Building Strong Collaborative Relationships for a Sustainable Water Resources Future

Understanding Integrated Water Resources Management (IWRM)

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Introduction

The history of water resources management in the United States and abroad has been fraught with conflicts over water use, confusing terminology and shifting public attitudes about how water should be managed. When a priority for a predominant planning objective or a single water use purpose overrides all other objectives or purposes, solutions may only satisfy narrow interests with limited benefits, and then conflicts may ensue among the many stakeholders who desire water for their diverse uses. For example, those desiring to use a reservoir for recreation may run into conflict with others who want to use water during peak hours for power generation. Those who want to dredge harbors for ease of navigation may run into conflict with others who desire to restore ecosystems in the same location. Those who want to maintain water at certain levels in a river for flood control purposes may run into conflict with others who want to use the water to supply municipal water. Water resources management inherently reflects geographical differences, dominant ideologies, political preferences, economic conditions and the state of technology for water resources development.

Today, water resources management reveals a key shift in philosophy away from single-purpose water resources development with limited sponsors for localized benefits to broad-based management at a river basin or watershed scale. With that, the practice of water resources management is becoming even more complex. Building on Naiman's (1992) work, Bruce Hooper (2010, p. 2) characterized the complexity of watershed or river basin management:

- *The scope of issues demands unparalleled cooperation between industry, governmental agencies, private institutions, and academic organizations.*
- *The increasing tendency to resort to technical solutions (e.g., hatcheries, silviculture) must be augmented with increased habitat protection and preservation of fundamental components of long-term watershed vitality.*
- *The complexity of information management and the scope of experimental manipulations needed often exceed the capacity of individual institutions.*
- *The current tendency to seek conceptual solutions at the expense of data-driven decisions must be reversed.*
- *Intra- and inter-agency inconsistencies in environmental regulations must be corrected.*
- *Human activities are a key element of ecosystem vitality and must be integrated with environmental considerations before long-term sustainability of the biosphere can be achieved.*

Although broad-scale water resources development and management are not new concepts, this philosophy reflects a move away from narrow objectives that, since publication of the *1983 Principles and Guidelines* (U.S.C., 1986) and the *Water Resources Development Act of 1986* (see http://planning.usace.army.mil/toolbox/library/PL/WRDA1986.pdf) have favored a narrow scope based on a predominant planning objective of national economic development (NED). In March 2013 the White House released the *Updated Principles and Requirements (P&R) for Federal Investments in Water Resources* to replace the *1983 Principles and Guidelines (P&G).* This *P&R* favors a broadened array of federal agencies to stipulate how and why they should achieve an expanded set of expected benefits based on integrating water and land use law through holistic allocation, and management of resources across entire basins or watersheds so as to balance all user needs for water resources:

> *America's water resources—streams, rivers, wetlands, estuaries, lakes, and coasts—are at the heart of our environment, our economy, and our history. These water resources support billions of dollars in commerce, provide safe drinking water for millions of Americans, supply needed habitat for fish and wildlife, affect public safety, and provide a variety of other important benefits. The quality and quantity of America's water resources has wide-ranging impacts at all levels of government and for all living things. The quality and quantity of water resources affect all levels of our society from the national to the individual citizen.* (The White House Council on Environmental Quality, March 2013, see http://www.whitehouse.gov/sites/default/files/final_principles_and_requirements_march_2013.pdf, p. 3.)

The *Principles and Requirements* emphasize that "water resource projects should maximize economic development, avoid the unwise use of floodplains, and protect and restore natural ecosystems." This modernization of the previous guidelines allows communities more flexibility in pursuing local priorities; takes a more comprehensive approach to water projects so as to maximize and integrate economic, environmental, and recreational benefits; promotes more transparent and informed decision-making across the federal

government; and promotes responsible taxpayer investment through smart front-end planning so that projects proceed quicker, within budgets, and achieve intended results. Furthermore, the revised *Principles and Requirements* address the inherent complexity of water management. For instance, the *P&R* address climate change and risk management to account for uncertainty.

Increasingly those who make decisions about water management recognize the importance of addressing the multi-faceted nature of water resources planning and decision-making for water use in varied contexts to meet diverse needs. **Integrated water resources management (IWRM)** reflects the sentiment that water resources should be managed holistically and collaboratively to manage uncertainty and complexity, and to satisfy varied water purposes having multiple benefits. With this, there is a heightened interest in concepts, tools, and resources for systems-based approaches.

Systems theory and scientific or technological advances make it easier to address the complexity arising from multiple factors influencing water management such as increasing demands for water, climate change, aging infrastructure, population growth, land use changes and evolving demands and processes for participatory decision-making. Concepts and models make it easier to consider water quantity, water quality, ecosystem needs, climate change, economic development, social effects, equity, risk management and the cumulative impacts of water resources decisions as a whole (Najjar & Collier, 2011). Advances more readily support achieving integrated objectives across multiple water uses or purposes (e.g., navigation, recreation, flood risk management, ecosystem restoration, water supply, hydropower generation, emergency management, and regulatory services) for more balanced outcomes.

In the past few decades there have been advances philosophically and technologically for integrated water resources management. There does remain a broad set of characteristics that define integrated water resources management, however. This paper explores the definitions of and key principles for IWRM.

What is Integrated Water Resources Management (IWRM)?

Definitions of IWRM

A commonly referenced definition of IWRM from the Global Water Partnership (2000) is that it is a "process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." At its simplest, IWRM is "a process that strives to balance regional economic growth while achieving wise environmental stewardship" (Bourget, 2006). Table 1 presents selected definitions of IWRM or descriptions of planning processes used for comprehensive and integrated results. These definitions cover a broad range of institutions with interests in water resources management.

The following expands on common IWRM themes and attributes suggested by Viessman (1998):

- **Multidimensionality**—a willingness to tackle water resources as a *problemshed* of temporal, spatial, environmental and institutional dimensions; to bring multiple stakeholders together; to consider multiple goals and objectives; to treat multiple water purposes; to seek multiple benefits from water resources decisions and interventions. This suggests that tackling a water problem or opportunity must take as many factors into account as are required through a comprehensive approach so as to understand all key issues with all key stakeholders with all resources available to take action. Effective action requires defining the *problemshed* as a whole system.

- **A Holistic Systems Approach**—taking a perspective that examines the whole—a whole system of variables and their interactions and impacts. Variables may include threats and opportunities, stakeholders, resources, goals and objectives, historical precedents, cultural factors, best management practices and impacts of water resources decisions and interventions. Natural systems are defined as entire river basins, watersheds and coastal zones. This allows for the application of theories, processes and models now available to describe, analyze and manage whole systems.

- **Sustainability Goals**—an appreciation for preserving natural and man-made resources to sustain the environment, economy, quality of life for current and future water uses and users, as well public safety and security standards. This shifts the focus of outcomes to long-lasting benefits that conserve water and related resources for future use.

- **Working at a Watershed Scale**—the advantage of taking a broader geographic view to identify the many factors, actors, issues and opportunities that characterize water resources development and management within an area defined by natural watershed boundaries. A systems perspective is naturally afforded through defining the *problemshed* in the context of a geospatially-defined hydrologic system: a watershed, river basin or coastal zone.

- **Collaborative and Participatory Approaches**—the practicality and benefits of using deliberate and deliberative processes to incorporate the views of diverse stakeholders and multiple objectives across multiple agencies and levels of government and multiple water uses (purposes) to join/share resources and to align aims and efforts. This acknowledges the advantages of using accepted methods and processes to bring people together to collaborate and to strive toward mutually-agreeable plans and actions deliberatively.

Table 1. Selected Definitions of Integrated Water Resources Management (IWRM)

International Organizations
The Global Water Partnership (GWP) "Integrated Water Resources Management (IWRM) is a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." **Source:** Global Water Partnership Technical Advisory Committee (TAC). 2000. *Integrated Water Resources Management. TAC Background Papers, No. 4.* See http://www.gwp.org/Global/ToolBox/Publications/Background%20papers/04%20Integrated%20Water%20Resources%20Management%20(2000)%20English.pdf, p. 22.
United Nations "IWRM is a step-by-step process and takes time. By responding to changing social, economic and environmental needs or impacts, one can gradually achieve better and sustainable water resources management as if moving up a spiral, through such means as progressively developing water resources in the basin, building a more integrated institutional framework, or improving environmental sustainability." **Source:** UNESCO-International Hydrological Programme (IHP), World Water Assessment Programme (WWAP) & Network of Asian River Basin Organizations (NARBO). 2009. *IWRM Guidelines at River Basin Level – Part 201: The Guidelines for IWRM Coordination.* United National Educational, Scientific and Cultural Organization. See http://unesdoc.unesco.org/images/0018/001864/186418e.pdf, p. 5.
Tribal Nation
Navajo Nation "Water is needed to develop coal...for growing crops…for people…for domestic use and for municipal and industrial development….From the Navajo perspective, integrated water resources management must be considered within the framework of satisfying a lot of needs…When we talk about integrated water resources management, meeting basic human needs must come first. That does not mean we're intolerant of water for other purposes such as habitat for endangered fish, but there must be a balanced allocation of this precious resource." **Source:** Pollack, S. M. (Special Counsel for Water Rights, Navajo Nation). September 1996. Integrated Water Resources Management in the San Juan Basin. The Navajo Perspective. *Integrated Water Resources Management: Northwestern New Mexico as a Case Study,* 31-39. New Mexico Water Resources Research Institute. See http://wrri.nmsu.edu/publish/watcon/proc41/Pollack.pdf, p. 32.
Federal Agencies
U. S. Army Corps of Engineers (USACE) IWRM is "a holistic focus on water resources challenges and opportunities that reflects the coordinated development and management of water land and related resources. IWRM maximizes economic services and environmental quality and ensures public safety, while providing for the sustainability of vital ecosystems. IWRM promotes the coordinated development and management of water, land, and related resources to maximize economic and social welfare without compromising the sustainability of vital ecosystems." **Source:** U. S. Army Corps of Engineers (USACE). 2011. *Sustainable Solutions to America's Water Resources Needs. Civil Works Strategic Plan 2011-2015*. Washington, D.C., p. 4. See http://www.usace.army.mil/Portals/2/docs/civilworks/news/2011-15_cw%20stratplan.pdf "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." **Source:** U. S. Army Corps of Engineers. 2010. *National Report: Responding to Water Resources Challenges.* Washington, D.C. See http://www.building-collaboration-for-water.org/ "Integrated Water Resource Management is a coordinated, goal-directed process for controlling the development and use of river, lake, ocean, wetland, and other water assets."

Table 1. Selected Definitions of Integrated Water Resources Management (IWRM)

Source: Cardwell et al., 2006. See http://www.ucowr.org/files/Achieved_Journal_Issues/v135Integrated%20Water%20Resources%20Management%20definitions%20and%20conceptual%20musings.pdf, p. 9. "IWRM is a goal-driven process – different goals for management can result in different management actions. Water resources management can be integrated – over time, institutions, objectives and space. The goal of IWRM as practiced by the Corps is sustainability. IWRM is a better term [than the 'watershed approach'] to describe a participatory, broadly scoped management philosophy that integrates time, space and institutions." **Source:** Hooper, B. 2010, Taken from Box 4. *Findings on IWRM and its use in the Corps of Engineers Civil Works Program* (Modified from Cardwell et al., 2006), p. 8.
Environmental Protection Agency (EPA) IWRM is "a voluntary collaboration of state, interstate, local, and tribal governments, and economic sectors, supported by federal agencies to sustainably manage the quality and quantity of water resources within watersheds and underlying aquifers." It is a *one-water* framework promoting "opportunities for state, interstate, tribal, and local officials to voluntarily collaborate at watershed or aquifer scales, with support from federal agencies, to protect and preserve freshwater resources through mutually beneficial solutions." IWRM "account[s for] water quantity and quality, surface water and ground water, salinity of coastal estuaries, land use, floodplain management, point and nonpoint sources of pollution, green and grey infrastructure, and climate change adaptation and mitigation." **Source:** Environmental Protection Agency (EPA). December 2012. *National Water Program 2012 Strategy: Response to Climate Change*. Washington, D.C. See http://www.epa_2012_climate_water_strategy_full_report_final.pdf, pp. 25-26.
U. S. Department of Agriculture—Forest Service IWRM is "a comprehensive, all-lands approach…. The future of our country's forests and the valuable ecosystem services they provide depend on our ability to manage for an uncertain climate and uncertain market. This means landscape-level restoration, working across ownership boundaries, relying upon a foundation of strong science to guide decisions, and collaborating with tribal, state, local, private, and other federal stakeholders to achieve common goals. A comprehensive approach to restoring unhealthy ecosystems will help make our forests more resilient to stressors and disturbances related to climate change and protect our vital water resources. At the same time, we can significantly contribute to economic recovery and job support by building a forest restoration economy. Greater involvement of citizens and communities is key to successfully implementing restoration efforts at large geographic scales. Our vision in creating healthy landscapes not only includes creating healthy ecosystems, but also creating healthy, thriving communities around our Nation's forests and grasslands and providing jobs in rural areas." "A healthy and prosperous America relies on healthy forests and grasslands and the benefits they provide: clean air and water, carbon storage, renewable energy, food and fiber, fertile soils, wildlife habitat, and recreation opportunities. The Forest Service delivers incredible value to the public by protecting and enhancing these benefits through forest health restoration, research, and financial and technical assistance to partners." **Source:** Statement of Tom Tidwell, USDA Forest Service Chief, before the Senate Committee on Energy and Natural Resources Concerning The President's Budget Request for the USDA Forest Service in Fiscal Year 2012. March 3, 2011. See http://www.fs.fed.us/congress/112thCongress/Documents/CY%202011/SENR_03-03-2011_Testimony.pdf
States
California Department of Water Resources "Integrated water management is a collection of policies, practices, and tools applied to water resources planning and management to achieve multiple objectives and enhanced outcomes." **Source:** California Department of Water Resources. 2013. *California Water Plan 2013 Update.* See http://www.waterplan.water.ca.gov/docs/cwpu2013/cwpu2013-brochure-lettersize.pdf, p. 1. "Integrated regional water management incorporates the physical, environmental, societal, economic, legal, and jurisdictional aspects of water management into regional solutions through open, collaborative stakeholder processes to promote sustainable water use. IWRM improves water management and helps ensure economic stability, environmental stewardship, public safety, and other benefits." "Integrated flood management – IFM is a comprehensive approach to flood management that considers land and water resources at a watershed scale within the context of integrated water management; employs both structural and non-structural measures to maximize the benefits of floodplains and minimize loss of life and damage to property from flooding; and recognizes the benefits to ecosystems from periodic flooding." **Source:** California Department of Water Resources. 2013. Glossary of *California Water Plan Update 2013.* See http://www.waterplan.water.ca.gov/docs/cwpu2013/ae/_glossary.pdf, p. 16.

Table 1. Selected Definitions of Integrated Water Resources Management (IWRM)

Oregon Water Resources Department
An Integrated Water Resources Strategy to meet current and future water needs…"considers instream needs (where water remains in the environment) along with out-of-stream needs (where water is diverted for use), including water quality, water quantity, and ecosystem needs…. Oregon water law now recognizes the close connection between groundwater and surface water. It also recognizes that instream needs are beneficial uses. It provides tools for water right transfers. And, it provides tools to encourage water conservation [while] working with partners, adjusting to additional information, adapting to changing circumstances, and adopting new techniques and technologies in order to better understand and meet Oregon's instream and out-of-stream water needs." **Source:** Oregon Water Resources Department. 2012. *Oregon's Integrated Water Resources Strategy. Executive Summary.* Available at http://www.oregon.gov/owrd/LAW/docs/IWRS_Executive_Summary_Final.pdf, pp. 1, 7, 10, 11.
Pennsylvania Department of Environmental Protection
"For over a decade, Pennsylvania has administered its water resources management programs on a watershed scale…. Successful water resources planning and management now demand a more organized and integrated course that combines the assets of all levels of government, private sector interests, and citizen participation. Integrated water resources management entails making common sense decisions while considering water quantity and water quality needs… three strategic areas must be addressed including: • Blending the components and processes of water resources management within [the Department of Environmental Protection]; • Improving coordination across state agencies and throughout the federal, interstate, state, and local government hierarchy; and • Solidifying the connection between land use and water resources management." "Develop and evaluate a framework and incentives for integrated water resources planning and management – the Department of Environmental Protection with assistance from other state agencies, compact basin commissions and local government representatives, should develop a framework that links water resources planning elements from the State Water Plan and programs such as Sewage Facilities Planning, Stormwater Management Planning, Source Water Protection Planning, Water Supply and Wastewater Planning, Flood Control Planning, and the Watershed Restoration and Protection Program." **Source:** Commonwealth of Pennsylvania, Department of Environmental Protection. 2009. *State Water Plan Principles. Executive Summary.* Available at http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-76834/3010-BK-DEP4227.pdf, pp. 8-9.
Interstate Organization
Upper Mississippi River Basin Association
"Integrated Management – the UMR [Upper Mississippi River] and its watershed are a nationally significant economic, environmental, and social resource that requires balanced and integrated management. Integrated, multi-purpose management exceeds the capacity and authority of any one entity and must be done collaboratively." **Source:** Upper Mississippi River Basin Association. January 2013. *2013-17 Strategic Plan.* Available at http://www.umrba.org/aboutumrba/umrba-strategic-plan2013-17.pdf, pp. 2-3.
Nongovernmental Organization
American Water Resources Association (AWRA)
"Integrated Water Resources Management is 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." **Source:** AWRA Policy Statement approved by the Board of Directors of the American Water Resources Association at their January 21-22, 2011, meeting. See http://www.awra.org/policy/policy-statements-IWRM.html.

IWRM Approaches

The availability and quality of water are essential to life, but too much or too little can bring disasters. The manner in which water is managed for multiple uses is critical to whether or not positive or negative outcomes will result.

Effective water management should promote "the coordinated development and management of water, land and related resources to maximize economic and social welfare without compromising the sustainability of vital ecosystems" (GWP, 2000). The IWRM perspective defines many desired outcomes: positive changes in national economic efficiency, national environmental quality effects, public safety, and social effects (Shabman & Scodari, 2012). An expansive view and collaborative approach expand expected benefits of water resources decisions: inclusion of more and key stakeholders with vested interests in how water should and can be used, better planning and management of water supply and quality, increased cost efficiencies and effectiveness, integration of physical and human systems, improvements in how water is distributed and consumed and better balance among competing uses and requirements for water. Consensus-based processes used to integrate ideas, programs, priorities, and activities strengthen ownership of ideas and solutions and foster anticipatory planning to preclude unintended consequences.

A key benefit of IWRM is to foster a shared vision of current challenges and a common desired future, i.e., an improved standard or quality of life of people, alleviation of poverty, conservation of the environment, and equitably distributed resources in a socially acceptable and economically efficient manner.

Per the *Water Resources Development Act of 2007* the federal objective for water resources management is to reflect national priorities, encourage economic development and protect the environment by seeking to maximize sustainable development, avoid the unwise use of floodplains and flood-prone areas, minimize adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used and protect and restore the functions of natural systems while mitigating any unavoidable damage to natural systems (see http://www.govtrack.us/congress/bills/110/hr1495/text).

The American Water Resources Association (AWRA) highlights that an IWRM approach is as much about the method as it is about the outcome: "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" as effected through budgets, appropriations, legislation, policies, guidance, training and constructive reinforcements (AWRA, 2012). This cycle includes four iterative phases as elaborated by the Global Water Partnership Technical Committee (UNESCO-IHP, WWAP & NARBO, 2009, p. 53):

1. **Phase I**—Assess the current situation, recognize problems, build governmental and public awareness, generate the incentives and capacity for action. Recognize and identify problems, threats, opportunities, and needs.

2. **Phase II**—Assess problems and identify potential solutions. Conceptualize at a broad scale so as to include all relevant participants and variables.

3. **Phase III**—Evaluate options in order to identify a plan. Coordinate and plan in detail.

4. **Phase IV**—Implement IWRM actions, monitor, and evaluate the results so as to start the cycle (plan) again with forethought and hindsight generated by evaluation and feedback.

The Global Water Partnership Technical Committee clarifies that this life cycle, as shown in Figure 1, requires an ***enabling environment*** (e.g., policies, goals, legislation, financing, incentive structures), ***clear institutional roles*** (e.g., organizational structure, the institutional capacity conducive to coordinating water management), and ***management instruments*** (e.g., needs assessments, IWRM plans, water efficiency measures, social change instruments that encourage changes in public attitudes, conflict resolution strategies, regulations, economic tools for efficiency and social equity, and knowledge management and information exchanges) (Global Water Partnership Technical Committee, 2005).

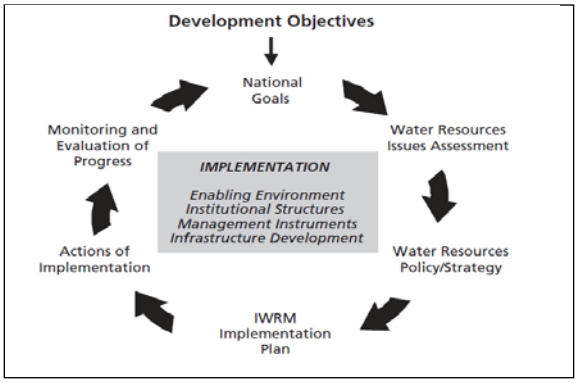

Figure 1
Stages in IWRM Planning and Implementation
Source: United Nations Department of Economic and Social Affairs (UNDESA), UN Water, International Decade for Action, Water for Life, 2005-2015. Retrieved from http://www.un.org/waterforlifedecade/iwrm.shtml

Common Principles

A primary goal of IWRM is to manage water in a sustainable fashion achieving balance among the competing uses and requirements for water. To achieve this basic goal, IWRM is as much about process as it is about substance. That is, IWRM recognizes that an inclusive process that provides the opportunity for the engagement of the public, stakeholders, and all levels of government is essential for finding the balance necessary for sustainable water management outcomes.

Thus, IWRM embraces a number of **key principles**. These principles are characterized using a variety of terms depending on where IWRM is being described, but they generally reflect similar key concepts. For purposes of this paper, a number of key concepts identified in the USACE *Civil Works Strategic Plan 2011-2015* (USACE 2011, http://www.usace.army.mil/Portals/2/docs/civilworks/news/2011-15_cw%20stratplan.pdf), as well as those identified in a recently completed examination of IWRM in practice prepared by the American Water Resources Association (AWRA, 2012), form the basis for describing key IWRM principles presented below. While presented as separate principles, they cannot be employed in isolation from each other. To be effective, these principles must interact and reinforce each other.

Holism (Adopt a Watershed Approach and Perspective)

In contrast to a narrow, project-oriented focus with benefits defined to maximize local support within a localized footprint, the principle of holism advocates that water management should adopt a watershed perspective and look for the interconnections among local water issues and broader regional or watershed issues. The Corps Policy Guidance Letter 61, *Application of the Watershed Perspective*, presents an ambitious policy for incorporating this perspective into Corps planning:

> *There is a growing recognition that 'locally perceived water resources problems' have regional dimensions and are of concern to numerous, diverse interest groups. Many activities occurring in a watershed are inter-related and, therefore, managing water resources has evolved to more of a holistic, collaborative effort. [The Corps] watershed perspective accommodates the multi-objective, multi-purpose planning and investigations necessary for exploring these concerns* (U. S. Army Corps of Engineers, Planning Guidance Letter 61, 1999).

Given the watershed perspective, the interrelationships of water resources across geographic and political boundaries means that water management policies must view systems holistically and explore the interactions and impacts within the watershed.

IWRM should begin by identifying the entire relevant watershed associated with the problem or opportunity under consideration, including all of the water resources projects and programs ongoing or planned within the watershed and all of

the proponents, managers and other stakeholders who have interests or responsibilities for water and land management in the watershed.

Sustainability (Seek Balance among Economic, Social, and Environmental Needs)

In contrast to a focus on maximizing any one water resources objective (e.g., national economic development [NED] or environmental quality [EQ]), a focus on sustainability strives to achieve an acceptable balance among diverse water resources objectives achieving an acceptable mix of economic development, ecosystem enhancement, public safety, and social equity benefits.

Similarly, the USACE *Environmental Operating Principles* (EOP) (USACE, 2002 and reaffirmed in 2012) were developed to ensure that Corps of Engineers missions include totally integrated sustainable environmental practices (http://www.usace.army.mil/Missions/Environmental/EnvironmentalOperatingPrinciples.aspx). The Principles provide corporate direction to ensure that the workforce recognizes the Corps of Engineers' role in and responsibility for sustainable use, stewardship, and restoration of natural resources across the Nation and through the international reach of its support missions.

This means that a variety of expected benefits or outcomes spanning economic, environmental, quality of life, safety and security outputs and performance measures must be defined holistically. These benefits must be directed at ensuring that water and related land resources are not used up or harmed but rather are available for future use. Plans must include ways to assess whether or not desired outputs and outcomes have been achieved.

Collaboration (Build and Sustain Collaboration and Partnerships at All Levels)

Collaboration leverages authorities, funding, talent, data, and research from multiple agencies and organizations (USACE, *Civil Works Strategic Plan 2011-2015*, 2011). An oft-repeated prescription in many agencies over the years has been "stay in your lane," meaning that employees, and agencies should focus on their narrowly defined duties and authorities and not spend much time or resources coordinating and integrating with others. When faced with complex, multi-faceted water resources issues and challenges, collaboration with others is the only way to ensure that creative and more expansive solutions can be achieved. Agencies are increasingly creating memoranda of understanding (or agreement) to facilitate cooperation on interagency partnerships. These agreements facilitate the exchange of information, technology, and in some cases, staff to leverage programs, tools, and expertise to support improved water management. Similarly, collaboration among federal, state, and local levels is also encouraged to share technology and expertise and to provide technical assistance.

This means that water resources planners, specialists, managers and committees plan, manage and evaluate interventions designed to achieve multiple economic, environmental, social, safety and security outputs and outcomes. They coordinate and work together as common practice from the initial planning stages through the final evaluation phases. This collaboration facilitates information and technology sharing, and technical assistance to leverage authorities, programs, data, tools, research and talent for improved water management. Collaboration ensures creative and more expansive solutions in the face of complex and multi-faceted water resources issues and challenges. Collaboration involves bringing many parties to the same table to talk, plan and evaluate together.

The *National Action Plan (NAP): Priorities for Managing Freshwater Resources in a Changing Climate,* sponsored by the Council on Environmental Quality's Interagency Climate Change Adaptation Task Force, with input from the U. S. Army Corps of Engineers (USACE) and the U. S. Geological Survey (USGS), similarly emphasized that "government agencies and citizens collaboratively manage freshwater resources in response to a changing climate in order to ensure adequate water supplies, to safeguard human life, health and property, and to protect water quality and aquatic ecosystems" (The White House Council on Environmental Quality, 2011). A result is the Federal Climate Change and Water Working Group, which consists of USACE, USGS, the National Oceanic and Atmospheric Administration (NOAA), and the Bureau of Reclamation (see http://www.esrl.noaa.gov/psd/ccawwg).

Another good example of collaborative efforts on a watershed scale is the Western States Water Council's **Western States Federal Agency Support Team** (WestFAST). WestFAST is the collaboration among 12 federal agencies with water management responsibilities in the Western United States. This group was established to support the Western States Water Council and the Western Governors Association in coordinating federal efforts regarding water resources (see http://www.westernstateswater.org/westfast/).

Participation (Encourage Broad Participation)

Achieving the goal of IWRM is a challenge that demands a robust *participatory process*. It is critical to facilitate the communication of diverse views and information about water resources issues and needs to and from a broad constituent base of stakeholders (i.e., those that have a stake in a management outcome). Too often, however, the dynamics of contemporary public discourse create a hostile space that stifles the exchange of information and views. Effective IWRM processes create forums with a wide range of stakeholders, permitting clear communication of diverse viewpoints and enabling participants to work effectively through the diversity of issues related to values, content, and priorities in ways that provide satisfaction to parties—if not on all outcomes, at least on the basis of procedure and fairness of process used. Participation breeds shared understanding and aims through communication and consensus-building.

Integration (Use a System Approach)

The principle of integration is a central theme of IWRM and is also inherent in each of the other principles. IWRM means to ***integrate***. There is no such thing as an isolated water resource; all resources are parts of larger systems. The principle of integration highlights the connectedness of resources, resource managers, stakeholders and resource decisions. Its concept promotes a comprehensive planning approach, viewing water and related land resources as a system rather than as a combination of fragmented parts.

Agenda 21 is an international document that recommended that all nation states "adopt an integrated approach to environmentally sustainable management of water resources, including the protection of aquatic ecosystems and freshwater

living resources" (United Nations General Assembly, 1997). It emphasized that the formulation and implementation of policies and programs for integrated watershed management should address a wide array of issues:

> *Pollution and waste, the interrelation between water and land, including mountains, forests, upstream and downstream users, estuarine environments, biodiversity and the preservation of aquatic ecosystems, wetlands, climate and land degradation and desertification, recognizing that subnational, national and regional approaches to fresh-water protection and consumption following a watershed basin or river basin approach offer a useful model for the protection of fresh-water supplies.* (See http://www.un.org/documents/ga/res/spec/aress19-2.htm, Section 34a).

Integration means that expected benefits defined in a water resources plan are many, inclusive and interrelated.

Sound Science (Leverage and Share Information and Technology)

At a National Collaborative Water Resources Conference held in Washington, D.C., in August 2009, Ms. Barbara Naramore, Executive Director of the Upper Mississippi River Basin Commission, told attendees (USACE, 2010):

> *We do not need perfect knowledge to take sound action. We need to bring better and more relevant information to decision makers to make better decisions with limited resources. It is our responsibility to help decisions makers anticipate needs and take smart action with a wide range of players.*

A key principle of IWRM is to use sound data and science. Enhanced collaboration, networking, and information sharing across the water resources management community (international, federal, interstate, state agencies, etc.) can enhance IWRM.

Increasing attention is also focusing on the uncertainty in the water resources planning and management process and the fact that there are inherent risks as part of that uncertainty. Addressing the **risks and uncertainties** in the water resources planning process is related to the IWRM principle to use sound science. Risk management is essential for making practical and effective decisions in uncertain circumstances. It requires planning, analyzing, organizing, implementing and monitoring efforts to control for the effects of uncertainty.

Adaptive management is also part of the sound science principle. Adaptive management acknowledges uncertainty in natural systems and recognizes that resource management can be improved by "flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood" (NRC, 2004).

Tools and technology enhance the practice of integrated water resources management and risk management. Tools and processes for collaboration, such as shared vision planning developed in cooperation with the USACE Institute for Water Resources (IWR), provide a participatory process to engage key stakeholders around structured and collaborative computer-based model building, which in turn builds a common *language* for communication in a safe and productive environment (see http://www.sharedvisionplanning.us/). IWR has also developed an online **Collaborative Planning Toolkit** to provide information about the collaborative planning process, as well as tools, techniques, and software for collaborative planning. For example; there are collaborative process techniques (e.g., focus groups, circles of influence) as well as computer models and tools (e.g., problem definition, analytical, and synthesis/optimization tools and products) (see http://www.sharedvisionplanning.us/CPToolkit/Default.asp). Analytical and synthesis/ optimization methods and tools are important for IWRM decision making. They provide mechanisms for evaluating and/or ranking a series of possible alternatives. These methods and tools allow decision makers, preferably in a collaborative environment, to better understand the impacts of alternatives and various decisions.

The **Federal Support Toolbox for Integrated Water Resources Management** provides a single data access portal to valuable databases, innovative programs and initiatives, policies and regulations, state-of-the-art tools, lessons learned from practice, best management practices and opportunities for collaborative partnerships for water resources development and management (see http://watertoolbox.us). Initiated by USACE, the toolbox is an ongoing collaboration with numerous international, federal, state, tribal, non-governmental, and interstate water management agencies to facilitate information sharing and technology transfer.

Summary

Table 2 highlights the principles of IWRM from a spectrum of international, federal, state and non-governmental organizations (NGOs). The principles share the common notion to:

- **Seek sustainability**—balance economic, environmental, and/or social outcomes: economic development and the protection of ecosystems without harm to quality of life, safety or security through:
  - **holism**—adopting a watershed approach and perspective to look at the interconnections among local water issues and broader regional or watershed issues;
  - **integration**—integrating water resources planning and management with that of other resources (human, natural and financial) for a balanced approach;
  - **collaboration**—collaborating with all stakeholders whether governmental, institutional, business, or the public;
  - **participative decision making and collaborative modeling**—engaging stakeholders throughout a planning/decision-making process and tools that help visualize the impacts of management decisions on the watershed system;
  - **sound science and innovation**—leveraging the best available information, processes, and tools to support decision making; and
  - **adaptive management**—recognizing that in light of uncertainties, management is a dynamic process that requires ongoing monitoring and adaptation to changing conditions
- While respecting **transparency** and **accountability**—sharing information and processes with stakeholders so that decision makers are accountable to their publics and constituencies.

Table 2. Integrated Water Resources Management Principles

International Organizations

Dublin-Rio Principles

1. Fresh water is a finite and vulnerable resource essential to sustain life, development and the environment.
2. Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.
3. Women play a central part in the provision, management and safeguarding of water.
4. Water has an economic value in all its competing uses and should be recognized as an economic good.

The Dublin Statement on Water and Sustainable Development created at the International Conference on Water and Environment (the *Earth Summit*) held in Ireland in and presented at the World Summit in Rio de Janeiro in 1992.
Source: Global Water Partnership. See http://www.gwp.org/en/The-Challenge/What-is-IWRM/IWRM-Principles/

Global Water Partnership

The GWP reaffirms the Dublin-Rio principles and also adds that: "integrated water resources management is based on the equitable and efficient management and sustainable use of water."
Source: Global Water Partnership. See http://www.gwp.org/en/The-Challenge/What-is-IWRM/IWRM-Principles/

World Summit on Sustainable Development

IWRM Principles for Urban Areas

- Apply IWRM at a catchment level, the smallest hydrological unit of analysis and management but do not interpret this principle too narrowly.
- Integrate water and environmental management, i.e., manage water alongside the management of codependent natural resources, e.g., soil, forests, air, biota.
- Use a systems approach to recognize key individual components and the linkages between them, recognizing that a disturbance in one part of the system will be translated into other parts of the system directly or indirectly.
- Seek full participation by all stakeholders, including workers and the community.
- Pay attention to social dimensions.
- Build capacity through education, awareness building, policy making, regulations and compliance.
- Make information on hydrological, bio-physical, economic, social and environmental characteristics of a catchment available for informed policy making.
- Provide incentives for water conservation such as full-cost pricing complemented by targeted subsidies.
- Create and maintain leadership, such as through central government support, to facilitate and coordinate the development and transfer of skills, assist in providing technical advice and financial support, especially to local groups. Ensure appropriate institutional arrangements to ensure effective inter-departmental collaboration.
- Adopt the best existing technologies and practices.
- Secure reliable and sustained financing.
- Equitably allocate water resources.
- Recognize water as an economic good.
- Strengthen the role of women in water management.

Source: International Water Association. 2007. *The Industry Sector Report for the World Summit on Sustainable Development*. Johannesburg, Africa in 2007. See: http://www.gdrc.org/uem/water/iwrm/1pager-01.html.

Federal Agencies

U. S. Army Corps of Engineers

Environmental Operating Principles (2002, refreshed in 2012)

- Foster sustainability as a way of life throughout the organization.
- Proactively consider environmental consequences of all Corps activities and act accordingly.
- Create mutually supporting economic and environmentally sustainable solutions.
- Continue to meet our corporate responsibility and accountability under the law for activities undertaken by the Corps, which may impact human and natural environments.
- Consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs.
- Leverage scientific, economic and social knowledge to understand the environmental context and effects of Corps actions in a collaborative manner.
- Employ an open, transparent process that respects views of individuals and groups interested in Corps activities.

Source: USACE, 2002. Available at http://www.usace.army.mil/Missions/Environmental/EnvironmentalOperatingPrinciples.aspx.

Policy Guidance Letter #61 (1999)

- Integrate water and related resources management.
- Seek sustainable water resources management, taking into consideration environmental protection, economic development, and social well-being.
- Coordinate planning with responsible federal, tribal, state and local governments.
- Promote interagency cooperation that incorporates local, regional, tribal and national water resource management goals.
- Leverage resources and programs among federal, tribal, state and local interests.

Table 2. Integrated Water Resources Management Principles

- Identify existing and future water resource use demands.
- Use interdisciplinary teams.
- Evaluate the monetary and non-monetary trade-offs.
- Use sound science and data.
- Apply the principles of adaptive management. Solicit public input to water resources development and management.

Source: USACE, 1999. Available at See: http://planning.usace.army.mil/toolbox/library/PGL/pgl61.pdf.

USACE, Institute for Water Resources - Principles for Success in Collaborative Modeling

- Principle 1. Collaborative modeling is appropriate for complex, conflict-laden decision making processes where stakeholders are willing to work together.
- Principle 2. All stakeholder representatives participate early and often to ensure that all their relevant interests are included.
- Principle 3. Both the model and the process remain accessible and transparent to all participants.
- Principle 4. Collaborative modeling builds trust and respect among parties.
- Principle 5. The model supports the decision process by easily accommodating new information and quickly simulating alternatives.
- Principle 6. The model addresses questions that are important to decision makers and stakeholders.
- Principle 7. Parties share interests and clarify the facts before negotiating alternatives.
- Principle 8. Collaborative modeling requires both modeling and facilitation skills.

Source: USACE—Institute for Water Resources and Environmental Water Resources Institute. *Collaborative Modeling for Decision Support in Water Resources: Principles and Best Practices*. See http://www.computeraideddisputeresolution.us/bestpractices/section3.cfm.

States

Oregon Water Resources Department

- Accountability and enforceable actions.
- Balance.
- Collaboration.
- Conflict resolution.
- Facilitation by the state.
- Incentives.
- Implementation.
- Interconnections/integration.
- Public process.
- Reasonable cost.
- Science-based, flexible approaches.
- Streamlining.
- Sustainability.

Source: Oregon Water Resources Department, 2012. See http://cms.oregon.gov/owrd/pages/lwa/integrated_water_supply_strategy.aspx.

Nongovernmental Organization

American Water Resources Association (AWRA)

- Clean water as a basic human right, and as an economic and ecological necessity.
- Planning for long term sustainability.
- Participatory decision making.
- Management based on sound science and hydrologic units.
- Realistic measurement of outcomes.
- Continuous improvement of institutional capacity at all levels.

Source: AWRA Policy Statement, January 2011. Available at http://www.awra.org/policy/policy-statements-IWRM.html

Case Studies

Case studies exemplify the IWRM principles. Table 3 captures the principles reinforced by IWRM practice. The various case studies suggest that a path forward for integrated water resources management is to pursue collaborations with those with vested interests in conserving resources; restoring degradation; ensuring adequate funding; doing research to anticipate problems; aligning programs and projects to get the most for the money and synergy from common goals; and availing state-of-the-art research and innovations. Case examples help water resources practitioners take steps to approach water issues holistically through systems models and comprehensive plans that integrate objectives for multiple benefits with measurable ways to assess progress. Additional case studies can be found in the following resources:

American Water Resources Association report entitled ***Case Studies in Integrated Water Resources Management: from Local Stewardship to National Vision*** (2012, http://www.awra.org/committees/AWRA-Case-Studies-IWRM.pdf)

Global Water Partnership Toolbox on Integrated Water Resources Management: Examples of Practical Implementation of IWRM (http://www.gwptoolbox.org/)

Shared Vision Planning case studies from the USACE—Institute for Water Resources (http://www.sharedvisionplanning.us/resCase.cfm)

United Nations Department of Economic and Social Affairs (USNDESA) (**http://www.un.org/waterforlifedecade/iwrm.shtml**)

NATO Science Programme: Integrated Water Management: Practical Experiences and Case Studies (**http://freegeobook.files.wordpress.com/2009/01/1402065507.pdf**)

Table 3. IWRM Principles Reflected in Selected Case Studies

International Organizations

International Joint Commission, International Upper Great Lakes Levels Study, U. S. and Canada

Synopsis:

Initiated by the International Joint Commission in 2007, the five-year peer-reviewed International Upper Great Lakes Study, released in March 2012, focused on "how to manage fluctuating lake levels in the face of uncertainty over future water supplies to the basin while seeking to balance the needs of those interests served by the system." The Upper Great Lakes area encompasses parts of the U.S. and Canada. The effort involved state-of-the-art climate research, a shared vision planning process to detail improved options for fish habitat and active public engagement. The study report provided for expanded benefits (e.g., environmental restoration, commercial navigation, hydroelectric generation and coastal interests under both wet and dry water supply conditions), recommended more natural river flows to sustain ecosystem health, suggested a set of flexible, adaptable and less complex rules and a multi-lake regulatory policy (the Lake Superior Regulation Plan) for meeting diverse water flow needs. Key results included a continuous and coordinated bi-national effort to improve scientific understanding of lake hydroclimatic processes, strengthened hydroclimatic monitoring and modeling, ongoing risk assessment, a comprehensive information and outreach strategy, improved decision support tools, integration of water quality and quantity monitoring and an adaptive management strategy to deal with extreme water levels. Another outcome was the establishment of a bi-national advisory board.

Challenges:

1. Future projected water levels are outside the traditional range of expected adaptation to change.
2. Broad underlying economic, environmental and social forces are affecting water use.
3. Climate change will increase temperatures and change the frequency, and intensity of weather events and precipitation patterns, causing a decrease in water supply to the region.
4. Heavy industry and manufacturing in the region has declined. This has led to declines in income, population and municipal taxes, which in turn affect the:
   - Demand for shipping, energy and recreation.
   - New and more water-intensive industries (e.g., irrigated agriculture, biofuels, oil sands refining and electricity production).
   - Native indigenous populations in the region are worried about the effect of government decisions on their economic, cultural and spiritual well-being.

Principle(s) Emphasized:

- **Holism:** Balance multiple interests for water: domestic and sanitary water uses, navigation, power, irrigation, ecosystem vitality, coastal zone management, recreational boating and tourism.
- **Regulation/Role of Government:** Respect regulatory rights and the power of regulation to regulate outflows.
- **Collaboration:** Solicit the input of key stakeholders widely and often.
- **Adaptive Management:** Use adaptive management processes to build capacity, design or reform institutions, conduct and gather research and data, host training and planning sessions, monitor climate change impacts and adaptation efficacy, improve governance and policy and create new or enhance existing policies and regulations.

Source: International Joint Commission, 2012. *International Upper Great Lakes Study, Study Findings and Recommendations*. See http://ijc.org/iuglsreport/?page_id=14

Murray-Darling Basin Commission/Authority, Australia

Synopsis:

The Murray-Darling basin comprises the catchment area for the Murray and Darling rivers and their tributaries in Australia, which comprises 23 river valleys, a basin area of over 1 million sq. KM, and five different state governments. The Murray-Darling Basin Commission (MDBC) was established in 1988 to move toward basin-wide policies and programs for water management. Upon establishment, the mission of the MDBC was:

"Through the Government-community partnership, to foster joint action to achieve the sustainable use of water, land and other environmental resources of the Basin for the national benefit of present and future generations, and to maintain responsible, efficient and cost effective delivery services of water of agreed quality from the River Murray."

Table 3. IWRM Principles Reflected in Selected Case Studies

As part of a wave of institutional water reform and the National Water Initiative, in 2008, the Murray-Darling Basin Authority took over the responsibility of the MDBC with the aim "to manage the Basin's water resources" in the national interest.

Challenges:

By the 1980s there were concerns about degradation of the natural resources of the basin, including:

1. Increasing competition, resistance to land clearing controls.
2. Conflicts over who would pay for remediation of degraded resources.
3. Risks to the condition or continued availability of Basin resources, including:
   - The taking and use of water, including through interception activities;
   - Insufficient water available for the environment;
   - The water is of quality unsuitable for use;
   - There is poor health of water-dependent ecosystems;
   - Water is unsuitable or insufficient to maintain social, cultural, indigenous population values or pubic benefits;
   - The effects of climate change;
   - Changes to land use;
   - Limitations on the state of knowledge used as the basis to estimate matters relating to use of resources in the Basin.

Principle(s) Emphasized:

- **Holism:** The MDBA is now the single body responsible for water resource planning in the Basin. The stated purpose of the "Murray–Darling Basin Agreement is to 'promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water and other natural resources of the Murray-Darling Basin, including by implementing arrangements agreed between the Contracting Governments to give effect to the Basin Plan, the Water Act and State water entitlements."
- **Integration:** Part of the management objectives are (1) ensuring reliable water supplies for all users (communities, industries, and the natural environment), (2) addressing water storage, management and delivery at four major storage facilities, (3) addressing salinity management schemes, and (4) maintaining the rivers operating structures (including weirs, locks, and barrages).
- **Sustainability:** One of the key strategies in the framework is the development of a Basin Sustainability Plan that targeted investments in sustainable management activities, promoted coordinated planning and management, and focused long term objectives on "sustainable agriculture, water quality, nature conservation, and cultural heritage."
- **Collaboration and Participation:** Basin strategies coordinate the activities across governments and the community. The Stakeholder Engagement Strategy of 2009 outlines how stakeholders will be used as part of the Basin Plan process as well as a communication strategy (see http://www.mdba.gov.au/files/publications/Stakeholder-Engagement-Strategy-brochure.pdf).

Source: Excerpts for this entry from the Global Water Partnership Toolbox. Hooper, B. The Murray-Darling Basin Commission, Australia, Case #25, **http://www.gwptoolbox.org/index.php?option=com_case&id=22&Itemid=9**. See also http://www.mdba.gov.au/; http://www.gwptoolbox.org/index.php?option=com_case&id=22&Itemid=9; http://www.environment.gov.au/water/australia/nwi/index.html

Tribal Nations

Yakima River Basin Water Enhancement Project (YRBWEP), Washington State

Synopsis:

The Yakima River Basin in central Washington State is a diversified and agriculturally rich area whose exports support the Washington State economy. Fish runs of anadromous salmonids have long sustained the culture and economy of the Yakima Nation. The existing water resources infrastructure, programs and policies in the Basin state were not capable of consistently meeting aquatic resource demands for fish and wildlife habitat, dry-year irrigation demands, and municipal water supply demands. Fish passage problems were identified as needing immediate early attention, so Congress passed legislation in 1979 to conduct a feasibility study. But the Washington State Department of Ecology recognized that congressional authorizations were too narrowly focused and so the Congress authorized the Yakima River Basin Water Enhancement Project working group in 1979. A collaborative working group was formed in 2009. The Bureau of Reclamation and the Washington State Department of Ecology issued An *Integrated Water Resource Management Plan* in April 2011 and a joint Final Programmatic Environmental Impact Statement in March 2012. Project-specific environmental reviews will follow.

Challenges:

1. Droughts and declines in fish runs;
2. Blocked habitat;
3. Land use changes;
4. Altered streamflows;
5. Lawsuits consistently slowed progress;
6. Climate change is worsening water supplies to municipal systems and rural homes.

Principle(s) Emphasized:

- **Collaboration and Participation:** This is a joint project of the staff from U. S. Department of the Interior's Bureau of Reclamation, the Washington State Department of Ecology and the Yakima Indian Reservation; elected officials and local staff from three counties and the city of Yakima; and irrigation and environmental stakeholders representing diverse perspectives who all serve on the Yakima River Basin Water Enhancement Project Work Group (YRBWEP Workgroup). The group seeks consensus, not full agreement, on every project. Federal agencies represented on the Workgroup include the Bureau of Reclamation, National Marine Fisheries Service, Fish and Wildlife Service, and the Forest Service. They communicate with members of Congress, Washington State legislators and other federal and state officials to request funding to implement The Integrated Water Resource Management Plan. Washington State agencies include the Department of Ecology, the Department of Agriculture and the

Table 3. IWRM Principles Reflected in Selected Case Studies

Department of Fish & Wildlife. Irrigated Agriculture representatives include those from the Kennewick, Roza, Sunnyside Valley and Yakima-Tieton Irrigation Districts and the Kittitas Reclamation Districts. Other stakeholders include American Rivers, National Wildlife Federation, the Yakima Basin Fish & Wildlife Recovery Board and the Yakima Basin Storage Alliance.

- **Holism:** The objective was to develop a comprehensive and integrated water resource plan for efficient management of basin water supplies through integrated objectives related to surface and groundwater, floodplains and uplands, watershed protections and associated recreational opportunities.
- **Multidimensionality:** Objectives include providing supplemental water for presently irrigated lands, water for new lands within the Yakima Indiana Reservation and water for increased in-stream flows for aquatic life, specifically:
  - Enhanced water supply reliability;
  - Improved streamflows;
  - Improved fish habitat conditions to multiply the population of salmon, steelhead and bull trout;
  - Improved access to b locked fish habitat;
  - Increased supply for Basin population growth.
- **Integration:** The YRBWEP Workgroup recommended the *integrated alternative*, which include 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.

  Technical studies in each of these categories used an integrated modeling platform to evaluate how different combinations of projects would improve water supply and streamflow conditions. The Yakima River Basin Proposed Integrated Water Resources Management Plan (Integrated Plan) resulted.
- **Adaptive management:** The Integrated Water Resource Management Plan will be implemented using an adaptive management approach.

Source: AWRA, 2012, http://www.awra.org/committees/AWRA-Case-Studies-IWRM.pdf pp. 31-36

Federal Agencies

Protection and Restoration of Coastal Louisiana

Synopsis:

The Mississippi River is the largest and longest river in North America—a unique ecosystem of wetlands, birds, fish, shellfish and plant species. It is home to two million people and supports vital ecosystems, national energy security, and thousands of jobs within a unique culture. The city of New Orleans is an economic powerhouse supporting international shipping, ship-building, health care, agriculture, recreation, seafood and tourism. Severe floods of recent history have destroyed or put ecosystems at risk. Demonstrating its commitment to the resiliency of the coast, the Coastal Protection and Restoration Authority developed the *2012 Coastal Master Plan* (see http://www.coastalmasterplan.louisiana.gov/2012-master-plan/final-master-plan/).

Challenges:

1. Flooding remains a supreme threat, especially given that human activity has attempted to control flooding in this coastal zone through levees and other flood control interventions.
2. Hurricanes Katrina and Rita ravaged the coastal zone. As a result, 1,900 square miles of coastal land (most wetlands and barrier islands) have been lost.
3. Dredging has changed the hydrology of the area. Channeled sediment deposits in the Gulf have created a massive "dead zone."
4. Wetlands have been lost. Beaches, dunes and barrier islands are disappearing.
5. There is substantial erosion and subsidence.
6. Climate change and sea-level rise are giving way to storms, storm surges and repeated flooding.
7. Hypoxia and saltwater intrusion threaten the sustainability of Louisiana's coast.
8. If sustainability is not restored to the coastal ecosystem land will continue to be lost at a rapid rate and critical infrastructure will be damaged or destroyed. Pipelines, offshore support centers and other facilities constructed for inland conditions will be subjected to the open Gulf of Mexico waters.
9. Fisheries and wildlife stocks will decline as spawning, breeding and foraging grounds are lost to the Gulf.
10. The Nation will lose priceless habitat. Loss of fish threatens commercial fishing and shipping companies.
11. Population along the coast is increasing, which brings more buildings and puts these structures at risk of damage or loss.
12. Pollution increases from population increases, which threaten plants and animals with extinction from losing their natural habitat.
13. If beaches are eroded or polluted, tourists stay away, which adversely impacts tourism, a big source of income for shoreline states.

Principle(s) Emphasized:

- **Collaboration:** Louisiana's *Coast 2050* Plan and the 2006 Water Resources Development Act authorized expense of $1.12 billion to restore the coast and achieve a sustainable ecosystem and to avail collaboration for protection and emergency preparedness and response. *Coast 2050* is a collaboration of the State of Louisiana (Department of Natural Resources) and its federal partners (U. S. Army Corps of Engineers, New Orleans District). The systems approach requires the participation and collaboration of all level of governments. The Louisiana Recovery Authority is guiding social and economic authority through *Louisiana Speaks*, a long-term

Table 3. IWRM Principles Reflected in Selected Case Studies

communication-based and collaborative community planning initiative.

- **Multidimensionality:** The approach is to consider multiple purposes in developing alternatives. The 2006 Defense Appropriations Act authorized the Louisiana Coastal Protection and Restoration Project (LACPR) and supplemental appropriations provided for a full range of flood control, coastal restoration and risk-oriented Category 5 hurricane measures.
- **Holism:** Planning officials view the Louisiana coast as a system of interrelated parts. Louisiana's Coastal Protection and Restoration Authority provided hurricane protection, conservation, restoration and enhancement of coastal wetlands and barrier shorelines/reefs with both short-term and long-term structural, management and institutional interventions. A systems approach and dispensation from Corps project development policies are being used to plan water resources projects more flexibly for a strong structural hurricane risk-reduction system of levees and other structures and a restored and sustainable coastal ecosystem – both national economic development and non-economic objectives.
- **Integration:** Decisions are seeking to integrate diverse stakeholder views with existing authorities, science-based options, the political will of decision makers and long-term funding.
- **Best Science**: Planning models are considering all kinds of risks, including loss of life and social and infrastructure rebuilding costs in risks analysis. Risk-based decision models of storm damage and risk to human life and property are being used to assess residual risk (risks resulting from exposure of people, property, infrastructure, the ecosystem the local economy, and social and cultural aspects) and to incorporate non-structural measures (e.g., education, evacuation procedures, flood proofing, elevation, relocation).

Source: The National Academy of Public Administration, 2007, *Prioritizing America's Water Resources Investments: Budget Reform for Civil Works Construction Projects at the U.S. Army Corps of Engineers*. See http://www.napawash.org/publications-reports/prioritizing-america%E2%80%99s-water-resources-investments-budget-reform-for-civil-works-construction-projects-at-the-u-s-army-corps-of-engineers/; State of Louisiana, Coastal Protection and Restoration Authority, http://coastal.louisiana.gov/index.cfm?md=pagebuilder&tmp=home&nid=152&pnid=0&pid=112&catid=0&elid=0;

Comprehensive Restoration Plan for the Hudson-Raritan Estuary

Synopsis:

The Hudson Raritan Estuary (HRE) is where the Hudson, Hackensack, Passaic, Rahway and Raritan Rivers meet the Atlantic Ocean. It stands as a rich and complex ecosystem for essential benefits, e.g., nourishment, clean water, flood protection, erosion control and recreational opportunities. It is home to the Port of New York-New Jersey – and thus has nearly constant ship traffic—in the midst of a well-developed metropolitan area. Accumulating environmental degradation from urbanization and other human activities brought about a public outcry to restore the effects of degradation to habitat and species in the estuary.

A partnership among federal, state, municipal and non-governmental organizations and regional stakeholders (environmental and community groups) as sponsors led to a study sponsored by the U. S. Army Corps of Engineers, the Port Authority of New York and New Jersey, which in turn led to a consensus vision of comprehensive restoration in 2009—*The Comprehensive Restoration Plan* (CRP)—for habitat (coastal wetlands, oyster reefs, improvement of water and sediment quality, and access to regional recreational benefits), a master plan and a strategy to restore the New York/New Jersey Harbor.

Benefits include improvement in terms of 10 multi-outcome targets (TECs or Target Ecosystem Characteristics) related to healthier habitats, cleaner air and water, increased aesthetic value and recreational opportunities for more livable and desirable communities, healthier families and stronger local economies. Specific improvements encompass living resources (more stable and healthier habitat; stabilization of harbor heron populations; recovery of fishes, shellfish and wildlife; and control of pests and invasive species); efforts to mitigate and adapt to climate change and to conserve energy; pollution prevention/control/reduction of nutrients and dissolved oxygen, pathogens, toxic chemicals and floatable debris; and efforts to keep all stakeholders informed about gains and remaining challenges.

Evidence of measurable results shows that threats to habitats, loss of species and degradation have slowed while improvements to wastewater treatment infrastructure have been made, cleanup of noxious chemicals has begun, and the amount of floatable debris has decreased from continual monitoring. Public recognition of the value of a healthy ecosystem has increased.

Challenges:

1. Environmental degradation from centuries of industrialization and urbanization;
2. Severe habitat loss;
3. Poor water quality;
4. Pervasive sediment contamination;
5. Lack of public access to the estuary;
6. Lack of a comprehensive system-wide plan but tendency to plan project-by-project.; little effort is given to past restoration of efforts or alternate restoration opportunities;
7. Cost of implementing restoration projects and their associated monitoring programs;
8. Multi-jurisdictional regulatory boundaries impede restoration planning. There are multiple and often conflicting goals of resource conservation and compatible uses of the environment, e.g., for habitat exchange, placement of fill-in water, beneficial use of dredged material for habitat restoration, nuisance species, management of contaminated sediments.

Principle(s) Emphasized:

- **Multidimensionality:** *The Comprehensive Restoration Plan* includes a framework for comprehensive restoration of the Estuary, defines short-term and long-term restoration goals and objectives, identifies specific targets that address multiple factors (severe habitat degradation, poor water quality, pervasive sediment contamination and lack of public access to the estuary's resources) and presents potential strategies and mechanisms for successful implementation and management. Development of a comprehensive plan shows the power of a whole region to work toward common restoration goals that provide benefits to the Estuary.
- **Collaboration:** The collaboration of federal, state, municipal and non-governmental organizations and regional stakeholders,

Table 3. IWRM Principles Reflected in Selected Case Studies

including environmental and community groups. The Hudson-Raritan Estuary study was incorporated into the National Estuary Program, which put into play an organizational structure, the New York-New Jersey Harbor Estuary Program (HEP), to provide program direction. Active participants in the HEP Program include NOAA, the National Park Service, the U. S. Army Corps of Engineers, the U. S. Department of the Interior, the U. S. Environmental Protection Agency, many state and local governments (e.g., Interstate Environmental Commission, New Jersey Department of Environmental Protection, New Jersey Meadowlands Commission, New York City Department of Environmental Protection, New York State Department of Environmental Conservation, New York State Department of State, the Port Authority of New York/New Jersey, State of New Jersey, State of New York) and several non-governmental organizations: Citizens Advisory Committee, Hudson River Foundation, National Parks Conservation Association, New Jersey Harbor Dischargers Group, Science and Technology Advisory Committee, NY/NJ Baykeeper, Metropolitan Waterfront Alliance.

  - The Plan emanated from numerous public outreach meetings and a coalition of non-governmental partners within each planning region of the Hudson-Raritan Estuary (HRE). The Hudson River Foundation led the collaborative effort to develop a scientific basis for a comprehensive ecosystem restoration plan for the HRE. Communication was constant during the Feasibility Study phase. Project Summary sheets were made available for stakeholder and partner review within each Planning Region.
  - The U. S. Army Corps of Engineers New York District explicitly expressed interest in receiving stakeholder feedback throughout the development of the Feasibility Study and the revision of *The Comprehensive Restoration Plan*.

- **Innovation:** An innovative plan formulation tool was used to compare and evaluate the value of each proposed design for restoration.

Sources: USACE, New York District. 2009. *Comprehensive Restoration Plan for the Hudson-Raritan Estuary*. Available at http://www.nan.usace.army.mil/Missions/Navigation/NewYorkNewJerseyHarbor/HudsonRaritanEstuary.aspx. Also see:
http://www.harborestuary.org/pdf/StateOfTheEstuary2012/Factsheet_English.pdf
http://education.nationalgeographic.com/education/media/hudson-raritan-estuary/?ar_a=1
http://www.harborestuary.org/news/TEWinter09.pdf
http://www.nan.usace.army.mil/Portals/37/docs/harbor/Harbor%20Program%20Images/CRP%20vol1.pdf

State

California's Integrated Regional Water Management

Synopsis:

In 2002 California set out a plan for implementing integrated water resources management at both the state and regional levels through the Integrated Regional Water Management Act (IRWM). It authorized the development of Integrated Regional Water Management Plans (IRWMPs) within a regional planning and implementation framework to increase collaboration between local agencies through a bottoms-up approach. In 2003 California voters authorized a grant program to fund IRWM projects, a key success factor. The California Department of Water Resources (DWR) and the State Water Resources Control Board developed program guidelines to facilitate local agencies in creating voluntary regional water management groups to develop IWRMPs.

The California State Water Management Strategies include:

1. Reduce water demand.
2. Improve operational efficiency and transfers.
3. Increase water supply.
4. Improve water quality.
5. Practice resources stewardship.
6. Improve flood management.
7. Other strategies.

At first, local planning regions were not defined so as to encourage local leadership in developing the IWRMP. The DWR did set standards for regions to meet eligible grants, however, within a framework grounded in integrated Water Resources Management (IWRM) principles. How the Regional Water Management Groups are set up thus varies, although this flexibility suffices to meet unique regional conditions and to adapt to local needs. There are 48 different regional plan areas in California ranging from 170,000 acres to 12.5 million acres. The California Department of Water Resources is developing *The Strategic Plan for the Future of IRWM in California* to ascertain how to achieve the IRWM vision for integrated regional water resources development and management.

Challenges:

1. Funding remains an issue. Despite the fact that the IRWM program is facilitating more efficient water management through pooled resources and a broader set of water issues, it is not certain if the IRWM approach will continue without a grant program.
2. Environmental resources are in peril.
3. Record drought.
4. Environmental trouble with the state's main water system.
5. Water prices have been driven up.
6. The state's agriculture industry is hobbled.
7. Lack of sufficient water supply. Water supply cutbacks.
8. The state of the state's economy is weak.
9. The water supply and delivery system may not be able to meet the growing needs of the state.
10. An aging infrastructure.
11. Population growth.
12. Climate change.

Table 3. IWRM Principles Reflected in Selected Case Studies

13. Deteriorating Sacramento-San Joaquin Delta.
14. Conservation constraints.

Principle(s) Emphasized:

- **Holism:** The California Water Plan (2009) promotes a regional planning framework that addresses water supply, water quality, flood and ecosystem challenges through a collaborative, multi-partner process. 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. California encourages holistic management at the local level. The integrated regional planning process has advanced sustainable and holistic management of shared surface and groundwater resources among competing users.
- **Multidimensionality:** Data and analytic tools are being developed to enable regions to participate in integrated regional management, to manage risk and uncertainty, and to improve water resources management in the face of climate change. Multidimensionality is eased through publication of an online library of documents–including project proposals, plans and data. California is investing in streamlining data management, information sharing and decision-making through data protocols and standards.
- **Integration:** The state has incorporated social equity and integrated data management into water planning.
  - The DWR defined a region as a contiguous geographic area encompassing the service areas of multiple local agencies so as to integrate water management activities, i.e., water management programs and projects within a hydrologic region.
  - The DWR's grant program facilitates integration through incentives for multi-objective planning (e.g., opportunities to integrate individual projects within regional schemes and projects and inclusion of diverse stakeholder groups).
- **Collaboration:** A core IRWM concept is that better water management results from coordination across water use sectors, governmental entities, stakeholders and the public. The IRWMP process facilitates participation from diverse interest, which in turn facilitates multipurpose planning.
  - Partners include federal/state/local governments, water managers, tribes, non-governmental organizations and disadvantaged communities.
  - Regional Water Resources Management Groups must define public involvement efforts and approaches to inter-regional coordination. Water purveyors, wastewater and flood control agencies, local governments and special water districts, electrical companies, tribes, environmental and community organizations, industry groups, water users, cross-governmental level agencies, universities, and disadvantage community members must participate in development of the Integrated Regional Water Management Plan.
  - The process of developing regional water management plans has led to conflict resolution models and processes while increasing collaboration and coordination. This process involves stakeholders from the start and thus promotes buy-in.
- **Innovation:** The use of guidelines with local flexibility in defining planning regions encourages innovation. The search for local water supplies encourages nontraditional water development, e.g., recycling, conservation and modification of operations. Innovation is encouraged at the local level. Regions benefit by learning from the diverse approaches used by local and regional planning groups; these are being codified as case studies to share successes and lessons learned.

Sources: *California's Water Crisis: A Public Education Program*. Available at: http://www.calwatercrisis.org/problem.htm. AWRA, 2012, http://www.awra.org/committees/AWRA-Case-Studies-IWRM.pdf pp. 17-24.

Interstate Organization

Delaware River Basin Commission

Synopsis:

The Delaware River drains a portion of the states of New York, New Jersey, Pennsylvania and Delaware. At 330 miles in length it is the longest undammed river east of the Mississippi River. Congress created the Delaware River Basin Commission (DRBC) in 1961 to coordinate federal interests in the basin with the interests of the four basin states. The focus on functionally interrelated water resources reinforces a one river, one basin approach and has led to comprehensive planning and coordination through the DRBC as an integration agency for efficient development and operation of water and related land resources. For example, the broad powers of the DRBC to "plan, develop, conserve, regulate, allocate and manage water resources in the basin enables the DRBC to manage the sustainable use and supply of potable water for 9 million persons living outside the basin in New York City through adherence to IWRM principles."

Challenges:

1. There is a need to test for and to understand the effects of a wide array of emerging chemicals of concern.
2. Many species are feeling the effects of water quality problems, less space to live in, competition from non-native species; such conditions make it difficult to survive and impossible to be healthy. Some species are threatened. All but the most common mussels are hard to find in freshwater streams. News for oysters and shad is mixed.
3. The habitat of the Atlantic sturgeon is at risk from natural conditions and human activity in the river, thus endangering its survival.
4. Bayshore marshes are being eroded or inundated by rising sea levels. Natural landscapes are important for water supply and habitat.
5. Demand for electricity is increasing the need for water.
6. Forested land is being converted to other uses at a rate of 2,400 football fields a year.
7. Better tools are needed to predict conditions in advance to ensure that enough water is available where it is needed in the future.
8. It may be necessary to seek water quality improvements to maintain the current levels of dissolved oxygen for fish reproduction.

Table 3. IWRM Principles Reflected in Selected Case Studies

Principle(s) Emphasized:

- **Holism:** The DRBC encompasses the entire basin. All governing bodies are represented on the Commission. The mission is encompassing: to manage the resource using the natural watershed boundaries without regard to political boundaries.
- **Sustainability:** The DRBC practices Integrated Resources Planning to preserve and enhance the basin's environmental quality while ensuring economic development in the accomplishment of its multiple missions. The process involves evaluating and developing specific management objectives on sub-basin levels that reflect the needs, stakeholder inputs and resource base of the sub-basin.
- **Collaboration and Participation:** Management of complexity and interconnectedness of factors within a dynamic system are facilitated by the involvement of all water sectors, levels of government, and the public through robust interagency coordination and public participation processes and forums. For example, the 2004 *Basin Plan* was developed with a 36-member stakeholder Watershed Advisory Council, which provided input from diverse basin interests. The DRBC also uses Technical Advisory Panels composed of technical staff from state and federal agencies as well as stakeholders from the regulated, environmental and academic communities who provide input on various technical issues (e.g., water quality, toxins, regulated flows, and monitoring and flood management in the basin.

Sources: AWRA, 2012, http://www.awra.org/ committees/AWRA-Case-Studies-IWRM.pdf; http://www.state.nj.us/drbc/about/public/publications/index.html

Overcoming Barriers to Implementation

There are few arguments against IWRM on a philosophical or conceptual basis. However, there have been noted barriers to operational implementation of IWRM.

Referring to IWRM, Biswas (2004) raised the question: "why it has not been possible to properly implement a concept that has been around for some two generations in the real world for macro- and meso-level water projects and programs?"

IHP-NARBO (2009) declares "the principles and concepts have been widely recognized, but the implementation of IWRM is not satisfactorily progressing in many basins. This is perhaps because the practitioners responsible for water resources management at the basin level encounter difficulties in understanding where and how to begin, or the advantages of applying IWRM with respect to their actual situation may not be so apparent."

In its 2011 policy statement, the American Water Resources Association notes that IWRM "suffers from a lack of clear definition, the lack of standard measures to track the success of integrated water resource management plans and projects, and the absence of guidance for those involved in planning and project development,"(see (www.awra.org/policy/policy-statements-IWRM.html).

As this discussion paper and the professional literature demonstrate, there is no single all-encompassing definition of IWRM or any cook-book approach to IWRM implementation. Clearly, IWRM is a philosophical concept and process that is adapted to unique water resource management challenges. The Global Water Partnership notes: "IWRM should be viewed as a process rather than a one-shot approach—one that is long-term and forward moving but iterative, rather than linear in nature. There is not one correct administrative model. The art of IWRM lies in selecting, adjusting and applying the right mix of these tools for a given situation." (See: http://www.gwp.org/en/The-Challenge/What-is-IWRM/IWRM-Application/). There are a number of existing frameworks that can be tailored to meet unique geographic and water resources challenges (the previous Figure 1 is only one example).

The GWP also promotes that IWRM implementation can be facilitated by change in several key areas, particularly in water governance (see Box 1) (i.e., the enabling environment). The barriers to implementation can be overcome by accepting and implementing the foundational principles of IWRM; tailoring strategies based upon the unique water challenges and physical, social, and political characteristics of the geographic area; and adapting tools and processes to meet the evolving water resource challenges.

Box 1. Global Water Partnership—Change Areas to Facilitate IWRM Implementation

The enabling environment

1. Policies – setting goals for water use, protection and conservation.
2. Legislative framework – the rules to follow to achieve policies and goals.
3. Financing and incentive structures – allocating financial resources to meet water needs.

Institutional roles

4. Creating an organizational framework – forms and functions.
5. Institutional capacity building – developing human resources.

Management instruments

6. Water resources assessment – understanding resources and needs.
7. Plans for IWRM – combining development options, resource use and human interaction.
8. Demand management – using water more efficiently.
9. Social change instruments – encouraging a water-oriented civil society.
10. Conflict resolution – managing disputes, ensuring sharing of water.
11. Regulatory instruments – allocation and water use limits.
12. Economic instruments – using value and prices for efficiency and equity.
13. Information management and exchange– improving knowledge for better water management.

Source: Global Water Partnership Technical Committee (2005)

Conclusion

IWRM is a 21st century water management paradigm. While not a new concept, application of IWRM principles and approaches is the way to coalesce resources (people, authorities, and funding) to achieve multiple goals and objectives for a myriad of benefits: a stable, improved or thriving economy; a healthy ecosystem capable of sustaining its characteristics and capabilities for future uses; and a population of residents confident in their national water safety and security.

Solutions to water challenges that are thoughtful, representative of diverse views, effective in achieving desired performance levels, grounded in sound science and methodologies, and integrated so as to satisfy multiple objectives across multiple stakeholders at multiple locations for multiple water purposes or uses are needed to address the complexity of water management. Consequently, approaches must match the challenges.

IWRM is a sophisticated approach being practiced in the United States and abroad. It can be promoted through attention to the principles highlighted in this paper and through development of measurable indicators of success. The initial steps to apply the principles of IWRM must be taken so as to learn from experience, discussion and reflection about what works, what does not work and why. Case studies help water managers learn about best practices and understand lessons learned. Taking concrete action reveals that IWRM is also a complicated process with fits of starts and stops and critical lessons learned from reflection upon failure as well as success.

Taking action to make IWRM a holistic approach widely used by water managers will require a clear vision of integrated water and related land resources management, collaboration, integration frameworks, sufficient resources, transparency of best practices and lessons learned, as well as rampant and enabled information sharing to benefit from both failure and success.

An enabling environment, clear and accepted institutional roles, and facilitative management means and instruments are needed (AWRA, 2012). These features may include:

- **Policies and legislation** that promote IWRM.
- **Financing and incentive structures** that make resources available for implementation and innovation.
- **Organizational structures** that facilitate IWRM, institutional capacity building through training, information sharing, and other communication and analytic tools and models.
- **Water resources assessments.**
- **Planning and plans** that require and encourage integration and collaboration.
- **Public participation and conflict resolution** processes.
- Appropriate **regulatory instruments.**
- **Economic tools and information management processes.**
- **Understanding of key principles** for Integrated Water Resources Management.

A key to success is to understand and apply IWRM principles:

- Encourage holistic understanding and management.
- Coordinate and integrate to achieve economic, social and ecological purposes and benefits.
- Plan for a life-cycle process that is goal driven, process-oriented, and iterative through phases and stages accommodating adaptive management.
- Engage fervent public and stakeholder participation and commitment.
- Practice active and trustworthy intergovernmental coordination for planning, development, protection, and management of water and related land resources in a way that sustains economic vitality, environmental health, public health and safety, and communities and ecosystems.

Progress toward IWRM holds the promise to sustain ecological, economic, and social resources for citizens today and into the future. It is the foundation for the future.

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