya are the two major rivers feeding into the lake. Until the 1960s, the Aral Sea was the world's fourth largest inland water body with a surface area of more than 67,000 km^2. The lake was brackish and supported a major fishery and functioned as a key regional transportation route. The extensive deltas of the two major inflowing rivers sustained diverse flora and fauna, irrigated agriculture, animal husbandry, hunting and trapping, fishing and harvesting of reeds. The deltas and wetlands also provided extremely important foraging and breeding habitat for birds, with the basin being located at the convergence of the Central Asian, Indian, and East African flyways for north-south migratory species.

During the Soviet era, the Amu Darya and Syr Darya were progressively developed for hydropower and irrigation. Water withdrawals almost doubled between 1960 and 2000, with irrigation accounting for 92 percent of the water use in the basin.[29] These agricultural developments stabilized food production in the region and created employment and incomes for some 8 million people who settled in the new area. The water control and irrigation infrastructure still constitutes a major economic asset of the region. However, the majority of the irrigation and hydraulic infrastructure is very inefficient, with on-farm water use efficiency about two to three times lower than that of a well-managed system (World Bank 2001).

The annual inflow from the Amu Darya progressively declined from 56,000 Mm^3 before 1960 to 43,000 Mm^3 in the 1960s, to 17,000 Mm^3 in the 1970s, and to 4,000 Mm^3 in the 1980s (International Lake Environment Committee 2004). This precipitous decline in inflows caused the lake to dry out. The surface area dropped to 17,000 km^2 by 2003, with a loss of volume of approximately 90 percent. Salinity increased to 34 g/l, about equal to seawater. The sea split into a number of parts with the Northern Aral Sea (NAS) and the Large Aral Sea (LAS) being the largest components. A channel has intermittently connected the two with flow from the NAS to the LAS. Inflows from the Syr Darya reduced salinity in the NAS to 19 g/l by 1997. The LAS, however, has continued to shrink and salinity has continued to rise above 40 g/l, with the sea becoming almost biologically dead except in the immediate delta area of the Amu Darya.

The desiccation of the Aral Sea has brought significant environmental, economic, and social problems (World Bank 2001, Global Environment Facility 1998). The environmental problems include:

- shrinkage and salinization of the lake has led to a loss of fish and other aquatic species, with the 24 endemic fish species all becoming extinct

[29] Scientific Information Center, Inter-State Coordination Water Commission 2002. Quoted in International Lake Environment Committee, 2004.

- health and environmental damage from wind-blown salt and sediment from the lake bed into the surrounding district
- soil erosion in the upper basin, which threatens the operation of the irrigation infrastructure
- loss of wetlands and their biodiversity in the deltas of the inflowing rivers because of greatly reduced flows, the virtual elimination of spring floods by the river operations, and the lowering of the NAS level, which has resulted in river bed erosion and lowering of river water levels, making diversions of water for filling of inland delta lakes difficult or even impossible
- declining groundwater levels because of the falling Aral Sea affecting groundwater dependent ecosystems

The legal basis for cooperation between the countries is embryonic, with no agreement for cost sharing of operations and capital and no agreement for information exchange. The Interstate Commission for Water Coordination (ICWC) was formed following the breakup of the Soviet Union to manage annual allocation and scheduling of water releases throughout the Aral Sea Basin. However, the member countries do not always abide by the decisions of the ICWC. It is very difficult to operate the basin coherently under these circumstances and there are regular disagreements on water sharing. There have been tensions between countries in the Syr Darya Basin over the management of the water stored in the Toktogul reservoir, the largest storage in the basin. Kazakhstan and Uzebekistan give priority to irrigation, while the Kyrgyz Republic and Tajikistan give priority to electric power generation.

It is technically and politically impossible to revive the Aral Sea to its former extent. Even if the full flow of the Amu Darya and Syr Darya were allocated to the Aral Sea, it would take many decades to refill because of the shallowness of the sea and its high evaporation rate. Politically it was not possible to divert significant quantities of water to the restoration of the sea because of the large number of people now dependent on the upstream irrigation areas. The only realistic option is to increase inflows using a mix of infrastructure and improved operations and use these flows to restore potentially productive or ecologically important parts of the Aral Sea.

The World Bank and GEF Projects

UNEP, the basin countries, and the World Bank developed the Aral Sea Basin Program (ASBP) to support the ICWC. The GEF's Aral Sea Basin Program Water and Environmental Management Project (1998–2003) and the $64.5 million World Bank-supported Syr Darya Control and Northern Aral Sea Phase-I Project (approved May 2001) contributed to the ASBP. Because of the difficulty of developing coordinated programs with basin countries, the World Bank and other donors have funded a number of independent projects to rehabilitate irrigation infrastructure within the Aral Sea Basin and thereby increase safety for downstream populations, improve irrigation efficiencies, and provide for better environmental outcomes within the irrigation districts and in downstream areas. This case study focuses on the GEF-funded Water and Environmental Management Project and the World Bank-funded Syr Darya Control and Northern Aral Sea Project.

The Water and Environmental Management Project had the objectives of (a) stabilizing the environment; (b) rehabilitating the disaster zone around the sea; (c) improving the management of international waters; and (d) building the capacity of regional institutions.

The project was completed in 2003 (World Bank 2004). Analyses conducted under the project showed that additional water of suitable quality can be made available to restore the deltas of the Amu and Syr Darya by improving water management throughout the basin. In addition, Lake Sudoche (a 40,000 hectare delta lake on the border of the LAS), which had become desiccated due to poor water management, was restored through engineering works that diverted

a mix of saline drainage water and fresh river water to the lake. The restoration appears to have fully met its biodiversity and social/economic targets, with the wetland attracting various birds, including some endangered species. Economic benefits were also gained as the local population is able to use the restored area for fishing, hunting, and grazing. The success of the Lake Sudoche restoration led the government of Uzbekistan to continue the program of wetland restoration with three new projects in the Amu Darya delta.

However, the project was overly ambitious in other areas where its objectives were not consistent with its modest financing. Thus, the project identified a target of a 15 percent reduction in the water withdrawn for irrigation as one of its targets. Such a significant reduction in water use would require a major investment in rehabilitation of irrigation and drainage systems as well as capacity building, public awareness, and technical assistance, well beyond the $9.1million budget of this project.

The subsequent World Bank-funded Syr Darya Control and Northern Aral Sea Project provided a $64.5million loan to the Republic of Kazakhstan, with the objectives of:

- sustaining and increasing agriculture (including livestock) and fish production in the Syr Darya Basin in Kazakhstan
- securing the existence of the NAS and improving the ecological/environmental conditions in the delta and around NAS, leading to improved human and health and conservation of biodiversity

The first objective is being achieved through rehabilitation of the deteriorating hydraulic infrastructure within the basin and providing reliable water to irrigated agriculture; the second is to be achieved by creating a permanent dike across the Berg Strait between the NAS and the LAS to capture inflows through the Syr Darya Delta and isolate the NAS from the highly saline LAS, together with rehabilitation of hydraulic infrastructure and improved operations of upstream dams. The project design included a series of subprojects to increase freshwater inflows by 1,300 Mm^3 to the Syr Darya delta wetlands and lakes through the construction and rehabilitation of infrastructure along the Syr Darya; in fact, the actual inflows turned out to be much larger because excess water that was previously diverted to the desert was retained and passed on to the Aral Sea, and winter flows that had previously caused flooding were able to be retained within the channel and delivered to the Sea.[30]

The dyke was completed in August 2005. It was originally predicted that it would take 5 to 10 years to fill the NAS. Instead, the NAS's level has risen more swiftly than expected to 38m, from a low of less than 30m, because of the additional water. The additional inflows eliminated the flooding that used to occur along the Syr Darya and contributed to improved relations between Kazakhstan and the Kyrgyz Republic. The returning waters have allowed fishing to expand in the lake, including an export-oriented commercial fishery. The new and rehabilitated infrastructure along the Syr Darya has also improved irrigation of riparian farmlands and partially restored lakes in the Syr Darya delta, which are important for fishing.

Overall, the restoration of the NAS has proven to be remarkably successful in spite of the initial widespread publicity about the impossibility of restoring this heavily degraded system. The partial recovery of the ecosystem has received extensive press coverage.[31]

[30] An ice cap formed on the Syr Darya during winter and, when it broke because of fluctuations in flow rates, formed large blocks of ice that blocked the channel and caused lateral flooding. Once the upstream dams were rehabilitated, they could be operated to allow the ice cap to be formed high enough to permit large volumes to flow at a continuous rate so that the ice cap did not break up.
[31] "As a Sea Rises, So Do Hopes for Fish, Jobs and Riches," New York Times, April 6, 2006; "Kazakhs get Loan to Save Aral Sea," BBC, April 9, 2007.

Drivers

There had been numerous ineffective investigations and studies prior to the Syr Darya Control and Northern Aral Sea project. The main driver for this project came from the determination of the local populations to restore their livelihoods and the support of the government of the Republic of Kazakhstan.

Widespread publicity, led by international NGOs, about the deterioration of the Aral Sea raised awareness of the plight of the Aral Sea. However, the NGOs did little to actually bring about the restoration.

The projects triggered a number of World Bank safeguard policies, including the EA policy (OP/BP4.01). However, in this case these safeguard policies did not act as drivers for the development of environmental flows because the restoration of these environmentally degraded areas were already primary objectives for the projects.

Assessment

Recognition. The need for flows to maintain the Aral Sea ecosystem and all the productive activities that depended on it was not recognized by the Soviet government at the time the upstream developments were being undertaken. The potential problems were recognized by some scientists, but their views were ignored.

However, after the breakup of the Soviet Union, the government of the Republic of Kazakhstan was fully aware of the benefits of restoring the NAS. The environmental flows component of most projects is designed to mitigate some deleterious aspect of the main objective of the project. However, this project was quite different. Its main objective was to use increased downstream flows to restore the NAS ecosystem. However, the increased flows were not labeled as environmental flows because there was such a close connection between restoring the downstream aquatic environment and restoring people's livelihoods that the increased flows were regarded as simply an improved water allocation.

Participation. The GEF-funded Water and Environmental Management Project was a transboundary project requiring the participation of five governments. However, there were difficulties in getting adequate cooperation between the regional governments and, in some instances, between governments and donor partners. The national components of the project, including the restoration of Lake Sudoche, were more successful partly because they did not require cooperation between governments.

The ICR for the GEF-funded project noted that the project design did not place much emphasis on public participation, except in the components that sponsored a competition for innovative water savings proposals from farmers, and attempted to change water users' behaviors by creating public awareness of the urgent need to conserve water. However, neither component worked well. The first had such high overhead costs that it was terminated early, and the second was ineffective because the major causes of inefficient water use were dilapidated infrastructure and poor government policies. Consequently, the second component was scaled down and the level of public involvement was reduced to be more commensurate with the capacities of people who had little experience of individual contributions to national issues.

The Syr Darya Control and Northern Aral Sea project included a component to increase the capacity of national authorities and agencies in river basin management, including promotion of public participation in water allocation and management process in the Kazakhstan part of the Basin through a Basin Consultative Group. The group was intended to ensure stakeholder participation in water allocation decisions affecting the major water users, such as irrigation command areas, fresh water lakes, hayfields and the NAS. In fact, the group was not formed because the authorities were able to undertake the

necessary consultations without the need of a special committee.

The project itself was developed through extensive consultation, meetings, and workshops with government institutions. Consultations were also carried out with civil society and stakeholders at local and regional levels, with sector institutions, environmental representatives, media, local and international NGOs, and with representatives of international organizations such as UNDP. The PAD comments that there was very strong ownership of the project at the local level and that the local population became frustrated at what they saw as too much consultation and too little action on the ground.

Assessment. In most projects, environmental flows are included to mitigate the deleterious downstream effects of a development proposal. This project is different in that the return of flows to the Aral Sea was one of the prime project objectives because of the environmental, social, and economic benefits from restoring the sea. EFA techniques, which are designed to identify environmental flow requirements in the face of other proposed uses of the water, were not directly relevant for this project. Even so, the EIA that was undertaken as part of project preparation predicted the likely changes in lake level (an additional average inflow of 1,300 Mm^3/year and a water level between 39.2 and 42.0 m asl) and effects on fish species composition. It predicted that the NAS fisheries production will be dominated by species that at present are largely confined to delta lakes and the Syr Darya, provided that the fish could migrate from the NAS to the spawning grounds in the delta and its wetlands and lakes. Consequently, the regulatory structures between the NAS and the spawning grounds were revised to allow for fish passage. The effects on other environmental components were only predicted in general terms "The effects on biodiversity in the NAS will be mainly positive: desalinization, restoration of flora and habitat for resident and migratory birds and other species in combination with the restoration of the NAS as a staging area for migrating birds, will all contribute to biodiversity conservation" (ARCADIS Euroconsult 2000).

The environmental assessment recommended that a monitoring program be instituted both during project implementation and subsequently to track the recovery progress. The program would monitor primarily hydrological indicators and some social/economic indicators. Impacts on biodiversity and fisheries catches are the recommended biological indicators. However, the newly formed Kazakhstan Ministry of Natural Resources and Environmental Protection, which would be responsible for monitoring and enforcement activities, was recognized to be weak and to lack the capacity to monitor project activities. A $500,000 management and training program has been included in the project to help improve skills within the ministry.

Integration. The environmental assessment predicted social and economic improvements for local populations following the recovery of some of the NAS and delta ecosystems. However, these benefits were not analyzed in depth and were not closely integrated into the environmental assessment. In spite of this lack of analysis of the integration between the biophysical outcomes and the social and economic benefits, the social and economic benefits were qualitatively clear and the lack of detailed analysis did not constitute a significant deficiency.

Cost effectiveness. While the recovery of the NAS has occurred faster than anticipated and there have already been some environmental and economic benefits, it is too early to assess the cost effectiveness of the project.

Influential. The successful restoration of Lake Sudoche has been influential in encouraging the government of Uzbekistan to extend the number of lakes to be rehabilitated. The rehabilitation of the NAS has contributed to improved water sharing between Kazakhstan and the Kyrgyz Republic, and the discharge of the winter flows from the dams in the headwaters of the Syr Darya to the Aral Sea has overcome the tensions

that used to arise from flooding within Kazakhstan when the Syr Darya became blocked with ice. The rapid success of the project has also contributed to an increase in confidence within Kazakhstan to tackle other environmental degradation.

Lessons

1. The NAS was restored through a mixture of infrastructure (the Berg Strait dike); improved operations (avoiding ice blockages and spillage to the desert); and rehabilitation of dam operating structures. With a project of this size it is not possible to provide the volumes of water needed without combining engineering with improved efficiency of water use.
2. Success breeds confidence. The successful restoration of Lake Sudoche and the clear benefits to the local people have encouraged the government of Uzbekistan to unilaterally undertake additional lake restoration projects. The partial, but rapid, restoration of the NAS has also encouraged the government of Kazakhstan to consider other restoration.
3. The environmental restoration of Lake Sudoche and the NAS has brought about obvious social and economic benefits and so received strong support from local populations. The impact from the degradation of these resources was so profound that there was no dispute about restoring the aquatic environment—in fact, the flows were regarded as economic/social flows rather than environmental flows.
4. The widespread publicity generated by international NGOs turned the problems of the Aral Sea into an international cause. However, it was the determination of the local population, supported by the government of Kazakhstan and the World Bank's funding, that really drove the rehabilitation.

Acknowledgments

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Case Study 11. Berg Water Project

Background

The Berg Water Project (BWP) was the first large water resources infrastructure development project in South Africa to be designed, constructed, and operated within the framework of the National Water Act (No. 36, 1998), requiring that water be provided for human needs and an ecological reserve (Case Study 3), and in accordance with the guidelines of the World Commission on Dams. It represents the culmination of a detailed options analysis carried out by the Department of Water Affairs and Forestry (DWAF) over a 14-year period to identify appropriate measures to address the water requirements of the Western Cape of South Africa. Impounded on July 26, 2007, it is the first bulk water resource development project directly linked to water demand management in South Africa.

The Berg River[32] is the only major river within the Berg Water Management Area (Berg-WMA), an area of 13 000 km^2 in the southwestern corner of South Africa that supports a strong and diversified economy. The gross economic production of the Berg WMA was R63,8 bn in 1997, 12 billion of which came from the Berg River catchment (2.5 percent of RSA's GDP). Economic activities are dominated by industrial and other activities in the Cape Town Metropolitan Area, intensive vineyards and fruit growing under sophisticated irrigation in mountain valley's and foothills, and dryland wheat cultivation in the lower reaches.

The Berg-WMA is situated within the Cape Floral Kingdom, which covers an area of approximately 90,000 km^2. It was recognized in 2004 as a World Heritage Site due to its incredible diversity and levels of endemism. Comprising only 6 percent of the area of southern Africa, it has more than 9,000 plant species, 70 percent of which are endemic, accounting for half the species on the subcontinent and almost one in five of all plant species in Africa. This makes it the smallest yet most diverse of the world's six plant kingdoms. Similar levels of endemism are observed among other groups. The major vegetation types found in the area of the Berg Water Project are well-represented within the Cape Floral Kingdom and their status is classified as least threatened.

The Berg River Dam watershed is not pristine and has been intensively utilized in historical and prehistorical periods. Since the 19th century, the area was used for stock farming, while in prehistorical periods the indigenous Khoekhoe used the valley for grazing. In 1903, a state pine forest was established and covered the entire valley. In addition to the forestry and a trout farm located within the dam basin area, there was also

[32] The Berg River may be divided into a number of major geomorphological zones: (1) *Source Zone*, including cliff waterfalls and sponges; (2) *Mountain Headwater Stream*, with steep, rocky slopes; (3) *Mountain Stream*, with fast-flowing streams with a rapid fall; (4) *Transitional River*, which is an intermediate zone between mountain stream and upper foothill river; (5) *Upper Foothill River*, where the riverbed is less steep, more stable, and comprises mixed cobble and instream vegetation; (6) *Lower Foothill River*, which is similar to the upper foothill river, but has significantly more sedimentation comprising mainly quartzitic sand; (7*) Lowland River*, where the river now adopts a shallow gradient with cobbled runs being replaced with a soft-bottomed system made up of sand and/or clay. The Berg Water Project is located within the source and upper foothill river zones.

water resource infrastructure within the area prior to the construction of the Berg River Dam. Thus the area has been extensively transformed. At the time of the implementation of the Berg Water Project, the area was entirely and densely covered in alien vegetation.

Despite the area being exposed to historically intensive land use, the conservation status of the quaternary catchment is rated as very high. The conservation value was based on the underpinning ecosystem processes and the likely presence of particular bird and amphibian species, but particularly fish species, which is a priority conservation group for this area. Of the 19 indigenous fish species in the Cape, 16 are endemic and four are historically found in the Berg River catchment. The Berg-Breede White Fish (*Barbus andrewi*) is now extinct in the catchment, while the Berg River redfin (*Pseudobarbus burgi*) is critically endangered, and the Cape galaxias (*Galaxias zebratus*) and Cape kurper (*Sandelia capensis*) are near threatened. The upper reaches of the Berg River along with a limited number of tributaries are the last refuge areas where indigenous fish are still relatively abundant.

An assessment of the state of the river (River Health Program 2004) shows that, although the river is moderately modified (Table 11.1), the overall condition is "good".Since the 1980s, cumulative impacts associated with encroachment of alien vegetation, urban and agricultural development, and a number of diversion weirs have resulted in deteriorating water quality, and elevated summer flows as a result of water transferred from the Breede River into the Upper Berg River. The Berg River estuary is the second most important in South Africa in terms of national conservation importance, providing important recreational and tourism opportunities.

The Berg Water Project

The BWP is considered essential if the Greater Cape Metropolitan area continues to experience strong economic and population growth and predicted water shortages are to be avoided. The yield of all existing sources within the Western Cape Water Supply System (WCWSS) is 475 Mm^3/a. The ZAR1.55 billion BWP (including the Dam), located in the upper reaches of the Berg River, is designed to capture winter rainfall and store it for supply to the City of Cape Town (CCT) during the dry summer months, augmenting the available yield in the WCWS by 81 Mm^3 (18 percent) to 523 Mm^3/a. Total unrestricted water use in the 2005/06 year was estimated to be 465 Mm^3/a and predicted to grow to 560 Mm^3/a by 2011 under a high-growth scenario. The catchment above the Berg River dam site, although constituting only 7 percent of the WMA, contributes 14 percent of the runoff because of the high rainfall in the upper mountainous area of the WMA. The dam's capacity is equivalent to the mean annual runoff.

The BWP includes the Berg River Dam, a 2.5 km pipeline from the dam to the Dasbos inlet, allowing water to be pumped from the dam into the Riviersonderend Tunnel System, and the supplement scheme. Water will be pumped either directly into the

Table 11.1 Condition Ratings for the Berg River

	CONDITION RATING					
INDEX	**Above Dam**	**Below Dam**	**Jim Fouche**	**Paarl**	**Hermon**	**Lower Berg**
Habitat integrity	Natural to Fair	Good to Poor	Fair	Poor to Poor	Fair to Poor	Fair to Poor
In-stream geomorphology	Natural	Good	Fair	Poor	Fair	Fair
Riparian vegetation	Poor	Poor	Poor	Poor	Fair	Poor
Invertebrates	Natural	Good	Fair	Poor	Fair	Fair
Fish	Good	Fair	Fair	Poor	Poor	Poor
Water quality	Natural	Good	Good	Poor	Fair	Fair
Desired health (overall)	Natural	Good	Fair	Fair	Fair	Fair

Source: River Health Program 2004.

Riviersonderend Tunnel System where it can be gravity fed to the City of Cape Town or pumped into the Theewaterskloof Dam in the Breede River catchment for storage. The dam's design also includes a 63m high multilevel inlet tower that allows for environmental releases of up to 200m^3/s to mimic floods and the management of downstream water quality. The streams and runoff flowing into the Berg River Dam provide a sustained yield of approximately 56 Mm^3/a. The supplement scheme will increase this yield from 56 to 81 Mm^3/a through a weir, 4ha balancing dam, and pump station that allows pumping of a portion of the winter flows to the Berg River Dam via a 10km pipeline.

The process of identifying appropriate measures to address the water requirements of the Western Cape of South Africa started in 1989 when the DWAF initiated the Western Cape Systems Analysis (WCSA) to determine future needs, water resources availability, and appropriate measures to address water shortages. The options identified underwent public consultation in 1996 from which 12 additional schemes were identified for further investigation. One of the options considered was the development of the Berg River Dam (then called Skuifraam Dam) and the "supplement scheme."

Environmental impact reports were completed for the Berg River Dam in November, 1996, and for the supplement scheme in October, 1997. These included a preliminary reserve determination for the river downstream of the dam but not for the estuary. On the basis of these submissions, a Record of Decision was issued by the Department of Environmental Affairs and Tourism in May 1999 with a seven-year authorization period. The RoD provides authorization subject to three sets of conditions. These include six general conditions, seven relating to the environmental management plan (EMP), and six relating specifically to the ecological reserve, defined in the RoD in accordance with the National Water Act (Act No. 36, 1998). This included a requirement that the design did not foreclose the option of releasing floods in excess of the "damage control" instream flow requirements[33] (IFR), that any changes in the magnitude of the IFR require the authorization from the DEAT and the DEAT's approval of the detailed water release patterns. Further provisions were included in the RoD to accommodate any subsequent revisions of the reserve based on the findings of the monitoring program.

In April 2002, the cabinet approved the implementation of BWP. The original proposal had been withheld while the national government assessed water conservation, demand management, and alternative supply options. The decision to augment supply was conditional upon the CCT reducing the demand for water by 20 percent by the year 2020. The BWP Raw Water Supply Agreement between the DWAF and the CCT specifically commits the CCT to achieving the "low water demand curve."

In response, the CCT has been implementing a Comprehensive Water Conservation and Water Demand Management Programme. This includes the reuse of effluent from wastewater treatment works, water conservation and demand management measures, restructuring of water tariffs, and bans and restrictions on nonessential water uses. As part of the demand measures, the TCTA awarded a ZAR21 million, eight-year contract to the Working for Water Programme to facilitate the removal of alien vegetation from the Berg River catchments. This is expected to significantly increase the amount of runoff available for storage in the dam. In 2005/6, the targets established by the DWAF in terms of the "low water demand curve" were exceeded by 13 percent. Continued success in implementing water demand measures could delay any further interventions until 2015.

[33] The term instream flow requirement (IFR) is commonly used in South Africa, while other international terms such as environmental flow and ecological flow are also used. All these terms are used synonymously and refer to the collective amount of water needed to sustain healthy, natural ecosystems based on scientific studies.

In May 2002, the Minister of Water Affairs and Forestry directed the Trans-Caledon Tunnel Authority (TCTA) to fund and implement the BWP as an implementing agency of the DWAF (Box 11.1).

The issue of environmental flows was addressed at various stages during design, construction, and operation of the dam. Preliminary assessments of the environmental flow requirements were carried out in 1992/93 as part of prefeasibility investigations for the Skuifraam Dam and again in 1996 as part of the feasibility studies. These initial approaches were based on early versions of the building block method (Case Study 7) and relied on specialist studies to explore the impact of flow reductions on the riverine environment. A series of workshops and specialist meetings during the following decade focused on more detailed specialist inputs and the assessment of different scenarios undertaken by a range of stakeholders.

This process resulted in the recommendation of a reserve determination based on a high confidence, preliminary determination for the Upper Berg. The preliminary ecological category was set as category C. This represents a moderately modified state where a loss and change of natural habitat and biota have occurred, but where the basic ecosystem functions are still predominantly unchanged. Preliminary determination of the reserve was set at 31.1 percent of the mean annual runoff of 141.683 Mm^3. A comprehensive determination of the reserve, including that for the estuary, is expected following finalization of the three-year Berg River monitoring program.

Drivers

Professional drivers were important in both the early and later stages of planning for the Skuifraam Dam. During the late 1980s and early 1990s, there had been an increasing recognition among water resource planners and ecologists of the need for scientifically based approaches to determining environmental flows (Case Study 4) and this had led to the initial estimates of instream flow requirements for the upper Berg River.

The political transition in South Africa provided a unique opportunity for translation of these professional drivers into legislative provisions that provided stronger protection for aquatic ecosystems. The 1998 National Water Act gave legal standing and legitimacy to the

Box 11.1 The Trans-Caledon Tunnel Authority (TCTA)

The TCTA is a public entity established in October 1986, with the signing of the Treaty between Lesotho and South Africa, to facilitate ancillary developments in South Africa associated with the Lesotho Highlands Water Project (LHWP).

TCTA was legislatively incorporated into the National Water Act in 1998 as a body established under Section 103(2) to implement international agreements in respect of the management and development of water resources shared with neighboring countries, and on regional cooperation over water resources. Under the act, the Minister of Water Affairs and Forestry can allocate additional functions insofar as these do not compromise the ability to discharge primary functions, including, but not limited to, management services, financial services, training and other support services. A Revised Establishment Notice published in March 2000 amended the TCTA's mandate to assume responsibility for all additional projects in the water sector. In May 2002, TCTA was directed in terms of Section 103(2) of the National Water Act to fund and implement BWP as the agent for the DWAF.

In 2004, TCTA was further directed to fund and implement the ZAR2.5 billion Vaal Pipeline Project to meet the rising water demands of Eskom and Sasol in the Mpumalanga Highveld region. In August 2005, DWAF presented to the Parliament Water and Forestry Portfolio Committee the business case for the creation of an agency for the management and development of national water resource infrastructure. This may lead to the merger of TCTA with the DWAF's National Water Resource Infrastructure Branch to form the National Water Resource Infrastructure Agency. The NWRIA is intended to have responsibility for the operations and maintenance of South Africa's major national dams and water transfer schemes and the implementation and funding of social and economic bulk water infrastructure

professional judgment and methodologies developed over the previous decade. The legal framework along with progressive leadership was central to maintaining the momentum and ensuring compliance with environmental water requirements during the design, construction, and operation.

The global significance of the Cape Floral Region has also been an important indirect driver in the development agenda of the Western Cape Region. Although the development of the Berg River dam did not directly threaten the Floral Region, the public awareness of the importance of good environmental management produced an enabling environment for conservation-oriented measures such as those contained within the environmental flow assessments. Government authorities, local and international conservation agencies, water resource professionals, and local NGOs have invested significant efforts into providing a solid scientific basis that highlights the importance of the Cape region, including its rivers and estuaries, and the benefits that these have at the community level through tourism and natural-resource-based activities. Recognition of these important linkages has increased public awareness, both locally and internationally, on the need to ensure environmentally sustainable solutions to development needs and an enabling framework for environmental flows.

Assessment

Recognition. Although there was broad recognition of the need to provide water for downstream environments, agreeing on the reserve has not been easy. Using a scenario-based approach to facilitate discussion among principal stakeholders, the preliminary reserve reflects a negotiated agreement among the principal stakeholders on the allocation of water to ensure sustainable allocation among competing demands. This agreement included reductions in the recommended peak flood flows and increases in summer low flows intended to facilitate a compromise among prior established uses.

Downstream irrigators have historically held riparian water rights and have had to adapt to the changing legal framework governing water use and primacy of the ecological reserve. There have also been significant challenges for DWAF to reorient itself in line with the rights-based approach that recognizes the reserve as a primary right (the only right in law), while continuing to ensure the development of water resources in support of social and economic growth. The initial motivations from the ecologists for the proposed peak flood flows were deemed by the DWAF to be not technically feasible. Similarly, the ecologists have been forced to refine the methodologies for determining environmental flows. This is acknowledged through the adoption of scenario-based approaches that allow weighted consideration of the options to address sometimes competing social needs and economic demands.

Participation. Arrival at the decision to proceed with the BWP, and the project itself, has been through a detailed consultative process. This was initiated through the WCSA, and the BWP has since established a number of participatory mechanisms to include a wide range of stakeholders. An Environmental Monitoring Committee (EMC) was established to encourage participative monitoring of the conditions specified in the RoD and the performance and implementation of the EMP. The EMC includes representatives from the DWAF, TCTA, civil society, water users, local communities, and consultants for the project.

Broad-based participation in the reserve determination itself was limited. The initial process of determining the reserve through the BBM-based approach focused only on water for the environment and involved specialist inputs facilitated through a series of workshops. These were limited to professionals within the DWAF, water resource engineers, and ecologists. However, as methodologies for reserve determination developed and scenario-based approaches were adopted, these came to reflect negotiated agreements among a larger number of stakeholders on the allocation of water. This wider participation was also facilitated by the increased

recognition of the reserve following the provisions of the act and the explicit requirement to address the social component within the same planning framework.

The increased participation of a range of diverse stakeholders has often been complicated by the exclusionary nature of professional dialogue. Engineers and ecologists have had to adapt to different terminology and approaches, accept differences in the resolution of their respective science disciplines, and reach agreement on the principles encapsulated in the provisions of the legislation. This process has often been facilitated by one, or a small number of, professionals who are vital to bridging the disciplinary divide and facilitating a mutual understanding. For example, ecological arguments for flood flows to maintain important ecosystem processes within the system were more successful once translated into more engineering orientated, sediment transport models and associated with sedimentation and the frequency and magnitude of flood risks.

Assessment Technique and Scientific Data. Preliminary determination of the ecological reserve was built on a number of earlier estimates of environmental water requirements. The method for determining the IFRs in the early 1990s was based on an early version of the building block methodology that was under development in South Africa at that time (Case Study 6). The recommended flow regime from that assessment included three freshets per annum and four controlled floods. However, the IFR was only determined for one "critical reach" and lacked hydraulic data that had been specifically designed to help determine the IFR.

A workshop was undertaken at the feasibility stage in 1996 to reassess and/or refine the recommended IFRs. Three characteristic reaches were identified, although only two were assessed due to the extreme degradation of the third. Determination of the reserve was based on specialist studies undertaken for vegetation, fish, macro-invertebrates, water quality and geomorphology. Data inputs to the determination process were also provided on the hydrology, habitat integrity, and biodiversity conservation importance. While the recommended flow regime was similar to that previously recommended, it proposed slightly higher flood requirements, with a medium-sized flood of 70–100 m^3/s in June and a larger release of 100–220 m^3/s between July and September.

Subsequent hydrological yield analyses identified that the IFR could not be met without affecting the yield and relative costs of the water supplied from the scheme. Consequently, scenario meetings were held to compare flow regimes more suited to off-stream users with the recommended IFR and assess the affects of these on the river ecosystem. A "damage control" scenario was adopted where environmental flows were reduced from the recommended IFR in a way that was thought to have the least impact on the river ecosystem. Changes included a reduction in the volume of the recommended flood flows and an increase in the frequency and duration of summer irrigation releases that were up to four times the capping flows, resulting in permanently elevated flow conditions in the Berg River.

Two additional workshops were convened in 1998 and 2001 to assess the design criteria for the outlet works after it was acknowledged that additional work was required to deepen the scientific understanding of the relationship between ecological processes and a particular flow magnitude or frequency. Concerns had also been raised on the potential impact of the recommended flood releases (200m^3/s) on the project costs and dam safety. The Record of Decision specifically required that the design be such that it did not foreclose the option of releasing floods in excess of the "damage control" IFR flood regime, and so this information was necessary to inform the design of the dam. Consequently, provisions were included in the design of the dam and the diversion conduit for both low flow and flood releases. A 5.5m diameter concrete tunnel through the dam wall, which was used during construction for river diversion, is now used for peak flood releases. The operating rules provide for the required volumes, frequency, and variability of water to be released from the dam to maintain the flow and integrity of the Berg River downstream of the dam.

Consultations conducted in 1996 also recognized the need for a detailed monitoring program to provide the basis for an adaptive management framework to facilitate implementation of the reserve. This was reflected in the conditions outlined in the RoD, which required sufficient baseline information to be collected prior to completion of the dam to assess the effectiveness of the environmental flows. If the monitoring demonstrates that the BWP has an unacceptable ecological affect on the river or estuary, the RoD requires that the environmental flows be revised.

The baseline monitoring program, initiated in 2002, included eight specialist studies for the riverine environment, nine specialist studies for the estuary, and a series of general catchment reports that included groundwater elements. The aim was to monitor the effects of the artificial flow regime imposed downstream of the dam as required under the conditions laid forth in the RoD. The objectives of this program were to:

- confirm compliance with the IFR
- verify the nature and accuracy of the changes to the ecosystem that were predicted as a result of the dam
- determine the effectiveness of the environmental flow releases in terms of their predicted effects on ecosystem processes
- facilitate implementation of adaptive management where undesirable and/or unpredicted changes in ecosystem characteristics are detected; such adaptive management would seek to minimize the impacts of these changes

Data collection was completed in 2005 and a conceptual model was developed for determining and managing changes brought about by the BWP. The program focused on the flow regime and the physical, chemical, and biological characteristics that the environmental flow is intended to support. Among other elements, the program included sediment transport monitoring and hydraulic and salinity modeling of the Berg River estuary. This comprehensive monitoring provides the baseline against which the project's environmental allocations are assessed, and will be used to establish a comprehensive reserve for both the river and the estuary. The issue of appropriate flood releases is now under discussion in the light of advances in environmental flow assessment methodologies, the information available from the three-year baseline monitoring program, and concerns over water quality (salinity is a key issue in the lower reaches of the Berg River).

Integration. The environmental flow determinations were integrated with the environmental assessments during the feasibility stage and the RoD issued by the Department of Environmental Affairs and Tourism in 1999 covers implementation of the EMP and the reserve determination. Following initial determinations, there was an ongoing process of consultation on integrating the recommended flow regime into the design parameters for the dam.

The preliminary freshwater requirements for the Berg River estuary were investigated at a workshop in 1993 as part of the Western Cape System Analysis. While it was acknowledged the estuary was an important and integral part of the Berg River, it was not included in the preliminary determination because of inadequate baseline data and information available and because the workshop concluded that the contribution of flows from the upper reaches of the Berg River to the estuary was low enough for the BWP not to impact on the estuary significantly (in comparison to the contribution of flows from the tributaries and the middle and lower reaches). Subsequent concerns have seen the estuarine environment included under the broader monitoring program and included in the comprehensive determination, which included estimates of the estuarine reserve in 2008.

Cost Effective. Several concerns were raised during feasibility studies in 1996 that the cost of incorporating the required environmental flow requirements into the dam's design and operation would reduce the effective

yield, reducing the number of users and increasing the unit cost of water. This would reduce the availability of capital to fund other social needs and bring forward the date for new schemes. However, ecologists and geomorphologists identified the deterioration of the river condition in the absence of adequate sediment-sorting floods and argued for inclusion of provisions enabling flood releases of at least 160m^3/s. Estimates at the time suggested that the additional cost to address the recommended peak flood flows of 160m^3/s would result in an additional 20 percent to the overall cost of the dam. A detailed project completion report is being prepared, including a detailed cost breakdown, and will be issued by the end of 2009.

To facilitate determination and setting of the reserve, an economic analysis was undertaken to assess the impact of four scenarios on the yield and relative cost of water (Table 11.2). Final agreement on the design parameters and acceptance of the peak flood flows was facilitated by recognition that these floods would help remove sediments and therefore reduce the potential for flooding of urban and industrial areas downstream, particularly in the Paarl area.

Reporting. The process of arriving at and then implementing the BWP has produced a large number of specialized reports covering a wide range of different topics relating to the sustainable development and use of the water resources in the Berg-WMA. This process has been linked to a detailed options assessment for providing water to the CCT and developed over a unique period of political transition. This in itself has brought about significant changes in the legal framework for the management and development of water resources in South Africa. While the legal provisions providing for the access to information ensures that this is available upon request, specific reports and detailed information is difficult to track and trace and so not readily accessible. Recognizing this, and the value of the lessons that can be derived from the process for determining the reserve, the TCTA will commission as part of the project closure reporting process a detailed review to reflect on the experience and derive the lessons learned.

Influential. The determination of environmental flows for the BWP has had a direct influence on the design and operation of the dam. However, the process of arriving at an environmental flow regime has also had broader significance. First, the BWP is the first large, water resources infrastructure development project in South Africa to be designed, constructed, and operated within the framework of the National Water Act. The provisions of the act are viewed globally as being at the forefront of efforts to ensure sustainable water resources use through recognition of the reserve, and so will have an important global impact.

Lessons

1. The Berg Water Project was implemented within the framework of renewed focus on the development of bulk water supply infrastructure provided by the World Commission on Dams, and within the inclusive environment of progressive governance created by the democratic transition in South Africa.
2. A strong bottom-up process, driven by the scientific community and progressive technocrats in water affairs, can provide important professional drivers.

Table 11.2 The Yield, Cost, and other Implications of Environmental Release Scenarios

Env Release (Mm^3 a^{-1})	Scenario	Effective yield (Mm^3 a^{-1})	Equivalent hectares[1]	Urban people provided for	Years before next scheme	Additional capital expenditure (ZARm)	Illustrative water cost	Relative cost of water
0	No IFR	88	13,500	800,000	5.9	0	65	1.00
19	Drought IFR every year	73	11,200	667,000	4.9	50	74	1.14
43/19	Damage control IFR	61	9,400	560,000	4.0	89	85	1.30
51/19	Full maintenance IFR	54	8,300	493,000	3.6	112	94	1.45

Source: DWAF 1996b.

However, legislative provisions are important for maintaining momentum and ensuring commitment to the development of specific policies and procedures to ensure determination and implementation of the reserve.

3. Design parameters need to be carefully integrated into the determination of environmental flows. The process of determining the reserve is a data-intensive, capital process that requires time, sufficient resources, and a long-term commitment. Three years of data-intensive monitoring followed two previous determinations to ensure adequate inputs. The results reveal additional complexity and highlight the need for adaptive measures to respond to changing context and ensure appropriate data feedback loops.
4. Reaching agreement requires comprehensive analysis of the full costs and benefits associated with water use within the system. Environmental flows are an integral, legislated component of an allocation framework that should be extended to encompass a full economic analysis of the value of water and the services that it supports.

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Case Study 12. Bridge River Water Use Plan

Background

Hydroelectric power has been the engine of economic growth in the entire Pacific Northwest of North America and remains a vital and integral part of the culture, economy, recreation, and identity of its people. Within this economy, energy, forestry and mining-related activities (such as large pulp mills, lumber milling, mining, metal refining) have been the greatest contributors to gross domestic product.

Hydropower is developed and managed within British Columbia by BC Hydro, a Crown corporation enacted under the Hydro and Power Authority Act. BC Hydro is owned by the government of British Columbia and by extension the people of British Columbia. Pre-1980, most development decisions were made and directed by government. Compared to a privately owned utility, its Crown corporation status gives BC Hydro substantial access to relatively inexpensive capital. In 1980, the Utilities Commission Act came into force and provided a level of regulatory oversight for rate-making purposes and ensured an adequate rate of return to shareholders (the people). Permission to construct and operate hydroelectric plants in British Columbia is governed by water licenses that are acquired from the provincial comptroller of water rights under the Water Act.

A license specifies the terms and conditions of use, including the quantity of water diverted, the time period over which the diversion is allowed,[34] whether storage is permissible, and the kinds of works that may be constructed, maintained and operated; and whether the licensee is permitted to alter or improve a stream or channel and whether they may construct fences, screens and fish or game guards across streams for the purpose of conserving fish or wildlife.[35] While the province is delegated authority to manage natural resources under the British North America Act,[36] including the fish-related works just noted, there continues to be some challenges over who has the ultimate responsibility for managing fisheries resource—British Columbia, or Canada under the Fisheries Act.[37]

In the late 1990s, BC became a significant exporter of electricity to the rest of Canada and the United States. As a result, the integration of economies across borders became even more tightly tied. In general, electricity

[34] For the most part all of BC Hydro's water licenses have no end date and therefore an indefinite approval to use water for the purpose of hydroelectric generation has been given.
[35] The Water Act requires "beneficial use of water," which only recognized power generation, agriculture, and flood control. As a result, there was a culture shift required within the provincial Ministry of Water, Lands and Air Protection (now Ministry of Environment) that would ensure a multiple interest perspective when considering changes to the water license terms and conditions.
[36] The 1867 BNA Act serves as a base document for the Canadian constitution, which is not a single document but rather a set of documents known as Constitution Acts and just as importantly a set of unwritten laws and conventions.
[37] The Fisheries Act dates back to the British North America Act. However, the focus of much of the department's work up to the late 1970s was on oceans-related fisheries management (stock assessment, quotas, fish fleet management, etc.). In fact, British Columbia did not have a Pacific Office until the early 1990s. In 1977, Section 35 of the act was passed and was followed by the department's "Policy for the Management of Fish Habitat" (including the "no net loss" working principle) in 1986. Since the adoption of the "no net loss" policy, there has been increased pressure on BC Hydro to resolve fish/power issues.

has been a catalyst for much of the trade relationships between British Columbia and Alberta in Canada and Washington State, Oregon, California, Idaho, and Montana since the 1960s.

Most water licenses granted for large hydroelectric developments were granted before 1962. During this era, public values leaned heavily and almost exclusively toward economic development (power generation) and flood control. Environmental and social assessments were cursory, at best, as the focus was on providing energy to feed the rapid growth of the post-war Vancouver and the Pacific Northwest of North America. In addition, most water licenses did not have sunset clauses and did not have provisions for dealing with other values—such as fish and fish habitat, recreation interests, water quality, First Nations' traditional use, and transportation—which were considered incidental to the growth-oriented objectives of the day. The assessment of environmental, social, and cultural effects as it is known today did not exist in a robust form and public involvement was almost nonexistent. As well, First Nations were only beginning the legal process to establish rights and title and authority within their traditional territories.

Rivers are central to the identity of many BC communities. Most importantly, the salmon resources of many of BC's large rivers, including the Bridge River, are significant cultural and economic assets. The province's coastal communities rely on salmon to derive their livelihood, and coastal First Nations have a 10,000-year history and heritage centered around salmon.

In the late 1980s, there was an increasing public concern about declining or endangered fish stocks and aquatic habitat, in part been driven by more active role taken by local public interest groups. These local (regional small scale and provincial) interest groups are a key characteristic of British Columbia's activist history. Given the large province and small population, interest groups were able to have a direct influence on public opinion and government decisions.

In addition, the federal Department of Fisheries and Oceans (DFO) has worked with BC Hydro at several facilities to negotiate flow releases. DFO has collected a considerable amount of fish habitat and flow data and the analysis of these data raised awareness of potential habitat restoration opportunities. Habitat restoration was seen as being beyond the scope of BC Hydro's responsibilities because it was not required under the licensing rights. However, water management grew in importance and federal and provincial governments took a stronger stance on the management of fish and fish habitat, particularly at power facilities.

Bridge River Hydropower Complex

The Bridge River Basin is in the rain shadow of the southern coastal mountains about 200 km northeast of Vancouver in British Columbia. The Bridge River hydroelectric project consists of three reservoirs (Downton, Carpenter, Seton), three diversions (La Joie, Terzaghi, Seton) and four powerhouses (La Joie, Bridge 1 and 2, and Seton). It generates 466 MW (2,479 GWh/year), representing 4 percent of BC Hydro's total generating capacity of about 12,000 MW.

The source of Bridge River is the Bridge Glacier in the Coast Mountain Range. The glacier comprises about 140 km^2 of the 998 km^2 watershed area above La Joie Dam. The Bridge River is about 120 km long and flows southeast from the snowfields of Monmouth Mountain. Tributaries to the Terzaghi sub-basin below La Joie Dam drain 2,691 km^2.

The Bridge River development was one of the most complicated engineering projects in North America, with impacts that were not well-understood at the time of its construction in 1948. The La Joie Dam, the most upstream structure, impounds Downton Lake and Terzaghi Dam impounds Carpenter Lake. The La Joie generating station has a maximum discharge of 48.1 m^3/s and the turbine is equipped with a pressure release valve, which is also used to maintain fish flows. All releases from the La Joie facility discharge into the

Middle Bridge to Carpenter Reservoir, which is in turn impounded by Terzaghi Dam. Spills from Carpenter Reservoir occur through spill release structures at Terzaghi Dam into the Lower Bridge River, which subsequently joins the Fraser River.

From Carpenter Reservoir, water is diverted by two tunnels and penstocks through Monmouth Mountain to the Bridge River generating station (1 and 2). Each station houses four turbines and discharges in the Seton Reservoir. At Seton Dam, 23 km below the Bridge River stations, water is diverted along a 3.7 km power canal to the Seton Generation Station located on the banks of the Fraser River. Spills from the Seton Lake Reservoir occur through release structures at Seton Dam into the Seton River, which joins the Fraser River upstream of the generating station and downstream of the Lower Bridge River. The Seton Lake Reservoir has a very narrow operating range and is only capable of providing daily flow regulation. The dam has a fish-water release gate and a fish ladder. These facilities are operated in various combinations during spills and to provide fishery requirements.

The Terzaghi Dam does not have a minimum flow release mechanism. Since construction, the facility operated with water releases into the Bridge River only during spill events (apart from some brief test releases in the 1980s). Consequently, there was often a dry riverbed for approximately 4-km downstream of the dam until the river receives groundwater and tributary inflows to provide a surface flow. Historically, habitat improvement work consisted of gravel placement and was undertaken by BC Hydro to replace lost spawning gravel areas due to spill events. The gravel was well-used by spawning salmon. A release of flows (approximately 0.56 m^3/sec) was provided in 1988 to test the release structure itself and to assess the improvement in habitat in the river as a result of the increased flows. The test indicated that the flows were not sufficient to improve fish habitat since most of the water flowed sub-gravel in the dry part of the riverbed, and did not appreciably increase the depth of water or the wetted width in the lower portion of the river.

In 1991 and 1992, BC Hydro spilled water from the Terzaghi Dam into the Bridge River in response to major inflows to the reservoir. These spills removed gravel and hence had a fisheries habitat impact. DFO charged BC Hydro for the 1991 and 1992 spills under three sections of the Fisheries Act. Charges for the 1991 spill were heard in court and BC Hydro was found to have acted appropriately under the circumstances and with respect to the gravel replacement and fish mitigation actions.

In May 1996, because of public concern over impacts to the fisheries resources and the draining of the Downton reservoir, the province of British Columbia appointed a special environmental auditor to review actions taken by BC Hydro. The auditor's report acknowledged that BC Hydro had made credible and ongoing efforts to address fisheries issues, and that trade-offs made during operations were acceptable in terms of mitigating risks. The report also noted that fines under federal Fisheries Act can only be imposed after damage has occurred and that the monetary value of fines does not act as an effective deterrent to future outcomes.[38] The report recommended that "BC Hydro and the Ministry of Environment establish an independent, multistakeholder process to complete a proper [process], which would gather the environmental and other information necessary to fully assess options for management strategies that would balance power, flood control, social, recreational, and environmental impacts."

In 1997, BC Hydro spilled water once again under the same conditions as in 1991 and 1992 and despite progress made on addressing many of the DFO's issues, concerns and requested changes to accommodate fish and fish habitat, the federal Department of Fisheries and Oceans charged BC Hydro for destruction of fish habitat on the lower Bridge River.

[38] Fines only highlight a concern/behavior, but do not necessarily lead to good solutions as the "fix" is usually short rather than long term and not necessarily based on good science or a full assessment of possible options.

In 1998, BC Hydro decided to remove the issues from the federal court. It and DFO agreed to a settlement involving release of water into the Bridge River downstream of the Terzaghi Dam. Included in the agreement was the provision of habitat restoration/improvement through channel shaping to accommodate the flow regime, monitoring programs, and development of a yearly water budget that would provide for a minimum flow and operational plan. The increased interim flow release was negotiated pending the completion of a water use plan.

WUP Management Structure and Bridge River WUP

The Bridge River Water Use Plan attempts to balance environmental, social, and economic values over the entire complex (3 reservoirs, 3 dams, and 4 powerhouses). The plan was designed over 3 years; BC Hydro was responsible for the management of the planning process.

There were three committees: (1) a WUP Management Committee, comprising staff-level cross-government (inter-government and intra-government) and BC Hydro; (2) a WUP Steering Committee (assistant deputy minister level and BC Hydro vice president); and (3) a WUP Policy Committee (deputy minister/director general level and BC Hydro vice president/president). The management committee was responsible for overall program coordination. The steering committee provided guidance to the management committee and resolved outstanding process issues. The policy committee provided policy and direction on public interest issues and concerns as part of making trade-offs generally at the program level as well as support to a facility-specific consultative committee, as required. Federal and provincial government agencies and BC Hydro were members of the management and technical committees of the WUP. First Nations provided input on an advisory level.[39]

In addition, advisory teams assisted the management committee and the program in five key areas: First Nations, fisheries, resource valuation, power modeling, and communications/engagement. These teams maintained a system-wide perspective, and in some cases (such as fisheries and resource valuation) provided a forum for scientific review and assurance that methods used were consistent across individual WUPs. Each team included representatives from DFO,[40]provincial agencies, BC Hydro, and, where appropriate, other external experts.

The WUP had a BC Hydro Project management team, a consultative committee (CC), and advisory teams. The role of the CC members was to participate in good faith according to the following seven principles: (1) recognition of multiple objectives; (2) no change to existing legal and constitutional rights and responsibilities; (3) collaborative, cooperative, and inclusive process; (4) recognition that trade-offs (choices) have and will occur; (5) embodies science and continuous learning through information gathering and analysis; (6) focus on issue resolution and long-term benefits; and (7) paid compensation if rights are voluntarily diminished and there are financial impacts on the licensee.

The outcomes of the WUP were a set of recommendations contained in a consultative committee report that documented process, issues, objectives, performance measures, trade-offs, and

[39] Participation in the collaborative process was paid for by BC Hydro, except for government agencies who continued to pay staff salaries and travel costs. First Nations sat at the same table as the overall WUP Management Committee and provided strategic advice and input to ongoing program design and delivery issues as was necessary.

[40] DFO's participation in the process was dependent on their understanding that some incremental changes and adjustments to flows would occur in order to improve conditions for fish, thus allowing them to feel comfortable within the context of their obligations under the Fisheries Act and meeting requirements of the national policy for the management of habitat, as previously noted in the text above.

areas of agreement and disagreement. BC Hydro incorporated the recommendations into proposed amendments to water licenses, but reserved the right to reject some recommendations. As a result, the extent of consensus within each CC report became an important consideration; the higher the degree of agreement on proposed changes, the more difficult it was for BC Hydro to reject recommendations. The process and recommendations did not fetter the discretion of any regulatory decision maker (for example, the comptroller of water rights, minister of fisheries and oceans). The degree of consensus also influenced the decisions of regulators in much the same fashion as BC Hydro.

The final recommendations for the Bridge River hydroelectric system reflected a balance between the dominant[41] fish and wildlife interests in the reservoirs, while protecting and enhancing other values in the rivers. Specifically, minimum and maximum elevations were targeted to mitigate entrainment risks in Downton Reservoir and enhance fish and wildlife conditions in Carpenter Reservoir, respectively. A tension between fish and wildlife benefits became apparent in determining the final operating strategy, resulting in a recommendation for a five-year revegetation program to enhance riparian habitat in Carpenter Reservoir.

Maintaining flexibility in the main reservoirs was required in part to manage spills and flows in the Middle Bridge, Lower Bridge, and Seton Rivers. Spill events were of most concern in the Lower Bridge River for fish and wildlife reasons. Consequently, the recommended operating strategy set a priority to spill first at Seton River and limit spill events in the Lower Bridge River. For the Middle Bridge River, flow constraints were specified. Determining a flow regime in the Lower Bridge River proved difficult because regular flows had not been monitored there prior to 2002 and the understanding of flow needs and ecosystem response was extremely poor. A flow shape and magnitude was specified for the Seton River. The final recommendations also included elimination of operational constraints that have had positive impacts on environmental and social indictors while increasing power benefits. Relative to current operations, outcomes of the final recommendations will likely benefit wildlife habitat, fish conditions, power generation, aesthetics, and flood management

Drivers

The effects of the spills from the Terzaghi Dam (1991, 1992, 1997) and the impacts on fisheries habitat acted as the primary drivers for the Bridge River WUP. In addition, the DFO was either threatening to press charges or was pressing charges for destruction of fish habitat at other BC Hydro facilities (Cheakamus, Hugh Keenleyside, John Hart). BC Hydro had two choices: it could negotiate or litigate, and decided that the former was a more productive and cost-effective approach.

Other related drivers include the results from the 1993 Electric System Operations Review;[42] 1996 Ward Report;[43] the 1994 Stave Falls Minister Order, which included a requirement for the development of a WUP; increasing concern over the health of salmon stocks; increased presence of DFO in British Columbia; a government with strong environmental policy focus; and increased activism by environmental groups on water-related issues. All these actions occurred in the space of 5 years and provided the impetus and momentum necessary for the implementation of the WUP program.

[41] The trade-off analysis process focused on flows, not operations. As well, the process deliberately looked at dominance objectives and the costs and benefits of changes that would have the most positive outcomes at the least possible cost to flows and foregone power generation. In fact, preferred outcomes were all neutral to positive with respect to power generation.

[42] ESOR was prompted, in part, by historic complaints about reservoir impacts, primarily from the Columbia–Kootenay region. Driven by provincial and federal agency concerns, the province was concerned that BC Hydro was not operating its system in a manner that gave adequate consideration to non-power resource values. These non-power resource values included not only fish and fish habitat but also recreation, flood control, aesthetic values, wildlife, economic activity, etc.

[43] The report concluded that BC Hydro was operating out of compliance at six of the ten facilities examined.

Assessment

Recognition. While the actual development of facility WUPs began in 1998, the pre-planning for the WUP program began in 1993. In the end, the WUP process generally and specifically was accepted as legitimate by all participants—at the management and facility specific level (i.e., stakeholders). However, the process to build this understanding and support occurred gradually and required a concerted and considerable effort to build trust among government agencies, First Nations, environmental groups, and within BC Hydro over many years. It was a different approach to the historic and practiced tradition of an adversarial, position-based process for resolving natural resources challenges.

In relation to the Bridge WUP, First Nations participation was the most challenging. The Stl'atl'imx First Nation (SFN) (Box 12.1) are very independent and had been negotiating with BC Hydro for many years on past grievances. The SFN preferred government-to-government discussions and at first saw the WUP process as undermining that more political relationship. In concluding comments, however, the SFN were "impressed with the results of the consultative committee." While they did not "sign" off for political reasons, they provided positive reinforcement of the process and outcomes.

Initially, BC Hydro took the position that, since it had been given water licenses that conveyed the rights to use water for power generation, it did not need to accommodate requests for environmental flows. As a result, there was a need to build support for the WUP process within BC Hydro itself.

Environmental groups were also skeptical of WUPs because they feared that it was just another government process that would not provide a transparent vehicle for considering their interests and desires. Almost all environmental and community groups in the Bridge River area and in general supported the implementation of a minimum flow. Building trust through the principles of the WUP process was critical. By the end of the process, however, there was widespread support from both government agencies and the community.

For the Bridge River project there were no transboundary impacts as the river is contained entirely within the geography of British Columbia.

Participation. The Bridge River WUP consultative process was initiated in September 1999 and completed in December 2001. The consultative process followed the steps outlined in the provincial government guidelines (Province of British Columbia 19968).

Box 12.1 The Stl'atl'imx First Nation

The SFN is made up of 11 communities, each of which is represented at the Chief's Council Table. The total population is about 6,000 people. The governance vision statement includes a continuing and renewed relationship between Stl'atl'imx people (ucwalmicw) and the land (tmicw), employing the following four principles:

- respects Stl'atl'imx cultural traditions—using the ways (nt'akmen), laws (nxekmen) and standards of our people as passed down through the generations
- respects nature—putting the health of water, air, plants, and animals and the land itself before all else
- is under Stl'atl'imx authority—letting the people collectively decide how the land and resources of the Stl'atl'imx territory will be managed
- serves the Stl'atl'imx communities—recognizing that resources continue to provide sustenance in old and new ways to our people

The SFN have asserted their claim to the ownership of this tribal territory since the signing of a 1911 Declaration of the Lillooet Tribe in 1920. Three of the SFN communities are currently engaged in a treaty negotiations process and have an agreement in principle signed and are working toward a final agreement.

The CC comprised 13 members representing power generation, recreation, cultural use and heritage sites, fish, wildlife, water quality, socioeconomic interests, and First Nations. All participated in the process on an equal footing. The CC chose their facilitator, who was paid for by BC Hydro. Observers could attend but could not participate in the discussion process unless invited to do so through a member of the committee.

The SFN participated in the process at the main table, then at a separate First Nations table, then not at all in 2002. They returned to the table at the final meeting but only as observers, even though they had "accepted" the final recommendations of the CC. Reasons for this are noted above in relation to their desire for government-to-government relationships and concern that the WUP process would undermine negotiations.

The CC was supported by several technical working groups, including fisheries, wildlife, and recreation. BC Hydro provided the technical support on power modeling. The CC met regularly over the 3-year period. Additional meetings were held with SFN in order to ensure their unique issues and traditional knowledge was considered. The committee's work required all members to keep an open mind and understand the perspectives of others on the committee. Group discussions were structured to identify and explore a range of alternative operating regimes, and to seek compromises across interests while remaining within regulatory and other boundaries.

In general, the members of the CC worked well together. They participated in the discussion and analysis of very complex issues, within a large set of inter-related alternatives and asked questions of BC Hydro and government officials that forced better focus on the real issues and interests. BC Hydro's support for good science, transparent information sharing, strong project management, and defined timelines provided an important structure to the process. The SFN reticence to participate did not delay CC deliberations and BC Hydro made extra efforts to ensure SFN views could still be incorporated into the final CC report.

In addition, documentation of areas of agreement and disagreement played a critical role in ensuring the views of all CC members were heard. CC meeting minutes were produced after each meeting and each participant saw themselves reflected in the discussion and ultimately in the final recommendations.

Assessment Method. The structured process followed in the Bridge River WUP program was one of the keys to its success. The consultative process consisted of six key steps, based on multi-attribute techniques and value-focused thinking (Keeney 1992). The steps begin with clear articulation of objectives and performance measures, which describe the extent to which each alternative operating regime contributes to or detracts from each objective. Usually quantitative, the performance measures force specificity on the objectives, better educate each participant on the needs of others, and create a basis on which to collect decision-focused information.

The CC agreed to the following objectives for the Bridge River WUP:

- Fisheries: maximize the abundance and diversity of fish in all parts of the system
- Wildlife: maximize the area and productivity of wetland and riparian habitat
- Recreation and Tourism: maximize the quality of recreation and tourism experience in all parts of the system
- Power: maximize the value of the power produced at the Bridge, Seton and La Joie facilities
- Flood Management: minimize adverse effects of flooding on personal safety or property
- Dam Safety: ensure that facility operations meet requirements of BC Hydro's dam safety program
- Water Supply/Quality: preserve access to and maintain the quality of water for domestic and irrigation use

Where possible, performance measures were modeled quantitatively.

Operating alternatives were then developed to address the various objectives. In total, more than 20 alternatives were run through BC Hydro's operations model, and the consequences for each objective were discussed by the consultative committee against the agreed-to performance measures. Preferences and values were documented and areas of agreement sought. With the exception of one non-First Nations member (who abstained), the CC members eventually agreed on a single recommended operating alternative.

A total of 23 technical studies were completed during the 3-year process. These studies improved the knowledge base on the Bridge River system and helped calculate the performance measures for the CC. A clear, deliberate, and time-bounded process set the framework for completion of the studies. Expert judgment was also used to fill information gaps, including explicit recognition of First Nations values as part of a traditional ecological knowledge study.

An operations model using commercially available software was used to evaluate system operating alternatives. The model optimized the Bridge River facility operations for power production within specified constraints using 39-year inflow data. The primary model outputs were daily reservoir levels and releases from dams, along with daily power production. These data were used as input to an environment model and a power values model. The former used a Visual Basic program to simulate environmental and social performance measures,[44] while the latter model calculated the annual value of power based on information about energy prices, dispatchability, and plant characteristics.

Overall, the model outputs provided data that many CC members had little experience with. However, BC Hydro was able to synthesize the model outputs into a variety of understandable forms, such as maps, graphs, and graphics. Furthermore, since not all modeling was intended to monetize performance but rather to incorporate natural units of measure, where possible, the CC had a higher level of acceptance than would have been the case had the outputs been strictly mathematical.

The CC recommended that the Bridge River WUP be reviewed in 2012, which at the time was the end date of a proposed adaptive management program. It further recommended that a formal review based on the results of the monitoring programs be conducted after the fifth year of implementation. A recommendation may be forwarded to the comptroller of water rights to trigger an earlier review of the water use plan if there is evidence of significant unexpected and unacceptable impacts at that time.

Integration. The objectives, which represented different social, environmental, and economic values, were brought together through the deliberations of the CC. Decision methods included both intuitive response and ranking using technical methods (paired comparisons, consequence tables, etc.). In each round of assessments, key trade-offs and uncertainties were discussed to enhance understanding and allow participants to make more informed choices.

It became clear early on in the process that active adaptive management would be needed. This was driven by the complexity of the system, the desire for more information than could be collected during the timeframe of discussions, and a constrained budget. Sources of uncertainty associated with each outcome were discussed by the CC. Determining a flow regime

[44] A series of Excel spreadsheets was used to store model parameter, physical characteristics of the system (e.g., reservoir surface area as a function of elevation, etc.) and the hydrological scenarios (e.g., schedules of discharge and reservoir elevations associated with each alternative). Output, the performance measures and various diagnostic indicators, are viewed as data sets, time series graphs, and/or maps.

in the Lower Bridge River proved particularly difficult. Because the Lower Bridge River did not have regular flows until 2002, the understanding of flow needs and ecosystem response was extremely poor. An adaptive management program was proposed to test multiple alternative water management policies over specified periods of time. These trials were intended to be complete by 2012, but at this point have not been approved due to additional SFN concerns. When these flow trials are initiated, the monitoring data will be evaluated and subsequent discussion held with regulators about a long-term flow release program. The adoption of an adaptive management approach to implementation was a significant factor in allowing some CC members to support the final recommendations as it allowed them to accept model outputs that had considerable uncertainty.

Cost Effective. There were three components of cost for the Bridge WUP: the cost of plan production, cost of infrastructure improvements, and ongoing cost of implementation.

The full costs of plan production are unavailable, but the technical studies cost about $600,000. The recommended infrastructure improvements cost up to $6 million (the annualized costs of constructing and operating a new 12 MW facility at the Seton generating station). The implementation costs, including the annual costs of the monitoring plan, average about $520,000 per year (undiscounted) over the period of the plan.

Overall, the costs of developing the plan and implementing the actions were estimated to be less than the costs of the court proceedings as a result of charges being laid by the DFO. As an offset to these costs, the chosen alternative allowed BC Hydro to generate an extra $1.8 million in electricity.

Influential. The Bridge River WUP resulted in changed operational procedures that enhanced environmental, social, and cultural outcomes, while also increasing power generation. More broadly, it improved the capacity for environmental management within BC Hydro. It led to the development of new tools for assessing operating issues and it illustrated the importance of monitoring. The monitoring committee—made up of government (federal, provincial, and local), BC Hydro, First Nations, and public representatives—will be a vehicle for ongoing dialogue.

The Bridge River WUP is now the new benchmark for sustainable management. The WUP process, of which the Bridge WUP is one of 23 completed plans, has made a positive impact on policy and regulatory intervention at BC Hydro's facilities. The WUP process has now been adopted in multiuse planning in several non-hydropower watersheds throughout BC.

Lessons

1. A structured decision-making process is important for ensuring an organized approach to identifying and evaluating alternatives.
2. Data and information (both science based, traditional knowledge) and models can provide a valuable foundation for building agreement in complex decision-making environments.
3. Adoption of an adaptive management approach proved crucial to reaching a final decision when there was inadequate information.
4. Prosecutions, or the threat of legal action, may initiate action but will not, in the end, result in effective, long-term solutions.
5. Clarity of scope and a clear understanding of what issues are inside and outside of the process are essential for progress.
6. Time is needed for "airing" concerns.
7. Regulatory requirements are helpful but should not constrain the deliberations.
8. It was important to have participation of the traditional owners (First Nations) and to integrate their ecological knowledge with the scientific

knowledge. It takes time to "capture" and translate this information.

9. While the upfront development costs may seem large, the costs of not dealing with issues or concerns are higher and will involve a more adversarial, court-oriented process.
10. It takes time to build trust, especially with respect to complex modeling methodologies.
11. It is important to provide documentation and information in a form that is understandable and useful to all process participants and the public. The experience that this lesson comes from is not mentioned above.

Acknowledgments

This case study was written by Denise Mullen-Dalmer, DMD Management Ltd., and reviewed by Sue Foster and Kevin Conlin of BC Hydro.

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Case Study 13. Restoration of Chilika Lagoon

Background

Chilika Lagoon, located on the east coast of India in the state of Orissa, is the largest brackish lagoon in Asia. The lagoon runs parallel to the coast of the Bay of Bengal, separated by a 60 km barrier spit that varies from 0.5 to 2.0 km wide. The lagoon is a biodiversity hotspot, especially for waterbirds and other aquatic species. Over 160 species of waterbirds—totaling up to 2 million individuals—can be found at the peak migratory times during some seasons. The lagoon supports many aquatic species and is home to the Irrawaddy dolphin, which is listed as an endangered species by the IUCN.

The Chilika Lagoon ecosystem and surrounding catchment provides income for about 200,000 people who are directly or indirectly dependent upon the fish, crab, and prawn catch. There is intensive farming around the lagoon, mainly for cashews, with rice production taking place in fringe wetland areas. These areas also support grazing for over 50,000 cattle and provide fuelwood as well as for other products for home consumption and income generation. Chilika has a growing ecotourism industry due to the abundant wildlife; it also has numerous temples that draw large local populations.

The lagoon's ecosystem depends on the water, sediment, and salt balances of the water body. The lagoon lies within the Mahanadi Basin. The Mahanadi River reaches the ocean to the northeast of the lagoon. The Daya, Nuna, and Bhargavi branches of the river delta provide between 50 to 65 percent of the freshwater inflows and between 50 to 75 percent of the sediment inflows to the lagoon. Smaller rivers and streams from the catchments along the western side of the lagoon contribute the remainder. The lagoon is primarily connected to the Bay of Bengal through a channel in the north. The exchange of water through this channel, together with freshwater inflows and evaporation, controls the salinity of the lagoon.

The productivity of the lagoon declined significantly during the 1990s, primarily due to declining salinity as a result of reduced interchange between the lagoon and the ocean because of the northward littoral drift of the channel. There was an increase in sediment loading from the western catchments and irrigation areas of the Mahanadi Delta. These sediments are believed to have largely deposited within the lagoon itself, as well as near and along the mouth of the lagoon. As a result of the closing of the lagoon mouth, the salinity level of the lagoon dropped dramatically from 20–30g/l to 2–3 g/l during May as the freshwater buildup continued.

The hydrologic and water quality changes affected Chilika's biodiversity and productivity. Fish catches declined from 6,000 tons in 1980 to 1,641 tons in 1997/98 (a reduction of nearly 73 percent); crab and shrimp catches also declined by over 90 and 80 percent, respectively, during the 1990s; several sponge species became extinct; other species became endangered, including the Irrawaddy dolphin; and aquatic weeds flourished in the lagoon. The 1999 super cyclone further added large inflows of freshwater. The blockage of the lagoon outlet led to flooding and waterlogging of large areas of paddy crop in lakeside villages, with consequent sanitation problems and outbreaks of disease.

In 1992, the state government of Orissa formed the Chilika Development Authority (CDA) to manage conservation efforts for the lagoon, oversee research, and develop a management plan. It coordinates the activities of the various state departments that work in the Chilika lagoon catchment. The chief minister of Orissa is the chairperson of the CDA.

Following widespread concern about the declining fish catches and biodiversity, the lagoon has been rehabilitated through a combination of immediate and longer-term actions. The most important immediate actions were the cutting of a new exit to the ocean and the dredging of a new channel between the Mahanadi Delta and the new mouth to facilitate tidal influx and freshwater outflows, which helped restore the balance of freshwater, sediments, and saltwater. The new exit was completed in September 2000.

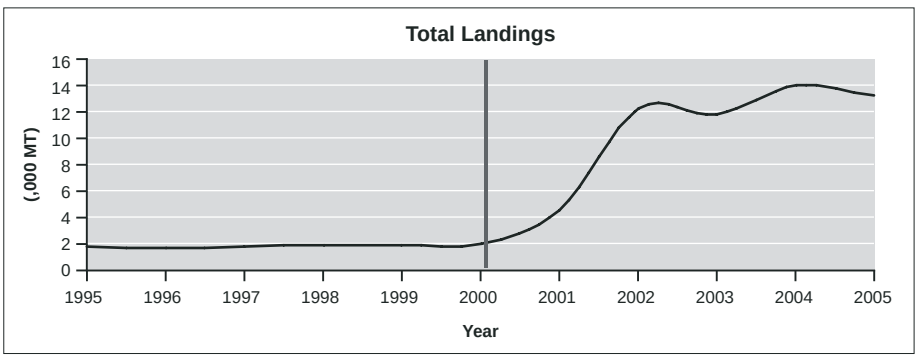
The decision to open the new exit was based on both extensive stakeholder consultations and scientific studies. Detailed 1- and 2-dimensional modeling of the lagoon hydrodynamics had predicted that the new exit would lead to a rapid return of higher salinity within the lagoon. These predictions were confirmed when the exit was opened.

Oceanic exchange through the new channel has led to a remarkable recovery of the lagoon. Salinity rose almost an order of magnitude, sediment flushing from the lagoon increased, the area under aquatic weeds was substantially reduced, and the lagoon's productivity recovered. Fish catches rose eight-fold between 1999/2000 and 2002/03. Total fish, prawn, and crab catches rose from 1,900 tons in 2000 to about 12,000 tons between 2002 and 2005 (Figure 13.1). A survey of local fisherman reported that they had earned, on average, an additional 50,000 rupees (about $1,040) per year.

Chilika Lagoon had been placed on the Montreux Record (Ramsar's list of sites undergoing ecological degradation) in 1993. It was taken off the list and awarded the prestigious Ramsar Wetland Award in 2002 in recognition of these improvements.

The longer term actions included control of sediment fluxes from the western catchments through promotion of income-earning, good agricultural practices; reductions in sediment from the irrigation areas feeding into the lagoon; and improvements in flows through the Mahanadi River Delta into the lagoon. A number of international organizations—including Wetlands International, JICA, Ramsar, DHI, JFGE and the

Figure 13.1 Total Fish, Prawn, and Crab Landings in Chilika Lagoon, 1995–2005



Note: The solid line marks the opening of the second channel to the ocean.

World Bank—assisted with these restoration activities. The World Bank provided assistance for determining the environmental flow needed to sustain the lagoon in the longer run through the Orissa Water Resources Consolidation Project (OWRCP) 1995–2004, with specialist expertise being provided through the Bank-administered BNWPP Environmental Flows Window. While the increased exchange with the ocean has clearly led to immediate and widespread benefits, it will not be sustainable if the natural flow regime from the Mahanadi River is not at least partially restored and if sediments continue to enter the lagoon and silt up the entrance. This case study focuses on the attempt to introduce environmental flows so as to help maintain the salinity dynamics of the lagoon.

The OWRCP and BNWPP Assistance

The OWRCP included various environmental management activities, including support for the restoration of Chilika Lagoon, the construction of a new barrage across the Kathajori branch of the Mahanadi River to replace the old Naraj weir; the development of a Strategic Environmental Policy for Water Resources Planning and an Environmental Action Plan; and strengthening the Department of Water Resources (DoWR) in technical and managerial areas. The Environmental Assessment for the OWRCP (Orissa Department of Water Resources and SMEC 1995) identified Chilika Lagoon as a critical natural habitat below the Naraj Barrage, and recommended that investigation be undertaken to guide the operation of the barrage. Consequently, through the BNWPP Environmental Flows Window, the Bank provided assistance in incorporating environmental flows into the operational rules for the new Narraj Barrage.

With OWRCP support, the CDA produced an integrated management action plan for Chilika Lagoon in July 1999. The plan was drawn up following extensive consultations with government departments and fisherfolk communities. In addition, the OWRCP supported a monitoring program in the rivers feeding into Chilika Lagoon that complemented the CDA's in-lagoon monitoring.

During the course of the OWRCP, the State Water Resources Board adopted a State Water Plan that included requirements for environmental flows, environmental guidelines for all water resources projects, and a Strategic Environmental Policy for the water resources sector. Although the Department of Water Resources had made a commitment to modify the operating rules of the Barrage to include environmental water requirements, it was apparent that the department was having difficulty understanding the concepts of environmental flows. Departmental staff members were more concerned with reducing the quantity of water reaching the lagoon from the Barrage to reduce the sediment flux from the Mahanadi Delta than increasing it to allow for environmental outcomes.

Between 2002 and 2005, the BNWPP Environmental Flows Window provided specific training on EFA concepts, methods, and applications to help the DOWR and the CDA determine the environmental flow requirements. The window funded a specialist consultant to conduct workshops on EFA for both managers and technical specialists; develop hydrologic and sediment models for environmental flow applications; assist with community consultation processes; provide advice on the application of the hydrodynamic model for assessing in-lagoon water quality changes; and assist with biological-environmental modeling. As a result of this assistance, the CDA and the Department of Water Resources developed a draft set of Barrage operating rules that included environmental flow releases designed to benefit Chilika Lagoon. However, the rules could not be finalized because the environmental and socioeconomic components were never completed during the OWRCP. The BNWPP support was extended after the OWRCP was closed to complete the technical work on the flow assessment, but the rules have not yet been operationalized by the Department of Water Resources.

The modeling that was carried out showed that, unlike many other environmental flow cases, there was no conflict between releasing water for the downstream environmental benefits and providing water to the irrigation farmers in the delta, because these water demands occurred at different times of year. However, the Department preceived a conflict between environmental flows and downstream flooding of irrigation farms within the delta. In fact, studies by Wildlife International showed that small to medium floods delivered net benefits to these farms and that it was only the large floods that caused financial losses. Nevertheless, departmental staff remained wary of releasing significant environmental flows through the delta and into the lagoon.

In 2007, the government of Orissa adopted a progressive new state water policy. This policy, unlike either the National Water Policy of India or most other state water policies in India, recognized the environment as a legal use of water and granted it second priority in the allocation decision making. The new water policy opens up opportunities—through the Orissa Water Sector Improvement/Mahanadi Basin Project, currently in preparation—to further the understanding within government departments of the importance of environmental flows to the welfare of downstream communities and to assist the inclusion of these flows in the operational rules for the Naraj Barrage.

Drivers

There were multiple drivers for restoring in-flows, and improving oceanic exchange and water quality in the lagoon. The disastrous effect on the local economy of the reduced interchange between the lagoon and the ocean was the primary driver. The social and economic costs led to pressure from fishermen, tourist operators, and conservationists for the restoration of the lagoon's ecosystems. The publicity from riots some years earlier and the deaths of some rioters had put extra pressure on the government to act[45]. Local and international NGOs had also become effective at voicing the concerns of these disadvantaged groups.

The inclusion of the lagoon on the Montreaux Record of deteriorating Ramsar sites brought international attention to the poor management of Chilika Lagoon, causing embarrassment to the state and national governments and providing an additional driver for restoring the lagoon.

The state water plan acted as a procedural driver that gave legitimacy to the EFA. However, it was not decisive; the need to provide for environmental flows was not accorded high priority within the Department of Water Resources, let alone other state departments. However, the new state water policy may act as a driver for future determinations and implementations of environmental flows.

Although the reconstruction of the Naraj Barrage was primarily driven by safety factors (World Bank 1995), the environmental assessment for OWRCP highlighted the need to address the protection and management of Chilika, a critical natural ecosystem. The reconstructed barrage had to be designed to ensure that appropriate environmental flows were provided to Chilika Lagoon. The restoration of the lagoon became an explicit objective later. The World Bank's safeguard policies were instrumental in identifying the need for managing this important downstream ecosystem even though an environmental flow assessment, to guide the development of the operating rules for the Naraj Barrage, was undertaken much later.

[45] The hardship from the decline in fish catches was accentuated by a change in government policy, which resulted in fishing rights in the lagoon being put up for tender. The resulting loss of access by traditional fishermen, coupled with investments by wealthy businessmen in cultured prawns farms, led to riots. The deaths of four fishermen during protests in May 1999 led to widespread publicity and embarrassment for the Orissa state government.

Assessment

Recognition. The need to restore the lagoon's hydrologic regime had been recognized for some years prior to the OWCRP. However, officers of the Water Resources Department had an expectation that these flow requirements could be specified through a technical exercise that resulted in a precise flow being calculated through hydrologic modeling. They were unable to appreciate—and found it difficult to understand—that establishing environmental water needs was necessarily a social exercise that balanced the conflicting interests of different stakeholder groups along with environmental needs.

In addition, calculating and implementing environmental flows required the collaboration of government departments that represented sectors dependent on the services provided by the environment—agriculture, tourism, fisheries, etc. However, the state government departments did not have a culture for—or experience in—engaging in such collaborative exercises. Departments were focused on their sectoral objectives and did not assign a priority to investigations into environmental flows.

These difficulties were never properly overcome during the time of the OWCRP and the BNWPP assistance and were a major factor in the reluctance to implement environmental flow recommendations.

Participation. The difficulty in getting active participation from state government agencies, apart from the CDA and the Department of Water Resources, is described above. Apart from their silo mentality, there was a regular turnover of senior staff within these government agencies. The purpose of the EFA had to be explained to each new appointee and it was impossible to build up any momentum for the study outside of visits by the international consultant.

A stakeholder executive committee (SEC) had been proposed at the outset of the EFA study. It was finally constituted toward the end of the EFA with representation from the departments of Water Resources, Fisheries and Animal Development, Forestry, and Agriculture and the CDA, as well as floodplain and fishing community representatives. Although it only met twice, it was crucial to the visibility and acceptance of the EFA within government.

There had been extensive stakeholder engagement in the preparation of the integrated management action plan and, as a result, there were good linkages between the CDA and the fishing community at the time of the EFA. Two workshops were held with fisherfolk and villages from the floodplain, where water-related problems were discussed, including issues related directly to the Narraj Barrage. Although they discussed issues very actively, their understanding of the operation of the barrage was limited, and it was not possible to discuss technical options with them.

The lagoon communities exhibited great interest in the opening of the new channel to the ocean, because the benefits from increasing the exchange between the lagoon and the ocean were immediately apparent to them. The erosion control projects under the OWCRP to reduce sediment inputs from the western catchments also included extensive community involvement.

Assessment technique. The environmental water requirements below the Naraj Barrage were estimated using models. A hydrological model was developed to predict water flows and sediment loads from the barrage into the lagoon; a hydrodynamic model of the lagoon was used to predict salinity under different flow regimes; and a simple fish catch model was developed based on salinity levels. While lagoon levels, which could be predicted by the hydrodynamic model, provided an estimate of water bird nesting potential, actual bird breeding events could not be estimated because global factors determine the occurrence of breeding events. There was insufficient information for the response of other important species, such as dolphins and shrimps, to be modeled.

The models were applied to four environmental flow scenarios, based on the community consultations and economic assessment of scenario impacts. Thus, the models suggested that a 60 percent reduction in freshwater flows would result in a net annual incremental cost of €138 million ($131 million) through losses to floodplain agriculture and fisheries[46]. Conversely, by maintaining the present levels of freshwater flows and reducing high intensity floods, an overall annual incremental benefit of €8,465 million ($8.04 million) would be realized through enhanced agricultural and fish productivity.

Different institutions developed the different models for CDA. The Central Water and Power Research Station (CWPRS) at Pune developed the hydrodynamic model, while the Orissa Department of Water Resources was responsible for the hydrological and sediment models, and the CDA was responsible for the ecological response models and for coordinating the different institutions. This arrangement proved to be too complex, and there was poor coordination between the CWPRS, the DOWR, and the CDA. Although the CDA had successfully coordinated the contributions of NGOs and government agencies to the immediate response to the lagoon's problems under the auspices of the national government, they did not have the necessary influence when required to coordinate input to a technical assistance project for a long-term response.

While the CWPRS modelers were readily able to develop the hydrodynamic model, they and DWR modelers were less familiar with catchment runoff models and could not easily grasp the concepts behind ecological and social response models. Consequently, these latter models were not developed until late in the project.

Integration. The EFA included modeling of the social and economic impacts of different flow scenarios. These models were not intended to be integrated with the existing physical models. However, the assessments of different flow regimes did integrate these physical, ecological, and social components.

The EFA integrated key water quality concerns—particularly salinity within the lagoon—with flows because of the importance of these parameters for the functioning of the lagoon ecosystem.

There was some integration at a technical level of flows and other considerations. However, more importantly, there was little integration at a management level of environmental flows with other management initiatives for the restoration of the lagoon, such as erosion control programs in the western catchments.

Cost effective. The EFA was completed technically, but was never put into effect. There were some benefits, such as an increase in understanding about environmental flows among some technical staff of the relevant Orissa state departments, but this understanding was never properly internalized by the organizations. Consequently, the project has not been cost effective at this stage. However, there is an opportunity for building on this initial understanding through a subsequent Bank-funded project.

Reporting. The analyses carried out clearly illustrated the environmental and social trade-offs to the CDA and the Department of Water Resources and, later in the project, the members of the stakeholder executive committee.

The Chilika restoration program is supported with a monitoring program—in both the lagoon and the inflowing rivers—that tracks changes in key physical and biological parameters. However, this monitoring is not designed to distinguish the contribution of environmental flows from the barrage to the sustained recovery of the lagoon; instead it integrates improvements arising from all the actions contained in the integrated management action plan.

Influential. The EFA was undertaken too late in the OWRCP to be influential when the operating rules for

[46] Flow Scenarios for Chilika Lagoon, India. Millenium Ecosystem Assessment.

the barrage were being established. It was concluded after the OWRCP was completed. While it has not succeeded in influencing the operation of the barrage at this point, there remains a possibility that it may still be influential through the follow-on project now being prepared.

The high level of senior staff turnover (which is a generic issue within the Indian civil service) meant that there was little opportunity to embed a strong understanding of environmental flows within the water resources bureaucracy, and this affected the seriousness with which the technical findings of the EFA are treated. While the EFA was accepted as providing an important input to management of the barrage by the CDA, it was never given a high priority by the Orissa Water Resources Department (Young 2005). The department has retained a strong orientation toward irrigation development and expansion, and not on water resources management or ecosystem services.

The EFA for the barrage has not, to date, resulted in the inclusion of environmental flow assessments in other development projects. However, it provided training and improved understanding of EFA procedures within state government agencies, although the improved understanding is still not deep enough for further EFAs to be carried out without expert assistance. There is not yet a widespread understanding of environmental flows among senior managers. Given the rotation of senior staff experienced in this project, it is likely that the senior managers responsible for future water-related development projects would need to be educated afresh about environmental flows. However, the clear priority given to water for the environment in the recent Orissa State Water Policy is very likely to have been influenced by the awareness of this issue as a result of the EFA conducted for the barrage.

Lessons

1. A crisis, such as the severe social disruption and economic hardship brought about by reduced downstream flows and increased sediment inputs into Chilika Lagoon, is sometimes necessary to precipitate action.
2. When environmental flows concerns are introduced late in project implementation where the implementing institution has no background or mandate for environmental and social issues, then environmental flows are likely to be treated as just a bureaucratic hurdle that needs to be overcome with minimal effort, rather than an integral part of project implementation.
3. It is difficult to introduce concepts that rely on social, economic, and environmental knowledge that do not have exact solutions; and require collaboration across multiple disciplines into sectoral, and in particular, engineering organizations.
4. In spite of a recognized institution (CDA) with responsibility for coordination, departments that were not directly responsible for water resources management continued to focus on their sectoral interests and did not engage in cross-sectoral management.
5. The inclusion of environmental flows in the state water plan provided legitimacy to the conduct of the EFA, but was not decisive in gaining the priority that was needed to ensure that staff were assigned to carry out the agreed tasks.
6. The high turnover in senior staff in the Water Resources Department required continual justification for the EFA and contributed to the low priority assigned to the activity within the department.
7. The stakeholder executive committee was available only toward the end of the project. The project would have progressed more effectively if this assistance was available earlier.
8. The level of participation of villagers and fisherfolk needs to be tailored to their capacity. They were able to articulate problems and discuss general solutions, but were not equipped to engage in technical discussions concerning the provision of environmental flows.

9. Good science, even backed by a state water plan, cannot guarantee good decisions. It needs to receive high-level bureaucratic support and have access to coordinated technical expertise across relevant government institutions.
10. To be effective, the EFA process needs to be embedded in an existing planning process, such as a project EA or water resources allocation plan.
11. EFAs must address livelihood concerns if they are to be relevant in water allocation in developing countries.
12. There needs to be functioning water resource management frameworks before environmental flow issues can be addressed effectively.

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Case Study 14. Lesotho Highlands Water Project

Background

In 1986, the governments of Lesotho and the Republic of South Africa signed a treaty to implement the Lesotho Highlands Water Project (LHWP). The project was intended to meet the growing demand for water in the heartland of the Republic of South Africa (RSA); to produce hydropower to reduce Lesotho's dependence on imported energy; and to apply the project-generated export revenues to development-oriented programs within Lesotho. The project was largely funded by the government of South Africa. At the time, Lesotho had a per capita income of around $440. Close to half of this came from remittances of 150,000 Lesotho nationals working in the gold and coal mines in South Africa. With possible mechanization of the mining industry, employment growth for Lesotho workers was uncertain, and so the project offered Lesotho an opportunity for job creation, infrastructure development, and a stable revenue source to support the country's development.

The LHWP (a transboundary, inter-basin water transfer project) was thus of considerable economic importance for both RSA and Lesotho.

The Lesotho Highlands Water Project

The five-phase LHWP was to be progressively implemented over a 30-year period starting in 1990. Phase 1A and 1B of the project were supported by 11 donor agencies, four export credit agencies, four European commercial banks, four regional capital markets, and the government of Lesotho. The World Bank contributed only about 3 percent of the project financing[47] (under Phases 1A and 1B), but its role and participation was crucial to obtain broad international support and ensure that the project met sound economic, technical, dam safety, and environmental standards. The project was implemented by the Lesotho Highlands Development Authority (LHDA) under the Lesotho Highlands Water Commission, a binational commission headed by permanent representatives from the governments of Lesotho and South Africa.

Phase 1A involved the construction of the Katse Dam (185 meter) and the Muela Dam (55 meter), tunnels to transfer water from Katse to Muela and from Muela to the RSA (18m^3/s), and an underground hydropower station at Muela. This phase ran from 1992 to 1998. Phase 1B comprised the Mohale Dam (145 meters), a transfer tunnel connecting the Mohale and Katse reservoirs, a 19m high concrete diversion weir on the Matsoku River, and a 5.6km long tunnel. It was completed in 2006.

At the time of the project, Lesotho did not have a water resources or environmental policy that either recognized environment as a legal use of water or that mandated environmental flow requirements in infrastructure projects. The environmental assessment was carried out according to World Bank requirements. There were few general provisions for environmental protection in the 1986 treaty. The treaty provided for minimum downstream compensation flows of 0.5 m^3/s from Katse Dam and 0.3 m^3/s from Mohale

[47] Total project cost of Phases 1A and 1B was $ 2.9 billion.

Dam, representing about 3 percent of the mean annual runoff of the respective river systems; the remainder was to be diverted and exported to RSA. These flows were stipulated without adequate understanding of the implications on downstream water uses.

The social and environmental assessment for Phase 1A concluded that the project did not present any insurmountable environmental obstacles to development, and detailed baseline studies for Phase 1A were conducted after construction of the project had already started.

The contractors for Phase 1A were willing to continue with Phase 1B without any major interruption and thereby avoid substantial mobilization costs. Consequently, the government of Lesotho requested the World Bank to avoid delays in commencing Phase 1B and to approve the Phase 1B environmental assessment (which had largely focused on upstream issues and impacts) and agreed to carry out an instream flow requirement study (essentially an EFA) during the initial construction phase of Phase 1B. The Bank agreed to this request, subject to an EFA being conducted and the implementation of measures to provide "compensation" releases from the Matsoku, Katse and Mohale dams prior to commencing impoundment of water in Mohale Reservoir. This requirement was stipulated as a legal covenant to the Bank loan in the project appraisal document. In fact, the EFA was substantially delayed, and so the environmental flow releases were not agreed with the World Bank before the date of impoundment.

A new method—the downstream response to imposed flow transformations (DRIFT)—was developed for the EFA, specifically to integrate the environmental, social, and economic impacts on populations downstream of the Lesotho Highlands dams. The EFA considered four flow release scenarios:

1. minimum degradation—60 to 65 percent of MAR maintained for downstream ecosystems
2. Treaty releases—the releases provided for in the 1988 treaty (about 3 percent of MAR)
3. design limitation—maximum releases possible consistent with the design of Phase 1 structures
4. intermediate—flow releases between the design limitation and the treaty requirements

The EFA study highlighted that:

- nearly 39,000 people were estimated to be impacted directly or indirectly downstream of the dams, compared with a few thousand impacted upstream
- sites close to the dams would be severely impacted under all but scenario 1
- significant losses could occur to downstream communities under all scenarios; even under scenario 1, losses amount to over $2 million annually
- while increasing environmental flow releases would improve the condition of downstream users, adopting the fourth (intermediate) scenario would cost Lesotho about $17 million in net present benefit compared to the treaty minimum scenario, a 3.3 percent loss in revenue (Watson 2006)
- the benefits from the LHWP are large enough for the economic rate of return to not be substantially affected by increasing the downstream flow

Agreeing on environmental flow releases proved to be difficult. This was partly because (a) the LHDA and the funding partners had different expectations of the EFA; (b) the treaty was seen to have already stipulated minimum flow releases (that were 3 percent to 5 percent of the total mean annual runoff); (c) of the absence of a clear policy and legal framework in Lesotho that recognized environment as a legitimate user of water; (d) of the inherent uncertainties in the study predictions; (e) of the delayed decision-making process; and (f) the scientific results were complex and not presented in ways that could be easily grasped by decision makers.

After intensive negotiation, the LHDA agreed on a flow release policy with environmental water releases

that were three and four times the treaty minimum for Mohale and Katse dams respectively. The Mohale Dam outlet valves had to be re-sized to accommodate the anticipated higher flows, and a new valve had to be added to Katse Dam to accommodate higher EFA releases. Although costly in terms of lost revenue from water diversions, these larger environmental water releases should substantially reduce downstream environmental impacts and the size of compensation payments. These costs, however, did not entail any significant changes in the project's economic rate of return.

Downstream river health targets were established as part of the EFA study, together with agreed compensation payments for the remaining losses in ecosystem services. Local community development projects would be funded with villages in the proximal river reaches, while compensation would be provided through broad development programs in the distal reaches. In both cases, the present value of 10 years predicted losses would be paid up front. Actual losses, based on monitoring data, would then be used to determine the amount of a second compensation payment that would cover another 40 years.

The collection of environmental monitoring data was meant to commence in 2001 but actually commenced in 2004, largely due to delays internally within LHDA. The program has now been established and early indications are that, under the agreed flow release policy, the river health targets have been met or exceeded in all except two reaches. While people in the proximal reaches received the agreed initial compensation packages, the authorities have delayed paying any compensation to those in the distal reaches because of the uncertainty regarding the potential losses in these reaches. The lack of monitoring data may mean that it is impossible to demonstrate losses, exposing the authorities to a serious reputational risk if the affected people mount a challenge to their position.

Drivers

The World Bank's environmental assessment safeguard policy was the principal driver for the EFA. Lesotho did not have policy or legislative requirements for EFAs and there was no evaluative oversight from a Lesotho government agency. In fact, the Environment Ministry from Lesotho was absent from any debate over downstream effects. The implementation of Phase 1A raised awareness about the need to better define, understand, and address the downstream issues.

The professional drivers for the EFA in Lesotho were weak. When the EFA was being designed, there was no in-house capacity in environmental flows within the LHDA. The environmental adviser at LHDA contributed to discussions about the need for an EFA and supported the preparation of terms of reference for such an assessment. Although local NGOs were active in pursuing compensation and resettlement issues, they were not influential in driving the EFA process itself.

The other partner in the project, the RSA, on the other hand, had not only been a world leader in developing EFA techniques during the 1990s, but had adopted a progressive water policy and legislation that recognized and mandated water for environment as a very high priority in its allocation decision making (Case Study 3). Further, the professional capacity for both advancing and implementing EFA was also strong in RSA. Thus, there were strong procedural as well as professional drivers for EFA in South Africa.

Although there was, at times, reluctance by LHDA to provide water for environmental flows in a timely manner, the implemention of the environmental flow policy and associated operating rules for the dams have eventually resulted in good downstream environmental outcomes, although the social and economic outcomes are less certain. The latter is in part due to the absence of adequate socioeconomic data and information on downstream communities.

Assessment

Recognition. One of the major difficulties in implementing the EFA was the absence of any policy or legislative framework in Lesotho for recognizing environmental flows as a legal use of water. Consequently, the discussion about the EFA had to deal with both, not just the immediate issue of the quantity and timing of water needed, but even the legitimacy of the concept of environmental flows. Thus, even after the government of Lesotho had accepted the need to provide adequate environmental flows, there was some reluctance on the part of managers and dam operators to release valuable water, particularly when the benefits were not obvious and the financial loss associated with such releases due to reduced export of water were quite obvious.

Undertaking the EFA concurrently with the construction of the Phase 1B infrastructure exacerbated this problem. It proved difficult to alter the earlier treaty minimum flow release, even when it became apparent that the treaty minimal flows were inadequate, because of the costs involved in re-engineering the dams' offtake structures.

Participation. The DRIFT method was developed to ensure that the effects of flow changes on populations were measured. Thus, DRIFT included social and economic studies that identified the populations dependent on the river and assessed the effects of different flow scenarios on these populations (or the populations at risk). In the socioeconomic analyses, the social implications associated with resource quantity and quality loss or alterations were translated into the costs of mitigation and compensation for the affected population. The impacted population was kept informed of these decisions, but were not part of this decision-making process.

The lack of government policy on environmental flows also meant that there was no in-country guidance on the purpose or extent of participatory activities. The Bank safeguard policies filled this gap and became the guides for participation.

Although an ambitious program of development support (based on the experience of Phase 1A) was designed for the highlands during Phase 1B to offset upstream impacts and disruptions, none were designed for the downstream communities affected by the dams. At that time, there was no knowledge about the extent and severity of downstream impacts. Moreover, downstream issues and impacts were assessed much later in the decision-making process (during the construction of the dams) compared to upstream impacts (which were reviewed before the appraisal of the project).

Scientific method. The DRIFT technique remains a cutting edge method for systematic integration of environmental, social, and socioeconomic effects from changes in river flows. It is holistic in that it considers all relevant components of the flow regime. It was developed during the LHWP and so met the project's requirements of allowing the impacts of different potential flow regimes to be analyzed. The four flow scenarios described above were augmented with others as decision makers moved toward a decision.

The DRIFT technique required extensive fieldwork to collect the environmental, social, and economic data. While this ensured that its environmental and social predictions were well-founded, it also meant that it was time-consuming and expensive to apply. However, given that there was no baseline data, that the LHWP will entail several other phases, and that the LHDA was skeptical about the value of EFA and required convincing evidence, it was appropriate to design and implement such a comprehensive method.

DRIFT was designed and implemented by expert groups with international standing. In addition, a panel of international experts was appointed to oversee the process. They contributed to the content of the flow release policy, the monitoring protocol, a program to

protect the endangered Maloti minnow, and designing and establishing the Lesotho Biodiversity Trust.

Overall, the project resulted in the development and application of a world-class EFA methodology.

Cost effective. The EFA (which included the assessments for both the Phase 1–1A and 1B, and the proposed Phase 2 project) cost approximately $2 million. It was relatively expensive, but in comparison with the scale of the project, it was not that expensive. The cost of the EFA amounts to only 0.07 percent of the total project costs, while the downstream compensation costs ($14 million) amounted to 0.5 percent of the total project costs (Watson 2006). In comparison, the cost of upstream resettlement alone was $68 million. Given that there was no baseline data for the region and that the LHWP will entail several other phases, this initial investment provides a solid foundation for future investments. And as noted above, the EFA includes an assessment of the future Phase 2 project impacts as well.

Reporting. The four chosen scenarios provided situations that were readily understandable to the decision makers. However, the results of the EFA were less understandable, at least initially. The comprehensiveness of the DRIFT method meant that extensive information and data were generated, making it almost impossible for a decision maker to understand how an individual expert's predictions had been built into aggregate weighted indices. While decision makers could easily understand the financial implications of exporting less water to South Africa, they could not easily grasp what it meant to move from one "river condition" class to another.

Given these difficulties, a decision framework was devised to summarize the EFA outputs in a form that the decision makers could understand. While this illustrated diagrammatically the trade-offs between water users and river condition, it still required the decision makers to understand the implications of changes in river condition.

The lesson here is that much more needs to be done by the scientists to simplify and translate environmental flows information to ensure that political decision makers can access and absorb the scientific findings and make appropriate use of them when making decisions.

Influential. The comprehensiveness of the EFA analysis and its recognition globally was a major factor in the LHDA's eventual acceptance of the need to provide for downstream flows. The study findings resulted in the Mohale Dam outlet valves being re-sized to accommodate the anticipated higher flows, and a new valve being added to the Katse Dam to accommodate higher EFA releases. The EFA also provided the information for the development program to compensate affected communities downstream of the dam. However, there has been reluctance by the LDHA to provide agreed compensatory development packages for the affected communities in the distal reaches (reaches further downstream from the dam) until it is demonstrated that impacts on distal communities are measurable and significant..

In principle, the experience during Phase 1B of the project will lead to easier adoption and better acceptance of EFAs in subsequent stages of the LHDP; in fact, as noted above, the EFA for the Phase 2 development was included in the EFA. However, the lower-than-expected demand for water from RSA has meant that there has been no further development of the highlands water, although studies for Phase 2 are already under way. Nevertheless, the knowledge and experience gained during the EFA has contributed to environmental flows capacity in Lesotho and is being used both in the planning and design of the Metalong Dam on the Phuthiatsana River, southeast of Maseru, as well as in the LHWP Phase 2 studies.

According to the independent audit supported by LHDA, the LHWP environmental flow policy development and implementation experience represents the most complete, most analyzed, and best documented project-level environmental flows

case globally. It contains the key steps in the decision-making process—from the science of assessing ecological impacts under different flow scenarios, to the integration of biophysical and social issues with the ecological impacts, the incorporation of early study findings into the decisions about sizing dam outlets valve, the economic analyses of the four flow scenarios, a decision framework that led to the environmental flow recommendations and policy, and to implementation and monitoring. The EFA process (as noted above) was also subjected to an independent audit which identified important lessons.

The LHWP experience has also contributed to environmental flows practice elsewhere, primarily through the application of the DRIFT method. DRIFT remains one of the few EFA techniques that integrates environmental, social, and economic concerns. Thus, the Mekong Basin and Pangani Basin environmental flow assessments (Case Studies 7, 8) use modified versions of DRIFT, and the technique has been applied within South Africa in establishing the ecological reserve.

Lessons

1. Without policy and legislative backing, a project-level EFA will likely struggle to be readily accepted by development-oriented managers. Developing such a policy simultaneously with the project-level EFA can lead to delays, confusion, and conflict. It is advisable to have a policy and legal framework in place to guide EFA.
2. The values of stakeholders should be made as explicit as possible as early as possible in the process of assessing and determining EFRs. This is most easily accomplished if there is a catchment-level water allocation process or plan in place where the values of stakeholders are already defined. This provides a baseline of water sharing against which the changes resulting from a project, such as a dam, can be assessed.
3. Continuing dialogue and sharing of knowledge between project proponents and funding agencies can lead to a convergence of views on the importance of environmental flow assessments in countries without a history of environmental flow assessments.
4. To put the EFA determinations into effect, it is essential to have a well-defined decision-making process.
5. Downstream impacts can be significant. When the EFA was carried out in this case, it revealed that the number of people affected downstream was, in fact, greater by an order of magnitude (nearly 39,000 people) than the number affected upstream of the dams.
6. Full-scale EFAs (such as the one undertaken in this case study) take considerable time to complete. Biophysical data need to be collected, affected communities need to be identified, social impacts need to be predicted and explained, and economic analyses need to be undertaken. The EFA needs to be designed and data collection needs to commence as early as possible.
7. Science needs to be made more accessible. Unless scientists can present their findings from such a complex environmental, social, economic study in a readily understood format, decision makers will not be able grasp the full implications of alternative decision choices. Decision makers should be educated in the science and the methodology at an early stage and provided with continuous feedback as the study progresses to ensure that they are not surprised by unexpected outcomes.
8. A decision framework should be established that shows the benefits and costs of a range of decisions using financial, environmental, and social metrics. Presenting them with a framework rather than specific predictions gives decision makers control over the choices.
9. The EFA process should make specific predictions that are able to be subsequently tested through

a monitoring program. The budget for the project should include funds for the monitoring program and there should be opportunities for the monitoring results to feed back into the operational plan for the infrastructure.

Acknowledgments

This case study drew from Watson 2006. Andrew Macoun of the World Bank provided additional information.

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Case Study 15.
Lower Kihansi Gorge Restoration Project

Background

The Lower Kihansi hydroelectric plant was constructed on the Kihansi River within the Rufiji Basin in Tanzania during the mid-1990s (World Bank 1993) to augment the country's limited electricity supply generation capacity.[48] The hydropower plant had been designed as a 180MW run-of-the-river development with provision for expansion to 300MW in the future, making it a significant power source for the energy-strapped country. The Lower Kihansi site was an attractive site for a hydropower plant because of the availability of high head in a short stretch of the river and the favorable hydrology with a good reliability of flows (Mkhandi and Birhanu 2007), coupled with the absence of settlement below the dam site.

The catchment above the dam site is 584 km^2 in area and is characterized by hilly terrain. Mean annual rainfall in the catchment is 1944mm. The high-biodiversity Udzungwa Forest Reserve covers the land to the east; the rest of the catchment is covered with small forest reserves, grassland, and bush. Most of the lower parts of the catchment are under agriculture. Downstream of the hydropower site, the Kihansi River drops some 800 m through a narrow gorge cut into the escarpment, with difficult physical access.

Although the EA for the Lower Kihansi Hydropower Project (LKHP) (based on a 1991 EIA) had concluded that there were no significant environmental issues arising from the proposed hydropower plant[49], it did not include an assessment of impacts downstream of the proposed dam. The Bank initially accepted the EA for the LKHP on the assumption that the downstream was uninhabited and unlikely to possess significant environmental value. The steep terrain and difficult access may have contributed to the inadequate attention to the downstream gorge area in the EA. To address this gap, NORAD, a cofinancier of the project, commissioned in the mid-1990s a series of baseline and ecological monitoring studies.

It was during these subsequent ecological monitoring studies (by Norplan consultants during project construction in 1996) that led to the discovery of the endemic toad, the Kihansi spray toad (KST), in a rare wetland system in the Kihansi Gorge downstream from the dam. The hydropower plant was designed to divert water from a small reservoir above the gorge through an underground tunnel to drive turbines in a power plant located below the gorge. Thus, operation of the hydroelectric plant would drastically reduce flows through the gorge and consequently the spray that sustains the wetland.

Once discovered and classified as a critically endangered species under IUCN's red book, temporary measures had to be taken to safeguard the downstream Lower Kihansi Gorge ecosystem, including a captive breeding

[48] Around 10 percent of Tanzania's population has access to electricity.

[49] Environmental studies found the Lower Kihansi hydro site preferable to other potential sites because of the smaller size of the reservoir, and a relatively uninhabited catchment meant that the project would disturb less land area, and there were not expected to be serious social and resettlement issues.

program for the spray toad in the United States, the design of special nozzles that could generate fine spray and construction of an irrigation sprinkler system to generate fine artificial spray in the gorge, and the implementation of an environmental management plan. The environmental flow required to maintain the ecosystem was not known, and as a consequence, the granting of a final water right for generating hydropower was difficult and delayed. At the time, Tanzania did not have a water or an environment policy that explicitly recognized the environment as a legitimate use of water (like other uses of water such as drinking, agriculture, or energy), did not have legislation requiring EIAs for development projects, and had no technical capacity to undertake an environmental flow assessment or institutional capacity to facilitate and negotiate an environmental flow requirement for complex water resources investments.

The Lower Kihansi power plant came on-stream in 2000, only 6 months later than the original commencement date. The plant met its objective of helping meet rising demand for hydropower and reducing the amount of thermal plant use. Since 2000, the 180 MW Lower Kihansi power plant has been supplying between one-third and one-quarter of Tanzania's electricity production (World Bank 2003).

A year elapsed between the diversion of the river flow and the installation of the emergency measures. During this time, the available habitat of the spray toad was dramatically reduced and the spray-dependent ecosystem was at great risk of extinction. The various mitigation measures (including a specially designed irrigation sprinkler system to generate artificial spray) restored a limited amount of spray-dependent habitat, and the Kihansi spray toad population subsequently increased. The artificial spray appeared to stabilize the population in the areas where it was installed. Unfortunately, in August 2003 the spray toad population crashed, with the last documented sighting of a spray toad in May 2006. Subsequent biannual surveys since 2006 have not documented any spray toads. The exact cause(s) of the disappearance of the spray toad are not known, although introduced chytrid fungus (known to have caused extinctions in amphibians world-wide and detected in the gorge), and pesticides (endosulfans have been found in concentrations 13 time the concentrations known to be lethal to amphibians) or some combination of the two factors are possible causes under the heavily stressed conditions of the gorge. Chytrid fungus could have been introduced through human traffic in and out of the gorge, whereas pesticides may have been introduced during the flushing of the dam or during the high-flow studies or even via the bypass flow releases. Although the population of spray toads held in captivity in the United States declined from the 499 initially transported to about 72 in March 2004, more recently, as a result of good animal care, it has recovered and increased to over 1,000 individuals.

The Lower Kihansi Environmental Management Project

The Lower Kihansi Environmental Management Program is a restoration project aimed at conserving the unique Kihansi Gorge ecosystem, while at the same time balancing the nation's electricity needs. It is centered around the water needs of the Kihansi Gorge.

The Tanzania National Electricity Supply Company (TANESCO) applied for the final water right as the construction of the dam was nearing completion. The provision of this final water right, after the Kihansi spray toad was discovered, was highly contested. A provisional water right had been granted when construction started with the condition that the dam be constructed with provision for a bypass flow structure of capacity 7 m^3/s—to release the minimum historical flow that was on record. The Rufiji Basin Water Office (RBWO) monitored the provision of these bypass flows.

In July 2000, in response to a complaint filed by Friends of the Earth, an international environmental organization, the World Bank launched an environmental review of the circumstances surrounding

the LKHP and the steps needed to mitigate its downstream impacts. The review found that the power plant was being operated for baseload generation and not peaking purpose as it had been designed[50] and found that the installed bypass pipe capacity to release environmental flows was between 1.5–1.9 m^3/s. The review recommended that, in addition to the actual interim bypass flow of between 1.5 and 1.9 m^3/s, further mitigation measures be investigated.

In 2001, the World Bank approved an emergency loan to protect the Kihansi Gorge ecosystem and improve Tanzania's water resources management (World Bank 2002). The Lower Kihansi Environmental Management Project (LKEMP) funded studies into the conservation of the Gorge ecosystem; developed a catchment conservation plan for the area upstream of the dam; supported capacity building in conservation biology and environmental and water resources management at University level; developed a process for establishing the final water right for operating the power station; formulated an EMP for the gorge, including an environmental monitoring plan, as part of the final water right; and supported the improvement of the legal and institutional structure for environmental management in Tanzania.

Following extensive scientific studies and negotiations between TANESCO, the RBWO, NEMC, and LKEMP, a final water right for the LKHP was granted to TANESCO by the Rufiji Basin Water Board in June 2004. It included an EMP that stipulated environmental flows of 1.5–2.0 m^3/s, coupled with other measures to ensure the conservation of the Kihansi Gorge, including ecological monitoring, the continuation of the artificial sprays in the most ecologically sensitive parts of the gorge, and measures to quarantine the gorge from the entry of further fungal infestations.

However, implementation of these conditions on the final water right has not been easy. Monitoring by the RBWO showed that the bypass flows were about 30 percent less than the flows that TANESCO reported it was providing. As a result of an audit requested by the LKEMP, TANESCO has retrofitted the low-level discharge pipe from the dam to provide additional head so that bypass flows now meet the requirements of the water right.

In spite of the flows through the gorge being less than required during both the construction and operational periods of the dam, the flows, together with the artificial spray system, have stabilized the gorge's spray wetland vegetation to the point where it may be possible in the future to reintroduce the spray toads from the populations held in the United States. This will however require other factors, such as the chytrid fungus and pesticides, to be controlled and the establishment of a captive population in Tanzania.

The LKEMP also assisted the Tanzanian government in revising its environmental legislation. A new Environmental Management Act was passed in 2004, containing specific provisions for EIAs, inclusion of environmental flows in basin plans, and strategic environmental assessments for hydropower and major water projects.

The LKHP however faces new challenges. There are now growing concerns about the threat from deforestation and uncontrolled bottom valley cultivation of the catchment above the dam. Clearing of forests for agricultural activities is common and is being extended to the hills. Most of the lower accessible areas are cultivated because the valleys are wet and valley bottom cultivation is a growing practice in the dry season. This practice has the potential to increase erosion rates, bringing more sediment into the reservoir and into the spray system in the gorge. The increase in agriculture may also lead to an increase in the use of pesticides, adding further pressure on the gorge if the spray toads were to be reintroduced. A landscape-wide conservation plan (LWCP) for the Upstream Kihansi Catchment was completed in 2005

[50] This means that there is much less water spilling over the dam and flowing through the gorge than originally envisaged.

as apart of the LKEMP project (SMEC 2005) to provide the basis for controlling this threat. Additional threats include flood flows from spills over the dam and mudslides during periods of heavy rain that have recently caused damage to the sprinkler system and related infrastructure in the gorge.

Additional funding for the LKEMP was approved in September 2007 and commenced in March 2008. Its objectives are (a) to maintain the captive populations and the gorge ecosystem, and re-introduce the spray toad to the gorge; (b) to implement the LWCP to protect the upper catchment from further degradation; and (c) to further strengthen capacity for environmental management and compliance in Tanzania.

Drivers

The Lower Kihansi work has occurred in three distinct phases. The initial construction of the LKHP and belated discovery of the Kihansi Gorge ecosystem occurred under the Bank-funded Power VI project between 1993 and 2001; the LKEMP project commenced in 2001 to respond to the emergency arising from the discovery and stabilize the gorge ecosystem and safeguard the spray toad population; and additional funding for LKEMP has extended the project to 2010 to facilitate the reintroduction of the spray toad and improve the management of the catchment above the dam. This section deals with the last two phases where the environmental flow assessment and implementation occurred.

Once the Kihansi spray toad was discovered, the safeguard policies acted as a powerful driver for action, and the Bank funded mitigation and protection measures. This instrumental driver was accompanied by a powerful public driver in the form of pressure on both the government of Tanzania and development partners funding the project—including the World Bank and the governments of Norway, Sweden, and Germany—from international environmental organizations to save the spray toad and its associated ecosystem.

There were few institutional drivers from within Tanzania at that time, partly because there was no policy or legislative requirement for either recognizing water needs for the environment or EIA, and partly because the value of the spray toad appeared to be small or was intangible compared to the very high economic value of the electricity generated from the waters of the Kihansi River. The DOE, NEMC, and the RBWO played a key role in highlighting the complex issues, but had limited technical and institutional capacity in environmental flow work, as this was the first such case nationally. In fact, internationally, it was also the first environmental flow case of a wetland with a specific micro-climate dependent on the spray from the falls instead of river flows.

The RBWO acts as the driver for enforcement of the environmental flow requirements of the TANESCO water right. The RBWO grants the water right and actively monitors and enforces the conditions of the water right as part of its responsibility for managing water allocations within the Rufiji Basin. An additional professional driver has arisen in recent years. Because of the publicity arising from the discovery of the rare ecosystem and the Kihansi Spray Toad and the development of national pride in this unique ecosystem and species, Tanzanian environmental and water agencies are now actively engaged in supporting the recovery efforts.

Assessment

Recognition. The crisis over the Lower Kihansi hydropower plant arose from a lack of recognition of the importance of water needs for the environment and of maintaining downstream environmental flows. The environmental assessment carried out at the time of the Power VI loan, like similar EAs at that time, concentrated on the upstream impacts of the development.

Nevertheless, the LKHP lessons have improved the understanding of the importance of environmental flows within Tanzanian institutions, partly driven

by this internationally recognized case. The 2002 National Water Policy and the draft Water Resources Act (Case Study 4) provide for environmental flow determinations and, more importantly, among water resources professional there is now an internalization of the need to provide for flows that maintain downstream environments. Thus, NEMC, DOE, and the Ministry of Water are all much more aware of the need to take downstream effects into account when assessing infrastructure development applications.

Participation. Extensive consultations were held with key sectors of the government between 1996 and 2003 once the threat to the downstream ecosystem and the KST were recognized and publicized. These consultations included DOE and NEMC, the Ministry of Energy and TANESCO, the Ministry of Water and the RBWO, the Ministry of Natural Resources, and the Forestry Department. Under LKEMP, the discussions were conducted at intergovernmental meetings through the Multi-sectoral Technical Advisory Committee (MTAC) and overseen by a high level inter-ministerial steering committee.

The case study is unusual in that there are no communities downstream of the dam in the Kihansi Gorge. The only affected people were essentially environmentally concerned people in the international community, initially represented by Friends of the Earth. The government of Tanzania had a responsibility, through the International Convention on Biodiversity, to protect the KST and its habitat. No public consultations were held, but extensive consultations have taken place among the many government agencies, the academic community, and development agencies. Many debates have also taken place in the Parliament over the development challenge facing the country from the project related issues, including the electricity challenges facing the nation, the contribution of LKHP in the national electricity grid, the cost of the conservation effort, the value of KST to the nation and its people, and who is benefiting from the conservation of the Kihansi Gorge ecosystem and the KST.

Although there were no legal requirements that determined the breadth and types of consultations required, the consultations were conducted in the spirit of national priority that surrounded this complex issue.

Assessment technique. The environmental flow assessment was, on the one hand, relatively simple spatially in that the environmental values were concentrated in the Kihansi Gorge. But on the other hand, it was also complex and novel in that the gorge ecosystem was driven by the micro-climate—spray form, size, distribution, humidity, wind patterns, and temperature—generated by the falls, rather than directly by the river flow. Therefore, none of the known EFA methods were applicable for the LKEMP. New scientific techniques, based on experimental work—ecological studies and flow tests—had to be developed and applied to model the spray fineness, size, concentration and distribution, humidity, wind direction and speed, and temperature in order to assess the effects of different flow regimes on the gorge habitat. High-flow trials during the dry and wet seasons—both prior to and after the commissioning of the dam—established the area of gorge ecosystem wetted by different levels of flow.

Financial and economic evaluation studies of various flow regimes provided estimates of the costs of foregone power production. The final flow recommendation was based on the flow trials, economic studies, and the efficacies of the mitigation measures such as the artificial sprinkler systems.

Data and science. Following its discovery, extensive ecological studies were mounted in the Kihansi Gorge ecosystem, with a focus on the spray toad and the Kihansi Gorge ecosystem. The habitat, feeding, reproduction, behavior, and predation and disease characteristics of the spray toad were established (Channing and others 2006). Ironically, the Kihansi spray toad is both Africa's most well-studied amphibian and its most endangered, yet knowledge of the overall Kihansi catchment remains patchy at best.

These studies showed that the KST is dependent upon the spray wetlands, which in turn are maintained by spray that is generated by the waterfalls within the Kihansi Gorge. Humidity and temperature are two important factors for KST's survival. The toad's thin skin restricts it to cool, humid areas, where it lives on the vertical rock faces within the direct spray zone of the various falls. Food is mostly small insects that themselves feed on the vegetation in the spray wetlands. The extent of spray from the falls, and hence the extent of habitat suitable for the toads, was established through high-flow trials during both the wet and the dry seasons (World Bank 2004).

Integration. The results of the environmental investigations—the bypass flows plus the engineered solution of an artificially generated spray—were integrated with economic/financial assessments in order to arrive at a minimum flow from the dam. Social values were difficult to incorporate because of different value systems. The intangible value of an endangered species was high to people external to Tanzania, but not to Tanzanians. Nonetheless, the government of Tanzania (as a signatory to the International Convention on Biological Diversity and under pressure from external interests) agreed to protect these values. The other relevant social value was the loss of amenity by Tanzanians, who would forego electricity consumption if some flows were assigned to environmental protection. This value was represented through the loss of revenue by TANESCO resulting from a decision to provide water for the downstream ecosystem.

Cost effective. It took some years to establish the environmental flow requirements because of both the complexity and novelty of the situation and the need to conduct the scientific studies, and the extended negotiations required to achieve a balance between ecological sustainability and electricity generation.

Most of the original LKEMP project ($6.3m) and its subsequent extension ($3.5m) were devoted to the conservation of the Kihansi Gorge ecosystem, including the EFA and the establishment of the flow requirements of the final water right. Thus, the cost of the EFA and implementation was approximately $8m. The intangible benefits have not been costed.

This is clearly an expensive restoration project. Some of the costs, such as the establishment of the flows needed to generate certain levels of spray, would have been incurred if the environmental flows had been established as part of project preparation. Other costs, such as the retrofitting of the increased bypass flows and the protracted negotiation of the final water right, were incurred because of the delayed recognition of the importance of the downstream ecosystem. Overall, the project illustrates that delaying EFAs can significantly increase the total project costs as well as the reputational costs.

Reporting. The environmental management plan was the key document produced by the first phase of LKEMP. It was well-written and its conclusions were clearly based on scientific studies. However, the value of the downstream ecosystem was not established in this report, and so the trade-off between flows for electricity production and flows for the downstream environment could only be established through protracted negotiations.

Influential. The EFA was specifically commissioned to establish the flow requirements for the downstream ecosystem and its outcome and mitigation measures were highly influential in establishing the final water right for the power plant. Although the flow requirements in the provisional water right were not adhered to by TANESCO, the EFA provided a solid basis for the necessary mitigation measures and for the oversight agency (RBWO) to require the company to enforce the water right and to increase bypass flows when the final water right was not being enforced.

The belated discovery of the spray toad in 1996 highlighted the limited understanding of the environmental water needs in operational terms and

also exposed the limitations of institutional and legal structures for environmental protection and the lack of capacity within Tanzania for carrying out EFAs. It also highlighted weakness in the project planning and preparation process.

The LKEMP lessons and experience have contributed to major policy and legal reforms in Tanzania's water (Case Study 4) and environment sectors. Thus, as a result of LKEMP, the new environmental legislation mandates EIAs for major projects, there is an improved awareness of environmental flows within water and environmental institutions, as well as for specialist tertiary-level training in environmental conservation (Acreman and King 2005). While these advances have yet to be used for an EFA of a new project, the resulting wider understanding of environmental flows has played a significant role in the conduct of EFAs for basin water resources plans being developed in the Pangani (Case Study 8), Rufiji, and Wami-Ruvu basins in Tanzania. The case has also contributed to improved awareness within the Bank about downstream impacts and environmental flows.

Lessons

1. Unique and spatially limited ecosystems can easily be vulnerable to collapse with additional pressure because they have little resilience.
2. Neglect of environmental flow considerations at an early stage of project preparation can lead to substantial monetary costs during project implementation because of limited options available to alter the project design and operations, to retrofit already constructed infrastructure, and to carry out additional studies.
3. There are significant reputational costs arising from the omission of or delaying the recognition of downstream effects from the assessment of development projects.
4. International obligations (such as the CBD) provide a means of (and are an important driver for) protecting unique and fragile ecosystems.
5. International pressure can sometimes play a powerful role in ensuring that critical ecosystems, including those downstream of infrastructure developments, are protected from damage.
6. Monitoring is essential to ensure that the agreed environmental flows are adhered to, especially when there is pressure to favor critical economic water uses such as hydropower production and when production-oriented authorities are reluctant to understand or accept the need for environmental flows.
7. Ecosystems can have indirect as well as direct dependence on flows; in this case, the ecosystem depended on the spray from the Kihansi Falls. None of the traditional EFA methods were applicable in these circumstances and new technical methods based on on-site and experimental fieldwork and testing had to be developed.
8. The restoration of the spray-dependent ecosystem depended on both high-quality scientific studies and engineering solutions, as well as government commitment to conservation.
9. The government of Tanzania took the opportunity offered by lessons learned from the crisis over the Kihansi Gorge ecosystem to incorporate them into the new environmental act legislation. It strengthened the environmental aspects of its water policy and built capacity for environmental assessments, including EFAs.
10. This difficult case has also contributed to improved awareness within the Bank about environmental flows and the need to systematically address downstream impacts of water resources developments.

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Case Study 16. Senegal River Basin

Background

The Senegal River Basin (290,000 km^2) is shared by Guinea, Mali, Mauritania, and Senegal and has three distinct zones: the mountainous upper basin lying mainly in Guinea and partly in Mali; the river valley and its associated floodplain, which varies between 10 to 20 km wide and forms the border between Senegal and Mauritania; and the delta where the river empties into the Atlantic Ocean. Flows in the 1,800 km river, one of the largest in Africa, originate almost entirely in the upper watershed from the monsoonal rains between April and October. Historically, the river has produced a two-month flood, bringing water and life to the delta and the valley, which is mainly in a desert and arid landscape. Management of the Senegal River Basin is vital to the economies of the four riparian countries, whose inhabitants depend upon the river for their livelihood in the form of agriculture, animal husbandry, and fisheries.

During the 1970s and 1980s, the Sahelian region experienced an extended period of drought. Compounded with the high natural inter-annual variability in rainfall and in river flows, the drought led to a chronic water deficit in the region. In response to this situation, Mauritania, Mali, and Senegal signed a treaty in 1972 to establish the Senegal River Basin Authority (L'Organisation pour la Mise en Valeur du Fleuve Sénégal – OMVS) with the mandate of "securing countries' economies and reducing the vulnerability of peoples' livelihoods through water resources and energy development" (World Bank 2006). Guinea joined OMVS in 2006.

The objectives of OMVS are to (a) stabilize and improve the livelihoods of the inhabitants of the basin and adjacent areas; (b) maintain an ecological balance within the basin and promote its sustainability within the sahelian zone; (c) render the member states less vulnerable to climatic variations and external factors; and (d) accelerate the economic development of the member states through intensive regional cooperation. A key element of the plan of OMVS includes the implementation of a regional infrastructure, including (a) the Manantali storage reservoir and hydroelectric project; (b) the Diama saline intrusion and irrigation barrage with embankments along the lower river; (c) the construction of ports at Saint Louis and Kayes, as well berthing facilities at nine locations between the two towns, and (d) the development of a navigable channel.

The structure of OMVS has also evolved over time. It has been reorganized to meet the changing requirements of the initial construction of infrastructure, followed by its management, operation, and maintenance. The present structure provides an institutional framework for transboundary river basin management that is essential for implementing environmental flows in an international river basin. OMVS allows basin-scale water management and allocation of benefits between the basin states, such as irrigation water and electricity generated from hydropower.

In addition, OMVS developed an inclusive framework that set the legal provisions for inclusion of Guinea into OMVS and established a joint Basin Development Program, which has reoriented the strategy for the development of the basin. The present OMVS's vision

is to "implement a joint basin development program that reinforces regional integration, yields benefits and sustains growth among the four associated riparian countries."

Senegal River Infrastructure

The following description will focus on World Bank-supported projects for water resources development in the Senegal River basin. However, a number of other donors, including the African Development Bank (regional infrastructure development and sound environmental management), *Agence Francaise de Developpement* (water resource management tools), the Netherlands Cooperation (environmental mitigation and restoration, and water-weeds removal and the rehabilitation in the delta), and the European Union (preparation of the Senegal River Master Plan) are also supporting the OMVS.

The Diama Barrage was constructed at the mouth of the river between 1981 and 1986 to stop saline water entering the river, thus making the river a reservoir of freshwater for irrigation. About 375,000 hectares of land are under irrigation. Embankments were built from the dam upstream on both banks in the early 1990s to store water in the river at an elevation that allowed gravity feed to the floodplains and provided sufficient depth for year-round navigation along the river into Mali. The barrage also provided water supply for stock and for Dakar.

The construction of the upstream storage reservoir at Manantali on the Bafing River was undertaken during the period 1982–87 with funding from a consortium of banks and international agencies. The World Bank declined to be involved. The reservoir, with a capacity of 11,270 Mm^3, was filled over the three subsequent years. The purpose of the dam was to generate 800 GWh/year of electricity (90 percent certainty) and to provide water for irrigation. The dam site controls 50 percent of the flow on average and 70 percent in dry years. The hydroelectric power station was postponed pending further studies, which were carried out in the early 1990s. Under the original project, irrigation has been developed on about 100,000 hectares of the potential 375,000 hectares of land suited for irrigation. A fishery has developed on the Manantali Reservoir, leading to settlement.

The decision to proceed with the 200 MW power plant at Manantali Dam and associated transmission works was finally taken in 1997 and construction began in 1998, with the power generation and transmission equipment being funded with World Bank assistance through the Regional Hydropower Development Project (1997–2003) (World Bank 1997). The transmission lines to Bamako were commissioned in 2002, with the inter-connections to Dakar and Nouakchott shortly thereafter. The navigation project has not been implemented due to lack of financing, but OMVS is still planning to proceed with a scaled-down version of the original concept. The Bank agreed to participate in the Regional Hydropower Development Project because the dams being funded would have a large influence on the economies of the three countries in OMVS at that time. The Bank was able to help coordinate the development across the countries because of its existing experience in a number of sectors in all three countries.

The project provided an opportunity to address some of the difficult environmental and social issues that accompanied the original project, especially impacts of altered flood regimes. Prior to construction of the Manantali Dam, natural inundation of the floodplain of the Senegal valley supported up to 250,000 hectares of flood recession agriculture, forests which provide fuelwood and construction timber, fishing, grazing for livestock, recharge of groundwaters, wildlife habitat, and maintenance of wetlands in the Senegal River Delta (Table 16.1). While there is considerable debate about the actual values derived in Table 16.1, the principle has been accepted that the floodplain ecosystem has a high value that was not recognized in initial planning of the river basin.

Table 16.1 Value of Floodplain Production under Pre-dam Conditions

Activity	Value ($/ha)
Recession agriculture	56–136
Fishing	140
Grazing	70
TOTAL	266–345

The construction of the Manantali and Diama dams created significant environmental and social impacts. A primary impact was the loss of flood-recession agriculture, fuelwood, and grazing on the floodplain. There was a 90 percent drop in the productivity of the fisheries of the Senegal Delta, which relied on inputs of freshwater from upstream. In addition, the character of the vegetation in the Djoudj National Park, adjacent to the river, changed significantly as the periods of saline water intrusion into the river, which used to occur during the dry season, were replaced by a regime of continuous freshwater. For example, the river channel became chocked with *typha australis*, which had previously been controlled natural by saline water, and led to increased incidence of bilharzia and malaria. The Diama Barrage and embankments along both sides of the river led to severe degradation of the delta and loss of biodiversity in the Diawling National Park in Mauritania and also in the Senegal River Delta.

The release of a managed environmental flood flow was made in each year following the filling of Manantali Dam in 1991 (Acreman 2003). Because of the delay between dam construction and installation of turbines, OMVS agreed that managed floods should be released for a transitional period of 10 years to benefit people undertaking flood-recession agriculture, herding, and fishing. Although the environmental flows included in the plan were small and inundated only around 50,000 hectares (20 percent of the original area), they had impressive benefits. Fishermen in the Senegal River at Mauritania saw their annual catch rise from 10 tons to 110 tons once the annual floods were re-established.

Since installation of the turbines in 2001 through the Regional Hydropower Development Project, the economics of environmental flows changed. The release of water for managed floods reduced the amount of power that could be generated. Even the minimum environmental flood flow release reduces the mean annual energy from some 800 GWh by an amount varying from 140 to 190 GWh depending on the hydrological regime. The value attached to each kWh in the justification of the energy project was of the order of $20 to $0.05/kWh.

Assistance under the Regional Hydropower Project was conditional on the basis that OMVS retained the managed floods as a possible long-term option. A Plan for Mitigating and Monitoring Impacts on the Environment (Plan d'Atténuation et de suivi des Impacts sur l'Environnement – PASIE) (Adams 2000) was undertaken during the implementation of the Regional Hydropower Development Project to mitigate the environmental and social issues that had occurred as a result of the construction of the original dams. Among other activities, PASIE included a program for optimizing management of the Manantali Reservoir, so as to restore some level of benefit to downstream farmers.

Further environmental flow programs were implemented to release water through the embankments to re-inundate the Diawling National Park in the north of the delta. Such releases were possible from the water stored within the river embankments immediately behind the lower Diama Dam, and thus did not require additional water from Manantali and so did not impact on electricity generation. In addition, since development of intensive irrigation was considerably less than planned, the releases did not compromise the agricultural sector. These environmental flows led to a major revival in fish stocks, particularly mullet; birds, such as white pelicans; and revitalization of traditional handicrafts. The total costs of the restoration over 12 years was around $100 per ha, while the added value of annual natural resource production was $65 per hectare (Hamerlynck and others 2006).

The GEF-funded Senegal River Valley Water and Environmental Management Project, which included IUCN, commenced in 2003. The aim is to develop a basin-wide framework to integrate national water resources activities within an environmental action program. Along with strengthening monitoring networks and building technical capacity, the project will assess the impacts of the seasonal floods from changes to the flow regime due to Manantali Dam.

In 2002, the governments of Mali, Senegal, and Mauritania signed a Water Charter that guarantees an annual artificial flooding (Article 14) and minimal environmental flows (Article 6), except under extraordinary circumstances. The objective of the Water Charter is to "provide for efficient allocation of the waters of the Senegal River among many different sectors, such as domestic uses, urban and water supply, irrigation and agriculture, hydropower production, navigation, fisheries, while paying attention to minimum stream flows and other ecosystem services."

Implementation of the charter is being assisted through the $341 million Senegal River Basin Multi-Purpose Water Resources Development Project, which was approved by the World Bank Board in 2006 (World Bank 2006). The project will strengthen existing monitoring and information networks and lay the foundation for an expansion of hydropower generation in the Senegal River valley by preparing a comprehensive master plan for the basin, completing the hydropower feasibility study for the Gouina hydropower site, and undertaking preliminary technical studies at the Gourbassi, Koukoutamba, and Balassa sites.

In addition, the project will mitigate some of the downstream problems that have arisen from the dam developments:

- recessional agriculture and irrigation in the mid-valley will be improved through the development of small-scale hydraulic structures and assistance with irrigation management
- fisheries will be assisted through a technical modernization program and training in sustainable fisheries management
- waterborne diseases, which have increased since the flow regime was modified, will be tackled through a program to improve water management techniques, treat affected communities, and provide advice on disease prevention

Drivers

A succession of drivers helped propel the provision of environmental flows within the Senegal River basin. The initial driver was the realization by Senegal that the belated development of the dams would cause significant economic and social disruption to the floodplain communities. This was reinforced by academic research (Horowitz and Salem-Murdock 1990) that emphasized the importance of the flows to the floodplain agricultural system, as well as NGO studies that introduced the importance of environmental flows to the delta ecosystem (Hamerlynck and Duvail 2003).

Initially OMVS took a water engineering approach with objectives focused on hydropower, irrigation, and navigation. Pressure was applied by IUCN to take a more integrated approach to development that included conservation of ecosystems that provide goods and services to local communities and for these communities to be involved in decision making. OMVS invited IUCN as an independent organization to initiate community participation. The Permanent Water Commission of OMVS, which makes water allocation decisions, was originally made up of water engineers, but now includes representatives from local coordinating committees that provide stakeholder input and embraces the environmental flow concept. NGO input is now coordinated under an umbrella organisation (CODESEN), which was expanded from its initial membership of Senegalese NGOs to include those from Mali and Mauritania. Input from national agencies has also improved.

The World Bank safeguard policies, triggered during the appraisal of the Regional Hydropower Development Project, acted as an additional driver for environmental flows. The project included the provision of environmental flows as a condition after the installation of the turbines.

Assessment

Recognition. OMVS did not initially recognize either the importance of maintaining either flood flows or dry season flows to water users downstream of the Manantali Dam, or the potential environmental impacts from the exclusion of seawater into the estuary of the Senegal River by the Diama Barrage. Subsistence farmers, who did not contribute to the national economy, were not considered in economic decisions. The infrastructure development plan was driven by economic development considerations (Sir Alexander Gibb and Partners 1987). Once investigations took place, it was realized that the traditional flood-recession agricultural practices on the floodplain had significant economic and social importance. These floodplain communities were not part of the original plan because they were considered subsistence farmers who would not be impacted by the developments.

Environmental flood flows could be provided relatively easily during the period prior to the installation of the turbines. It was hoped that, eventually, economic development brought by the dams would provide alternative employment for floodplain communities, such as through intensive irrigation schemes, so that flood releases would not be required in the long term.

The concept of environmental flows is now accepted within OMVS, through recognition of the need for floodplain inundation and for appropriate ecologically low flows.

Comprehensiveness. Because management of the water resources of the Senegal basin is coordinated by OMVS, transboundary issues are automatically included. The main principle followed is one of sharing the benefits of infrastructure operation between countries, not sharing the water itself. For example, Mali does not receive a specific share of water, but a share of the electricity generated at Manantali. OMVS decides on the trade-offs between the various sectors: electricity production, commercial irrigation, subsistence farming, and nature conservation; in this way, it addresses the integration of environmental, social, and economic issues. The sharing of costs, such as the downstream environmental/economic costs of upstream development, was not considered explicitly. As yet, climate change issues have not been mainstreamed into policy and decision making, but its impacts on future water resources availability are beginning to be studied.

The annual flood is seen as the most important aspect of the natural flow hydrograph for the river valley ecosystem, supporting floodplain vegetation and habitat for fish breeding. Releases from Manantali for hydropower also maintained high river levels for gravity irrigation and deep water navigation. These elevated levels were thought to support the in-river ecosystem; no consideration was given that elevated flows and levels during the dry season might be inappropriately high for some species at this time of year. Minimum flows are also an issue, but unlike most managed river systems, low flows in the Senegal River are often higher than natural because of the need to maintain water depth for navigation and gravity irrigation. However, it is increasingly being recognized that too much flow is as detrimental to the ecosystem as too little flow.

Various analyses have been undertaken to calculate the best economic option for use of water in Manantali dam. Horowitz and Salem-Murdock (1990) concluded that a combination of environmental flood flow releases and generation of some hydropower was the most efficient economically. Hollis (1996) reviewed the original consultancies' reports and suggested that an environmental flood release could be made that would inundate 100,000 hectares while retaining sufficient water to generate 912 GWh of electricity with a 95

percent certainty, complying with the original terms of teference of the management plan. These studies were noted by OMVS, but taken more seriously when they were supported by recognized international bodies such as IUCN.

Environmental water status. The existence of two national parks in the Senegal River floodplain/delta—and the recognition that these areas provide essential ecosystem services for local communities—means that environmental flows are included implicitly in decision making. Environmental objectives take the form of the size of the area inundated by flood releases and various scenarios (50,000, 75,000 and 100,000 hectares) have been considered. However, a decision on the precise environmental flood flow release from Manantali Dam, as in many other situations, depends on trade-offs among a wide range of issues. For example, a release is less acceptable if a higher certainty of hydropower electric power is required. OMVS considers the supply of power to Mali, which does not benefit directly from an environmental flow release to the floodplain and delta. A further political issue within Senegal and Mauritania concerns the distribution of benefits. Electricity benefits the urban elite, commerce, and industry (there being little rural electrification), while environmental flood releases primarily benefit the rural poor. The expansion of irrigation is potentially in conflict with flood-recession cropping in terms of space. However, the irrigation has not been particularly successful, with much irrigated land already abandoned due to salinization and the resultant increase in diseases, such as bilharzia and Rift Valley fever.

Further environmental flow programs were implemented to release water through the embankments to re-inundate the Diawling National Park in the north of the delta. The precise timing and volume of flows was derived through participation of local resource users. The return of freshwater flows revised the fishery and the growth of grasses (*Sporobolus robustus*) used by local women to make mats (their main source of income). Different users initially requested different flow release patterns, but an optimal environmental flow was achieved by negotiation through stakeholder workshops and discussions with individuals facilitated by IUCN. The release of water through the embankments was then approved by OMVS.

Participation. OMVS was established as a top-down organization driven largely by the Council of Ministers and High Commission. OMVS operates consultative bodies, such as the Permanent Water Commission, but these also comprise government officials from member states and are charged with allocation of resources. There is no forum for local communities' participation in the policies or implementation work of OMVS. Local resource users only had influence on decisions through participation in studies and workshops run by outsiders such as IUCN. It is likely that without IUCN facilitating local resolutions, OMVS would have been unable to resolve differences of opinion and that top-down decisions would have led to disputes. This can be a generic problem with top-down approaches, in which the aim is to act in the national interest regardless of the distributional impacts on local people.

The Water Charter extended stakeholder involvement within the Senegal basin to include farmers and NGOs. Further stakeholder participation was stimulated by the GEF project, which included participation in its design and implementation. Now local coordination committees exist throughout all countries of the basin.

Data and science. OMVS has supported a wide range of consultancy studies over the management of water resources, such as the work of Sir Alexander Gibb and Partners. This included hydrological models of the basin to study the implications of different release patterns from Manantali on inundation extent on the floodplain downstream. The hydrological studies were integrated with economic analysis of natural floodplain goods and services, intensive irrigation, hydropower generation, and navigation. This work produced a series of scenarios under which different areas of the floodplain would be inundated, different amounts of electricity generated,

and different degrees of irrigation could be achieved. The relationship between surface and groundwater in the Senegal valley has also been studied in some detail (OMVS/USAID 1990). The environmental flow releases from Manantali were based on these studies.

Independent research has also been undertaken, such as the hydrological, ecological and socioeconomic studies of the Diawling Park (Duvail 2001); these studies defined the environmental flow releases through the embankments to the delta.

In general, OMVS did not move radically from its original primary objective of delivering economic development to Senegal, Mali, and Mauritania through hydropower generation, with the benefits shared between the countries. The second priority was to manage the downstream dam at Diama to maintain high water levels for irrigation and navigation. Concessions were made to release environmental flood flows to inundate 50,000 hectares (20 percent of the original area) until the turbines were installed. The distributional effects were not seriously considered (i.e. which communities benefit or lost out); the objectives were focused on national and regional economic growth. Pressure from IUCN, the World Bank, and others enabled small-scale environmental flow releases to continue, such as releases through the downstream embankments to the delta. These were largely to avoid political conflict rather than recognition of economic value of the ecosystems to local people.

Lessons

1. The structure of OMVS, with its membership of basin countries, provides an institutional framework for managing water resources of the transboundary Senegal basin. The principle followed is one of sharing the benefits (electricity, irrigable land, and navigation) rather than the water itself. It allows for transboundary mitigation of ecological impacts, such as releasing water from the Manantali Dam in Mali to support the river ecosystem in Senegal and Mauritania. It also allows for the needs of the rural poor to be balanced against the developed sectors. OMVS allows basin-scale water management and allocation of benefits between the basin states, such as irrigation water and electricity generated from hydropower.
2. Certain elements of the river flow hydrograph can be the most important aspect of environmental flows. In the Senegal basin, it is floodplain inundation that supports an ecosystem that provides goods and services for local livelihoods. On the other hand, the delivery of flows that are beneficial for navigation during the dry season may have harmful environmental consequences.
3. Environmental economics and social economic justifications can be used to make a powerful case for environmental flows in many cases. The reports commissioned by OMVS identified the economic value of the functions of the floodplain, which were previously not appreciated by senior decision makers in the Senegal basin states. This encouraged the inclusion of flood releases from Manantali Dam to maintain the floodplain ecosystem at least in the short term; without these social economic data, releases from Manantali would have been restricted purely to the needs of the power generation, intensive irrigation, and navigation sectors.
4. Release of freshwater to the coastal zone, such as deltas and estuaries, can be as important as environmental flows to freshwater ecosystems. The original plans of OMVS did not allow for any flow releases below Diama Dam, as it did not recognize these as important. However, the IUCN studies recommended the release of water through the embankments immediately around Diama to restore the delta ecosystem and its dependent livelihoods, and this was approved by OMVS.
5. There are many issues to consider when making a decision about implementation of environmental flows, such as wider transboundary agreements and distribution of benefits to different members of society. Research and studies by independent

organizations should be assessed in addition to those commissioned by a river basin authority. OMVS was established to support economic development of the Senegal River basin through electricity production, intensive irrigation, and navigation. It adapted its operational plan (and made environmental flow releases from Manantali) based on its own consultancy reports, but was reluctant to accept results of independent studies as they were considered too radical. Some results—for example, environmental flow releases to the delta—were eventually accepted when supported by international organizations such as IUCN.

6. OMVS was organized as a top-down institution focused on national and regional objectives; the involvement of local communities as stakeholders was not embraced. It was largely through the actions of international organizations, such as IUCN, that impacts on local communities were considered. Subsequently, the Water Charter recognized the rights of communities, including those affected by flood flows, and a network of local coordination committees was established to represent their views.

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Case Study 17. Tarim Basin

Background[51]

Feeding China's population is a continuing challenge for the government of China (GOC). As of 1998, the annual consumption of grains was about 480 million tons and was expected to grow to about 700 million tons by the year 2020, partly due to the increasing population and partly due to the increased consumption of grain for animal feed resulting from increasing meat consumption as incomes rise. To meet these needs, the government's long-term policies and strategies are designed to support increased food production by improving irrigated agriculture, increasing incomes and rural employment opportunities, and promoting the development of the western region. One particular area the government targeted for increased agriculture production is the Tarim River Basin (198,000 km^2) in the Xinjiang Uygur Autonomous Region (XUAR), China's largest autonomous region located in northwestern China.[52]

Despite an average rainfall of just 50 millimeters per year, the basin's farmers produce 80 percent of Xinjiang's cotton, or one-sixth of China's total cotton production through irrigated agriculture. Other agricultural products include grains, fruits, nuts, silk, and wool. The gross regional product is approximately $4.3 billion, agriculture being the main economic activity. The key to the basin's productivity lies in the water, which starts as glacier and snowmelt in the high mountain ranges surrounding the basin on three sides—the Kunlun Mountains to the southwest, the Tibet Plateau to the southeast, and the Tien Shan Mountains to the north. This water runs into the Taklimakan Desert, feeding oases and tributaries that flow into the Tarim River, which runs from west to east across the basin for over 1,300 kilometers.

Historically there has been continual expansion of the irrigated agriculture upstream along the tributaries to the Tarim River to meet China's needs for food and fiber without consideration of the ecological balance or the needs of other water uses.

The abstraction of water for irrigation in the upper reaches of the Tarim Basin has had severe detrimental environmental effects, including soil alkalinity, decline in downstream water flow, loss of trees, desertification, and declining downstream agricultural productivity. The reasons for these unsustainable water use practices included (a) ineffective water-allocation institutions, (b) below-cost water prices, (c) inefficient water transmission and irrigation systems, (d) inappropriate agricultural practices, and (f) lack of management and information systems for water allocation, water pricing, and crop production at the local level.

Flows in the Tarim River, which traditionally flowed into the terminal Taitema Lake, had progressively diminished during the 1960s. The river ceased to flow in the lower reaches during the 1970s because of the excessive upstream withdrawals of water for irrigation.

[51] This section was drawn from World Bank (1998) and Hou and others (2006).
[52] In addition to its agricultural importance, the region is strategically important to China because of its transport links with Central Asia.

The only agriculturists in the region relying on natural systems are the Uygur herders, who free-range their sheep on the over-bank flow areas of the Tarim River. These areas support a savannah woodland with an understory dominated by tough grasses of very low feed value. The woodlands include a wide range of medicinal herbs and other useful species. The survival of this ecosystem is totally dependent on periodic flood flows in the Tarim River. Reductions in flows have been directly associated with reductions in the area of the riverine forest over the last 40 years. As a consequence, the natural riverine "green corridor" in the 300 km of the Tarim River upstream of Taitema Lake became ecologically stressed, reducing the vegetative barrier to encroachment of the Taklamakan and Kukule Deserts, which border the river in that area. The advance of the deserts and the threat that they would link up and sever the transport links was a significant concern to the national government.

Administratively, the management of water in the Tarim basin is based on a provincial/regional structure. The regional water resources bureau (WRB) is located in the provincial capital. There are prefecture-level water resources departments (WRD) located in each of the five prefectures (Aksu, Bayingol, Hotan, Kashgar, and Kisilzu). Each WRD reports to the respective prefecture government, rather than to the WRB. Management of the basin's water resources, including the coordinated management of upstream and downstream areas, has been handicapped by this poorly coordinated management system.

The Tarim Basin II Project

The Tarim Basin Project (1991–97) (World Bank 1991) focused on expansion of the area for irrigated crop production, improvement of agricultural services, promotion of livestock development, and the setting up of basin institutions. The Tarim River Committee (TRC) and Tarim River Management Bureau (TRMB) were established under the project for managing water in the main stem of the Tarim River. The TRC was a policy and coordination body, while the TRMB was established as the operational body responsible for operating hydraulic structures, investigating water management options, and monitoring and controlling water allocations. The project was successful in increasing agricultural production. The downstream impacts of the agricultural water abstractions were addressed in the EIA and provisions were included to release water to maintain the downstream vegetation. However, these provisions were inadequate and the green corridor on the lower reaches of the Tarim River continued to decline.

The Tarim Basin II Project (1998–2004) addressed the environmental issues that had arisen in the basin by helping establish sustainable water resources development and management. The project's objectives were to:

- increase incomes of poor farmers through irrigated agriculture development
- establish institutional mechanisms for sustainable use, development, and management of water resources and land in the Tarim Basin
- partially restore and preserve the "green corridor" in the lower reaches of the Tarim River

Improved environmental sustainability and economic development could be jointly achieved by an approach based on "beneficial consumptive use," where investing in improved water use efficiency and reducing nonbeneficial consumption provided water savings that could be allocated for downstream environmental benefit. An estimated 3,400 Mm^3 of non-beneficial evapotranspiration occurs in the areas affected by the Tarim II project. The intention was that increases in agricultural consumptive use would be more than offset by decreases in non-beneficial evapotranspiration through canal lining, drainage improvements, and water management improvements.

The project also improved management arrangements for the basin's water by establishing the Tarim Basin Water Resources Commission (TBWRC) and strengthening the TRMB, which was established

during the implementation of Tarim Basin I project. The TBWRC is a participative river basin commission comprising regional government water-related agencies, the five prefecture-level administrations, and the central government-controlled State Farms in the basin, in a partnership (Millington, Olson, and McMillan 2006). It has the responsibility for coordinating and managing water across the basin (Radosevich and Olson 1999).

The TBWRC was the first multiple prefecture water resource management agency with recognized authority to be established within a single province in China. Previous cross-jurisdictional river basin agencies, such as the Yellow River Basin Commission(YRBC), had been established for the major rivers that crossed provincial boundaries and had narrow responsibilities. Hence the TBWRC represents a shift toward more integrated and participatory water management within provinces.

Water use efficiency and the productivity of irrigation water were increased through a mixture of institutional improvements, on-farm efficiency measures, agricultural support activities, and engineering means (Davis and Hirji 2003). The institutional improvements included strengthening the TBWRC, improving the monitoring system, forming water user associations and decentralizing decision making, and improving the financial basis of the management. A volumetric quota for water diversions for agriculture was also established in 1999 for each prefecture that was less than historical diversions. During project implementation, control of water use (based on quotas) was instituted at different levels of water use down to individual water users. The on-farm improvements included improved crop types, extension services land leveling, improvements to on-farm irrigation systems, and mechanization. The water supply canals were concrete lined with an underlying waterproof geomembrane to reduce leakage that contributed to high water tables and non-beneficial water consumption from capillary flux. As a result of the canal lining, seepage losses are estimated to have been reduced by between 600 and 800 Mm^3 per annum.

Half of the water saved in the project will be delivered downstream to the green corridor. The remaining water will be consumptively used by grazing land, forest areas, irrigation, and through non-beneficial evapotranspiration. During the project, 41,462 hectares of new land were developed; all new land development was halted after that. The major production benefits from the project came from increasing yields and the value of production per unit of water consumed.

Environmental flows to restore the riverine ecology and Taitema Lake are not required on a continuous flow basis, but can be delivered in slugs over short periods. This mimics the historical hydrograph that only produced flows in the lower reaches of the river during annual high-flow months. During project implementation, the total volume of environmental water released to the green corridor was 1,700 Mm^3 from six releases over four years. The TBWRC now has a firm commitment to deliver 300 million cubic meters annually to this area. The Taitema Lake, which had not received water for 30 years, expanded to a surface area of 200km^2. The areas alongside the river with groundwater levels within 4m of the surface expanded from 4.7km^2 before these flows to 20.5km^2 afterwards. Riverine vegetation showed dramatic improvement in growth. Subsequent monitoring studies show that the vegetation coverage has increased gradually each year, the desertification area has decreased, some sand areas have obviously retreated, and the ecology of the lower reaches of the Tarim River has improved (Zhenglong and others 2007).

Drivers

The central government's desire to solve the desertification problem—with its threat to transport links and attendant production and health costs—was the principal driver for the release of water to the lower reaches of the Tarim River. One of the objectives of the Tarim Basin II project was to "partially restore and preserve the 'green corridor' in the lower reaches of the Tarim River." Environmental flows were not

an activity added to the project to remediate impacts of development activities within the project; rather they were a central objective, along with improved productivity of the project. Environmental flows achieved this centrality because the environmental degradation of the lower Tarim River was leading to obvious and costly impacts.

While the project objective of restoring the downstream environments was consistent with the 1998 National Water law (revised in 2002), which requires effective measures to protect and preserve water resources and the environment with specific reference to arid areas (Radosevich and Olson 1999), it was not driven by this legal requirement.

Neither international NGOs nor the growing international environmental awareness were major influences on the provincial officials. The restoration of the green corridor was basically a provincial government objective, strongly driven by the central government. The major international influence arose indirectly through Australian-funded technical assistance from the Murray Darling Basin Commission. Provincial officials and key staff carried out a number of study tours to Australia that influenced their thinking on IWRM and environmentally sound river basin management.

Assessment

Recognition. The importance of re-establishing flows in the lower Tarim River was recognized by the XUAR government prior to the project commencing. They specifically sought a mechanism to restore the downstream riverine environments in the Tarim Basin II project while also improving the productivity of irrigation within the basin. However, the WRBs and irrigation professions and irrigators initially saw the project, especially the quotas on diversions, as a regulatory measure that would result in decreased productivity and production potential. This resulted in considerable tension at the beginning of the project.

Once it was clear that the TWBRC was serious about enforcing the quotas,[53] there was a change in attitude leading to a genuine understanding and commitment by irrigators and government officials within the basin to controlling water use and an acceptance that water must be allocated both for productive and environmental purposes. Water users have learned to increase yields and the value of production with less water consumption. The introduction of a transparent system of volumetric quotas and volumetric-based irrigation water charges helped considerably in changing farmer attitudes. Accurate and transparent water measurement at all levels for the point of diversion through to the farmer level was a key success factor.

Not all government institutions were supportive of the project at the beginning. There had been considerable confusion over responsibilities under the institutional structure established in the Tarim I project. The TRC was not taken seriously by the decision makers of the province; it had no clear link with the TRMB and neither had any legal standing for managing water allocation. The TRMB was responsible only for the mainstream of the Tarim River. Most importantly, they had been set up in parallel to the provincial water resources bureau (WRB) which, by law, was responsible for water management (Xie, Jiang and Spencer 2006).

The general approach followed in the Tarim II project was to expand the TRMB and the TRC from "river" to "basin" institutions and to clarify the confusion of water management responsibilities. In 1997, the Xinjiang People's Congress passed "Regulations for Tarim Basin Water Resources Management" to establish the TBWRC as the sole authority for water management in the entire basin. The previous TRMB was changed to

[53] The enforcement was through both fines and rewards. The monetary value of the fines and rewards was quite low; however, the publicity accompanying them was the main inducement as there was considerable prestige in being publicly acknowledged for achieving the quota or public humiliation in being identified as not achieving it.

the Tarim Basin Management Bureau (TBMB), which became the technical secretariat for the commission.

Participation. The establishment of water user associations (WUAs) was a fundamental part of the institutional reform component of the Tarim II project and provided a focal point for communication and understanding by the farmers of their individual and collective responsibilities in efficiently using and managing water for irrigation. The WUAs encouraged farmer participation in local irrigation management, and demonstrated the functions and roles to the participatory management for development of irrigated agriculture. The WUAs were responsible for water delivery and measurement within the established quotas, water charge calculation and collection, representing the views of irrigators in the planning and management processes, and providing incentives and information for improving water-use efficiency and water conservation. The WUAs, in turn, were represented on the TBWRC through irrigation district committees, which had been established under the Tarim II project.

Data and Science. During project preparation, preliminary modeling studies were carried out to assess whether the project development activities would adversely affect the commitments to deliver water to downstream areas, to select the development alternatives with minimal impact on river flows, and to develop models for future use in evaluating different developments and strategies. These models included surface and groundwater models and salinity models within the irrigation areas. The modeling showed that the development components of the project will improve water management and would not adversely affect the flow deliveries in the Tarim River.

These models did not extend to the river downstream of the irrigation areas and so the project did not use any scientific assessment technique to estimate the water needed for restoring the environment in the lower reaches of Tarim Basin. Instead, sufficient water was made available from the upstream institutional reforms, on-farm practices, and engineering improvements to restore the environment. The delivery of water was made experimentally during implementation and the results evaluated to determine how much water should be delivered downstream in future to achieve beneficial ecological outcomes. The TBWRC developed specific water-share quotas for each of the five prefectures within the basin, on the basis that, over the long term, if annual diversions were held at these levels, the level of water flowing to downstream areas would restore the green corridor to an acceptable level of health. In this way, the situation was changed from an unsustainable continually decreasing downstream water delivery to a sustainable management system based on enforced water quotas.

One legacy of the previous fragmented approach to water management is that there was not an effective basin-wide monitoring program. The TBWRC has established a data collection and monitoring plan (Radosevich and Olson 1999). The Tarim Management Bureau now has in place an effective basin-wide monitoring program that is used to monitor and report to the TBWRC on how well the prefectures have stayed within their quotas. In this way, the TBWRC is able to enforce the quotas. There is also at the prefecture level a system of monitoring and delivery of water down to individual farmers, although the amounts in many cases are estimated based on rudimentary measurement systems.

In addition, there has been monitoring of the effectiveness of the increased flows to the downstream parts of the basin. Changes in vegetation responses have been established through tree ring analysis of riparian vegetation, water table levels have been monitored, and the response of birds and other wild life have been assessed.

Integration. The Tarim Basin II project established integrated water resources management through both "top-down" and "bottom-up" activities. The top-down aspects included (a) establishing policies, laws,

organizations, and regulations for managing water; (b) defining the availability of water and determining broad water allocations within river basins and aquifers for different sectors and political administrative entities; (c) setting water quality standards; and (d) establishing an effective forum for cross-sectoral cooperation and coordination. The "bottom-up" approach involved the participation and empowerment of water users and their representation on the TBWRC through irrigation district committees.

Consequently, the environmental water provisions were fully integrated with the changes in the consumptive water provisions and the changes in responsibilities for water management.

Cost effective. The economic analysis for the project demonstrated that the agricultural project benefits justified all of the project costs without taking into account the environmental benefits. However, it is difficult to estimate the costs and benefits of the environmental aspects of the project. The two project components that contributed to the water savings (water conservation and environmental improvements—$133.7million) and the delivery of water to the downstream areas also resulted in other local benefits, which confound the measurement. In addition, the environmental benefits should include intangibles such as increases in national security through maintenance of strategic links between China and Central Asia.

Influential. The institutional arrangements have provided a precedent within China in forming basin-wide water resource management organizations. The TBWRC is the first to include responsibility for all aspects of integrated river basin management and to have broader responsibilities than just specific tasks such as flood control or pollution abatement found in other Chinese river basin commissions.

Within the basin, the project has successfully changed the attitude of different stakeholders toward water use efficiency, acceptance of the importance of downstream flows, and responsibility for operations and maintenance. People now largely accept that an ecology- and equity-based approach that decrees limits on water use through quotas does not have to compromise production and incomes.

The project has led to tangible improvements in the environment of the downstream parts of the river basin, leading to an improved buffer against desertification and dust storms without penalizing upstream water users. A number of delegations, including one from Pakistan, have visited the Tarim Basin and are considering similar programs.

Lessons

1. The national importance of arresting the spread of the desert and its threat to strategically important transport links acted as a powerful driver for the return of environmental flows to the lower Tarim River.
2. The project illustrates the importance of integrating technical (e.g. geomembrane) improvements with institutional and social improvements in order to deliver water for downstream environmental benefit.
3. The project's success in providing environmental flows was largely due to the delivery of both tangible benefits to the irrigators, in terms of improved productivity, and benefits to downstream populations.
4. Well-designed institutional structures, backed by legislation, need to be established for major changes in water management to be effective in providing the river flows needed for downstream environmental benefits.
5. When the environmental benefits are readily apparent and integrated into the project objectives, the term "environmental flows" with its connotations of remedial actions, does not need to be used.

6. Rules without enforcement are of little use. The rules to limit consumptive water use and ensure environmental allocations need to be backed up by a monitoring program and a willingness to reward and punish transgressors.

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