November 2012

Case Studies in Integrated Water Resources Management: From Local Stewardship to National Vision

American Water Resources Association

Policy Committee

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This report was made possible by the Oregon Water Resources Department.

Cover Photos Courtesy of Racquel Rancier

Acknowledgements

Special thanks to AWRA's Policy Committee, led by Committee Chair Dr. Brenda Bateman and Vice-Chair John Wells; AWRA Past President Dr. Ari Michelsen; AWRA Immediate Past President, Dr. Michael E. Campana; AWRA President William Battaglin; and AWRA Executive Vice President Ken Reid for their leadership in the field of integrated water resources management.

Thanks to Kathy Bowman, Cheryl Ulrich, Michael E. Campana, Dick Engberg, and William Battaglin for assistance with editing and reviewing this report; Andrew Graham, Carol R. Collier, David Watt, Erik Webb, John Wells, and Tom Bartol for their efforts in writing the case studies; Kamyar Guivetchi, Michael Floyd, and Tom Lutterman for assistance with the California case study; Alyssa Mucken for reviewing the Oregon case study; and Michael Wyatt and Dr. Rebecca Seal-Soileau for reviewing the Minnesota River Basin case study.

Thanks are due to Director Philip C. Ward and the Oregon Water Resources Department for contributing the resources to make this report possible.

About the Policy Committee

AWRA's Policy Committee is comprised of water professionals and others with an interest in how public policy shapes our collective management of water resources. It is a diverse committee that includes scientists, educators, policy-makers and other experts at all stages of their careers.

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Introduction

Background and Purpose of Report

As social values have changed, traditional water management approaches focused narrowly on water supply development without consideration of social or ecosystem impacts are no longer sufficient.

Recognizing this, water professionals have sought to implement the principles of integrated water resources management (IWRM) to address threats from aging infrastructure, climate change, and population growth while balancing environmental, social, and economic needs (USACE, 2010).

Although the concept's foundation can be traced to early basin planning efforts in the United States in the 1920s, the use of the term "IWRM" became popular in the late 1990s in conjunction with work by the Global Water Partnership to promote its use (Biswas, 2008; Hooper, 2010).[1]

While in recent years there has been growing international and national recognition of the need to manage water using an IWRM approach (AWRA, 2011; USACE, 2010), implementation has progressed slowly (Najjar & Collier, 2011).

IWRM principles often involve *including all sources of water* in planning; addressing water quantity, water quality and ecosystem needs; incorporating principles of equity, efficiency, and public participation in water planning; and sharing information across disciplines and agencies (GWP Technical Committee, 2005; USACE, 2010).[2]

The expected benefits of implementing an IWRM approach include better planning and management of water quality and supply, more cost-efficient management, and improvements in distribution of water between ecosystem needs and consumptive uses (Najjar & Collier, 2011).

Despite the potential benefits of IWRM, adoption of the approach has not occurred as quickly as expected. Implementation has been hindered by the lack of a consistent definition that can be made operational with measurable criteria (AWRA, 2011; Biswas, 2008). Real-life political, social, and physical factors also make IWRM difficult to achieve in practice (Najjar & Collier, 2011).

For these reasons, water professionals have called for a greater focus on refining IWRM concepts through research and by quantifying results of IWRM implementation (AWRA, 2011; USACE, 2010).

In January of 2011, the American Water Resources Association (AWRA) Board of Directors approved two position statements from the AWRA Policy Committee. One supported the development of a national water vision and strategy (AWRA 2011a). The other position statement called for implementation of IWRM across the United States and committed the AWRA to help strengthen and refine IWRM concepts (AWRA, 2011). The Board has made a commitment to link these two concepts, calling for inclusion of the IWRM approach as a necessary component of any future national water vision.

As part of this endeavor to stimulate discussion of IWRM in the water community, IWRM was the focus of the 2011 AWRA Summer Specialty conference, *Integrated Water Resources Management: The Emperor's New Clothes or Indispensable Process?*

In addition, in March 2012, AWRA served as the primary IWRM lead organization for the Sixth World Water Forum. Past President Dr. Ari Michelsen organized eight IWRM sessions under *Priority for Action 2.1 – Balancing Multiple Uses through Integrated Water Resources Management*.[3] One of the sessions, organized by AWRA Immediate Past President Dr. Michael E. Campana, focused on IWRM and groundwater.[4]

To support implementation of IWRM, in 2012 AWRA instituted an award recognizing excellence

[1] For a more comprehensive history, see Hooper (2010).

[2] Biswas (2008) critiques the use of the term "integrated" and finds that more than 41 concepts have been associated with integration.

[3] The final report from the eight sessions can be downloaded at http://is.gd/7q3HIH.

[4] The session description and presentations are available at http://is.gd/WitwB9.

in the use of IWRM to develop and manage water resources.

AWRA's effort to advance and develop a better understanding of IWRM continue in this current publication, commissioned by the AWRA Policy Committee to explore how IWRM is guiding water management in the United States.

Report Structure

This report uses three components to build knowledge of IWRM approaches. First, the introduction provides an overview of the concepts and principles of IWRM. Next, seven case studies demonstrate efforts to practice IWRM in the United States at the state, multi-state, and local levels to show how theory translates into on the ground implementation. Finally, this report closes with the identification of themes and lessons learned from the case studies.

Defining IWRM

This report utilizes common themes from multiple definitions to provide a basis for discussion. It also acknowledges that there is still a need for further refinements to create a shared understanding (AWRA, 2011; Bourget, 2006; Najjar & Collier, 2011; USACE, 2010).

In general, there is recognition of the need to implement a more holistic approach to water management than has been practiced in the past. However, there is not a consensus on the definition of IWRM and what implementation of an IWRM approach entails. A survey of more than 600 professionals revealed that viewpoints on IWRM were so different that in the United States it was best described as "a process that strives to balance regional economic growth while achieving wise environmental stewardship" by encouraging the participation of seemingly disparate interests (Bourget, 2006, p. 107).

Overviews of three definitions of IWRM follow.

First, the definition of IWRM by the Global Water Partnership (GWP) Technical Advisory Committee (2000) is one of the most commonly cited:

> IWRM is a process that promotes the coordinated development and management of water, land, and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (p.22).

While this definition can be broadly interpreted (Biswas, 2008), an examination of other definitions of IWRM reveals a similarity in themes.

Second, the AWRA (2011) position statement[5] identifies IWRM as:

> The coordinated planning, development, protection, and management of water, land, and related resources in a manner that fosters sustainable economic activity, improves or sustains environmental quality, ensures public health and safety, and provides for the sustainability of communities and ecosystems.

Third, based on results from research during a series of regional conferences, the U.S. Army Corps of Engineers (USACE) stated:

> IWRM aims to develop and manage water, land, and related resources, while considering multiple viewpoints of how water should be managed (i.e. planned, designed and constructed, managed, evaluated, and regulated). It is a goal-directed process for controlling the development and use of river, lake, ocean, wetland, and other water assets in ways that integrate and balance stakeholder interests, objectives, and desired outcomes across levels of governance and water sectors for the sustainable use of the earth's resources (2010, p. 28).

In reviewing these three definitions, it is clear that IWRM is an approach to water management that seeks to integrate physical systems with human systems to shift away from fragmented planning (USACE, 2010).

Key concepts of IWRM are summarized below:

The goal of IWRM is to manage water sustainably. Water management must balance the multiple objectives of different interests with consideration for economic development, social equity and the

[5] This definition was developed from *Summary, Fourth National Water Resources Policy Dialogue*, Washington, D.C., September 2008.

environment as well as current and future generations.

Coordination is required for integration. Integrate water management between and within levels of government and other organizations, with recognition of the respective roles of each.

Encourage participation. Involve the local public and stakeholders from all water use sectors.

Resources are connected. Holistic management recognizes the interconnectedness of land and water, surface water and groundwater, water quantity and water quality, freshwater and coastal waters, and rivers and the broader watershed (GWP Technical Committee, 2004; USACE, 2010). Manage water in the context of a larger geographic region such as a watershed or basin (USACE, 2010).

To implement these key principles and allow for responsiveness to changing natural and human systems, IWRM is process-oriented. One process model suggests that the IWRM process is an iterative spiral of four phases: (1) recognizing and identifying, (2) conceptualizing, (3) coordinating and detail planning, and (4) implementing, monitoring and evaluating (UNESCO-IHP, WWAP & NARBO, 2009, p. 53).

Phase 1 involves assessing the current situation, recognizing problems, building governmental and public awareness, and generating the capacity for action. Phase 2 includes an assessment of the problems and identification of potential solutions. Phase 3 involves the evaluation of options by various stakeholders and levels of government in order to identify a plan. Finally, Phase 4 is an implementation of the IWRM actions followed by monitoring and an evaluation of the results. The information obtained from the evaluation then feeds back into the cycle to continue to advance water management (p. 53-58).

The spiral is set in the context of policies, legislation, and available resources for financing, which may require modification in order to support coordination throughout the process.

Another model asserts that IWRM is a continuous process with steps similar to the above phases, and suggests three key areas to target change to facilitate the implementation of IWRM: the enabling environment, institutional roles, and management instruments (GWP Technical Committee, 2005). These "change areas" as discussed below are outlined in Figure 1.

The *enabling environment* consists of setting policy and goals to drive the process with corresponding legislation and financial support.

The *institutional roles* involve developing the appropriate organizational structure and the institutional capacity to coordinate water management.

Figure 1 Areas to Facilitate Change for IWRM Implementation

A. Enabling Environment

- Policies
- Legislative Framework
- Financing and Incentive Structures

B. Institutional Roles

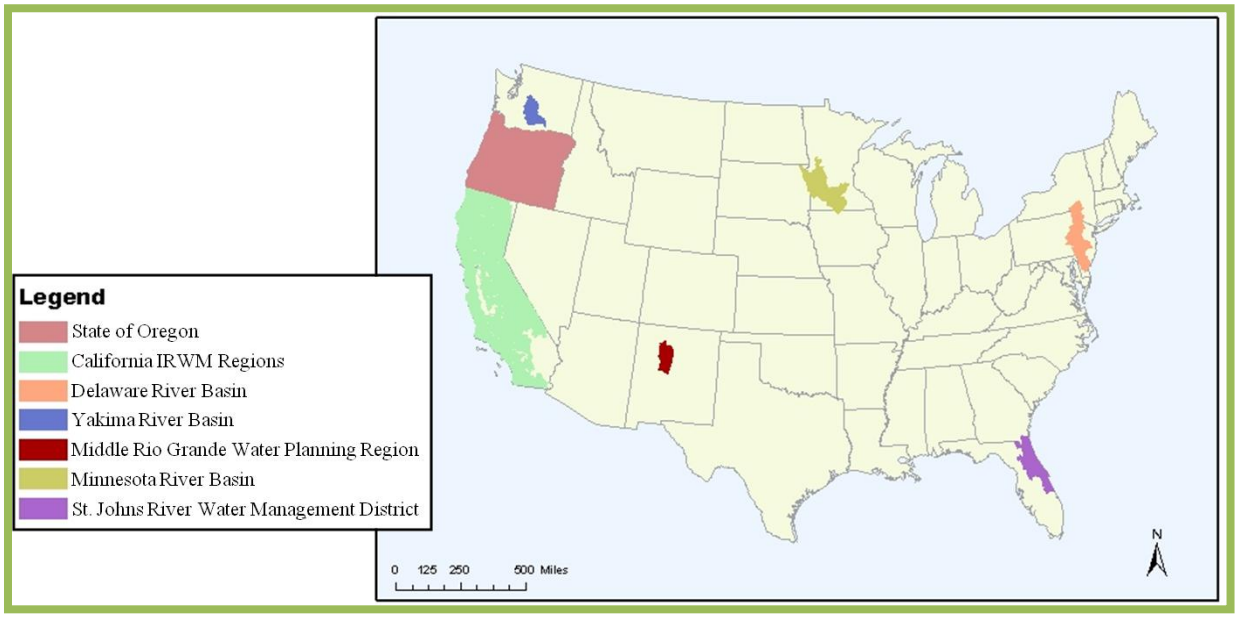
- Creating an Organizational Framework
- Institutional Capacity Building

C. Management Instruments

- Water Resources Assessment
- Plans for IWRM
- Demand Management
- Social Change Instruments
- Conflict Resolution
- Regulatory Instruments
- Economic Instruments
- Information Management and Exchange

Source: GWP Technical Committee (2005, p. 19-22).

Figure 2 Map of the Case Studies



Management instruments include: (1) assessing water resources availability and needs, (2) developing IWRM plans that balance economic, social and environmental needs, (3) implementing water efficiency measures to control demand, (4) encouraging changes in public attitudes to create a more water conscious culture, (5) resolving conflicts over water, (6) regulating to protect water supply and water quality, (7) implementing economic tools that promote social equity and efficiency, and (8) improving knowledge within and across sectors and agencies to manage water more effectively (p. 19-22).

The case studies in this report support the underpinnings of IWRM as a process, and demonstrate how change in these key areas can facilitate IWRM implementation.

While more research is needed to increase understanding of how IWRM can be successfully implemented in practice, this report explores local experiences with IWRM to understand its application in the United States.

About the Case Studies

These case studies were selected based on a sample of convenience. Each includes: (1) background information on what prompted IWRM efforts, (2) a description of the IWRM process, (3) a description of the outcome, (4) the costs and benefits, and (5) key contact information.

The first two studies highlight state efforts towards IWRM planning. The first study discusses Oregon's experience in developing a statewide integrated water resources strategy. The second study shows how a state level plan can serve as a foundation for regional integrated water planning and provides an overview of California's framework for implementing IWRM at the regional level. These studies point toward the need for new tools and additional information in order to holistically manage the resource.

The next three studies demonstrate regional integrated water planning efforts and the corresponding tools needed to manage water holistically.

First is a discussion of the success of the multi-state Delaware River Basin Commission in addressing water quality and groundwater issues as well as how it is planning for changing conditions in the future. Next is an overview of the Yakima River Basin Proposed Integrated Water Resource Management Plan, which shows the benefits of planning at the appropriate level of governance and incorporating all interests in the planning process. The third study highlights the unique governance structure and technical tools used to facilitate development of the Middle Rio Grande Regional Water Plan.

The final two studies discuss the complexity of managing water resources in a way that balances human and environmental needs. They provide overviews of the Minnesota River Integrated Watershed, Water Quality, and Ecosystem Study and the St. Johns River Water Supply Impact Study. They demonstrate the development of complex scientific models to understand the human impacts of water use on the ecosystem and facilitate decision-making that results in more sustainable management of the resource.

Collectively, these seven case studies provide a solid foundation for understanding how practitioners in the United States are implementing IWRM concepts.

In evaluating these case studies and the extent that an IWRM approach is implemented, it is important to keep in mind that IWRM requires a realistic approach to integration.

The challenge is to find a balance between a fully integrated approach (that risks getting mired in complexity) and an approach in which each sector blindly pursues its own narrowly defined interests without looking at larger impacts and opportunities (GWP Technical Committee, 2004, p. 3).

Collectively, the case studies highlight both the integration of physical systems and human systems with an emphasis on holistic management of the resource and the need for participation from the public and all water use sectors. They also show the benefits of multiple agencies working together in order to ensure that there is a sustainable supply of water for humans and ecosystems now and into the future.

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"Every living thing depends upon clean and abundant water to meet basic needs. Oregon's economic vitality, environmental integrity, and cultural identity depend upon it. Water is Oregon's most precious natural resource."

Oregon Water Resources Department (2012)

Oregon's Integrated Water Resources Strategy: Implementing IWRM at the State Level

Need for an Integrated Water Strategy: Creating the Enabling Environment

As integrated water resources management is couched in the concept of sustainable development, an IWRM approach in Oregon is important for effective management of water resources, allowing for economic development and the protection of ecosystems.

As with many states across the west, Oregon is experiencing significant challenges in managing water resources to provide for the multiple uses of water in the state. Oregon no longer has water available for appropriation in most areas during summer months and groundwater levels are declining in many regions.

The limits of available water are further exacerbated by degraded water quality and ecosystem needs. More than 1,861 water bodies are now listed as water quality impaired under the Federal Clean Water Act. In addition, twenty-four fish species have been listed as threatened or endangered under the Federal Endangered Species Act, and an additional 31 fish are listed as state sensitive species.

In the future, Oregon expects additional challenges in managing water resources due to land use change, population growth, and climate change (OWRD, 2012).

The Oregon Water Resources Commission (WRC) has long recognized the need for a statewide water strategy but it was not until 2009 that the joint efforts, leadership, and forward thinking of the WRC, state agencies, Governor's Office, Legislature, businesses, local governments, environmental organizations, agricultural interests, universities and other stakeholders, resulted in concerted efforts to generate a strategy.

In the fall of 2008, five roundtables were held "to receive input and advice from Oregonians and develop information to inform efforts to identify and communicate a vision" for water management (OSU Institute for Water and Watersheds, Oregon Sea Grant Extension, OUS Institute for Natural Resources, & Oregon House Committee on Energy and the Environment, 2008, p. 5).[6] One theme that emerged from the Oregon Water Roundtables was the need to create a statewide framework for integrated planning at the basin level.

Broad-based support for proactively managing the resource instead of waiting for a crisis made it an ideal time for the Oregon Water Resources Department (OWRD) to propose legislation to undertake the ambitious task of developing an integrated water resources strategy.

In 2009, the Oregon Legislature passed House Bill 3369, which required OWRD to work with the Oregon Department of Environmental Quality, the Oregon Department of Fish and Wildlife, and the Oregon Department of Agriculture to develop an integrated water resources strategy (IWRS).

In developing the IWRS, the OWRD was directed to consult with the public, stakeholders, Indian tribes and all levels of government. The legislation also required the IWRS to account for both consumptive and non-consumptive needs including water quantity, water quality, and ecosystem needs. It also required the strategy to discuss other influencing factors including climate change, population growth, and land use change. Finally, the IWRS was to be dynamic. To that end, it must be reviewed and updated every five years, thereby encouraging adaptive management (House Bill 3369, 2009).

[6] For more information on the Oregon Water Roundtables, visit http://water.oregonstate.edu/roundtables/index.php.

By securing legislative authority, the State agencies were able to set the foundation for future support from the Legislature and create a shared understanding of the challenges that Oregon faces, while ensuring cooperation from other State agencies. In reviewing the components of the legislation, it is clear that the active role of natural resource agencies and other water professionals shaped the law based on principles from IWRM.

Oregon's Integrated Water Resources Strategy is an ideal case study to demonstrate how the concepts of IWRM can be applied outside of theory.

Overview of the IWRS Development Process

Oregon's experience in creating the IWRS shows that the process of creating an integrated strategy is different from generating a customary water supply plan.

Unlike traditional water plan development, an IWRM strategy requires thinking about water in the context of economic, social and environmental needs and creating an adaptable framework for ongoing action and coordination instead of a static project-oriented plan. To accomplish this, it is imperative to include the public and all sectors affected by water planning (GWP Technical Committee, 2005).

Development and implementation of the Oregon IWRS was broken into five phases: planning and developing the process, identifying issues and needs, developing recommendations, generating the IWRS documents, and implementing and evaluating the final strategy. The first four development phases occurred from 2009-2012. The implementation stage began in 2012 (OWRD, 2012).

Phase 1 involved creating guiding principles and problem statements, designing a work plan, identifying the structure of workgroups, and creating capacity within agencies and other groups to contribute to the IWRS.

These guiding principles (outlined in Figure 3) and a vision, goals, and objectives were developed in consultation with advisory groups, the Water Resources Commission, stakeholders and the public, to guide the process as well as actions and implementation. The guiding principles provide insight into the character of the process, and demonstrate how closely the IWRS mirrors IWRM concepts discussed in the Introduction.

To develop the problem statements, a set of issue papers were written and distributed for public comment based on topics from the Oregon Water Roundtables. A Project Team comprised of senior agency staff revised issue papers and added additional themes, which were released for public comment.

The public then provided feedback on the work plan, which included the project timeline, public involvement calendar, process structure, roles and responsibilities, as well as a proposed outline for the IWRS.

Finally, members were selected for advisory groups and OWRD hired a policy coordinator and a scientific coordinator to assist in development of the IWRS.

In *Phase 2*, from January to August of 2010, the Project Team addressed the public comments on the issue papers and work plan, and used surveys, 11 open houses, quarterly meetings with advisory groups, and dozens of stakeholder workshops to identify issues critical to Oregon meeting current and future water demand.

Figure 3 Guiding Principles of Oregon's IWRS

The guiding principles emphasize the following:

1. Accountable and Enforceable Actions
2. Balance
3. Collaboration
4. Conflict Resolution
5. Facilitation by the State
6. Incentives
7. Implementation
8. Interconnection/Integration
9. Public Process
10. Reasonable Cost
11. Science-based, Flexible Approaches
12. Streamlining
13. Sustainability

Source: Oregon Water Resources Department (2012).

Over the next year, in *Phase 3*, the advisory groups developed and evaluated recommendations to address the critical water issues, while also continuing to solicit feedback from the public.

In *Phase 4*, a discussion draft of the IWRS was prepared and released for public comment in December 2011. It was followed by a revised draft in June. Ultimately, the August 2012 version was adopted by the WRC.

Implementation began immediately – *in Phase 5*.

As required, the IWRS will be reviewed and updated every five years to incorporate lessons learned and new information (OWRD, 2012).

IWRM Institutional Roles: Integrating the Public, Stakeholders, and Government

The emphasis on creating a holistic strategy that addresses all water uses meant that development of the IWRS relied heavily on input at every stage from the public, tribes, stakeholder groups, and public agencies representing a variety of interests (OWRD, 2012). The process and structure for integrating these groups is discussed next.

Public Involvement and Inter-Sector Stakeholder Input

The public and stakeholders were provided multiple opportunities to shape the IWRS. These opportunities encouraged participation from all sectors of the population and were designed to ensure that the IWRS would be supported by competing interests.

To those ends, information about the IWRS was communicated through a variety of media, including public meetings, newspapers, fliers, newsletters, email, and the project website. Feedback was received through an online survey, traditional public comment channels, email and more than 30 stakeholder workshops, as well as at open houses.

Open houses were a particularly successful outreach strategy. In the spring of 2010, twelve open houses[7] were held across the state with presentations on water management practices and a display of the water issues and opportunities in Oregon. Participants were asked to identify the key water issues facing their communities and the solutions they would like to see pursued.

Based on this information, a preliminary set of recommended actions were released for public comment, organized as twelve bulletins surrounding the identified critical issues. The bulletins and request for feedback were widely advertised through a variety of media and stakeholder workshops to encourage public participation. A discussion draft of the IWRS was then developed and released for public comment using similar methods as outlined above (OWRD, 2012).

The public also had a formal role in the process through the establishment of the *Policy Advisory Group*. This group included 18 appointed citizens from a variety of water-related backgrounds such as water and wastewater utilities, tribes, counties, conservation organizations, and irrigated agriculture. The Policy Advisory Group provided an avenue to receive ideas and feedback from citizens throughout the development of the IWRS, which provided a perspective outside of government interests.

These extensive efforts to engage the public and stakeholder groups were well received and the conscious effort to listen to and incorporate feedback helped foster an environment of a state-led but bottom-up approach. As a result of the diverse public interests represented throughout the development of the plan, the IWRS reflects Oregonian's water resource concerns and corresponding solutions to address future needs and challenges.

Integrating Government

Integrating water management is challenging in part due to the large number of federal and state agencies that take actions affecting water resources. To achieve a more coordinated plan, two additional groups were established.

The *Agency Advisory Group* was comprised of 18 state natural resource, economic development, and health agencies as well as the Governor's Office, while the *Federal Liaison Group* consisted of 10 federal agencies involved in managing land, water, and fish and wildlife.

[7] Eleven open houses were held in communities across the state, while one was a virtual open house.

Both groups met quarterly and provided technical input on problems, solutions, and existing programs (OWRD, 2012). For example, the Agency Advisory Group identified opportunities for the IWRS to integrate existing State natural resource and economic development plans.

In addition to the state and federal agencies, Oregon's *nine Federally-recognized Indian Tribes* – with whom Oregon has a Government-to-Government relationship – were invited to participate in the open houses. Eight tribes also participated in a State-Tribal Water Forum and one tribal member served on the Policy Advisory Group.

Although development of the IWRS was led by OWRD, the Oregon Department of Environmental Quality, Oregon Department of Fish and Wildlife, and Oregon Department of Agriculture were heavily involved. To facilitate coordination, a *Project Team* comprised of staff from the four agencies was established. The Project Team managed development of the IWRS and served as the key contact for the Agency and Policy Advisory Groups, the Federal Liaison Group, the nine tribes, as well as stakeholders and the public. In addition, the directors of the four agencies acted as *liaisons* between the Project Team and the Governor's Office, the Oregon Legislature, and the four commissions that have oversight responsibility for the four departments.

Incorporating such a broad array of state and federal agencies was necessary to shift away from managing water separately and move toward jointly managing the entire resource.

While integrating these various levels of government was complex and challenging, drawing from within and among the various levels of government greatly enriched the capacity to understand the current state of water resources as well as future opportunities and challenges.

A Goal-Driven Process to Achieve Integration and Address Critical Issues

A key concept in IWRM is to identify and acknowledge the interconnectedness of water resources and attempt to manage the entire system by incorporating land and water, surface water and groundwater, water quantity and water quality, freshwater and coastal waters, and the broader watershed (USACE, 2010).

The almost limitless reach of water requires a strategic focus on establishing the parameters of integration that will allow for better management of the resource, as there is a fine balance between effective integration and creating unmanageable complexity (GWP Technical Committee, 2004).

The approach taken by Oregon to embrace complexity is demonstrated by the IWRS itself and shows how IWRM as a goal-driven process helps to ensure that water is managed sustainably even in the face of extreme complexity. The two overarching goals of the IWRS were to better understand Oregon's water resources and to develop strategies to meet Oregon's water needs. These goals drove development of objectives and identification of critical issue areas, and kept the Project team focused on what was important to achieve in the IWRS.

The resulting set of recommended actions (see Figure 4 on the next page) illustrate the IWRM approach to coordinating water management across sectors and governmental entities to manage the entire resource for the benefit of humans and ecosystems.

As this is the first time such a strategy has been developed, it is not surprising that a significant portion of the IWRS is concerned with developing information to achieve a better understanding of the resource.

For example, the recommended actions highlight the opportunity for the State to assist local governments with integrated water resources planning by funding and distributing information and creating decision-making tools to help local governments understand the resource and make decisions that are more informed.

Facilitating local level action is particularly important for issues such as land use and population growth in which local governments have primary planning authority. Thus, the IWRS recommended actions encourage holistic management, while also recognizing the role of the State and other governmental entities.

Figure 4 Recommended Actions from Oregon's IWRS Framework

Understanding Water Resources / Supplies / Institutions

1a. Conduct additional groundwater investigations.
1b. Improve water resource data collection and monitoring.
1c. Coordinate interagency data collection, processing, and use in decision-making.

Understanding Oregon's Out-of-Stream Needs/Demands

2a. Update long-term water demand forecasts.
2b. Improve water-use measurement and reporting.
2c. Determine pre-1909 water right claims.
2d. Update water right records with contact information.
2e. Update Oregon's water-related permitting guide.

Understanding Oregon's Instream Needs/Demands

3a. Determine flows needed (quality and quantity) to support instream needs.
3b. Determine needs of groundwater dependent ecosystems.

The Water-Energy Nexus

4a. Analyze the effects on water from energy development projects and policies.
4b. Take advantage of existing infrastructure to develop hydroelectric power.
4c. Promote strategies that increase/integrate energy and water savings.

Climate Change

5a. Support continued basin-scale climate change research efforts.
5b. Assist with climate change adaptation and resiliency strategies.

Economic Development and Population Growth

(See Actions 2.A. and 3.A.)

The Water and Land Use Nexus

6a. Improve integration of water information into land use planning (and vice-versa).
6b. Update state agency coordination plans.
6c. Encourage low-impact development practices.

Infrastructure

7a. Develop and upgrade water and wastewater infrastructure.
7b. Encourage regional (subbasin) approaches to water and wastewater systems

Education and Outreach

8a. Support Oregon's K-12 environmental literacy plan.
8b. Provide education and training for Oregon's next generation of water experts.
8c. Promote community education and training opportunities.
8d. Identify ongoing water-related research needs.

Place-Based Efforts

9a. Undertake place-based integrated, water resources planning.
9b. Coordinate implementation of existing natural resource plans.
9c. Partner with federal agencies, tribes, and neighboring states in long-term water resources management.

Water Management and Development

10a. Improve water-use efficiency and water conservation.
10b. Improve access to built storage.
10c. Encourage additional water reuse projects.
10d. Reach environmental outcomes with non-regulatory alternatives.
10e. Authorize and fund a water supply development program.

Healthy Ecosystems

11a. Improve watershed health, resiliency, and capacity for natural storage.
11b. Develop additional instream protections.
11c. Prevent and eradicate invasive species.
11d. Protect and restore instream habitat and habitat access for fish and wildlife.

Public Health

12a. Ensure the safety of Oregon's drinking water.
12b. Reduce the use of and exposure to toxics and other pollutants.
12c. Implement water quality pollution control plans.

Funding

13a. Fund development and implementation of Oregon's IWRS.
13b. Fund water resources management at the state level.
13c. Fund communities needing feasibility studies for water conservation, storage, and reuse projects.

Source: Oregon Water Resources Department (2012).

The IWRS as adopted provides a broad overview of Oregon's water resources and identifies general solutions and next steps. It is a high-level document that will require further identification of specific projects in order to implement the recommended actions.

The Costs and Benefits of Creating the IWRS

An estimate of costs and benefits resulting from the IWRS is difficult to determine because much of the IWRS was developed through volunteer contributions and without the addition of further staffing resources to most agencies. In addition, while there are some costs that can be attributed to the development of the IWRS, most of the costs and benefits will largely be realized in the future as the plan is implemented and improved.

The OWRD received $283,000 in the 2009-2011 budget from lottery-backed bonds and $292,000 in the 2011-2013 budget in general funds to support a scientific coordinator and a public policy coordinator to work on development of the IWRS.

The overarching goal and intended benefit of the IWRS is embedded in the Policy Advisory Group's vision, which aspires to have "healthy waters that are able to sustain a healthy economy, environment, cultures, and communities" (OWRD, 2012, p.1).

The success of the IWRS will largely depend on funding support for implementation.

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Thanks to Alyssa Mucken for reviewing this case study.

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"Integrated regional water management is a paradigm shift for water agencies in the Kings Basin region. Solutions to water issues can happen, and it starts with collaboration. Instead of water discussions focused on the conflicts of the varying interests that are vying for water for cities, farms, and fish, and the resulting stalemate, the Kings Basin Water Authority is producing results in managing the region's water resources."

David Orth (2012)

California's Integrated Regional Water Management: Setting the Foundation for Regional Integrated Planning

Development and Growth of Integrated Regional Water Management

During the past 10 years, California sought to implement integrated water resources management at both the state and regional level.

California's Integrated Regional Water Management Act of 2002 set forth a new way of thinking about water by authorizing the development of Integrated Regional Water Management plans (IRWMPs) to increase collaboration between local agencies (DWR, 2012).

The Integrated Regional Water Management program is guided by overarching principles at the state level, but includes the flexibility to develop a bottom-up, truly local approach to water management.

As described in the 2009 California Water Plan:

> The broad purpose of Integrated Regional Water Management (IRWM) is to promote a regional planning and implementation framework to comprehensively address water supply, water quality, flood, and ecosystem challenges and to implement integrated solutions through a collaborative multi-partner process that includes water managers, Tribes, nongovernmental organizations, State, federal, and local governments, and disadvantaged communities (DWR, 2009, v.1 pp 7-8).

The 2002 legislation signaled the State's dedication to widespread implementation of IWRM. However, it did not provide funding or significant guidance on plan development, which hindered progress.

It was not until later that year, when voters authorized a grant program to fund IRWM projects, that California Department of Water Resources (DWR) and the State Water Resources Control Board developed program guidelines to aid local agencies in creating regional water management groups and generating IRWMPs. Later, voters approved additional grants for both planning and implementation. The funding and guidance provided by the grant program were integral to the progress made in advancing IRWM (DWR, n.d.).

Even though the program is voluntary, IRWM is now a key strategy in the California Water Plan (DWR, 2009). Today, IRWM regions encompass 87 percent of the area of the state, and about 99 percent of the population is represented by a planning region (DWR, 2012).

California is therefore an ideal case to demonstrate how states can serve as a foundation for implementation of IWRM principles to facilitate greater integration, and to encourage holistic management at the local level.

This case study focuses on California's IRWM framework with examples from regional planning areas to demonstrate how concepts have been translated into action. It begins with delineation of planning regions and regional governance structures, followed by an overview of IRWM plan requirements, and elements of the planning process. In addition, it highlights the State's efforts to incorporate social equity and integrated data management into water planning and identifies program challenges and costs.

Establishing Planning Areas: The Regional Acceptance Process

While the State of California set the foundation for regional water management, it elected not to define the planning regions in order to encourage local leadership in developing the IRWMP. The DWR did, however, set forth standards for regions to meet to be eligible for grants. Prior to creating an IRWMP, local groups must form a regional water management group (RWMG) and propose a regional planning area for approval by DWR.

> At a minimum, a region is defined as a contiguous geographic area encompassing the service areas of multiple local agencies; is defined to maximize the opportunities to integrate water management activities; and effectively integrates water management programs and projects within a hydrologic region defined in the California Water Plan, the Regional Water Quality Control Board…region, or subdivision or other region specifically identified by DWR (Public Resource Code Sec 75026(b) (1)).

The proposal must include an overview of the management group's composition, stakeholder and public involvement efforts, governance structure, justification of the area boundary, and approach to inter-regional coordination. These elements allow DWR to identify potentially competing regional management groups and determine the extent to which planning efforts are integrated (DWR, 2009). They also allow significant flexibility in establishing planning areas from the ground up based on unique local needs.

The composition of regional water management groups and corresponding governance structures are specific to each region.

The San Diego RWMG, for example, is comprised of the city of San Diego, San Diego County and San Diego Water Authority, which represents a joint effort between the land use planners and water managers. To balance interests, the San Diego RWMG is advised by a 32-member Regional Advisory Committee consisting of water agencies, water quality representatives, natural resource organizations and agencies, inter-regional coordinating entities, and members of the general public (San Diego IRWM Program, 2012).

Figure 5 Members of the Greater Monterey County Regional Water Management Group

- Big Sur Land Trust
- California Coastal Commission
- California Water Service Company
- Castroville Community Services District
- City of Salinas
- City of Soledad
- Coastlands Mutual Water Company
- Elkhorn Slough National Estuarine Research Reserve
- Environmental Justice Coalition for Water
- Garrapata Creek Watershed Council
- Marina Coast Water District
- Monterey Bay National Marine Sanctuary Water Quality Protection Program
- Monterey County Agricultural Commissioner's Office
- Monterey County Water Resources Agency
- Monterey Regional Water Pollution Control Agency
- San Jerardo Co-operative
- Watershed Institute at California State University Monterey Bay
- Moss Landing Marine Laboratories
- Resource Conservation District of Monterey County

Source: Greater Monterey County Integrated Regional Water Management Program (2012).

In contrast, the Greater Monterey County RWMG (see Figure 5) includes 19 members from a broad array of organizations that reflect the region's coastal location, water quality challenges, and concerns about social equity ("Greater Monterey County," 2012).

The differences in the organizational structures of RWMG's illustrates that the California framework is sufficiently flexible to meet the unique conditions of each region.

Figure 6 Requirements of California's Integrated Regional Water Management Plans

- Consideration of all the resource management strategies identified in the California Water Plan.
- Consideration of objectives in the appropriate regional basin plan or plans and strategies to meet applicable water quality standards.
- Description of major water-related objectives and conflicts within an IRWM planning region.
- Measurable regional objectives and criteria for developing regional project priorities.
- An integrated, collaborative, multibenefit approach to select and design projects and programs.
- Identification and consideration of the water-related needs of disadvantaged communities in the area within the boundaries of the plan.
- Performance measures and monitoring program to demonstrate progress toward meeting regional objectives.
- A plan for implementation and financing of projects and programs.
- Consideration of greenhouse gas emissions of identified projects and programs.
- Evaluation of adaptability to climate change of water management systems in the region.
- Documentation of data and technical analyses used in the development of the plan.
- A communication process to disseminate data and information related to the development and implementation of the plan.
- A facilitation process to engage and coordinate water management projects and activities of participating local agencies and governments, local stakeholders and Tribes to avoid conflicts and take advantage of efficiencies.
- Other matters as identified by DWR.

Source: California Water Code § 10541(e).

The self-identified planning areas also reflect this adaptability to local needs.

For example, the North Coast Regional Management area is the only region in the state that spans the entire hydrologic area from the headwaters to the coast encompassing 12.5 million acres.[8] Geographically, it is the largest planning region in the state due the realization that with its relatively low population, the region's best strategy would be to pool physical and political resources to gain funding for the area ("RMC Water," 2006).

In contrast, the Upper Kings Region focused on the need to coordinate management of declining shared groundwater resources. Consequently, the regional planning boundaries were set in accordance with the groundwater basin (Kings Basin Authority, 2012).

As shown by these two examples, the decision to allow areas to form their own regions has encouraged local communities to identify commonalities and coordinate actions to address water issues. Today, there are 48 different regional plan areas in California, ranging from 170,000 acres to 12.5 million acres (DWR, 2012).

The IRWM Framework

While California has empowered regions to adapt the IRWM process to regional and local needs, it has stipulated a framework for developing plans with a firm basis in IWRM principles.

First, all IRWMPs are required to address water supply reliability and efficiency, water quality, groundwater quantity and quality, ecosystem and watershed stewardship, and the needs of disadvantaged communities (CWC § 10540c). In addition, the Legislature requires all IRWM plans to include the 14 elements shown in Figure 6.

One of the elements requires IRWMPs to consider the use of water management strategies outlined in the California Water Plan; therefore, the regions have an initial toolbox from which to draw solutions (see Figure 7 on the next page).

[8] The entire drainage area within the state of California, excluding the portion in Oregon.

In addition, the grant program gives preference to statewide priorities, which currently include: drought preparedness, efficiency in water use, climate change response actions, environmental stewardship, integrated flood management, protection of surface water and groundwater quality, improving tribal water and natural resources, and ensuring equitable distribution of benefits (DWR, 2010, Table 1).

In this way, statewide goals and strategies are integrated into regional planning through the IRWM grant program.

Facilitating Integration, Inclusiveness and Social Equity

A core concept of IWRM is that better water management results from coordination between the various water use sectors, governmental entities, stakeholders and public. While California has not required that all interests be represented in the RWMG or the governance structure, the State does require the IRWMP development process to facilitate participation from diverse interests.

As outlined in the California Water Code § 10541(g), the IRWMP process must include water purveyors, wastewater and flood control agencies, local governments and special districts, electrical companies, tribes, environmental and community organizations, industry groups, water users, governmental agencies from all levels, universities, and disadvantaged community members and organizations. Participation of such a broad array of agencies and stakeholders encourages multipurpose planning that can improve the management of the physical resource and also reduce tensions between user groups.

In the Kings Basin, for example, almost two dozen entities managed groundwater resources separately within their own areas. This contributed to groundwater declines of 40 feet over 40 years. Now the region "is a textbook example of the effectiveness of local control and planning" with more than 50 entities involved in the Kings River Basin IRWMP (Orth, 2012, pp. 6).

The IRWM efforts in the Kings Basin have resulted in advances towards more holistic and sustainable management of the shared groundwater and surface water resources among competing users.

Figure 7 California Water Management Strategies

1. Reduce Water Demand
- Agricultural Water Use Efficiency
- Urban Water Use Efficiency

2. Improve Operational Efficiency and Transfers
- Conveyance – Delta
- Conveyance -- Regional / Local
- System Reoperation
- Water Transfers

3. Increase Water Supply
- Conjunctive Management & Groundwater
- Desalination
- Precipitation Enhancement
- Recycled Municipal Water
- Surface Storage – CALFED
- Surface Storage – Regional / Local

4. Improve Water Quality
- Drinking Water Treatment and Distribution
- Groundwater Remediation / Aquifer Remediation
- Matching Water Quality to Use
- Pollution Prevention
- Salt and Salinity Management
- Urban Runoff Management

5. Practice Resources Stewardship
- Agricultural Lands Stewardship
- Economic Incentives (Loans, Grants, and Water Pricing)
- Ecosystem Restoration
- Forest Management
- Land Use Planning and Management
- Recharge Area Protection
- Water-Dependent Recreation
- Watershed Management

6. Improve Flood Management
- Flood Risk Management

7. Other Strategies

Source: Department of Water Resources (2009). Vol. 2.

Similarly, the Greater Monterey County IRWM program has focused on reducing tension and increasing integration. Believing that methods in traditional conflict resolution models only generate mistrust, the group has developed a process to reduce regional conflicts, while increasing collaboration and coordination during project selection (RWMG, 2012).

The region now seeks to take a joint fact-finding approach by first identifying questions about projects that need to be answered to make a decision. After that, the group identifies areas of agreement and disagreement and determines how additional information will be obtained to resolve the questions. The key to this process is that it establishes buy-in from stakeholders by bringing them into the project at the beginning. The region believes this approach will help to move beyond the conflicts that have characterized the area in the past (RWMG, 2012).

California has also sought to improve participation from disadvantaged communities (DACs) in water planning.

In recent years, the State has recognized that DACs do not have the resources to put together comprehensive plans or identify potential projects without assistance (DWR, 2009). At the regional level, DACs were not competitive for IRWM grants because they did not have the resources to generate a project proposal. Thus, these regions were excluded from water planning due in part to the initial setup of the program ("RMC Water", 2006).

Recognizing the need for a focus on disadvantaged communities, the State emphasized DACs in IRWM program requirements, and created an additional incentive by setting aside $10 million of the proposition 84 funding for DACs (DWR, 2009).

Some regions have also acknowledged the difficulties faced by DACs and have attempted to improve social equity. For example, the North Coast IRWM capitalized on the power of regional coordination by leveraging resources to create the Water & Wastewater Service Provider Outreach & Support Program to help small service providers:

> …exchange information, pool resources such as qualified operators, specialized tools, equipment and technical consultants, target funding opportunities, identify infrastructure improvement projects, develop relevant training programs, establish standardized procedures for routine and occasional managerial responsibilities, and act as a forum for regional coordination (North Coast IRWMP, n.d).

The North Coast is one example of how the IWRM program has set the foundation for addressing social equity in the management of water in the state.

The Challenge of Achieving Integration

California has undertaken a remarkable and ambitious effort in choosing to encourage IRWM. Many regions have embraced the program's concepts and have found that it has helped to improve water management. However, integration and holistic management do not occur overnight and the program continues to evolve as challenges are identified.

For example, the initial IRWM plans lacked data integration and coordination and, therefore, were "only integrated conceptually and not quantitatively" as data was not only insufficient, but often stored and managed in a manner that was not conducive to sharing between agencies (DWR, 2009, v. 1 p. 6-6).

According to the California Water Plan, overcoming this difficulty is important, as data and analytical tools enable regions to participate in IRWM, manage risk and uncertainty, and improve management of the resource in the face of a changing climate.

The North Coast IRWM has approached this issue by establishing a library of documents, plans and other data accessible from its website, and has also implemented an online tool to upload project proposals (North Coast IRWMP, n.d).

The State has also invested resources into streamlining information to improve data management, information sharing, and decision-making by creating an online information exchange system and establishing protocols and standards for data (DWR, 2009). The Greater Monterey County RWMG, for example, is using the protocols established by the State to collect data. The group then inputs the information into the State's database

to facilitate sharing across the region (RWMG, 2012).

The DWR has also restructured its grant program to facilitate better integration. While the intent of the program is to encourage regional planning from the ground up instead of from the state down, the flexibility and vagueness of the first iteration of the program resulted in development of some plans as a means to obtain funding for already identified projects, thereby failing to increase integration.

The 2009 California Water Plan noted that there was therefore a need for more incentives to incorporate multi-objective planning and projects, and to include different stakeholder groups in the process. Since then, the State has focused on carefully structuring grant opportunities to encourage the desired behavior (DWR, 2009).

For example, the 2010 Guidelines for Prop 1E/Prop 84 funding included preferences for programs that are regional or based on hydrologic basins, resolve water conflicts, address the needs of disadvantaged communities, incorporate land use planning, or address other statewide priorities (DWR, 2010).

Despite difficulties, some regions have been successful at facilitating greater cooperation and coordinated planning, particularly during the development of the IRWMP when regions solicit and identify project proposals to be a part of the plan and grant proposal.

For example, during the proposal of projects for the Greater Monterey County IRWMP, the Project Review Committee looked for opportunities to integrate projects or to create regional instead of area specific programs (RWMG, 2012).

Similarly, the Upper Santa Clara River IRWM held presentations on each project, followed by discussions about how to improve the projects and opportunities to combine similar projects. This led to greater efficiencies simply due to the sharing of knowledge and data between agencies and non-profit groups (Kennedy/Jenks Consultants, 2008).

As demonstrated by the examples throughout this case study, while integration is an incremental process, areas that have shown a dedication to openly exploring and discussing projects can increase coordination and efficiency, leverage resources, and enhance cooperation. It is important to note that as these efforts are led by the region within a framework provided by the State, progress varies by region.

The Costs, Benefits and Future of Regional Planning

Grants have largely driven the success of the program as collaboration, cooperation, and data collection take significant resources. The initial Proposition 50 grant program authorized $500 million to fund IRWM projects. In 2005, voters approved Proposition 84, providing $1 billion for IRWM planning and projects, as well as Proposition 1E, authorizing an additional $300 million for IRWM stormwater projects with flood control benefits (DWR, n.d.).

The California IRWM program has been successful in achieving participation, due in part to these grants. However, it is uncertain if regions have sufficiently recognized the benefits to continue IRWM without the grant program ("San Diego Regional", 2011). As it is unclear if new sources of funding will become available, a priority for the State in the future will be to highlight the benefits of the IRWM approach and make it easier for regions to implement it (K. Guivetchi, personal communication, 2012).

California's IRWM program is facilitating more efficient water management in some regions through pooling of resources and consideration of a broader set of water issues to provide reliable and affordable water supplies for economic, environmental and social purposes. The State expects that regional planning will reduce duplicative efforts and allow areas to more effectively respond and adapt to climate change by pooling resources to reduce flooding, and coordinating local water supplies in the event of drought. The plans also provide water quality and water supply benefits by promoting more reliance on local supplies and nontraditional water development such as recycling, conservation, and modification of operations (DWR 2009). Essentially, IRWM is increasing coordination and facilitating more sustainable water management.

The program has also increased efficiency by encouraging innovation at the local level, while requiring regions to work through the same framework.

As shown by the examples incorporated into this case study, each region has its own approach and much can be learned by studying the 48 regional processes and plans. As a result, one important outcome is that not only do local agencies benefit from the combined resources of regional planning, but also regions benefit from sharing experiences and lessons learned with other areas. Therefore, as part of its strategic planning efforts, the State is currently working on developing case studies to showcase some of the successes and lessons learned (K. Guivetchi, personal communication, 2012).

During the past ten years, California has recognized the value of the IRWM program and remains dedicated to facilitating IRWM planning. Therefore, the DWR is in the early stages of developing *The Strategic Plan for the Future of IRWM in California*, which will critically analyze the current institutional setting and progress of the program, outline a vision for its future, and identify necessary actions to achieve that vision (DWR 2012).

It is a pivotal time in California's IRWM program history that will provide insight into the best practices for implementing IWRM at the regional scale.

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Thanks to Tom Lutterman, Michael Floyd, and Kamyar Guivetchi for their assistance with this case study.

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"Effective governance in the water sector is not linear, prescriptive and logical; rather it tends to be adaptive and 'messy', responding to the dynamic nature of the political and economic forces operating at the time, and in response to changing environmental conditions (floods, hurricanes, droughts)."

Bruce P. Hooper (2006)[9]

The Delaware River Basin Commission: A Classic Example of IWRM

The Delaware River Basin

In the eastern United States, the Delaware is the longest undammed river, extending 330 miles from the Catskill Mountains in New York State to the mouth of the Delaware Bay, where it enters the Atlantic Ocean. Its watershed covers 13,539 square miles, draining parts of the states of Pennsylvania, New Jersey, New York, and Delaware. Approximately 200 miles or two-thirds of the river length is non-tidal. About 150 miles of this stretch has been included in the National Wild and Scenic Rivers System.

The river and its surrounding land uses are very diverse. The upper basin is known for its natural beauty, world-class trout fishery, and rural communities. The headwaters – often considered the most important areas of a river system – are currently undergoing pressures from population growth and proposed natural gas development.

The lower, tidal portion of the basin is largely developed with major population centers and ports. The Delaware River Port Complex is the largest freshwater port in the world. While it is truly a "working river," the ring of brackish and saltwater marshes around Delaware Bay provides vital habitat, nursery and spawning areas.

The Delaware is a relatively small river, but with a large responsibility. Even though it drains only 0.4 percent of the total continental U.S. land area, the Delaware River Basin provides water for over 15 million people (5 percent of the nation's population), including 9 million living outside the watershed's borders in New York City.

For its whole length, the river forms the boundary between the states. A person standing on the banks of the Delaware River is always looking across at a different state. The waters of the Delaware are truly shared. Therefore, it is critical to have a water management system that manages the whole resource, and integrates the many agencies that have a role in managing water. Further, the shared importance of the river to the region requires that the management system have a mechanism to engage stakeholders in the process.

The Delaware River Basin Commission

Years before there was a U.S. Environmental Protection Agency, or a federal Clean Water Act, or even an environmental movement, a little government agency was hard at work restoring life to one of America's most polluted rivers.

A pioneer in environmental protection, the Delaware River Basin Commission (DRBC or Commission) got its start on October 27, 1961, the day the Delaware River Basin Compact became law. The compact's signing marked the first time since the nation's birth that the federal government and a group of states joined as equal partners in a river basin planning, development, and regulatory agency.

The clean-up of the Delaware River and numerous other DRBC accomplishments are rooted in the compact's chief canon – that the waters and related resources of the Delaware River Basin are regional assets vested with local, state, and national interests for which there is a joint responsibility.

The Commission's formation changed the Delaware Valley from an arena of conflict to a model of federal-state cooperation – unlike other parts of the country where across-the-border water squabbles continue to run up huge litigation costs.

Compact members have the collective power to enter into binding agreements on all water-related issues in the basin. Interstate disputes are settled by a vote of the members, which has the force of law without further state or congressional action.

[9] Hooper B. (2006). Integrated River Basin Governance and Key Performance Indicators. *IWA Yearbook.*

The financial savings in legal fees to all five commission members have historically far exceeded DRBC's operating costs. And that was exactly what Congress had in mind when it voted to create the commission back in 1961. As it stated then:

> The establishment of a single agency to coordinate federal interests in the Delaware River Basin is of as much importance as the joining together of the four states and the resultant coordination of the various state activities. In brief, there is one river, one basin, all water resources are functionally inter-related, and each one is dependent upon the other. Therefore, one comprehensive plan and one coordinating and integrating agency is essential for efficient development and operation.

As a testament to the DRBC's success, in 2011 the DRBC celebrated its 50th Anniversary.

The DRBC as a Model of IWRM

The DRBC mission is to manage the resource using the natural watershed boundaries without regard to political boundaries. It exemplifies the major aspects of IWRM: integration of the vertical and horizontal layers of governmental agencies and stakeholders and integration of the various sectors of water.

The members of the DRBC are the governors of the four basin states and an officer of the U.S. Army Corps of Engineers who represents the President and all federal agencies. Each commissioner has one vote of equal power with a majority vote needed to decide most issues. Each state and the federal government have relinquished a portion of their sovereign authority to come together and manage water resources on a watershed basis.

The Commission currently employs 41 full-time employees. The DRBC has seven advisory committees including water quality, toxics, regulated flows, monitoring and flood management that engage the technical staff of the state and federal agencies as well as stakeholders from the regulated, environmental, and academic communities.

The DRBC has authority to manage both water quality and quantity, including both surface water and groundwater from the estuary to the headwaters, and also engages in flood mitigation and drought management. The Delaware River Basin Compact grants DRBC broad powers to plan, develop, conserve, regulate, allocate and manage water resources in the basin. DRBC sets uniform water quality standards and, in concert with the states, regulates water withdrawals and wastewater effluents.

The Commission is also involved with allocation of waters among the basin states to protect the uses of human and instream communities. Unlike the prior appropriation doctrine in the western United States, the doctrine of equitable apportionment is the premise of both the 1954 U.S. Supreme Court Decree, which dictates diversions and releases from the New York City reservoirs, and the Delaware River Basin Compact.

One of DRBC's requirements is to ensure that there is enough freshwater flow coming down the river at all times so that salt water from the Delaware Estuary cannot be pushed upstream where it can affect industrial intakes and the water supplies of the city of Philadelphia and a significant portion of New Jersey's population. There are complex operating plans for the basin's reservoirs (all on tributaries), as well as a drought management plan.

Since its inception, the Commission has demonstrated its ability to use sound science, adaptation, and collaboration to bring about modifications to the 1954 U.S. Supreme Court Decree that apportioned the shared waters of the Delaware River through prescribed releases and diversions. On numerous occasions, the Commission has brought together and provided support to the decree parties (the four basin states, plus New York City) as they negotiate solutions to water allocation disputes and respond to evolving water challenges.

IWRM in Action

The DRBC demonstrates how programs can be implemented within the framework of IWRM. Examples follow, focused on three programs: (1) management of groundwater in a multi-county area of Pennsylvania on a cumulative, watershed basis to protect both groundwater and surface water; (2) protection of very high water quality in the non-tidal river; and (3) planning for the future.

Southeast Pennsylvania Groundwater Protected Area

Sometimes the DRBC – because of its unique structure and powers – is able to implement programs that would be politically difficult, if not impossible, for a state to accomplish on its own.

An example is the management of the 1,200 square mile Ground Water Protected Area of Southeastern Pennsylvania (Protected Area), which covers all or portions of five counties in the Philadelphia metropolitan area and includes 76 sub-watersheds.

The Protected Area was established after it became evident that increases in land use development were decreasing groundwater levels in the area. Lowered water tables in the Protected Area have reduced base flows in some streams and dried up others, which affects downstream water uses, harms aquatic life, and reduces the capacity of waterways in the region to assimilate pollutants.

The goal of the Protected Area is to prevent depletion of groundwater, protect the interests and rights of lawful users of the same water source, and balance competing uses of limited water resources in the region.

Water withdrawals in the Protected Area greater than 10,000 gallons per day (gpd) require DRBC approval. The regulatory threshold in the rest of the basin is greater than 100,000 gpd.

In addition, the Protected Area is subject to a two-tiered system of water withdrawal limits. A maximum limit for each sub-watershed is set at a cumulative groundwater withdrawal that would affect the 1-in-25-year streamflow. At 75 percent of the maximum limit, subbasins are designated as "potentially stressed."

In potentially stressed subbasins, applicants for new or expanded groundwater withdrawals are required to implement one or more programs to mitigate adverse impacts of additional groundwater withdrawals. Acceptable programs include artificial recharge, spray irrigation conjunctive use of groundwater and surface water, expanded water conservation programs, comprehensive planning at the watershed level, and programs to control groundwater infiltration.

Land use has a significant influence on groundwater in the Protected Area. In the Delaware Basin states, land-use regulation is controlled at the municipal level. Due to the small size of municipalities, there can be five or more jurisdictions within one 50-square-mile watershed. The DRBC has a program that encourages municipalities within a watershed to work together to develop a multi-municipal Integrated Resource Plan (IRP).

Integrated Resource Planning is a comprehensive approach to water resource management that evaluates water resources availability and demands on a watershed level. The process encourages planning to meet multiple objectives and evaluate competing uses of water resources.

Under the DRBC's regulations, Integrated Resource Planning is a tool to: (1) evaluate and develop management objectives and strategies on a subbasin basis to ensure that groundwater and surface water withdrawals are managed in a manner that protects both instream and withdrawal uses in the subbasin; (2) evaluate the adequacy of existing groundwater and surface water resources to meet all existing and future needs in the subbasin, and to assess options for meeting those needs; (3) engage stakeholders as active participants in developing effective, long-term water resource management objectives and strategies; (4) consider the inter-relationship of water quality and water availability for current and future water uses in a subbasin; and (5) assist planners to better integrate water resources protection in land-use planning.

Almost all land-use decisions affect water resources. Growth is occurring in most subbasins of the Protected Area. As Integrated Resource Plans can assist in better managing how that growth occurs, the DRBC encourages municipalities to adopt and include IRPs in their Comprehensive Plans.

Special Protection Waters – Keeping the Clean Water Clean

Although states can have water quality standards that are more stringent, the DRBC has the authority to set uniform minimum standards for the basin. In 1967, the DRBC adopted the most comprehensive water quality standards of any interstate river basin in the nation. The standards, which focused on dissolved oxygen levels, were tied to an innovative wasteload allocation program that factored in the waste assimilative capacity of the tidal Delaware River - a TMDL (total maximum daily load) before its time.

Interior Secretary Stewart Udall declared at the time:

> Only the Delaware among the nation's river basins is moving into high gear in its program to combat water pollution.

A year later, the DRBC adopted regulations for implementing and enforcing the standards, prompting the Federal Water Pollution Control Administration to observe:

> This is the only place in the country where such a procedure is being followed. Hopefully, it will provide a model for other regulatory agencies.

The DRBC, working with the basin states and federal agencies, has developed a Toxics Management Program for the tidal waters of the basin with uniform toxic standards, TMDLs and implementation plans for the cleanup of persistent bio-accumulative PCBs (polychlorinated biophenyls). Implementation addresses point and nonpoint sources and requires pollutant minimization plans, source track down studies, monitoring, and annual reporting.

One of the most forward-thinking actions of the Commission was to establish the Special Protection Waters Program that requires any new or expanding discharger to show no measurable change to the existing water quality of the non-tidal shared waters. The Special Protection Waters designation has created the longest stretch of anti-degradation waters in the United States. The program addresses both point and nonpoint inputs. Protection of the headwaters is critical in order to maintain the high water quality supporting over 15 million water users and unique aquatic systems.

In an October 2011 University of Delaware socioeconomic study, the ample, clean waters of the Delaware Basin were shown to support:

1. Annual economic activity of $25 billion.
2. Ecosystem goods and services worth $21 billion per year (2010$), with a net present value of $683 billion, discounted over 100 years.
3. Greater than 600,000 jobs and $10 billion per year in wages.

The DRBC's role in creating water quality standards minimizes conflict among the states by recognizing the connection between upstream and downstream and ensuring that economic development is balanced with social equity and environmental health throughout the shared river.

Planning for the Future

The only effective way to manage the resource is to embrace its complexity and interconnections. A dynamic system requires adaptation, which is facilitated by the involvement of all water sectors, levels of government, and the public. This is the successful model the DRBC has followed since its inception and continues to follow today in its planning efforts.

In 2004, the DRBC Commissioners and a number of federal agencies approved the Water Resources Plan for the Delaware Basin. The 30-year plan was developed with extensive stakeholder input, including a 36-member stakeholder Watershed Advisory Council to ensure that the plan was representative of the basin interests.

The Water Resources Plan provides a holistic goal-driven framework to guide policy and actions by water resources-related organizations, as is often espoused in IWRM. The framework is organized around five interrelated key result areas:

1. Sustainable Use and Supply.
2. Waterway Corridor Management.
3. Linking Land and Water Resource Management.
4. Institutional Coordination and Cooperation.
5. Education and Involvement for Stewardship.

As in the past, the Commission continues to be at the forefront of holistic water management with its latest initiative to increase resiliency through the DRBC Strategy for Sustainable Resources - 2060 (DRBC Strategy).

The DRBC Strategy is needed in recognition of changing conditions that have a high level of uncertainty. During the next 50 years, the Delaware River Basin is expected to undergo changes, including population growth and land-use change, shifts in energy generation, and natural gas development in the headwaters.

The DRBC is also studying the potential to establish an environmental flow program in the basin. Climate change brings an added layer of uncertainty and volatility as sea level rises, temperatures increase, and precipitation patterns change.

The basin will be more adept at responding to changes by modeling various scenarios, testing sensitivities, and developing action plans that address the range of potential impacts. The DRBC Strategy will help the region understand answers to questions such as those listed in Figure 8.

Separate tools are being developed to model scenarios of landscape change, water supply needs, ecological flow needs, water quality and influences on ecological systems, and a range of intensities of floods and drought.

The DRBC is working with federal agencies to help develop the data and models. Future water needs will be projected to generate scenarios. As a result, the DRBC hopes to understand: (1) river flows needed to prevent saltwater intrusion; (2) the minimum flows necessary for tributaries; (3) the capacity for water conservation programs and land management to increase water supply; (4) the results of status quo management in the future (no action scenario); and (5) the actions necessary to increase the region's capacity to adapt and recover as well maintain a reliable supply of water.

The development of scenarios will allow the DRBC to identify and model a range of management options, including modifications to existing facilities, construction of new facilities, and non-structural solutions such as riparian buffers, low impact development, and operational changes. The strong scientific foundation will be coupled with stakeholder outreach and public participation to ensure that the basin has sustainable water supply for both human and ecological needs into the future.

Figure 8 Potential Questions to be Addressed in the DRBC Strategy

- Does the basin have an adequate availability of freshwater to meet both human and ecological needs now and into the future?
- Can the Philadelphia and southern New Jersey potable water supplies be protected from sea level rise?
- What flows are needed to maintain the assimilative capacity of the river for pollutants under future scenarios?
- What flows are needed to protect freshwater marshes, oysters, and migratory fish under future scenarios?
- How will groundwater aquifers be affected by withdrawals and what programs need to be established for their protection?
- How would intense storms and droughts affect water supply storage? How will they compare to the current drought and flood of record?
- Can modification of the water management system and land cover address future water needs?
- Are additional structural solutions for water supply storage and flood mitigation needed?
- How does the management of the New York City reservoirs fit into the DRBC Strategy?
- What should be done in the short term next 5 years?

Benefits and Costs

The region has benefitted greatly from state and federal coordination, which allows this shared river basin to be managed effectively without conflict and with respect to the common goals of the region. The capacity for the DRBC to make decisions that affect the entire watershed helps the region avoid inconsistencies in management that could lead to inequities and conflict. The Commission's programs dealing with water quality, water quantity, watershed health, flow protection, and planning for floods and droughts are leading to improved water management that balances social, economic, and environmental values and priorities.

Approximately 40 percent of the annual funding for the Delaware River Basin Commission is provided by the member states and federal government, although the federal fair share has been nearly non-existent since 1997. The DRBC's 2012-2013 current expense budget was approved at $5.8 million.

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Thanks to Carol R. Collier for writing this case study.

"It's got the kind of broad-base of support we've never had before; from irrigators, government agencies, the Yakama Nation and environmental and conservation groups."

Urban Eberhart (2012)[10]

The Yakima River Basin Integrated Water Resource Management Plan

Background

The Yakima River Basin (Basin) in central Washington State has consistently experienced challenges supporting agricultural, ecosystem, domestic and municipal water needs.

The Basin is one of the most diversified and productive agricultural areas in the world. Its agricultural exports are a major component of the Washington State economy. The Federal Yakima Project irrigates 464,000 acres and underpins most of the agricultural activity in the Basin. However, the Basin is subject to periodic droughts that reduce water supplies for many agricultural users.

Under legal decisions that date back to the 1940's, users of federal project water are divided into two classes. Non-proratable users have seniority over proratable users.[11]

In recent decades, dry years have occurred roughly every five years on average. During dry years proratable users have had their supplies cut dramatically, causing significant economic hardship, particularly in the agricultural sector.

The Yakima River historically supported large runs of anadromous salmonids, estimated at 300,000 to 960,000 fish a year in the 1880s. These fish runs have long sustained the culture and economy of the Yakama Nation, whose treaty rights require preservation of salmon runs for harvest. The runs have declined drastically, and three salmon species were eliminated from the Basin – Sockeye, summer Chinook and Coho.

There are many causes within and outside of the Basin for these declines, including blocked habitat, land use changes and altered streamflows.

The Basin includes portions of Benton, Kittitas and Yakima Counties with 22 incorporated cities and towns and a large rural population. The Basin had approximately 325,000 people in 2010 and growth projections forecast a population of 415,000 by 2025. The largest city is Yakima, the center of an urban area of approximately 95,000 people. It also has a large rural population.

In the seniority system of water rights, most groundwater users are junior to surface water users. This means municipal systems and rural homes could be forced to curtail water use in water-short years. Because water supplies rely heavily on snowpack in the Cascade Range, this problem is expected to worsen under any scenario involving climate change.

In 2003, Congress directed the Bureau of Reclamation (Reclamation) to conduct a feasibility study of options for additional surface water storage in the Basin. The state of Washington partnered with Reclamation in funding and implementing a storage study. Reclamation issued a Final Planning Report and Environmental Impact Statement (PR/EIS) in 2008, which concluded that none of the surface water storage features by themselves met federal criteria for an economically and environmentally sound water project. Therefore, Reclamation recommended No Action as the preferred alternative.

Based on comments received on the draft PR/EIS, Washington State Department of Ecology (Ecology) determined that the alternatives that Congress had authorized for consideration under the storage study were too narrowly focused.

[10] As quoted in Johnston, M. (2012, July 7). Advocates Seek Wider Support from Public. *Daily Record News*. http://www.dailyrecordnews.com.

[11] Proratable users' allocations are reduced equally in water short years.

Comments from environmental groups, the Yakama Nation and others recommended consideration of a wider range of alternatives, using an integrated approach to benefit all resources, including fish passage and habitat improvements in addition to water storage. In response to these comments, and after consultation with Reclamation, Ecology identified an Integrated Water Resource Management Alternative (Integrated Alternative) as a new vision for resolving the long-standing issues described above.

The Integrated Alternative included seven interrelated elements:

1. Fish passage.
2. Structural and operational changes to Yakima Project features.
3. Surface water storage.
4. Groundwater storage.
5. Habitat protection and enhancement.
6. Water conservation.
7. Market reallocation.

This became the basis for the subsequent work described in this case study.

The YRBWEP Workgroup

Reclamation and Ecology jointly convened the YRBWEP[12] Workgroup to further develop the Integrated Alternative.

The YRBWEP Workgroup, shown in Figure 9 on the next page, consists of elected officials from the three counties and the city of Yakima; local, state, federal and Yakama Nation staff; and irrigation and environmental stakeholders representing a wide array of perspectives.

The YRBWEP Workgroup has been meeting regularly since June 2009.

The group explored each of the seven categories of water resource management within the Integrated Alternative and how the different elements combined to improve fisheries and resolve supply reliability problems.

Hydrologic and fish habitat benefits were estimated, together with funding needs and an implementation approach and schedule.

Technical studies were funded jointly by Reclamation and Ecology. These studies used an integrated modeling platform to evaluate how the combination of projects considered would improve water supply and streamflow conditions.

The Integrated Water Resource Management Plan

As a result of these discussions, an array of projects and programs grouped by the seven categories listed above were proposed in the *Yakima River Basin Proposed Integrated Water Resource Management Plan* (Integrated Plan).

The combination of resource management programs and infrastructure projects included in the Integrated Plan meets multiple objectives, including: enhanced water supply reliability; improved streamflows; improved fish habitat conditions; improved access to habitat that has been blocked for decades; and increased supply to meet the needs of population growth within the Basin (see Figure 10 on page 34).

After modeling a combination of projects and resource allocations, the set of programs identified in the Integrated Plan alternative was the only set that met all of the objectives.

Actions in the plan address surface water, groundwater, floodplains and uplands to benefit the fish and people that rely on the Yakima River System. In addition to water resources, it includes protection of significant watershed land resources and associated recreational opportunities.

The Integrated Plan is expected to provide substantial improvements in water supply reliability and greatly multiply the population of salmon, steelhead and bull trout within the Basin (Bureau of Reclamation & Department of Ecology, 2011).

In April 2011, the YRBWEP Workgroup unanimously approved the Integrated Plan, contained in Volume 1 of the Yakima Basin Study. Technical studies performed in 2010 and 2011 comprise Volume 2 of the study.

[12] YRBWEP is the Yakima River Basin Water Enhancement Project, a federal initiative authorized by Congress in 1979.

Figure 9 Members of the YRBWEP Workgroup

Federal Agencies
Bureau of Reclamation
National Marine Fisheries Service
U.S. Fish and Wildlife Service
U.S. Forest Service[13]

Yakama Nation
Yakama Nation Natural Resources
Yakima/Klickitat Fisheries Project

Irrigated Agriculture
Kennewick Irrigation District
Kittitas Reclamation District
Roza Irrigation District
Sunnyside Valley Irrigation District
Yakima-Tieton Irrigation District

Washington State Agencies
Department of Ecology
Department of Agriculture
Department of Fish & Wildlife

Local Governments
Benton County
Kittitas County
Yakima County
City of Yakima

Other Stakeholders
American Rivers
National Wildlife Federation[14]
Yakima Basin Fish & Wildlife Recovery Board
Yakima Basin Storage Alliance

Individual members of the YRBWEP Workgroup commented on various occasions that they did not necessarily endorse every specific project within the Integrated Plan, but that the plan, as a whole, was equitable and offered a reasonable solution to the range of water resource and fisheries problems affecting the Basin.

The consensus agreement forged by this effort marks an unprecedented achievement in a region that has struggled for decades to reach agreement on solutions to serious water supply and ecosystem restoration needs.

Costs and Benefits

The total cost of the Yakima River Basin Study was $2.64 million, split between the State and federal governments. Considerable analysis has been done of costs of the suite of projects and programs included in the Integrated Plan. Total capital costs are estimated to be $4.1 billion in 2012 dollars.

Benefits of the plan have been quantified in three categories. These are: (1) improvements in populations of salmon and steelhead, (2) improvements in reliability of agricultural supplies, and (3) provision of water for municipal systems and domestic wells. An economic analysis conducted in 2010 is currently being updated and expanded to account for national-scale effects. Draft results show quantified benefits from the plan are significantly greater than the costs listed above.

Next Steps

Ecology and Reclamation jointly issued a Final Programmatic Environmental Impact Statement (FPEIS) in March 2012. The FPEIS analyzes environmental impacts for the plan overall, and will be supplemented in the future by project-specific environmental reviews. The Integrated Plan will be implemented using an adaptive management approach as new information emerges.

Since publication of the Integrated Plan, the YRBWEP Workgroup has continued to meet regularly. Its nonfederal members are now communicating with members of Congress, Washington State legislators, and a range of state and federal officials to request funding for the actions contained in the plan.

[13] Joined workgroup in 2012.

[14] Alternate for American Rivers.

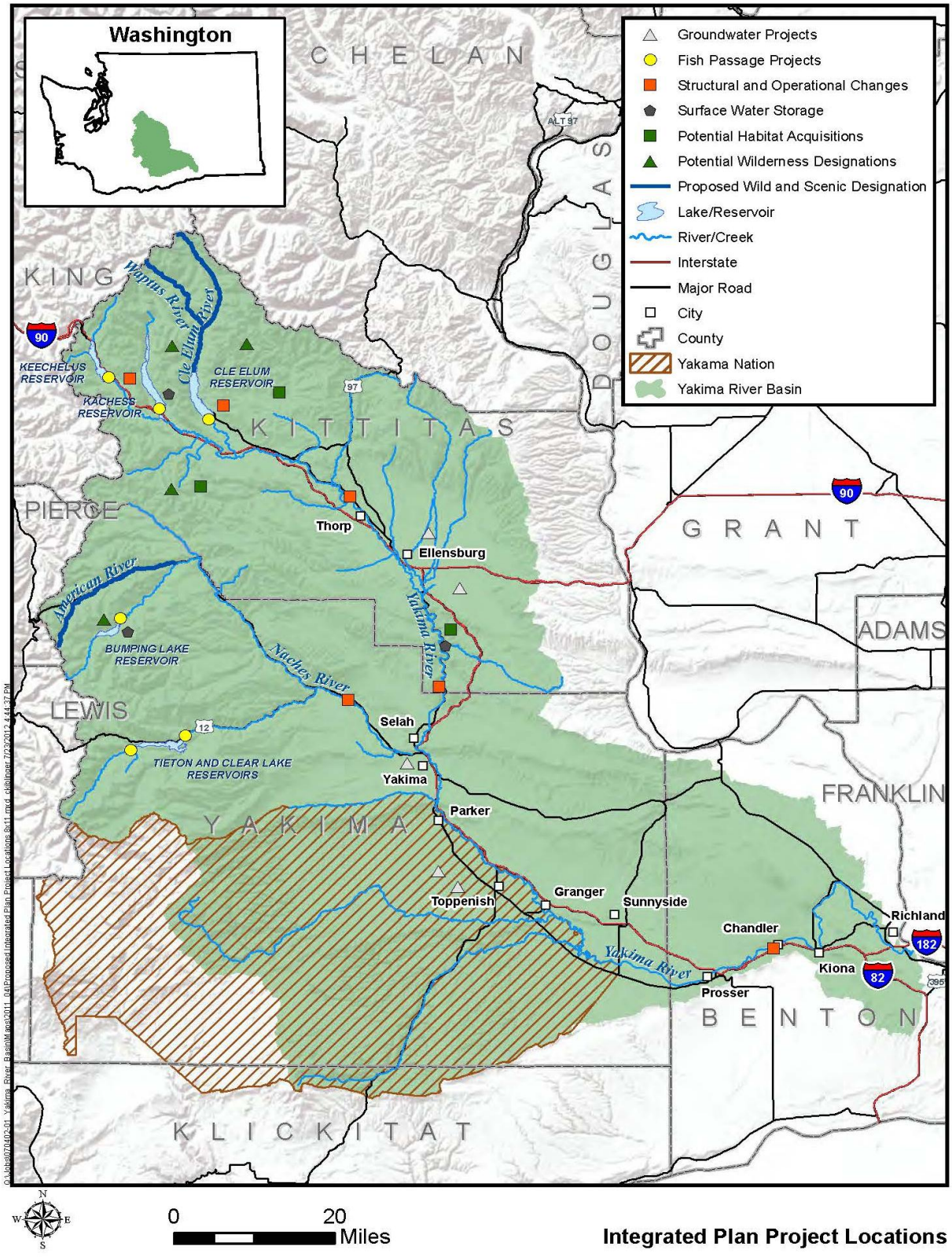
Figure 10 Actions and Corresponding Elements of the Yakima River Basin Integrated Plan

Element/Action	Description
Fish Passage	
Clear Creek Dam passage	Improve upstream and downstream fish passage at Clear Lake.
Cle Elum Dam passage	Add upstream and downstream fish passage facilities at other existing dam sites.
Bumping Dam passage	
Tieton Dam passage	
Keechelus Dam passage	
Kachess Dam passage	
Structural and Operational Changes	
Raise Pool at Cle Elum Dam	Three-foot increase in storage pool elevation.
KRD[15] Canal Changes	Reduce seepage and enhance tributary flows.
Keechelus to Kachess Pipeline	Optimize storage between two reservoirs.
Subordinate Power at Roza Dam and Chandler Power Plants	Reduce water diversions to support fish migration.
Wapatox Canal Improvements	Improve efficiency and consolidate diversions.
Surface Water Storage	
Wymer Dam	New off-channel reservoir (162,500 acre-feet). Investigate removal of Roza Dam.
Lake Kachess Inactive Storage	Tap inactive storage volume (up to 200,000 acre-feet).
Enlarged Bumping Lake Reservoir	Enlarge reservoir to 190,000 acre-feet.
Columbia River Pump Exchange with Yakima Basin Storage	Conduct feasibility study; and periodically evaluate need for additional supplies.
Groundwater Storage	
Shallow Aquifer Recharge	Late winter/early spring infiltration prior to storage control.
Aquifer Storage and Recovery	Off-season recharge of municipal supplies.
Habitat Protection and Enhancement	
Mainstem Floodplain Restoration	Program to fund a range of fish habitat projects.
Tributaries Habitat Enhancement	Program to fund a range of fish habitat projects.
Targeted Watershed Protection and Enhancements	Program to acquire and protect sensitive lands, including aquatic and terrestrial habitats.
Enhanced Water Conservation	
Agricultural Water Conservation	Program to fund a range of projects.
Municipal Water Conservation	Program to fund a range of projects and encourage conservation by residents.
Market Reallocation	
Near-term Effort	Reduce barriers to trading.
Long-term Effort	Additional steps to reduce barriers.

Source: Bureau of Reclamation & Department of Ecology (2011)

[15] (KRD) Kittitas Reclamation District

Figure 11 Proposed Actions in the Integrated Plan



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Thanks to Andrew Graham of HDR Engineering, Inc. for writing this case study.

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"…the water planning process must be a collaborative one, involving as much balanced public and stakeholder participation as possible. Toward this end numerous public meetings, broad information distribution, and focused public and stakeholder outreach, as well as detailed technical work, are all an integral part of the plan development process."

Water Assembly & MRCOG (2004)

The Middle Rio Grande Regional Water Management Plan: Regional Planning Using an IWRM Approach

The Impetus for a Rio Grande Water Plan

Interstate water compact disputes rose in the 1950s on the Pecos, Gila and Rio Grande Rivers that resulted in Federal authorities dictating the distribution of water in the Pecos drainage and the prospect of similar Federal intervention within the State of New Mexico for other major systems.

In 1987, the New Mexico Legislature called for statewide regional water planning to identify water needs and to protect local water supplies from Federal action and out-of-state transfers.

The New Mexico Interstate Stream Commission through the Office of the State Engineer is responsible for managing the program, folding regional plans into the state water plan. Plans are revisited approximately every five years to adapt to changing conditions and new information.

The State requires regional water plans to identify water supply availability, evaluate water demand of multiple sectors, and analyze management alternatives. In addition, water plans must meet public participation requirements, obtain endorsements from local governments, and identify unresolved conflicts (Interstate Stream Commission, 1994).

To encourage integration among local water agencies and to facilitate greater public input, areas were allowed to self-identify their own planning region based on both hydrologic boundaries as well as political and economic interests. Thus, the State set the foundation for practicing IWRM principles at the regional scale, and today has 16 planning regions (Water Assembly & MRCOG, 2004).

The Middle Rio Grande region in central New Mexico is only one of the 16 planning regions, but it is home to about 39 percent of the state's population. The region is dependent on the Rio Grande, which is the largest source of surface water in the state. Groundwater from the Middle Rio Grande aquifer is the main source of water for municipal and drinking water supplies. Groundwater is hydrologically connected to surface water, primarily the Rio Grande, which supports other uses such as industrial, agricultural, and environmental.

Prior to 1998, substantial planning efforts had not been undertaken, as groundwater was initially thought to be inexhaustible. However, in the early 1990s, studies revealed that the region's use of groundwater was unsustainable, with withdrawals exceeding replenishment by about 50,000 acre-feet per year, leading to declining groundwater levels and river flows. As water suppliers drew from the same water sources, a regional approach was necessary to coordinate local efforts to achieve a sustainable supply of water.

In 1998, the region began a five-year process to develop the Middle Rio Grande Regional Water Plan. During the first two years, plan development focused on creating institutional capacity, developing a vision and goals (see Figure 12 on the next page), generating information on supply and demand, and helping the public to understand the water deficit. A period of drought that began in 1999 triggered legal action under the Endangered Species Act over water use from the Rio Grande River and accelerated completion of the regional water plan. In 2001, efforts shifted to identifying and evaluating alternative actions to balance water supply and demand. By 2002, efforts focused on evaluating different scenarios and drafting the plan, which was approved in 2004 (Water Assembly & MRCOG, 2004).

Creating a Structure for a Fair and Inclusive Planning Process

The process of developing the plan included working with approximately 80 institutions led by a partnership between the Mid-Region Council of Governments (MRCOG) and the Middle Rio Grande Water Assembly (Water Assembly).

The MRCOG is an organization of counties, municipalities and other governmental entities. In 1998, MRCOG established a Water Resources Board to prepare and adopt the plan.

The Water Assembly is an entirely voluntary organization centered around leadership from the University of New Mexico. Founded in 1997, it helped coordinate all the interested parties in the region to develop the plan. The two organizations signed a Memorandum of Understanding to work together, forming the basis of an integrated government/nongovernmental organization approach.

Because public and stakeholder involvement was important, the Water Assembly was structured to facilitate participation and coordination. Specifically, it consisted of five constituency groups, an Action Committee, an Executive Committee, and Working Teams.

The five constituency groups were made up of interested parties in the following categories: technical specialists, water managers, environmental advocates, urban and economic development advocates, and agricultural, cultural and historical advocates. Each constituency group appointed five representatives to the Action Committee and one representative to the Executive Committee to advocate for their interests.

The *Action Committee* was the primary leadership body, creating the process of interaction, outlining studies, evaluating options, and managing community engagement.

The *Executive Committee*, a subset of the Action Committee, provided final decision authority and direction to working teams.

Figure 12 Goals of the Middle Rio Grande Regional Water Plan

- Ensure that the mission is fulfilled through fair, open and inclusive public planning and implementation processes.
- Preserve water for a healthy native Rio Grande ecosystem.
- Preserve water for the region's agricultural, cultural, and historical values.
- Preserve water for economic and urban vitality.
- Preserve water for the qualities of life valued by residents in the region.
- Develop broad public and official awareness of water facts and issues, especially the limited nature of water resources.
- Conserve water.
- Promote a system of water laws and processes that support the regional water plan and its implementation.
- Provide appropriate water quality for each use.
- Manage water demand consistent with the stated mission.
- Balance growth with renewable supply.*

* Not approved by MRCOG

Source: Water Assembly & MRCOG (2004).

The Action Committee made recommendations to the Executive Committee about the planning process and the Executive Committee directed the working teams.

Working Teams focused on public participation and communication, analyzing alternative actions, cooperative modeling of the alternative actions, external coordination with other regions and agencies, technical analysis, administration and budget, public welfare, development of plan recommendations, and scenario development.

The Water Assembly structure and partnership with MRCOG resulted in a water plan that represented a truly joint effort between governmental entities, water professionals, and the public (Water Assembly & MRCOG, 2004).[16]

[16] While native peoples were invited to participate, they elected to only observe, likely to preserve their sovereign status. This underscores one challenge of planning at the regional level.

Overview of Outreach Efforts

While interested parties had the opportunity to formally participate as a member of the Water Assembly, there were also significant public outreach and involvement efforts at every stage in the development process. This was important, as failure to obtain local buy-in could affect local agencies' commitment to implementing the plan.

To maximize limited resources, outreach included free or low-cost uses of the media, directly communicating with public officials, and holding public meetings and targeted presentations. Letters, articles, op-eds, press releases and public service announcements were some of the primary means of keeping the public informed. In addition, media kits and planning information were distributed to media outlets and Water Assembly members served as experts on radio shows (Water Assembly & MRCOG, 2004).

The public was also engaged more directly through informational presentations, community conversations, regional forums, public opinion surveys, and annual water assemblies. These events were not only an opportunity to provide information to the public, but also involved activities that encouraged participants to generate a deeper understanding of the problem, formulate potential solutions, and provide feedback to shape the final plan.

Presentations and information were also provided to the federal congressional delegation, federal agencies, tribal groups, state agencies, local governments, special districts, regional neighbors and nongovernmental organizations.

By the time the plan was approved, more than a hundred public meetings had been held along with about the same number of briefings to groups and governmental organizations. In sum, twenty-three hundred public comments were received and 3,000 individuals had attended meetings held by the Water Assembly (Water Assembly & MRCOG, 2004).

The Water Budget as a Tool for Collective Action

Early in the process, a *water budget* was developed by determining the quantity of water used in the region and the quantity of water that was available. Although there was continuous discussion about the accuracy of the data used, regardless the water budget showed that the region was operating at a deficit that would increase in the future without concerted efforts to reduce water use or increase supply. The intuitive nature of the water budget made it an ideal tool to help diverse interests develop a common understanding of water as a finite resource in the region, and of the challenges faced in reducing demand.

Constituency groups and the public were provided with an electronic spreadsheet, which showed how much water was available in the region and how much was being used by each sector. Participants were provided with overarching allocation instructions to follow.

The instructions noted that: (1) total water use could not increase; (2) groundwater and surface water are connected; (3) efficiency improvements only increase supply to the extent that they reduce consumptive water use; and (4) certain flows must be met in order to meet obligations under the Rio Grande Compact.

Using this information, participants were then asked to balance the water budget so there was no longer a deficit. This allowed the different interests to comprehend just how difficult it was to balance the water budget without coordinated action. Further, it encouraged conversations about the regional impacts that might result from decreased uses in each water sector (Water Assembly & MRCOG, 2004).

Identifying and Evaluating Alternative Actions

Based on the water budget tool, 273 suggestions were received to address the disparity between water supply and demand. These were then pared down to 44 potential alternative actions outlined in Figure 13 on the next page.

Thereafter, each alternative was initially analyzed for water impacts, potential tradeoffs, cost, and time to implement. The alternatives were ranked on a five-point scale for technical feasibility; physical, hydrological, and environmental aspects; economic impacts; social and cultural implications; legal implications and political feasibility. The in-depth analysis of the alternatives was released to the public for discussion.

Figure 13 Alternative Water Actions to Balance the Water Budget in the Middle Rio Grande

Decrease or Regulate Water Demand

- Urban Conservation
- Urban Water Pricing
- Conservation Incentives
- Education
- Irrigation Efficiency
- Agricultural Metering
- Conveyance Systems
- Metering Water Supply Wells
- Domestic Well Controls
- Acequia Conservation Programs

Change Water Uses to Increase Supply/Decrease Demand

- Low-Water Crops
- Land Use
- In-Fill/Density
- Preserve Deep Water for Drinking

Water Rights Regulation

- Instream Flow
- Conjunctive Management
- Water Rights Adjudication
- Evaporative Loss Accounting

Water Quality Protection

- Water Quality
- Domestic Wastewater
- Well Head Protection

Increase Water Supply

- Watershed Plans
- Bosque Management
- Reservoir Management
- Surface Modeling
- Aquifer Storage
- Reuse Greywater
- Reuse Treated Effluent
- Desalination
- Importation of Water
- Water Harvesting
- Soil and Vegetation Management
- Vegetation Removal Products
- Storm Water Management
- Vegetation Management
- Wetlands
- Weather Modification

Implementation of Water Plan & Management of Water Resources

- Water Bank/Authority
- Growth Management
- Public Involvement Program
- Maintain Water Resource Database
- Active Water Resource Management

Water Funding

- Severance Tax
- Regional Water Planning Program

Source: Water Assembly and MRCOG (2004).

Individuals were asked to rank the alternative actions from least preferred to most preferred. The professional analysis and public preference rankings were then used to identify a suite of alternative actions that when combined would allow the region to achieve its water resources goals (Water Assembly & MRCOG, 2004).

Developing and Evaluating Scenarios

Identifying the best alternative actions proved to be a complex and challenging process. To assist, small businesses involved with the Water Assembly leveraged the New Mexico Small Business Assistance Program (a state tax rebate program) to commission a computer model from Sandia National Laboratories and the University of New Mexico Law School Utton Center. The model ran scenarios of implementing a specified set of alternative actions, calculating implementation costs, impacts on groundwater levels, and the effect on streamflows.

To ensure transparency and build credibility, representatives from the constituency groups, the working teams, and MRCOG worked with Sandia on the Cooperative Water Model. The model incorporated about half of the alternative actions and allowed for variations in the intensity of implementation for certain actions.

For example, in looking at residential water use, the model could identify the combined impact of requiring new developments to use greywater on-site and harvest rainwater; converting 30 percent of existing homes to xeriscaping; installing low flow appliances in 80 percent of existing homes; and raising water rates to $3.00 per 1,000 gallons.

For actions that were not included in the model, the constituency groups were asked to rank the importance of the action. Actions were then ranked "high" if it was important to all groups, or "split opinion" if there were inconsistent rankings among groups. The computer model and ranking results were utilized as tools for developing scenarios.

Both the public and scenario development committees were involved in the development of the model to ensure its credibility, and were provided the opportunity to utilize the model to help identify potential scenarios. The scenario development committees created a scenario that would represent the vision for their assigned interest group. Thereafter, each scenario was input into the computer model to identify the implications of the collective set of alternative actions. The results were presented to the public for discussion.

Based on feedback and technical analysis, the Action Committee then developed one scenario guided by the overarching goals of preserving water for: (1) the Rio Grande ecosystem, (2) economic and urban vitality, and (3) agricultural, cultural, and historical values.

This final scenario became the basis for the plan and recommended actions. Examples of the recommended actions are shown in Figure 14. After additional public input, local governments were asked to accept the finalized plan (Water Assembly & MRCOG, 2004).

Figure 14 Sample of Recommended Actions in the Middle Rio Grande Regional Water Plan

- Establish a Domestic Well Policy
- Conversion to Low Flow Appliances
- Urban Water Pricing
- Greywater Reuse
- Storm Water Management Plans
- Cooperative Regional Water Management
- Water Banking
- Land Use Management and Planning
- Measure All Water Uses
- Upgrade Agricultural Conveyance Systems
- Recognize Agricultural Traditions in the Region
- Mitigate Septic Tank Impacts
- Improve Water Quality Sampling and Testing
- Protect Water from Contamination
- Riparian Habitat Restoration
- Constructed Wetlands
- River Restoration
- Recognize the Importance of Healthy Native Ecosystems of the Rio Grande and its Tributaries
- Implement Aquifer Storage and Recovery for Drought
- Develop a Water Education Curriculum for Schools

Source: Water Assembly and MRCOG (2004).

The Plan as a Basis for Action

The Middle Rio Grande Regional Water Plan is the outcome of a shift towards holistic water management that resulted from identifying how coordination among all water use sectors and local governments could ensure that water is sustainably managed for the economic, social, cultural, and environmental benefit of the region.

Implementation of the plan recommendations was not mandated as a single set of requirements by state or federal law, although State policy requires funding for water development or environmental restoration to align with regional water plans. The plan, however, has become the basis for a number of efforts by individual implementation organizations.

Most of the recommendations are currently implemented or are underway, including: (1) the Middle Rio Grande Endangered Species Collaborative Program's efforts to protect endangered species through habitat restoration, biological salvage and purchasing water to augment flows; (2) Bernalillo County has strengthened septic tank regulations, the City of Albuquerque has extended sewage collection service areas, and the Village of Corrales has begun construction of their first sewage collection system; (3) the Middle Rio Grande Conservancy District has reduced its overall river diversion by approximately half through greatly improved delivery systems and diversion timing; (4) the State Engineer has issued a reduction in the amount of water that can be extracted from new domestic wells in the region; and (5) to motivate reduction of water use, the

largest municipal water supplier in the region has implemented a "conservation" fee structure and includes a message in the monthly bill that compares the customer's use with average residential use.

Costs and Benefits

In addition to the Small Business Assistant Tax Rebate program described above, MRCOG received $150,000 from the State for the initial plan development from 1999 to 2002, with local governments providing an additional $161,353. Starting in 2002, the State and local governments each paid for 25 percent of the costs (equal to $280,530 each), with the remaining 50 percent from in-kind services.

More than 2,000 individuals (Water Assembly, 2003) were involved with the project with volunteers providing approximately 30,000 hours of expertise. Overall, the analysis and plan development cost about $1.2 million (Water Assembly & MRCOG, 2004).

The benefits from regional water planning include the capacity to ensure that there will be sufficient water to meet human and environmental needs by eliminating short-term thinking to maximize more strategic actions that will benefit the region over the long-term.

The plan makes it clear that the benefits of planning are to avoid the costs of not planning:

> Specific risks include financial costs of failure to meet downstream obligations, economic costs of water shortages, drying or quality degradation of our water supply, impacts to the environment, land subsidence, outside appropriation of water, and loss of those lifestyle and cultural attributes that make New Mexico and the region unique (Water Assembly & MRCOG, 2004, p. 1-2).

Exact estimates of the cumulative investment across all organizations and the community to reduce use, communicate, improve environmental conditions and meet endangered species requirements have not been tallied, but estimates have reached $100 million. This is significantly less than the overall cost of other options such as increasing supply or engaging in litigation.

For example, the estimated deficit in water resources in the Middle Rio Grande was approximately 50,000 acre feet. At the current price for permanent water right transfers, the water deficit is worth between $600-750 million. These costs would either be borne by local municipalities, be implemented via forced use reductions in the municipal or agricultural sector, or be implemented via saline water extraction and treatment.

In sum, the region has greatly benefitted from coordination and planning efforts.

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Thanks to Erik Webb for assisting in writing this case study.

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"The integrated watershed study will produce a watershed management plan and decision support system to aid water and land managers in the basin. These tools will enable examination of existing conditions, forecasting of future conditions and simulation of alternatives to identify ecologically sustaining and economically and socially desirable management actions."

U.S. Army Corps of Engineers, St. Paul District (n.d.)

Developing a Plan and Decision Support System for Integrated Water Resources Management in the Minnesota River Basin

Background: The Connection between Water Challenges and Land Use

The Minnesota River Basin (MRB) drains an area of 16,770 square miles within Minnesota, South Dakota, North Dakota and Iowa. The MRB, primarily located in the state of Minnesota, has experienced significant changes in the hydrologic regime due to the conversion of native prairies, wetlands, and savannas to urban development and agriculture (USACE, 2004).

Tile drainage of agricultural fields has been cited as one potentially significant cause of changes to water quality and the hydrologic regime. But whatever the cause, increased problems associated with flooding, erosion, drought, degraded habitat, and poor water quality are threatening ecosystems and agricultural livelihoods.

The impetus for today's efforts in the MRB reach at least as far back as 1962 with a request by the Committee on Public Works of the House of Representatives for an evaluation of the Minnesota River Basin. In 2003, Congress funded the Minnesota River Basin Reconnaissance Study to determine if the federal government could assist with implementing "solutions to flooding, navigation, low flow augmentation, recreation, ecosystem restoration, and other related water resource problems and opportunities in the Minnesota River Basin" (USACE, 2004, p. 1).

The Corps of Engineers – which has embraced IWRM with goals of protecting the environment, promoting economic development, and restoring ecosystems to maximize their services – developed the study with input from state and federal agencies, cities, watershed districts, environmental organizations, the public and other stakeholders in the MRB.

It was determined that many of the problems in the basin were interconnected and would require several management approaches applied at different scales. Therefore, the MRB Reconnaissance Study explored potential plans for coordinated and purposeful action within the basin and identified three that met the objectives.

One proposal, *The Integrated Watershed, Water Quality, and Ecosystem Restoration Analysis*, emerged out of recognition that tools were necessary to understand the costs and benefits of management actions on both human and environmental systems in order to plan effectively.

The study proposal called for the development of a Decision Support System (DSS) that would allow water managers to simulate future conditions in order to identify, monitor and evaluate management approaches and restoration measures that would achieve desired results.

The DSS would integrate physical systems such as watershed processes, water quality, and ecosystems at various spatial levels ranging from subbasins to the main stem with a goal of identifying the most efficient ways to restore the ecosystem, while also sustaining agriculture (USACE, 2004). To achieve this, the DSS would include:

> …process-based simulation models, geographic information systems (GIS), topographic data, agricultural and ecological economics valuation models, plan formulation, alternatives analysis, and evaluation models (Project Management Plan, 2009).

Setting the Foundation to Create IWRM Tools: Generating Capacity

In December of 2007, Congress appropriated funds for the project and the Corps of Engineers (USACE) engaged the non-federal project sponsor, the Minnesota Environmental Quality Board (EQB), in developing the Project Management Plan.

In addition to the USACE and EQB, more than 20 partners were involved, representing federal, state, local, and tribal governments. As this study was undertaken by a broad coalition of federal and non-federal sponsors, the Project Management Plan ensured that all parties understood their responsibilities and cost-share obligations in order to reduce the potential for conflicts as the study progressed (Project Management Plan, 2009).

A *Study Coordination Team* comprised of senior staff from the lead agencies was established to oversee the study and make final recommendations to EQB and USACE.

The lead agencies also created an *Interagency Study Team* to provide guidance and advice throughout the study and to act as a liaison with the members' respective affiliations.

The Interagency Study Team included seven state agencies, two universities, five federal agencies, two tribal communities and the Minnesota River Board. The governmental agencies were health, transportation, natural resource, land, environment, and fish and wildlife related, while the Minnesota River Board, a joint powers board of more than 30 counties, was selected to represent the interests of local government.

The Project Management Plan also authorized additional federal and state agencies and local governments to participate in the study (Project Management Plan, 2009), although the opportunities to do so have yet to be developed and none have done so to date.

The project tapped experts from the partner organizations in the fields of hydrology, geomorphology, limnology, ecology, agriculture, economics, planning, and modeling to serve on technical teams, which perform many of the public process, research and modeling tasks (USACE, 2004).

As USACE policy limits the formal participation roles to governmental agencies, non-governmental organizations have not had an official role in the process thus far, but they will be invited to provide input and feedback at certain points in the development of the DSS and watershed management plan (Project Management Plan, 2009).

Model Development: Integrating Spatial, Temporal, Physical, and Social Conditions

The purpose of the study is to create a water resources plan and DSS that integrate water quality, watershed, and ecosystem restoration initiatives based on emerging technologies and models. Both the plan and DSS are still in development. The process began with the Interagency Team identifying technical teams and project goals, followed by a determination of available and needed data, and the selection of models (Project Management Plan, 2009, p. 6). To identify appropriate models, a list of planning questions was generated to determine desired outputs (see Figure 15).

For example, one planning question was, "What would be the economic impacts of watershed and water quality management and ecosystem restoration?" and the corresponding output will include forecasts of agricultural production (Planning Questions, 2011).

Figure 15 Planning Question Topic Areas of the MRB Study

- Hydrologic Regime
- Lakes and Wetlands
- Flooding Damages
- Land Use and Land Cover
- Sediment Mobilization and Transport
- Nutrient Loading
- Water Quality
- Fecal Coliform Bacteria
- Endocrine Disrupting Chemicals
- Aquatic Habitat Conditions
- Water Budget
- Social Conditions
- Economic Conditions

Source: Planning Questions (2011).

The challenge of creating a basin-wide model is finding enough small watersheds representative of the basin's diversity with sufficient data to simulate different conditions across the basin. To maximize use of the study's limited resources, the interagency team decided to start by modeling six to eight small watersheds considered representative of different conditions within the basin. The goal is to evaluate if they might sufficiently inform a basin-wide model to make reasonable generalizations to the rest of the basin.

Hydrologic models will be created for a range of precipitation conditions under natural, current, and potential future land-use patterns, which will be used to understand sediment and nutrient transport. After scaling the models up to larger watersheds, the outputs will be combined with flow models of the Minnesota River to understand influences on water quality.

These models will be combined with models of "future land use, urban development, climate, geomorphic processes, the agricultural drainage system, and watershed management" to understand the effects on hydrologic processes and water quality (Project Management Plan, 2009, p. 6).

After receiving input from the public, a model of desired future conditions will be developed to identify what changes in the inputs are necessary to reach that target, and what management actions are necessary to cause those changes.

Management actions to be modeled will include:

> …best management practices for watershed management, land cover changes, modifications to the agricultural drainage system, wetland restorations, tributary channel restoration, reservoir water level management, navigation traffic restrictions, and other measures (Project Management Plan, 2009, p. 6).

Thereafter, different scales in application of management practices and combinations will be simulated to understand the cumulative impacts on the larger watershed and main stem Minnesota River.

For example, in recent years, there has been an increase in agricultural drainage tiling in the basin, but it is not known exactly how this is affecting the hydrology and water quality. The model, once developed, will help people understand this connection between management activities and water resources.

The modeling is not limited to physical aspects, but will also include a simulation of the economic effects of management actions on agriculture and local communities, along with a simulation of the extent that management actions increase ecosystem services (Project Management Plan, 2009).

Based on the models described, a decision-support system will be developed to identify water quality, water quantity, groundwater management, aquatic ecosystem restoration, and watershed management actions to achieve desired future conditions. This model will allow users to understand the social, economic and ecosystem benefits and impacts associated with different decisions and allow for a balanced approach to watershed management.

It is expected that natural resource, land and water professionals will use the DSS tools, including State and local government planners and managers, tribal interests, federal authorities, and farmers and other landowners.

Land use planners, for example, may use it to understand interactions between floodplain development, flooding, and water quality. Fish and wildlife officials could use it to identify which wetlands, if restored, will have the maximum effect on improving water quality with minimal impacts on agricultural and urban economies.

The goal is to make the models and DSS into practical tools capable of helping professionals understand the interconnectedness of the system and manage it in a manner that balances social, economic, and environmental priorities.

Secondary user groups may include public and special interests affected by land and water management decisions.

The Challenges of Integration

The study has had to address a number of challenges.

First, the program relies on federal funding, which has been inconsistent from year-to-year, making it difficult to follow a precise development timeline and to maintain efforts to coordinate among partners.

Second, while the study's development has benefitted greatly from the support of participants, the inconsistent flow of funds has made it particularly difficult to maintain continuity of effort as key staff members inevitably move on.

Third, the study's stop-and-start funding cycle has also delayed efforts to engage the public. With concerns that the study could be perceived as "just another plan for the shelf," study leaders want to wait until it is on a firmer footing before they approach the public. However, there is also a balance that must be struck, as the public does have an important role to play in the development of the model. The longer it takes to engage them, the greater the risk that they will perceive the study to be a "top-down," rather than collaborative approach.

Project Benefits and Costs

As shown in Figure 16, this study will help the basin work toward a number of objectives. Although it will be years until the cumulative effects of this project are realized, these objectives demonstrate a commitment to holistically managing and understanding the interconnection between human actions and ecological systems. The DSS tool and plan will enable comparisons between current conditions and future conditions under different management scenarios to better understand how actions affect the social, ecological, and economic health of the Minnesota River Basin.

The tool will also allow for more integrated and efficient planning at both the local and regional watershed level. It also may help resource managers to understand how actions within one basin affect the rest of the watershed; thereby encouraging coordinated efforts to produce desired outcomes (EQB, n.d.; USACE, n.d.).

Figure 16 Objectives of the MRB Integrated Watershed Study

- A more natural hydrologic regime
- Reduced soil erosion from upland areas
- Stabilized stream channels
- Reduced sediment loading to the Minnesota River
- Reduced economic damages from flooding
- Restored prairie, wetland, and river ecosystems
- Quantified hydrologic effects and economics of urban and agricultural drainage, to provide for more informed design and regulation of drainage activities
- Reduced sediment and nutrient loadings; improved water quality throughout the Basin
- A sustainable agricultural economy

Source: USACE (2004)

Organizations across the basin will then be able to identify priority actions, reduce duplication, and increase efficiency to better leverage limited resources for maximum ecological benefits. Upon implementing the plan and associated restoration projects, the region will benefit from improved ecosystem services, including:

> …more sustainable agriculture and rural communities in the MRB, reduced flooding damages, improved water quality, improved human health, increased distribution and abundance of wildlife, and increased recreational opportunities (USACE, 2004, p. 47).

Although the project is estimated to cost $9.6 million (USACE, n.d.), the total cost of the project is difficult to determine, as it is still in the preliminary stages. Congress appropriated funds for the study in the 2008 Consolidated Appropriations Act, which was followed by a 50 percent cost-share agreement between USACE and the EQB. The non-federal cost-share can include cash or in-kind contributions (Project Management Plan, 2009).

To date, the federal government has allocated $1.6 million to the project (USACE, n.d.). The state of Minnesota has also contributed significantly with a $2.3 million purchase of LiDAR data for the basin.

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Thanks to John Wells for assisting in writing this case study and Michael Wyatt and Dr. Rebecca Seal-Soileau for reviewing the case.

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"An overarching goal of Florida's water policy is to realize the beneficial use of water resources, ensuring their sustainability and providing water for all reasonable-beneficial uses and for natural systems. To achieve this goal, the direct benefits of human water uses must be balanced against the indirect benefits provided by natural systems. Striking an appropriate balance requires development of a sound scientific understanding of the water requirements of natural systems."

St. Johns River Water Management District (2012b)

The St. Johns River Water Supply Impact Study: Creating Tools for Integrated Water Resources Management

Introduction: A Strong Foundation for IWRM

Florida is unique in that it has not followed the traditional approach to water management. Rather, it has engaged in water planning at the regional level since the Florida Water Resources Act of 1972, which established five water management districts based on hydrologic boundaries.

Today, the water management districts oversee water supply, water quality, flood control, and natural systems protection and restoration (SJRWMD, 2012b). Florida provides an ideal case study to examine and study IWRM concepts, since the institutional foundation was established forty years ago.

Florida law requires that the districts manage water so "existing water supply sources are adequate to meet existing and projected reasonable-beneficial needs of the local governments while sustaining water resources and related natural systems" (SJRWMD, 2006).

Florida's water management districts are well-aligned with the definition of IWRM, as they must plan how to meet consumptive water demand without violating minimum flows and levels – the point at which withdrawals have a significant adverse effect on the ecosystem (SJRWMD, 2012b).

The St. Johns River Water Management District (SJRWMD or District) is one of Florida's five regional water districts, spanning all or part of 18 counties across approximately eight million acres in the northeastern to central-eastern part of Florida (SJRWMD, 2006).

The region has highly productive aquifers, which have been the primary source of water for consumptive uses.

Although Florida on average receives 53 inches of rain annually, most is lost through evaporation. In addition, rivers, estuaries and wetlands require much of the remaining water to maintain the benefits of healthy ecosystems, particularly during times of the year when human demand is high (SJRWMD, 2012b).

The inherently integrated organizational structure requires that the District meet performance goals to retain wetlands, establish ecological minimum flows, protect groundwater and surface water quality, minimize flood damage, and increase water supplies for human consumption (SJRWMD, 2012a).

In 2000, the SJRWMD worked with the public and other government agencies to complete its first long-term District Water Supply Plan, which found that in some areas, aquifers would not be able to sustain growth over the 20-year planning horizon without impairing water resources and ecosystems (SJRWMD, 2012).

The Challenge: Increasing Supply without Harming Ecosystems and Water Resources

In response to the need for future alternative water sources, the District began a three-year study exploring the possibility of withdrawing water from the St. Johns River. The study found that it would be economically feasible to utilize the river as a water supply source (SJRWMD, 2012).

In 2005, the SJRWMD utilized feedback from the public, stakeholders, governmental entities and other parties to complete its first update to the District Water Supply Plan (SJRWMD, 2006). The plan again identified the St. Johns River and the Ocklawaha River as potential sources to meet the growing demand for water (SJRWMD, 2012).

Around the same time, a consumptive use permit to withdraw water from the St. Johns River was approved. It sparked some public opposition as well as concerns from other water suppliers, leading to uncertainty about authorizing withdrawals in the future.

By 2006, the SJRWMD and two other regional water management districts recognized a need for coordination among the three districts to reduce conflict and allow for better planning, as groundwater supplies were declining in the region where the districts' borders met (SJRWMD, 2012).

The three regional water districts set additional restrictions on consumptive use permits within this Central Florida Coordination Area, while also agreeing to plan and coordinate additional water supplies to meet new water demands beyond 2013 (SJRWMD, 2012b). As a result, the District continued to identify opportunities for water conservation and improved aquifer management, as well as the development of other sources such as reclaimed water, brackish groundwater, seawater, and surface water (SJRWMD, 2006).

Addressing the Unknown: Overview of the Water Supply Impact Study

The SJRWMD seeks to sustainably manage and balance the use of water in the state for both humans and ecosystems, recognizing that natural systems provide benefits that must be considered in water planning. The District attempts to find this balance through the use of science to understand the requirements of ecosystems and focuses on both developing data and generating public support through education and communication (SJRWMD, 2012b).

One challenge with this and the IWRM approach is not having the necessary information about human and physical systems to make holistic decisions. Although there was a desire to move forward with the identified surface water supply projects on the St. Johns River, there was recognition that developing projects with such a limited understanding of the ecosystem could potentially lead to harm.

The SJRWMD's Governing Board delayed project implementation so the district could first identify and understand the impacts of surface water withdrawals on natural systems (SJRWMD, 2012). Consequently, from 2007 to 2012 the District undertook the Water Supply Impact Study (WSIS), constructing one of the most comprehensive models of the effects of water withdrawals on the ecosystem.

First, the SJRWMD created a website to help the public understand the issues and provide information on options the District was considering as an alternative to groundwater supplies.

Given the desire to create a rigorous and comprehensive model, eight work groups with 81 scientists and engineers (SJRWMD, 2012b) were established in the following areas: hydrology and hydrodynamics, biogeochemistry, plankton, benthic macroinvertebrates, littoral zone vegetation, fish, wetlands vegetation, and floodplain wildlife.

The initial phase of the project involved the creation of hydrodynamic models to understand and identify connections among water levels, flow rates, and the rest of the ecosystem in order to determine the ecological impacts of potential water withdrawals. Where information was insufficient, efforts were made to collect more data. In September 2008, a technical symposium, open to the public and broadcast online, was held to receive feedback from outside experts as well as the public (SJRWMD, 2012).

Phase two of the study began in October 2008, when the SJRWMD engaged the National Research Council (NRC) to peer review the WSIS and make recommendations to strengthen it (SJRWMD, 2012).

Over the next three years, the NRC met with the District and held several technical review meetings where the public was allowed to ask questions of the NRC and provide comment. By the time the final report was completed in 2012, the SJRWMD had addressed almost all of the NRC's comments.

IWRM Tools: Addressing Complexity Through Models

Since the St. Johns River experiences tidal influences more than 100 miles inland, the effects of sea level change and the potential for a decrease in river flows to change the influx of seawater were important for the study to take into account to allow for proper planning (SJRWMD, 2006). Other hydrologic factors affected by water withdrawals

considered included salinity, nutrients, turbidity, and residence time (SJRWMD, 2012).

The approach of the work groups was to integrate hydrologic, water quality, and biologic datasets to develop models of the effects of withdrawing water from the St. Johns River and Ocklawaha River on "aquatic grasses, listed species, commercial fish species and their food base, wetlands and wetland wildlife, and potential changes to the severity, frequency and duration of algal blooms" (SJRWMD, 2012).

As the river is not homogenous, it was divided up into nine segments based on the geomorphology, hydrology, hydrodynamics, water quality, soils, and floodplain communities (SJRWMD, 2012b). As a result, there were more than 3,360 combinations of scenarios modeled.

The work groups characterized environmental impacts using a five-point scale from negligible to extreme based on the strength of the effects, persistence, and impact on diversity.

The product of this highly rigorous modeling was the development of a tool that could help identify the tradeoffs between the benefits of water withdrawal and the benefits (or harm) to the ecosystem.

For example, withdrawing 155 million gallons per day (mgd) or 77.5 mgd had minor or negligible effects on the ecological factors modeled, whereas 262 mgd had moderate effects within the estuary by altering the distribution of wetland vegetation, and the distribution and abundance of fish and wildlife.

The WSIS also helped identify thresholds and opportunities to mitigate impacts: One finding was that major injury to river herrings in the planktonic life stage would occur unless water intakes were engineered properly. The WSIS also led to some unexpected findings, which shows the value of modeling these complex systems for more informed decision-making.

For example, it was found that sea level rise would help maintain water levels in the lower estuary, while land-use change would increase water runoff, thereby offsetting the effects of water withdrawals. In addition, the completion of planned restoration projects could limit or even eliminate reductions in flow from the water withdrawals (SJRWMD, 2012b). As a result, the WSIS modeled physical and human processes to help select acceptable management actions.

This study was unique in that it took a holistic perspective of the river ecosystem incorporating all levels from the headwaters to the ocean, the riverbed to the river column and all the way to the upland part of the floodplain. The study itself, however, was limited to how water withdrawals affected the ecosystem. It did not integrate other potential human actions that could affect these environmental factors such as the effects of land use change on water pollution, or channel dredging on salinity (SJRWMD, 2012b).

The SJRWMD had to define the scope of the study and acknowledge the need for adaptive management in order to embrace the complexity of the system. The models will be tested over time and revised as necessary to increase accuracy as water withdrawals increase and more data is collected.

In the future, the model may incorporate other issues such as the effects of land use on water pollution. This approach aligns with IWRM, which uses adaptive management to effectively manage complicated systems and embrace new science (GWP Technical Committee, 2005).

The Role and Benefits of Tools in Integrated Water Resources Management

The Water Supply Impact Study represents an IWRM instrument that increased SJRWMD's understanding of the St. Johns River and resulted in the development of models that will allow for scientifically informed management. The models will be a tool for use in the future to set minimum flow levels, as well as to evaluate potential water withdrawals and water projects (SJRWMD, 2012b).

As the larger regional water agency with capacity to pool resources, the District is acting at the appropriate level of governance by facilitating local level water planning. The WSIS model and corresponding tools will help local water agencies determine where and when water is available from the St. Johns River based on water withdrawal impacts to the entire river system, while facilitating

coordination with the District (SJRWMD, 2012). In addition, the WSIS will provide a solid foundation for the planning of larger regional or shared cooperative projects, which some water suppliers in the SJRWMD have expressed an interest in building.

As with all projects, it must be recognized that the WSIS information is not a substitute for public involvement and coordinated decision-making; however, these tools will allow water managers and the public to better understand alternative options, balancing future water development with healthy ecosystems.

The WSIS also provided benefits beyond its original goal of creating a tool for managing the St. Johns River.

First, the District benefitted from staffs' increased understanding and knowledge of the entire river system, as in the past, staff had worked within subregions. This was the first time SJRWMD brought staff together from across the District to work on the entire river and it greatly benefitted the agency and public to have a more holistic perspective of the watershed and its ecosystems.

Second, the tool is also facilitating greater coordination between USACE and SJRWMD, as the USACE is utilizing WSIS tools to understand salinity impacts associated with deepening the mouth of the river channel.

Third, now that SJRWMD has set the foundation, other regions are less intimidated by the complexity of the project and have expressed an interest in utilizing the model.

The models and tools could possibly be adapted to other river systems, which will help to advance river management in other regions, while also providing greater resources to continue to add to, test, and revise the model.

Costs of the Tool

The scope and depth of the WSIS required allocation of significant resources in SJRWMD.

The total contract cost over the four-year period was approximately $3.5 million. The contract costs were equally distributed in three areas: data acquisition (mostly environmental data), expert consultants and peer review, and WSIS tool development.

The cost of in-house staff including salaries and benefits was about $3.5 million over the life of the project.

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Thanks to Tom Bartol and David Watt for assisting in writing this case study.

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Lessons from the Case Studies

The concepts in the Introduction together with the case studies provide a rich foundation to understand IWRM. The first section of this chapter will focus on changes made in the case studies to translate IWRM theory into practice, using the Global Water Partnership's Framework as a basis for discussion. The second section will explore the application of IWRM in the United States.

Targeting Change to Translate IWRM Theory into Practice

As discussed in the introduction and outlined in Figure 17, the enabling environment, institutional roles, and management instruments are three areas to focus efforts to facilitate IWRM implementation (GWP Technical Committee, 2005).

A review of the case studies in the context of these areas reveals how the goal of sustainable water management and core principles of IWRM can be achieved. To demonstrate the applicability of targeting these areas for change, this section highlights select examples from the case studies.

Enabling Environment

Policies and Legislative Framework: Policies and legislation set the foundation for IWRM actions in all of the case studies.

Legislation was necessary to initiate planning or authorize funding. For example, California's legislation authorized regional water plans, while Oregon's legislation directed state agencies to develop the IWRS. Currently, Yakima's plan is awaiting congressional authorization for funding.

While legislation facilitated the change to integrated planning, the resulting plans also called for changes in laws and policies.

Oregon's IWRS recommended policies to promote water reuse and legislation authorizing OWRD to update water rights. Similarly, the market reallocation component of the Yakima River Basin Integrated Plan includes changes to laws and policies to improve the efficiency and flexibility of water transfers and address existing barriers to water trading. The Middle Rio Grande Regional Plan called for establishing a domestic well policy. California has modified its policies and regulations throughout the history of the IRWM program and will identify further changes in its strategic plan.

Figure 17 The Global Water Partnership's Areas to Facilitate Change for IWRM Implementation

A. Enabling Environment

- Policies
- Legislative Framework
- Financing and Incentive Structures

B. Institutional Roles

- Creating an Organizational Framework
- Institutional Capacity Building

C. Management Instruments

- Water Resources Assessment
- Plans for IWRM
- Demand Management
- Social Change Instruments
- Conflict Resolution
- Regulatory Instruments
- Economic Instruments
- Information Management and Exchange

Source: GWP Technical Committee (2005, p. 19-22).

Financing and Incentive Structures: In each case study, adequate funding was a challenge, but was essential to progress. Resources were contributed from local, state, and federal sources.

Planning in Oregon, California and the Middle Rio Grande benefited from local contributions and in-kind services in addition to other sources.

California has invested heavily in water planning at the state level and has continued to do so through its IRWM grant program. While the grant program has been successful at encouraging regional participation in IRWM planning, the state itself has experienced financial setbacks over the past several years and it is unclear if new grant programs will be authorized. As a result, California is looking to demonstrate the value of coordinated regional planning even without the state resources and incentives.

Similarly, while Oregon's IWRS was developed with a small budget, successful implementation of the strategy will require more resources. The IWRS outlines a number of actions to target funding resources. For example, the IWRS recommends funding "communities needing feasibility studies for water conservation, storage, and reuse projects."

The federal government was also a source of funding, partnering with states in the Yakima, DRBC, and Minnesota case studies. Funding to implement the Yakima River Plan; however, is now awaiting congressional authorization, while the DRBC and Minnesota River Basin have experienced inconsistent federal funding. Thus, federal funding resources may be a challenge for IWRM implementation in the future.

For all of the case studies, the success of IWRM implementation efforts in the future will rely on finding funding. Implementing IWRM, therefore, will require funding from a variety of sources possibly including private, non-profit, local, state and federal.

An IWRM approach often requires significant data, technical, and modeling tools in order to identify the complex interactions between and within physical, biological, and human systems. As shown by the case studies, the more comprehensive and in-depth the analysis and the greater the number of issues addressed, the greater the cost. Therefore, funding and information are integrally tied together. Increasing data efficiencies will be important to conserve limited funding resources.

Institutional Roles

Creating an Organizational Framework: The case studies also highlighted some of the organizational structures formed to facilitate IWRM.

Two case studies show structures wherein the organization is responsible for holistic management of the resource. The Delaware River Basin Compact established the organizational structure of the DRBC to have broad enforcement authority between member states and the federal government. Similarly, the state of Florida requires the St. Johns River Water Management District to oversee water supply, water quality, flood control, and natural systems protection and restoration.

Other case studies highlighted the creation of groups to support greater coordination. The Minnesota River Basin study included local, state, federal and tribal governments, whereas planning activities in the Yakima River Basin and Oregon included these as well as irrigated agriculture and other stakeholder groups.

In contrast, the Middle Rio Grande planning structure paired an organization representing local governments with a nonprofit representing diverse stakeholder interests.

California's IRWM planning regions have developed different organizational structures and it is likely that much will be learned when the state analyzes the IRWM program.

Despite the differences in structure, it is clear that IWRM planning cannot be undertaken by one entity alone.

Institutional Capacity Building: All of the case studies attempted to develop greater institutional capacity by increasing the knowledge of the public, stakeholders, or water professionals. Several of the case studies focused on providing tools to help organizations and water professionals develop greater capacity to manage the resource.

California's program, for example, centered around facilitating institutional capacity for regional planning through its IRWMP program guidelines, planning grants, dedication of state staff to working with regional RWMGs, development of data protocols and a climate change guidebook, and other efforts to support regional planning. Oregon's IWRS recommendation for place-based planning is likely to take a similar approach with the state in a supporting role.

Similarly, the Minnesota River Basin, St. Johns River Basin and Middle Rio Grande Basin case studies involved development of tools to help water managers and the public understand the interconnectedness of the system and challenges faced in balancing needs for sustainable water management.

Management Instruments

Water Resources Assessment: Determining water availability and needs is the foundation for any planning effort.

The assessment of groundwater supplies in the Middle Rio Grande and St. Johns River shows the importance of investing in understanding water resources so that consumption does not exceed supply. The water assessments were a turning point in both of these regions towards holistic management of the resource.

As shown in the St. Johns River, Middle Rio Grande, Yakima, and Minnesota case studies, assessments can become quite complex and costly depending on the detail of the analysis. Understanding ecosystem needs in particular has been a challenge for all regions and the St. Johns River underscores the vast array of factors involved in modeling ecosystems.

Finally, Oregon's first three Recommended Actions in the IWRS (see Figure 3 on page 12) point towards the need for water resources assessments to enhance future planning and management efforts.

Plans for IWRM: Planning is essential to implementing IWRM. While the Oregon, California, Middle Rio Grande, DRBC and Yakima case studies all highlight plans, the Minnesota and St. Johns River studies highlight actions to inform future planning.

The IWRM approach resulted in plans that included a suite of actions from traditional infrastructure projects to conservation, efficiency and watershed protection programs. The comprehensive nature of the plans required complex modeling in order to identify the combination of outcomes that would achieve desired goals. Overall, plan development involved diverse interests and incorporated different aspects of the resource (e.g., water quality, groundwater).

Demand Management: A primary tool was to reduce water demand to minimize the need for new water supply development.

At minimum, conservation or efficiency programs were identified as demand reduction strategies. Some case studies, such as the Middle Rio Grande, also included other demand management tactics such as incentives, economic tools, educational programs, conversion to low flow appliances, and water metering (see Figure 13 on page 40).

Social Change Instruments: To the extent that the public was incorporated into the process and information was more accessible, all of the case studies could be considered to include a social change element; however, targeted social change instruments were less common.

Oregon and the Middle Rio Grande recommended educational programs in schools and educating the public on water issues. Oregon also included training and education for future water professionals as part of its recommended actions. The Global Water Partnership (2005) has identified these three components as factors that contribute to social change.

Conflict Resolution: As noted in several of the case studies, IWRM has emerged as a means to prevent or reduce conflict both within and between regions.

The St. Johns River WSIS was developed to assist with the fair distribution of water between local water agencies and facilitated coordination between the SJRWMD and other districts. Similarly, the DRBC has been successful in preventing interstate conflicts over water quality and other water issues due to the coordination and broad policy-making authority of its members.

The state of Oregon emphasized conflict resolution as a guiding principle for the IWRS, while New Mexico (Middle Rio Grande) required regional plans to state how the plan might conflict with other regions. A major priority in the Middle Rio Grande case was obtaining regional collaboration to ensure that flow obligations in the Rio Grande Compact were met to prevent conflict.

Similarly, the California IRWM program requires plans to discuss conflicts and gives preference to projects that resolve conflicts. Some of the IRWM planning regions experienced collaboration between entities that had previously been at odds over water issues.

Finally, the multi-objective Yakima Integrated Plan was a step towards resolving the ongoing conflict in the region between instream flow proponents and consumptive water users.

In sum, IWRM is facilitating collaborative, coordinated, multi-objective planning that satisfies a diverse set of interests. This leads to reduced conflicts and tensions.

Regulatory Instruments: "Reach environmental outcomes with non- regulatory alternatives" is one of Oregon's recommended actions and reflects the approach utilized in many of the case studies. Although regulatory instruments were included, water supply development, water demand management, and voluntary programs dominated.

Examples of regulatory instruments include the DRBC's implementation of water quality and groundwater protection programs, the Middle Rio Grande's proposed domestic well controls, and Oregon's recommendation for implementing ballast water management regulations to prevent invasive species.

In addition, the Minnesota River Basin is seeking to understand agricultural drainage to inform the design of regulations in the future. The St. Johns River WSIS will be a tool for use in the future to set minimum flow levels and make decisions in regulating potential water withdrawals.

Economic Instruments: Economic tools were highlighted in the California, Middle Rio Grande, Yakima, and Oregon case studies.

In California, water pricing and grants were a water management strategy to encourage resource stewardship. Similarly, in the Middle Rio Grande, a utility implemented a conservation rate structure to encourage water use efficiency, whereas the Yakima Integrated Plan proposed improvements to its water-banking program. Oregon's IWRS recommended developing protocols to translate streamflow restoration into credits and create accounting strategies.

Information Management and Exchange: All of the case studies underscore the need for data and modeling tools in order to make scientifically informed management decisions that take into account economic, social, and ecological factors. The greater the complexity in considering ecosystems, physical systems, and human interests, the greater the need for tools that can help to understand the outcomes of a combination of factors and actions.

The St. Johns River WSIS case study details the magnitude of the task of determining the effects of water withdrawals on ecological systems. However, the WSIS resulted in development of a tool that could help identify the tradeoffs between the benefits of water withdrawal and the benefits (or harm) to the ecosystem. The Minnesota River Basin hopes to develop a similar tool that will assist professionals in making informed management decisions. The DRBC, Yakima River Basin, Minnesota and Middle Rio Grande also enlisted the help of models to understand the complex interactions.

Regardless of whether it is possible to model all of the interactions of the systems, an adaptive management approach is necessary in order to move forward while also taking into account new information as it arises. This is particularly important since complexity and uncertainty have a tendency to create paralysis and stall progress. IWRM as a goal-driven process is helpful to ensure that water is managed sustainably even in the face of extreme complexity.

While the data and information tools are important for effective decision-making, they can also be a practical means to create public support and facilitate public participation in planning. As shown in the Middle Rio Grande case study, a water budget tool was provided to the public to help them understand the need for action and the difficult choices to be made in reducing water use. Similarly, after development of a model of scenarios, the public had the opportunity to see how changes in different management actions affected the overall water budget.

Therefore, opportunities exist to not only increase the knowledge and understanding of decision-makers but to also actively engage the public in the decision-making process.

It is apparent that no one entity has all of the information needed to manage water effectively, nor, does any one entity have the resources to do so. As noted in the California and Oregon case studies, in order to achieve integration, better means of collecting and sharing information is necessary.

California has worked to develop protocols and create an information storage system as a method of streamlining data for compatibility and sharing it with others to prevent duplication and increase coordination.

Oregon's IWRS included a number of recommendations regarding information and data.

For example, one recommendation was to establish and maintain an on-line water-use efficiency and conservation clearinghouse.

Thus, it is apparent from the case studies that implementation of IWRM also requires integrated data management.

Targeting Change for IWRM

The case studies demonstrate how regions in the United States have taken action to shift towards more sustainable management. As shown by the above examples, there are many areas that can be targeted for change to move towards more sustainable water management using an IWRM approach.

Regions seeking to implement IWRM should understand the key principles behind integrated water resources management outlined in the next section and then assess how actions in these key areas can advance their goals.

Application of IWRM in the United States

Revisiting the Definition and Goals of IWRM

As outlined in the Introduction, the goal of an IWRM approach is to holistically manage water for economic, social and ecological purposes using an iterative process that engages the public and stakeholders, and increases governmental coordination.

These seven case studies demonstrate how concepts from IWRM are being incorporated into water management across the United States.

Holistic Management: An analysis of the case studies reveals that each emphasized the importance of a holistic and integrated approach to water management.

All of the case studies addressed water quality and water quantity and the need to balance consumptive use with environmental needs. Groundwater was also considered, either due to declines in the resource or the potential to store water in aquifers as a water management tool.

All case studies recognized that upstream and downstream resources are connected, particularly in the context of water quantity and water quality. When management jurisdiction spanned from the headwaters to the ocean, coastal waters were addressed, mostly in regards to water quality and sea level change.

Land use management was also incorporated; however, there was variability in the level of integration with water management.

Economic, Social and Ecological Purposes: The case studies demonstrate that integration requires balancing ecosystem and economic needs to accommodate different interests, resulting in a diverse set of management approaches. Addressing social equity is also important and the California IRWM program provided a good example of efforts to involve all communities in water management.

Balancing social equity, ecosystem needs and economic purposes added complexity and required additional data, information, and tools in order to make informed management decisions.

Iterative Process: IWRM requires a goal-driven, process-oriented, and iterative approach that involves adaptive management. The case studies show the value of being grounded by goals and an established process to provide a focused framework for moving forward in the face of complexity, uncertainty and changing conditions.

Most of the plans and studies discussed are in the initial stages of the iterative IWRM process spiral outlined in the Introduction. The fourth phase – involving implementing, monitoring and evaluating – will merit further attention in the future.

Public and Stakeholder Engagement: The series of case studies show that participation from all water use sectors and the public is just as important as the role of water professionals and governmental agencies. In several case studies, organizations went beyond soliciting public input by creating a formal role for the public in the planning process.

In all of the instances where diverse stakeholders and the public were a part of the process, plans and studies not only considered a broad array of interests and management options, but also had broad-based support. As shown in the Yakima River Basin, development of an inclusive and holistic plan can result in advances that had not been possible in the past under more narrowly focused planning efforts.

Governmental Coordination: The case studies demonstrate the importance of acting at the appropriate level of governance to maximize limited resources to facilitate better water management and decision-making.

For example, in several of the case studies the federal government provided technical assistance and support, while states established the framework for integrated management and attempted to identify means to make planning and implementation more efficient and cost effective. In general, regions acted to solicit involvement from diverse interests and facilitated local participation in water planning. They were also able to pool resources and coordinate across local agencies to respond to local water resources needs and management challenges.

Lessons in IWRM: Overarching Themes

Four key themes emerged from the case studies examined on their approach to IWRM: commitment to sustainability, adaptive management, collaboration and information, and funding.

Commitment to Sustainability: Dedication to sustainability is key for IWRM. Sustainability embeds water management with the concept of balancing economic, environmental, and social equity needs for current and future generations. Sustainability requires holistic management of the entire resource in the context of a watershed or basin.

Adaptive Management: Practicing adaptive management is essential to facilitate progress towards goals in the face of complexity and finite resources.

Collaboration and Information: Coordination is required for integration. The amount of information needed to make decisions that consider all interests can be costly. The greatest obstacle to IWRM planning and implementation in the case studies was a lack of resources, information, data, and decision-support tools. More collaboration on modeling tools and data sharing protocols could allow for resource optimization.

Funding: To be successful, a concerted effort must be made to identify funding resources as well as potential partnerships and efficiencies. Opportunities exist to make significant use of in-kind services and volunteers. Incorporating the public, stakeholders, and universities can leverage limited resources. In addition, it encourages buy-in and results in a plan that reflects the priorities of the community.

The wisdom of IWRM is in the focus on the goals and process to move towards integration and sustainability with continued adaptation in an iterative cycle. Therefore, an IWRM approach is as much about the method as it is about the outcome. Within this context, all regions in the United States have the capacity to identify feasible steps to begin managing water by applying concepts from IWRM.

While the examples in this report demonstrate how states, basins, and regions have incorporated IWRM into water management, lessons from IWRM can also inform the federal role in water management. From the local to national level, water management in the United States is often fragmented and suffers from a lack of coordination. The case studies demonstrate the practical value of defining a vision and strategy that is implemented within the framework of concepts from IWRM. In its integrated planning efforts, the federal government can take the first step by developing a vision and strategy for more effective, coordinated management across sectors and levels of government.

Building upon a Foundation of Integrated Water Resources Management

As outlined in its position statements (AWRA, 2011, 2011a), regions across the United States are experiencing challenges to coordinate and manage water resources sustainably while addressing aging infrastructure, climate change and population growth.

These challenges are growing exponentially and will require new and creative approaches to overcome them.

To meet these challenges, AWRA's next step is to build upon the IWRM approach in the creation of a national water vision and strategy.

AWRA recommends that national water management goals, policies, programs, and plans be organized around the concept of IWRM – the coordinated planning, development, protection, and management of water, land and related resources in a manner that fosters sustainable economic activity, improves or sustains environmental quality, ensures public health and safety, and provides for the sustainability of communities and ecosystems.

In the future, AWRA will continue to help refine IWRM concepts and support IWRM as a critical element in shaping a national water vision and strategy.

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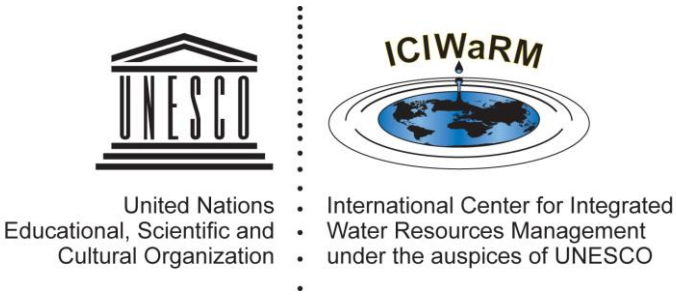
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