Moving Toward a Multi-Benefit Approach for Water Management

Sarah Diringer, Anne Thebo, Heather Cooley, and Morgan Shimabuku
Pacific Institute
and
Robert Wilkinson and McKenzie Bradford
Bren School of EnvironmentalScience and Management, University of California, Santa Barbara

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Pacific Institute
654 13th Street,
Preservation Park
Oakland, California 94612
510.251.1600 | info@pacinst.org
www.pacinst.org

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ABOUT THE PACIFIC INSTITUTE

The Pacific Institute envisions a world in which society, the economy, and the environment have the water they need to thrive now and in the future. In pursuit of this vision, the Institute creates and advances solutions to the world's most pressing water challenges, such as unsustainable water management and use; climate change; environmental degradation; food, fiber, and energy production for a growing population; and basic lack of access to freshwater and sanitation. Since 1987, the Pacific Institute has cut across traditional areas of study and actively collaborated with a diverse set of stakeholders, including policymakers, scientists, corporate leaders, international organizations such as the United Nations, advocacy groups, and local communities. This interdisciplinary and nonpartisan approach helps bring diverse interests together to forge effective real-world solutions. More information about the Institute and our staff, directors, and funders can be found at www.pacinst.org.

ABOUT THE AUTHORS

SARAH DIRINGER

Dr. Sarah Diringer is a Senior Researcher at the Pacific Institute, where her work focuses on the impacts of policy, technology, and land use on sustainable water management. Sarah has conducted research both domestically and abroad on watershed management and environmental health. Prior to joining the Institute, Sarah was a doctoral researcher at Duke University, conducting field work and lab research focused on the environmental and community impacts of mercury released from artisanal and small-scale gold mining in Peru. Sarah holds a B.S. in Environmental Science from the University of California, Los Angeles and a Ph.D. in Civil and Environmental Engineering from Duke University.

ANNE THEBO

Dr. Anne Thebo is a Senior Researcher at the Pacific Institute. Her work has spanned the topics of agricultural reuse of municipal wastewater in the United States and abroad; water, sanitation, and hygiene; stormwater design and planning; and spatial analysis and modeling. Anne holds Bachelor of Science degrees in Environmental Science and Civil Engineering from Ohio State University, a Master of Science in Civil and Environmental Engineering from Stanford University, and a doctorate in Civil and Environmental Engineering from the University of California, Berkeley, where her research focused on the water resources and health impacts of the indirect reuse of wastewater in irrigated agriculture.

HEATHER COOLEY

Heather Cooley is Director of Research at the Pacific Institute. Heather holds a Bachelor of Science degree in Molecular Environmental Biology and a Master of Science in Energy and Resources from the University of California, Berkeley. She received the US Environmental Protection Agency's Award for Outstanding Achievement for her work on agricultural water conservation and efficiency and has testified before the US Congress on the impacts of climate change on agriculture and innovative approaches to solving water problems in the Sacramento-San Joaquin Delta. Heather has served on several state task forces and working groups, including the California Commercial, Industrial, and Institutional Task Force and the California Urban Stakeholder Committee, as well as the board of the California Urban Water Conservation Council.

ROBERT WILKINSON

Dr. Robert C. Wilkinson is Adjunct Professor at the Bren School of Environmental Science and Management, and Senior Lecturer Emeritus in the Environmental Studies Program at the University of California, Santa Barbara. The focus of Robert's teaching, research, and consulting is on water, energy, and climate policy. Robert is also a Senior Fellow with the California Council for Science and Technology. He co-chairs the U.S. Sustainable Water Resources Roundtable; advises government agencies, NGOs, and businesses in the U.S. and abroad; and serves on a number of advisory boards.

MORGAN SHIMABUKU

Morgan Shimabuku is a Research Associate at the Pacific Institute where she has focused on stormwater policy and economics, integrated water management, and water and conflict around the world. Prior to joining the Institute, Morgan managed residential and commercial water conservation programs in partnership with municipal water providers. Her scientific background includes experience as a scientist at a water resource consulting firm and fieldwork as a stream technician for the US Forest Service and for her graduate and undergraduate studies. Ms. Shimabuku received a Bachelor of Arts degree in Environmental Studies and Geology from Whitman College and a Master of Arts from the Department of Geography at the University of Colorado, Boulder, where she studied climate change, hydrochemical cycling, and snow hydrology at the university's Institute of Arctic and Alpine Research.

MCKENZIE BRADFORD

McKenzie Bradford is a second year graduate student at the Bren School of Environmental Science & Management at the University of California, Santa Barbara, where she is specializing in Water Resources Management. Her past academic work includes a Bachelor of Science in Natural Sciences with a minor in Mathematics from the University of Alaska, Anchorage. Throughout her undergraduate studies, McKenzie was involved in Engineers Without Borders, where she held the position of Program Manager and Vice President. At Engineers Without Borders, McKenzie worked to implement a rainwater catchment system in an impoverished area in Cameroon, Africa. It was this experience that fostered her passion for environmental justice and water resources sustainability.

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The views expressed in this report are solely those of the authors and may not reflect the opinions of those who provided input and feedback.

ADVISORY GROUP

This initiative has relied on significant stakeholder engagement. In December 2017, we formed an Advisory Group that includes 30 representatives from local, state, and federal agencies; private sector and industry groups; academia; and non-governmental organizations with interest and expertise in water investment projects and multi-benefit valuation strategies. The Advisory Group was convened five times over 10 months and provided input on defining the multi-benefit framework goals, categorizing benefits and costs of water management strategies, and examining opportunities for incorporating multiple benefits into decision making. The advisory group included:

John Albert, Water Research Foundation
Rucker Alex, AECOM
Corinne Bell, Natural Resources Defense Council
Benjamin Bryant, Stanford Woods Institute for the Environment
Paula Conolly, Green Infrastructure Leadership Exchange
Martha Davis, Consultant, formerly Inland Empire Utility Agency
Mark Gold, University of California, Los Angeles
Roger Gorke, US Environmental Protection Agency
Kathy Jacobs, University of Arizona
Allison Jordan, Wine Institute
Greg Koch, Environmental Resources Management

Sharlene Leurig, Texas State University
Andy Lipkis, TreePeople
Felicia Marcus, California State Water Board
Laura Meadors, Apple Inc.
Erik Meyers, The Conservation Fund
Jeff Mosher, Carollo Engineers
Irene Ogata, City of Tucson
Tom Owens, US Water Alliance
Paul Reig, World Resources Institute
Matthew Ries, DC Water
Karen Ross, California Department of Food and Agriculture
Taj Schottland, Trust for Public Land
Patricia Sinicropi, WateReuse
Alisa Valderrama, Neptune Street
Kari Vigerstol, The Nature Conservancy
Brian Young, Autocase

Additionally, we held two convenings with stakeholders to solicit input on the framework as well as the challenges and opportunities for integrating multiple benefits into investment decisions. Convenings were held in Los Angeles (June 19, 2018) and Minneapolis (July 12, 2018), and included stakeholders from across the country, including local, state, and federal agencies; water utilities; academia; industry groups; businesses; community groups; and non-governmental organizations. The full list of participants from these convenings can be found in Appendix A.

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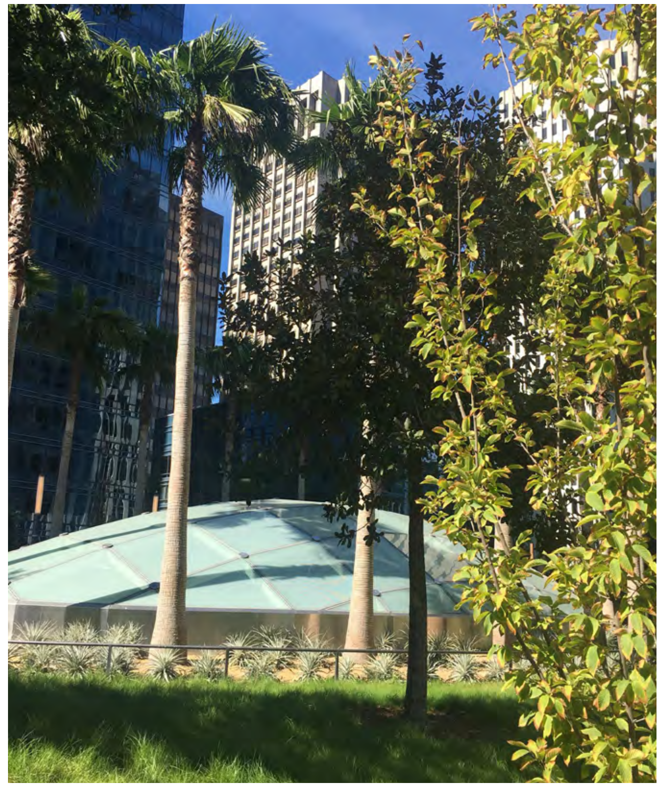
EXECUTIVE SUMMARY

There is broad recognition that adapting to climate change, coupled with the need to address aging infrastructure, population growth, and degraded ecosystems, will require rethinking programs and policies and investing in our natural and built water systems. There are a variety of strategies for addressing water challenges, from watershed restoration and efficiency improvements to vegetated swales and green roofs. Because water is deeply linked with economic, environmental, and community well-being, many of these strategies can also provide other benefits, such as reducing energy use and greenhouse gas emissions, providing wildlife habitat, and enhancing community livability.

Advancing Multiple Benefits: Opportunities and Challenges

Government agencies, businesses, and others have acknowledged the importance of multiple benefits and the potential for multi-benefit approaches to help build partnerships, leverage resources, optimize the value of investments, and garner public support. Communities throughout the United States are examining and advancing water management strategies that achieve multiple benefits, from complete street projects that create safe transportation options for all users and reduce pollutant runoff to water efficiency programs that reduce water and energy demand while increasing in-stream flows. For example, the City of Philadelphia is implementing low-impact development and green stormwater infrastructure options throughout the city based on the assessment of multiple benefits. Their analysis compared traditional grey infrastructure for



Source: Heather Cooley

Green infrastructure projects, such as the Transbay Transit Center rooftop garden in San Francisco, California pictured above, can provide multiple benefits, including reducing stormwater runoff, improving water quality, providing habitat, and providing public green space.

combined sewer overflow controls (e.g., storage tunnels) with alternative low-impact development options (e.g., tree planting, permeable pavement, green roofs) and examined the effectiveness of each option as well as associated co-benefits (reducing urban heat island effect, wetlands creation, air quality, electricity use, and more). When additional benefits were included, low-impact development increased the economic value of the investment by a factor of 20 compared to traditional grey infrastructure alone: from $122 million to $2.8 billion (Stratus Consulting, Inc. 2009). The benefits from low-impact development included more than $520 million in additional recreational activities, $1.1 billion in reduction of heat stress mortality, and $130 million in green jobs. Implementing either option would require a significant investment from the City of Philadelphia, but examining a broader suite of benefits allowed the city to select the option that would maximize the value of its investment.

There are examples from around the country of efforts to advance integrated projects that achieve multiple benefits. Yet, these efforts are not universal. One challenge is that the term multiple benefits is often loosely defined and thus associated benefits and costs are examined inconsistently. Multi-benefit projects are typically defined as projects that provide more than one benefit or serve more than one purpose (see, for example, California State Water Resources Control Board 2015). Yet, flood management, water quality, and water supply are so interconnected that nearly every water-related project will touch on at least two of these categories. In addition, by emphasizing only two or three benefits, decision makers may ignore others that could ultimately affect the project selected. Finally, the focus on multiple benefits often ignores potential costs or trade-offs, leading to an overly simplistic analysis of the project costs and benefits.

Various groups have developed tools and resources to assist in identifying and quantifying benefits of water management strategies; however, the tools often focus on a single strategy (e.g., stormwater management or watershed restoration) or a specific geographic region. For this reason, it is difficult to apply insights from the tools to a new project without significant investment of time and resources. As a result, the broad benefits and costs of water management are not routinely or systematically included in decision making, and water managers and decision makers cannot effectively compare alternative options.

A Framework for Incorporating Multiple Benefits into Decision Making

To address these challenges, researchers at the Pacific Institute and Professor Bob Wilkinson of the University of California, Santa Barbara launched an initiative to develop, build consensus around, and promote the uptake of a framework to embed the multiple benefits of water projects into decision-making processes. The framework seeks to outline a strategy for systematically identifying and incorporating the costs and benefits of water management strategies into decision making. The framework could be used by the public sector, for example, when evaluating which water supply/supplies or water quality interventions to pursue. Or, it could be used by the private sector, when assessing which projects to invest in within their value chains or as part of their philanthropic activities. By promoting a broader and more complete consideration of the wide range of benefits and costs associated with water management decisions, this work can help to:

- Broaden support for a policy or project;
- Identify opportunities to share costs among project beneficiaries;
- Minimize adverse and unintended consequences;
- Optimize the investment of time, money, and other resources; and
- Increase transparency associated with decisions.

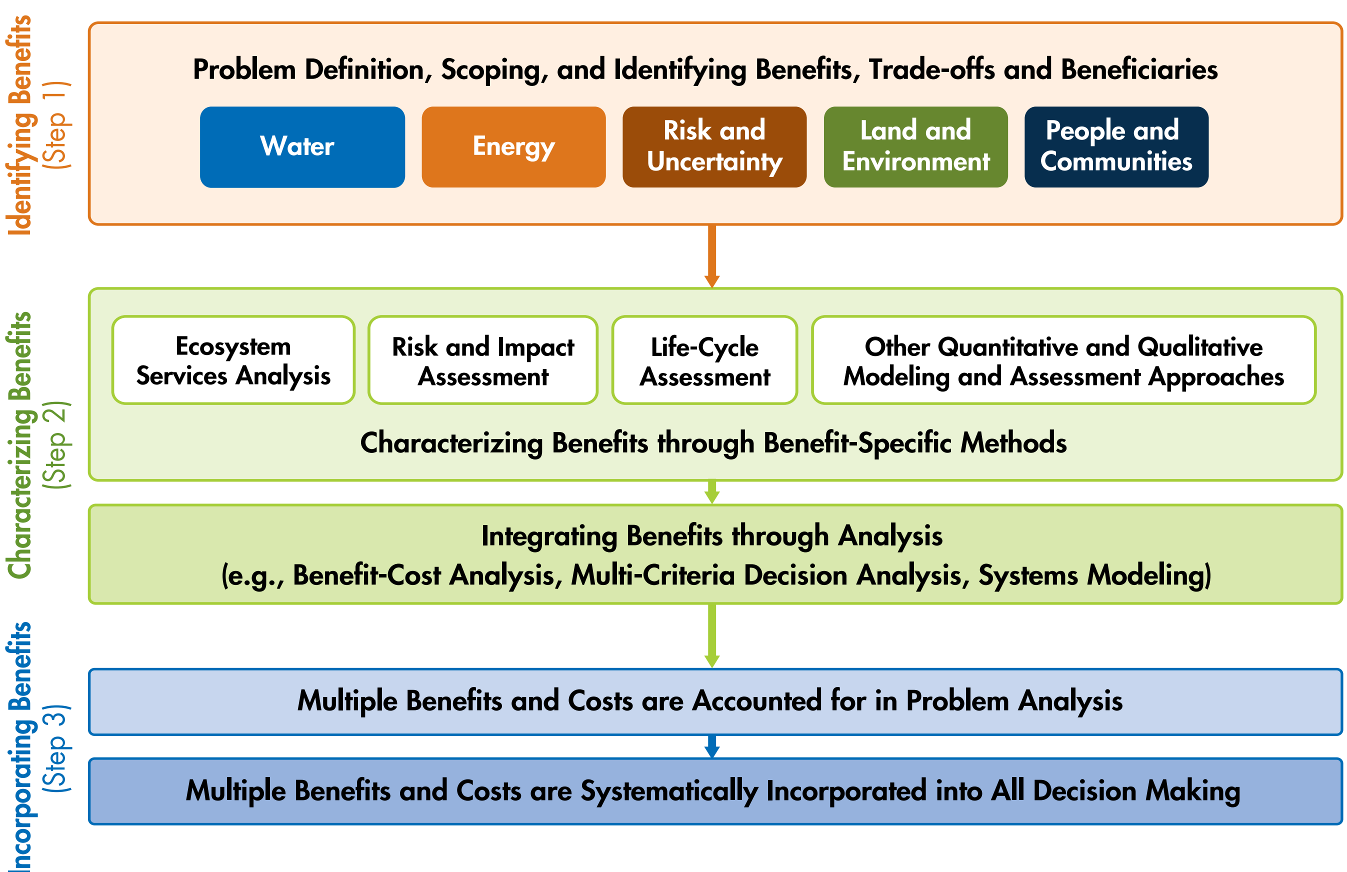
This initiative has three distinct phases. The goal of Phase 1 was to develop a draft framework and process for evaluating water projects by engaging a diverse set of stakeholders representing government, businesses, non-governmental organizations, investors, and decision makers. During Phase 2, we will be working with stakeholders to apply the framework to specific water management decisions, such as optimizing green infrastructure locations, evaluating the return on investment for water reuse, or developing an integrated water strategy. Phase 2 will allow us to refine the framework and develop resources to assist users in implementing the framework. Finally, in Phase 3, we will focus on embedding the framework into policy and planning. This report represents the culmination of Phase 1 of this work and includes a proposed framework for examining multiple benefits and trade-offs of water management.

Throughout Phase 1 of this work, we engaged with a diverse set of stakeholders (government, non-governmental organizations, businesses, water utilities, and community members) to develop a draft framework for evaluating multiple benefits of water projects. We identified a three-step, theoretical framework to expand the analysis of multiple benefits and better account for them in decision making (Figure ES1).

The **first step** of the framework is to define the problem, determine an appropriate scope, and identify the potential benefits and costs. This process is iterative and requires engagement with stakeholders to expand the framing of the

Figure ES-1.

Outline of the Multi-Benefit Framework, Including Three Steps Toward Systematically Incorporating Multiple Benefits into Decision Making



project, especially related to potential positive and negative impacts of water management strategies. In order to assist with identifying potential benefits and trade-offs, we conducted an extensive literature review and focused interviews with experts and practitioners. Through this process, we categorized over 100 potential benefits or trade-offs of water management strategies into five broad themes: (1) Water; (2) Energy; (3) Risk and Uncertainty; (4) Land and Environment; and (5) People and Community (Figure ES2). These themes provide a starting point for identifying and organizing benefits and costs more methodically and transparently.

The **second step** of the framework is to characterize benefits and costs. While there are many potential benefits, finding context-relevant, good-quality data to adequately assess each benefit is a common challenge. However, there are methods and tools available for conducting both quantitative and qualitative analyses of specific benefits and costs (e.g., an ecosystems services analysis) and for integrating these results into a comprehensive assessment of benefits (e.g., a benefit cost analysis).

The **third step** of the framework is to incorporate the benefits and costs characterized in step two into policy and decision making. The multi-benefit framework is designed to assist decision

Figure ES-2.

Benefit Themes for Identification of Relevant Benefits of Water Management Strategies

makers from government, corporations, non-governmental organizations, and other entities in developing the tools they need to consider the broad benefits and costs of water management strategies during decision making. This could include, for example, guidance for funding proposals on evaluation methods for multiple benefits or developing co-funding agreements and guidelines among agencies. In addition, we will explore how this framework can be integrated into existing decision-making and planning frameworks, such as Integrated Water Resources Management or One Water frameworks. Our research on improving decision-making processes to account for multiple benefits is in its early stages; however, we will continue to outline and expand this final step through continuing work.

KEY FINDINGS

We have developed several key conclusions and recommendations for integrating multiple benefits into water management decisions.

1. **Expanding the types of benefits and trade-offs considered in water management decisions can help broaden support for a policy or project; leverage resources from partners; minimize adverse and unintended consequences; increase transparency; and optimize the investment of time, money, and other resources.**

   While many government agencies, businesses, and non-profit organizations acknowledge the importance of multiple benefits, the full range of benefits are not routinely considered in analysis because we lack a consistent definition of multiple benefits and the tools and resources to adequately identify them. To address these challenges, we have developed a three-step process to support more deliberate consideration of benefits and trade-offs in water management decisions: (1) identifying benefits and trade-offs across five broad themes; (2) characterizing benefits using quantitative and qualitative metrics; and (3) incorporating that information into decision-making processes.

2. **Stakeholder engagement is essential for identifying and prioritizing benefits and trade-off**s.

   Throughout our research and discussions, water managers in the public and private sector stressed the importance of engaging with stakeholders to successfully identify and implement projects with multiple benefits. This process is not without challenges, such as the potential to delay projects. However, when effectively involved in the decision-making process, community members and agency stakeholders can drive projects that incorporate multiple benefits and reflect their needs and values. The multi-benefit framework may be able to assist water managers with stakeholder engagement by providing a platform for transparent and open discussions on project goals, broad benefits and beneficiaries, and trade-offs. In addition, the overall decision-making process is likely to benefit from stakeholder engagement through, for example, better communication with the public and support for the outcomes; financial support and improved relationships with partner organizations; and a smoother regulatory process (Jeffery 2009; Mitchell 2013; Alliance for Water Stewardship 2014).

3. **Equity should serve as an essential lens for evaluating water management strategies.**

   Water management projects are not intrinsically equitable or inequitable. Instead, equity is defined as the just distribution of benefits and trade-offs among stakeholders. For this reason, equity is not considered a "benefit" within the multi-benefit framework. Rather, it is a lens that should be applied to all benefits. In most decisions, benefits and costs cannot be distributed equally among stakeholders, and there will be communities, agencies, or ecosystems that benefit more or are harmed more than others. In order to advance equity, water managers and decision makers must identify stakeholders that are impacted by a decision, both positively and negatively, and work toward ensuring that the same stakeholders are not consistently receiving all the benefits or incurring all the costs. Examining the distribution of the proposed benefits and costs to a range of stakeholders through an equity lens in the initial project scoping can help promote a more transparent discussion about impacts to various stakeholders.

4. **Multi-benefit projects can advance collaboration among stakeholders and facilitate innovative funding opportunities.**

   Water management and infrastructure will require significant investment in order to address climate change, aging infrastructure, population growth, and environmental degradation. Funding for investments in water management remains a major challenge across the country. An explicit focus on multiple benefits provides an opportunity to more efficiently plan, implement, and fund projects that simultaneously meet multiple objectives. The prospect of incorporating new financial partners (i.e., co-financing) into water management projects is one of the strongest motivations for examining co-benefits. Significant effort is needed to support partnerships and co-fund projects that meet multiple objectives.

5. **Expanding the definition of the problem and the scope of the analysis will help to better integrate multiple benefits and trade-offs into water management decisions.**

   One of the keys to examining multiple benefits is carefully defining the water management challenges that are being addressed, and expanding the analysis to include a broader range of potential benefits and beneficiaries. The boundary or scope of the decision-making process determines the relevant stakeholders, geography, and benefits and costs considered within an analysis – what's in and what's out. Setting a scope that is too narrow runs the risk of ignoring important impacts that could alter the type of project pursued. On the other hand, expanding the scope of the analysis can increase the complexity of the project, resulting in a decision-making process that is too time and/or resource intensive. For example, a water supply agency may conclude that a stormwater capture project is not cost effective if it distributes the entire cost of the project over the amount of water that project yields and ignores other benefits, such as flood management and water quality, provided by the project. If these additional benefits are included, stormwater capture becomes significantly more cost-effective. If the scope is expanded to include multiple benefits, the water manager can more fairly compare projects and provide decision makers with adequate information to maximize investments in water management.

NEXT STEPS

The framework currently provides a theoretical approach to identifying and quantifying multiple benefits and costs of water management strategies. In Phase 2, we will conduct several test cases in order to refine and advance the framework. During

Phase 3, we will identify pathways to embed multi-benefit analyses and resultant information in policy and investment decision making, such as promoting uptake of the framework in funding proposal requirements and in integrated water management planning at the local, state, and federal levels. Ultimately, we believe that having a systematic framework will increase the usefulness and uptake of available data and allow for wider development of multi-benefit tools.

SECTION 1. INTRODUCTION

There is broad recognition that adapting to climate change, coupled with the need to address aging infrastructure, population growth, and degraded ecosystems, will require rethinking programs and policies and investing in our natural and built water systems. There are a variety of strategies for addressing water challenges, from watershed restoration and efficiency improvements to vegetated swales and green roofs. Because water is deeply linked with economic, environmental, and community well-being, many of these strategies can also provide other benefits, such as reducing energy use and greenhouse gas emissions, providing wildlife habitat, and enhancing community livability.

Source: Nathan Anderson, Unsplash

Water management relies on both natural systems and engineered infrastructure to address the broad range of global water challenges.

ADVANCING MULTIPLE BENEFITS: OPPORTUNITIES AND CHALLENGES

Government agencies, businesses, and others acknowledge the importance of multi-benefit projects and the potential for them to help build partnerships, leverage resources, and garner public support. Many have already developed and executed projects that achieve multiple benefits. For example, the Philadelphia Parks & Recreation, Capital Program, and Water Department co-funded improvements to the city's iconic recreation area on Benjamin Franklin Parkway, including infiltration trenches below the street that store and treat nearly 25,000 gallons of stormwater runoff per year. This project improved local water quality and supported Parks & Recreation's mission to connect communities with open space and recreation (Philadelphia Water Department 2018). Similarly, the Hampton Roads Sanitation District (HRSD) of southeast Virginia launched the Sustainable Water Initiative for Tomorrow (SWIFT) to address regional water quality impairments while mitigating land subsidence and saltwater intrusion from groundwater overdraft and rising seas (Mosher 2018). Rather than releasing nitrogen and phosphorous from treated wastewater effluent to nearby waterways, HRSD treats wastewater effluent to meet or exceed drinking water standards and injects it into the regional groundwater aquifer, which would eliminate more than 90 percent of HRSD's discharges to local waters by 2030, while recharging 120 million gallons per day into the local groundwater basin, and potentially reducing subsidence and mitigating some impacts of sea level rise in the region (SWIFT 2017).

While there are examples from around the United States of efforts to advance integrated projects that achieve multiple benefits, these efforts are not yet universal. One challenge is that the term multiple benefits is often loosely defined and thus associated benefits and costs are examined inconsistently. Multi-benefit projects are often defined as projects that provide more than one benefit or serve more than one purpose (see, for example, California State Water Resources Control Board 2015). This definition is inadequate for several reasons. First, flood management, water quality, and water supply are so interconnected that nearly every water-related project will touch on at least two of these categories. In addition, by emphasizing only two or three benefits, decision makers may ignore other benefits and/or trade-offs that could ultimately affect the project selected. For example, recycled water can be used to recharge groundwater, augmenting water supply while also raising groundwater levels and improving water quality (and thus reducing energy requirements for pumping and treatment). However, there may be additional energy requirements to treat the recycled water and impacts on environmental flows, highlighting the need to examine additional benefits or costs more systematically.

Various non-governmental organizations (NGOs), businesses, government entities, and academics have developed tools and resources to assist in identifying and quantifying the benefits of water management strategies; however, these tools and resources often focus on a single strategy (e.g., stormwater management or water efficiency) or a specific geographic location. For example, the Center for Neighborhood Technology developed a framework and the National Green Values Calculator for measuring and valuing the benefits of green infrastructure (Center for Neighborhood Technologies and American Rivers 2010). Similarly, the Greenprint Resource Hub is a web-based tool that helps communities identify conservation strategies and locations in their areas that will provide multiple benefits, including water supply and quality, open space, recreation, climate resilience, and others (Trust for Public Land, The Nature Conservancy, The Conservation Fund 2017). While these tools provide valuable insights into multiple benefits and water management, because these tools and resources are tailored to a single strategy or region, it is challenging to apply insights from the tools to a new project or strategy without significant investment of time and resources. For these reasons, water managers would benefit from a framework for systematically considering multiple benefits and costs and integrating them into existing decision-making frameworks.

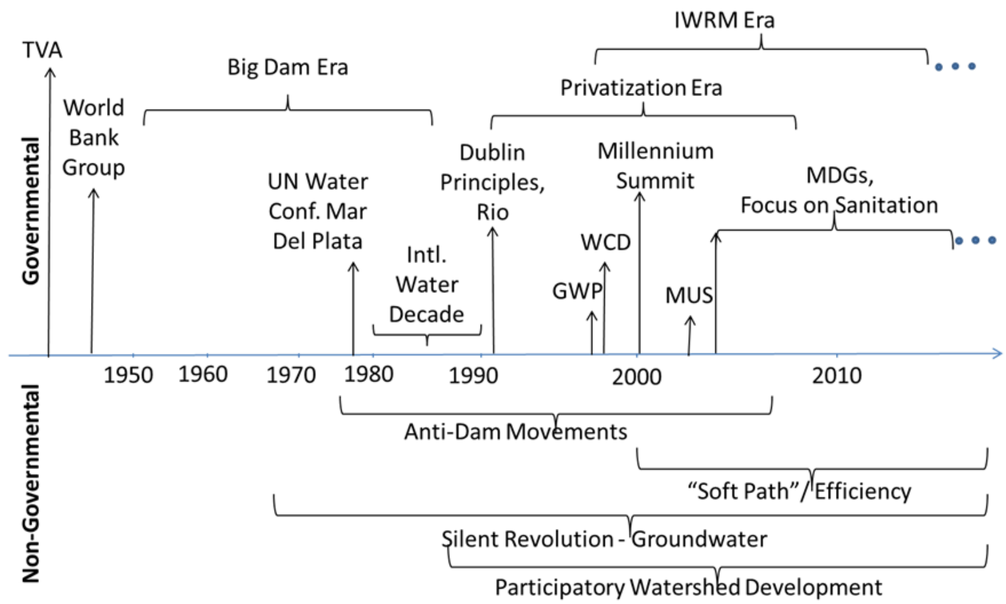
Advancements in Sustainable Water Management

Water management continues to progress over time as our understanding of the water cycle evolves, new issues emerge, and societal priorities change. Inclusion of multiple benefits into water management is a necessary continuation in water management that allows for a more holistic systems approach to achieving more sustainable water systems. Cooley et al. (2013) developed a timeline highlighting key conceptual frameworks for water resource development and management (Figure 1),

Figure 1.

Timeline Highlighting Key Conceptual Frameworks for Water Resource Development and Management

Source: Cooley et al. (2013)



including advances of both governmental and non-governmental frameworks. The current paradigm includes integrated water resources management (IWRM), millennium development goals and the UN's sustainable development goals, and a greater focus on efficiency, or the "soft path" to water management. In addition to the frameworks highlighted in Figure 1, there are additional efforts to address water challenges through corporate water stewardship, in which companies are identifying and managing water-related business risks and working to mitigate adverse impacts on the environment and communities. For example, companies such as Coca-Cola are setting "replenish" goals to return "an amount of water equivalent to what is used in finished beverages" to the environment (LimnoTech 2015).

There are a growing number of frameworks and resources for integrated planning and consideration of the multiple benefits of water management strategies. Frameworks, such as IWRM and One Water, can help facilitate consideration of broad themes and shape thinking around process and engagement. For example, the inclusion of specific benefits and costs is not explicitly addressed in IWRM, though there seems to be an implicit assumption that inclusion of relevant benefits and costs will occur organically if relevant stakeholder groups are meaningfully engaged throughout the basin planning process. The One Water approach specifically focuses on multi-objective projects and integration among water entities. Through this approach, One Water has significantly advanced work on multiple benefits by guiding entities to develop regional partnerships and integrate planning efforts among water-related entities.

A FRAMEWORK FOR MULTIPLE BENEFITS IN DECISION MAKING

To advance the consideration of multiple benefits and costs in water management, the Pacific Institute and Professor Bob Wilkinson of University of California, Santa Barbara launched an initiative to develop, build consensus around, and promote the uptake of a multi-benefit framework. This framework provides a general approach for examining benefits and trade-offs while allowing flexibility for application to a specific region, interest, or query. It can be used by the public sector, for example, when evaluating water supply or water quality management options. It can also be used by the private sector to prioritize investments within their value chains or as part of their philanthropic activities and by both the private and public sector when exploring partnerships. By promoting a broader and more complete consideration of the wide range of benefits and costs associated with water management decisions, this work can help to:

- Broaden support for a policy or project;
- Identify opportunities to share costs among project beneficiaries;
- Minimize adverse and unintended consequences;
- Optimize the investment of time, money, and other resources; and
- Increase transparency associated with decisions.

This initiative has three distinct phases. The goal of Phase 1 was to develop a draft framework and process for evaluating water projects by engaging a diverse set of stakeholders representing government, businesses, NGOs, investors, and decision makers. During Phase 2, we will work with stakeholders to apply the framework to specific water management decisions, such as optimizing green infrastructure locations, evaluating the return on investment for water reuse, or developing an integrated water strategy. Phase 2 will allow us to refine the framework and develop resources to assist users in implementing it. Finally, in Phase 3, we will focus on embedding the framework into policy and planning. In this report, we outline our initial thinking from Phase 1 around multiple benefits and water management and propose a process for advancing consideration of multiple benefits.

Organization of this Report

This report is organized into five sections. Section 1 provides an overview of the project and the report. Section 2 introduces the multi-benefit framework and outlines the three-step process for integrating multiple benefits into decision making. Section 3 focuses on the first step of this process: identifying and categorizing benefits and costs around five themes (water, energy, land and environment, risk and uncertainty, and people and community). This step has been the primary focus of our work to date. Section 4 is focused on step two of the framework and provides an initial assessment of approaches for characterizing benefits and costs, including analytical methods for specific topics (such as ecosystem services analysis) and integrating methods for consolidating individual benefits and costs into analyses (such as benefit cost analysis). Finally, Section 5 provides conclusions and recommendations for incorporating multiple benefits and costs into decision making.

SECTION 2. A PROPOSED MULTI-BENEFIT FRAMEWORK FOR WATER

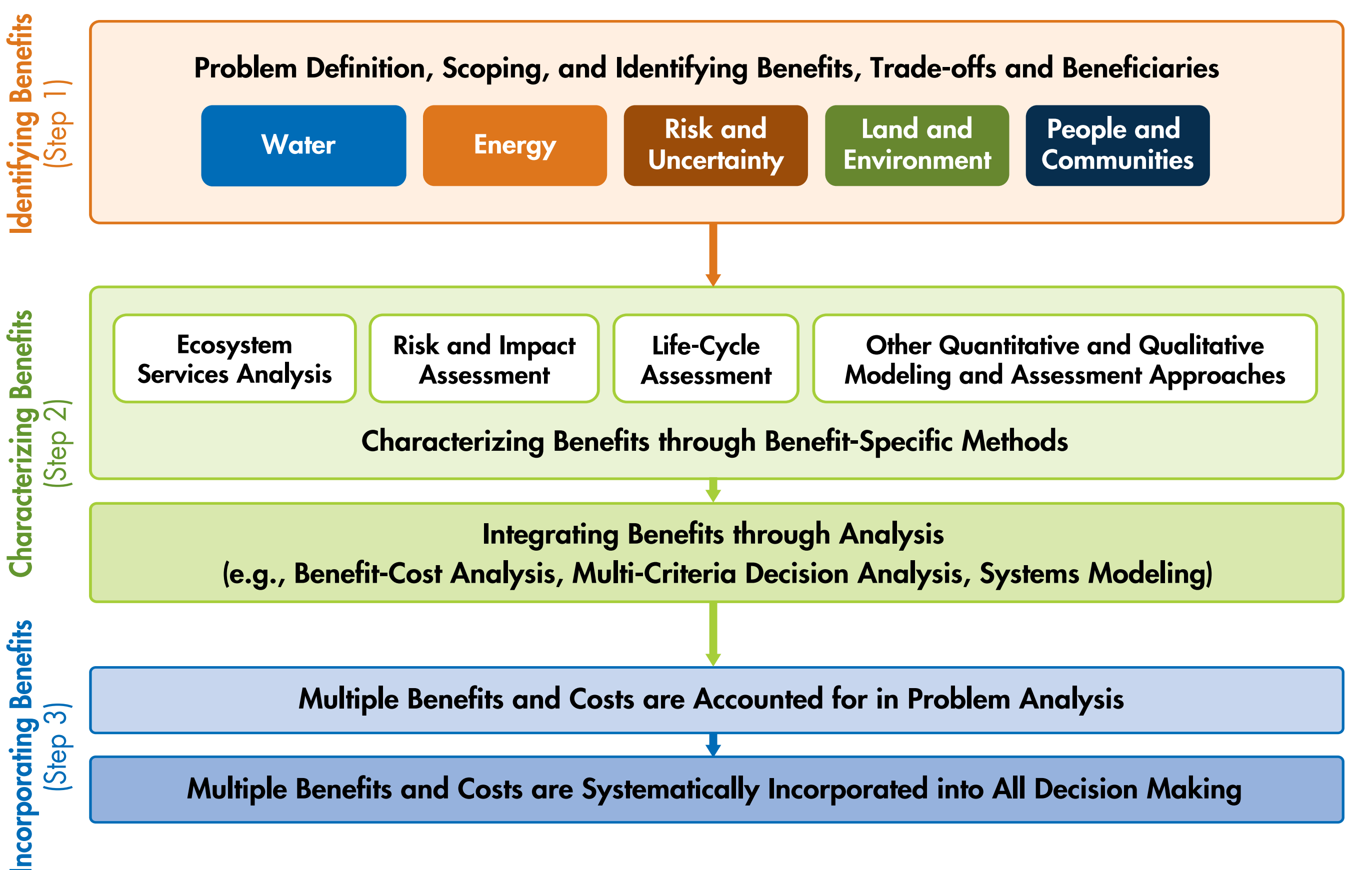
The goal of the multi-benefit framework is to provide a systematic and comprehensive approach for incorporating multiple benefits and costs into water management decisions. In support of this goal, we have developed a three-step process for an increasingly robust consideration of benefits and trade-offs (Figure 2). We describe each step in more detail below.

STEP 1: IDENTIFYING MULTIPLE BENEFITS AND COSTS OF WATER MANAGEMENT STRATEGIES

Recognizing that there are multiple benefits and trade-offs that often extend beyond the initial project motivation is the first step toward effectively integrating them into water investment decisions. For that reason, the multi-benefit framework begins with defining the problem, as well as identifying the range of benefits and costs and those affected by the decision, either positively and negatively. Deliberate consideration

Figure 2.

Outline of the Multi-Benefit Framework, Including Three Steps Toward Systematically Incorporating Multiple Benefits into Decision Making



of benefits and costs, even if a project does not advance through quantifying each benefit considered, can still provide advantages over the status quo by helping scope and develop projects, policies, and programs that acknowledge and/or address the needs and concerns of a diverse range of stakeholders.

Defining the Problem

Carefully defining the problem is critical. An overly narrow or ill-specified problem can limit the consideration of alternatives and potential benefits from the outset. For example, if an area is facing a water shortage, then defining the problem as lacking adequate water supplies tends to emphasize the development of new supplies as the solution. However, more broadly defining the problem as one of demand exceeding supply allows for consideration of measures to reduce demand as a solution. This requires a critical analysis of motivations, biases, and outcomes. Appendix B provides examples of questions to consider at the project outset to help clearly define the problem.

Source: Nserrano, Wikipedia Commons

In Los Angeles County, communities are working to improve water management through water conservation and alternative water supplies, improving water quality in rivers and at beaches, and reducing the impacts of flooding. In addition, stakeholders are engaging to improve the consideration of multiple benefits of water management, including engaging in urban greening and reducing energy demand.

Capturing multiple benefits and costs also often requires expanding the spatial and temporal boundaries for the assessment (i.e., what is in and what is out). Expanding these boundaries can also help to identify stakeholders, management strategies, and benefits and costs to consider throughout the analysis. Setting boundaries that are too narrow runs the risk of ignoring important impacts that could alter the type of project pursued. For example, a water supply agency may conclude that a stormwater capture project is not cost effective if it distributes the entire cost of the investment over the amount of water that the project yields and ignores the flood control, water quality, and other benefits provided by the project. On the other hand, setting boundaries that are too broad could increase the complexity of the project so much that the decision-making process becomes too time and/or resource intensive.

Identifying Benefits and Costs

Traditional cost-benefit analyses focus on tabulating benefits and costs that can be monetized, often missing important benefits and trade-offs that are more difficult to quantify. However, many decisions are informed by qualitative data or even emotions that are not included in these analyses. Beginning the analysis at identification of all benefits and costs (regardless of quantification or data availability) helps more transparently identify benefits and trade-offs that may have previously been ignored, as well as areas to continue research or analysis.

Stakeholders can be especially helpful in identifying potential benefits and trade-offs. Stakeholders are broadly defined as those who are affected by or have an interest in any project, program, or policy, and can include community members, NGOs, businesses, government agencies, and institutions. Engagement with stakeholders can help to get more ideas on the table and provide insights and perspectives that may have otherwise been missed. While decision makers often engage with stakeholders in later steps of project development, early engagement can substantially improve the decision-making process, by guiding and assisting with defining the problem, identifying the benefits and costs, defining the decision, and supporting the project process. Effective engagement relies on building relationships with stakeholders and then meaningfully incorporating their input into the decision.

For example, in 1998, the Watershed Management Division of the Los Angeles County Department of Public Works formed a stakeholder group to address significant flooding in the Sun Valley Watershed (Sudman et al. 2006). The group, called the Sun Valley Watershed Stakeholders Group, was composed of local, regional, and federal government agency representatives, environmental groups, local businesses, and community members. The group first identified planning objectives to broadly define and examine the potential costs and benefits of each project alternative. These included impacts to flood control impacts, water conservation, recreational opportunities, wildlife habitat, and reducing stormwater pollution (County of Los Angeles 2004). These potential benefits were then incorporated into the evaluation process using a matrix with quantitative and qualitative metrics for each project alternative. Comparing costs and benefits in a variety of categories allowed for a fairer comparison of each alternative and a more transparent process. Ultimately, the water management solutions implemented alleviate flooding while also providing many additional benefits, such as community park space that concurrently recharges groundwater, and bioswales along neighborhood streets that capture stormwater and improve water quality.

STEP 2: CHARACTERIZING BENEFITS AND COSTS

The second step of the framework is to characterize benefits and costs. While many potential benefits can be identified, finding context-relevant, good-quality data to adequately assess them is a common challenge. During this step, analysis tools are compiled or developed, and additional analysis criteria are set.

Quantitatively and Qualitatively Assessing Benefits and Costs

There are a variety of methods and tools available for conducting both quantitative and qualitative analyses of specific benefits and costs and integrating these results into a comprehensive assessment of multiple benefits. We have categorized these methods as benefit-specific methods and integrating methods. Benefit-specific methods are applied to characterizing a specific benefit or cost identified in step one, and integrating methods seek to compile the outputs of benefit-specific analyses to allow for comparison and decision-making. Several specific classes of tools, methodologies for conducting these analyses, and the pros and cons of each are discussed in Section 4.

Defining Decision Criteria and an Appropriate Baseline

At the characterization stage, it is necessary to define which decision criteria should be considered for comparing water management options, including weighting schemes and relevant metrics that account for specific benefits and costs to the project or policy context. For example, funding requirements or sustainability goals might dictate optimization of specific benefits, such as increased local water supply reliability. Decision makers can develop criteria and metrics to select a project, incorporating the importance of supply reliability and developing weighting against other facts, such as total cost or net cost (cost minus benefit), energy consumption, and/or impact on disadvantaged communities.

Stakeholder consensus can assist in setting effective decision criteria and providing weighting schemes for desired outcomes for both quantifiable and non-quantifiable benefits and trade-offs. In the Sun Valley Watershed example above, stakeholders helped to define the project objectives and increased the number of decision criteria and weighting to include additional positive environmental outcomes.

Engaging with stakeholders can also help define an appropriate baseline. The baseline determines the water management strategy that other projects will be compared against. This impacts both the directionality of the benefits or costs and overall perceived value of the project. For assessments of green infrastructure, the baseline is typically grey infrastructure. For example, the benefits and costs of a bioswale may be compared to those of a traditional curb and gutter system. In these cases, an impact is deemed a "benefit" if it improves conditions and a cost (or trade-off) if it worsens conditions relative to grey infrastructure. Explicitly setting the baseline at this step allows for a more systematic comparison of project benefits and trade-offs relative to a set standard.

STEP 3: INCORPORATING MULTIPLE BENEFITS AND COSTS INTO DECISION MAKING

Our goal through the multi-benefit framework is to assist decision makers from government, corporations, NGOs, and others in developing the tools they need to consider the broad benefits and costs of water management strategies during decision making. This could include, for example, guidance for funding proposals on evaluation methods for co-benefits or developing co-funding agreements for a broader range of benefits and guidelines among agencies. In addition, this could include incorporating multiple benefits into existing frameworks.

There are a growing number of frameworks and resources in a wide variety of sectors for integrated planning and consideration of multiple benefits to solve global challenges. Climate Interactive, for example, has developed and advanced a concept called "multi-solving," which is an approach for identifying solutions that can solve multiple problems with a single intervention (Sawin 2015). The multi-benefit framework seeks to use this systems-level thinking to support water managers in developing the connections between water management and multiple benefits, and integrating this into existing planning and decision-making frameworks.

SECTION 3. IDENTIFYING BENEFITS OF WATER MANAGEMENT

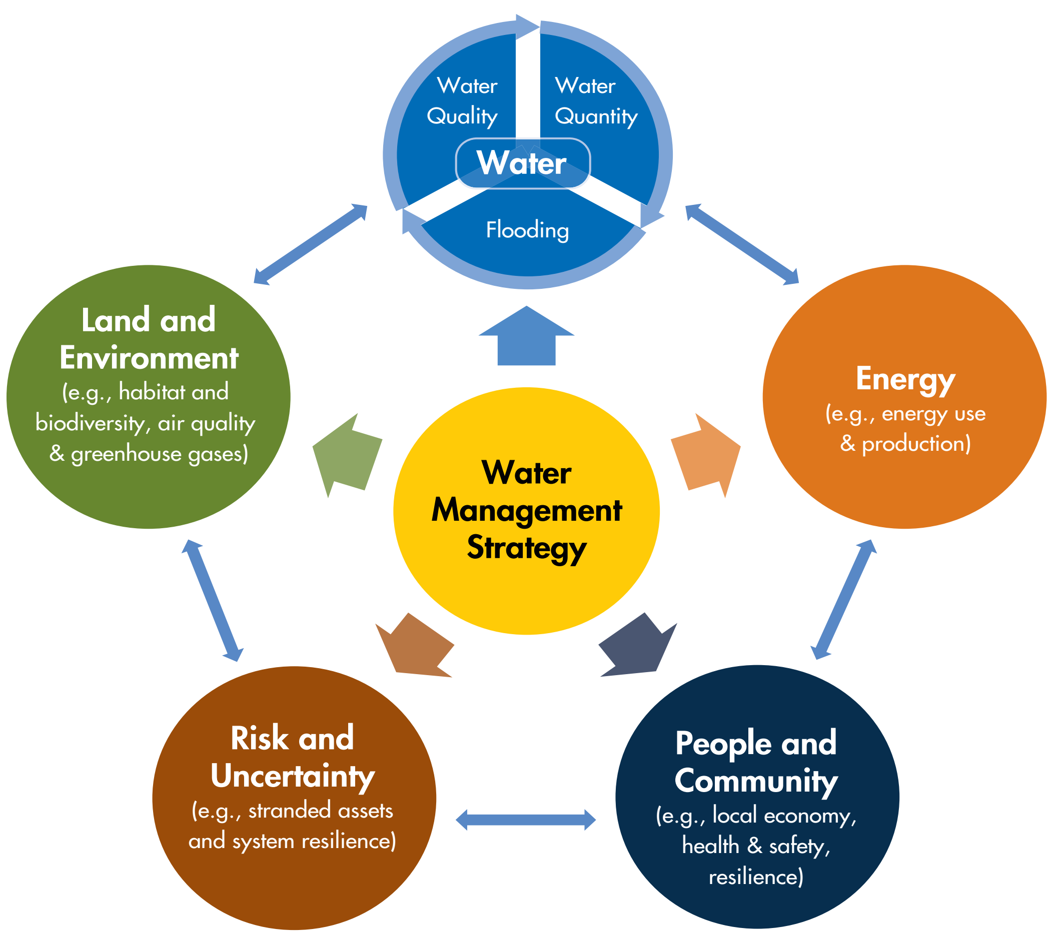
The first step in the framework is recognizing that benefits and trade-offs exist and often extend beyond the initial motivation of the project, program, or policy. To better understand the range of potential benefits associated with water management decisions, we conducted an extensive review of reports, journal articles, and government reports; interviewed subject matter experts and decision makers (see Appendix C); and facilitated discussions with stakeholders. Through this effort, we identified a broad range of unique benefits and costs (Appendix D), which we group into five broad themes (see Figure 3):

- Water (e.g., water quantity, water quality, and flood control);
- Energy (e.g., energy use and energy production potential);
- Land and environment (e.g., habitat and biodiversity, air quality, and greenhouse gas emissions or reductions);
- Risk and uncertainty (e.g., physical, reputational, and regulatory risk; and system resilience); and
- People and community (e.g., local economy, health and safety, vulnerability to water challenges, and community resilience).

Within the literature, we found direct connections between water and the other themes, as well as

Figure 3.

Benefit Themes for Identification of Relevant Benefits of Water Management Strategies



connections among and between the other themes. While this section focuses on a discussion of direct benefits of water management to each theme, additional relationships between strategies and benefits exist and should be explored in more detail. For example, water reuse may improve ocean water quality (water theme), which can foster the health of the marine ecosystem (land and environment theme) and in turn improve recreational opportunities and the local economy (people and community theme). Similarly, source water protection is increasingly viewed in concert with fire management, and thus can provide protection against catastrophic fires and decrease impacts resulting from the fires on water quality (Abell et al. 2017). In-turn, fire risk reduction and management can positively impact water quality and drinking water utilities (Sham, Tuccillo, and Rooke 2013). Careful consideration of the connections between these themes can allow for a more integrated and systems-level analysis of water policies, programs, and projects.

This section includes a discussion of benefits and trade-offs within each of the themes, focusing on direct relationships and using examples to highlight the relationships between the strategies and their benefits and costs.

WATER

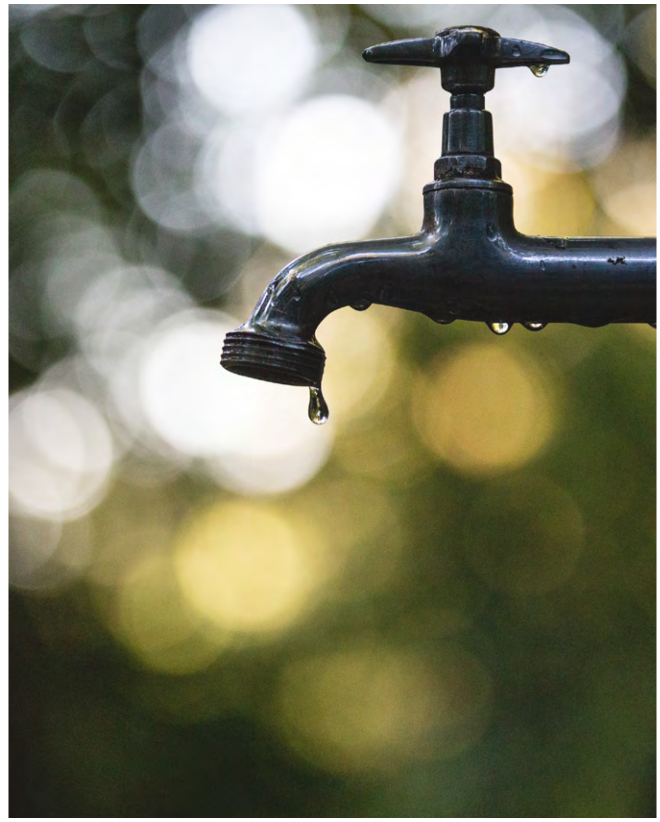
Water supply, water quality, and flood management improvements are often the primary objectives of water management decisions. While water management decisions are often designed and implemented to advance one of these objectives, there is now greater awareness of the relationships among them due, in part, to recent frameworks, such as IWRM and One Water. Increasingly, water managers are developing policies, programs, and projects that meet multiple water-related objectives.

Stormwater management is among the most commonly cited multi-purpose or multi-benefit strategy. Traditional stormwater management has sought to control flooding by quickly and efficiently routing stormwater away from urban centers through storm drains, gutters, pipes, channels, and tunnels. As the water is routed across urban surfaces, however, it carries pollutants, including oils, heavy metals, salts, and soils into nearby waterbodies (Arnold and Gibbons 1996). There is growing interest in using green infrastructure to mitigate flood risk by slowing floodwaters and allowing for greater infiltration, thereby improving water quality and augmenting water supply. For example, Odefey et al. (2012), entitled "Banking on Green," describes the economic benefits of stormwater management for managing runoff, reducing flood impacts, and additional benefits. Similarly, Mika et al. (2017) found that stormwater management could effectively improve water quality for a number of constituents while also increasing local water supplies in Los Angeles.

Managed aquifer recharge (MAR) is another water management strategy that can provide benefits to several aspects of water management. MAR generally denotes investing in large-scale water capture projects that route stormwater, surface water, treated wastewater, or flood water to a groundwater recharge area. Perrone and Rohde (2016) examined MAR projects in California to determine the economic costs and benefits of these projects. While the primary benefits reported were increased water supply, water supply diversification, and flood protection, many additional benefits were cited. Additional benefits (in decreasing number of citations) included improving water quality, protecting wetland habitat, banking groundwater, creating seawater barriers, reducing water imports, increasing efficiency, reducing greenhouse gases, and mitigating subsidence (Perrone and Rohde 2016). While these strategies do provide substantial water-related benefits, there are criticisms that MAR alters natural flow regimes and may impair receiving waters (Burns et al. 2012).

While stormwater and flood water management are often examined and implemented to achieve multiple water-related benefits, there are additional management strategies that can impact more than one aspect of the water cycle. For example, water conservation and efficiency are broadly recognized for their water supply benefits, but they provide additional benefits. Improving efficiency can save energy, reduce the cost of providing water and wastewater service, and improve in-stream flows (California Department of Water Resources (CA DWR) 2009; American Rivers 2010; Dziegielewski 1999; Alliance for Water Efficiency, American Rivers, and Environmental Law Institute 2011). In an example from southern California, water efficiency reduced demand for groundwater, allowing local groundwater levels to rebound, even during the 2012-2016 drought (Davis 2019). Cooley and Phurisamban (2017) showed that energy and maintenance benefits make water efficiency measures the most cost-effective option for improving water supply reliability.

There is growing interest in exploring the relationships between water quality, water quantity, and flooding within whole watersheds. For this reason, upstream watershed restoration and protection projects are increasingly being considered as part of water management for enhancing water quality, improving ecosystem health, and reducing water treatment costs (Abell et al. 2017). In addition to benefits to carbon sequestration, habitat, and biodiversity, forest protection can provide substantial benefits for flood control and water quality benefits, especially resulting from decreased runoff and



Source: Luis Tosta, Unsplash

Water conservation and efficiency play an essential role in ensuring long-term water supply reliability. In addition to reducing water demand, water conservation and efficiency can result in significant energy and cost savings.

erosion. Additional research is being conducted to examine the role that forest restoration can play in water yield. In a review of 666 journal articles and studies conducted on the impact of forest restoration and water yield, restoration activities generally decreased surface water yield; however, research has largely ignored potential benefits to other aspects of the water cycle, such as evapotranspiration (Filoso et al. 2017).

While many water management strategies provide multiple benefits, many of them also have costs or trade-offs associated with them. For example, while on-river water storage projects, such as dams and reservoirs, can provide multiple benefits, these benefits are not always weighed consistently against trade-offs. The majority of federal reservoirs are authorized for four or more purposes, including hydropower, recreation, water supply, navigation, irrigation, and flood control. Bonnet et al. (2015) developed a methodology for evaluating the economic benefits of multi-purpose reservoirs in the United States and found that recreation accounts for the largest overall economic benefits of many reservoirs, especially those with smaller hydropower capacity. However, the methods for examining the benefits of multi-purpose reservoirs did not include the costs or trade-offs, such as impacts to environmental flows, greenhouse gas emissions from submerged, decaying vegetation, or loss of land-based ecosystems.

ENERGY

Water and energy are intricately connected, and water management decisions can have a dramatic impact on energy use and generation. Water is used to extract and produce energy; process and refine fuels; construct, operate, and maintain energy generation facilities; cool power plants; generate hydroelectricity; and dispose of wastes. Thermoelectric power generation alone accounted for more than one-third of national freshwater withdrawals in 2015 (Deiter et al. 2018). Likewise, there are energy inputs at all phases of water provision and use, from extraction to treatment to distribution to use, and finally to the collection, treatment, and discharge of wastewater. Sanders and Webber (2012) estimated that 12.6 percent of national primary energy consumption (12.3 ± 0.346 quads) in 2010 was related to water, with the greatest consumption associated with end uses, such as heating water, in urban and agricultural settings. In some regions, such as California, the energy requirements of water provision and use are even higher because water is transported over long distances and steep terrain (California Energy Commission (CEC) 2005; GEI Consultants and Navigant Consulting 2010). Additionally, some water management strategies can affect building heating and cooling requirements. Green roofs, for example, reduce stormwater runoff while also insulating the building and reducing energy use (Carter and Keeler 2008).

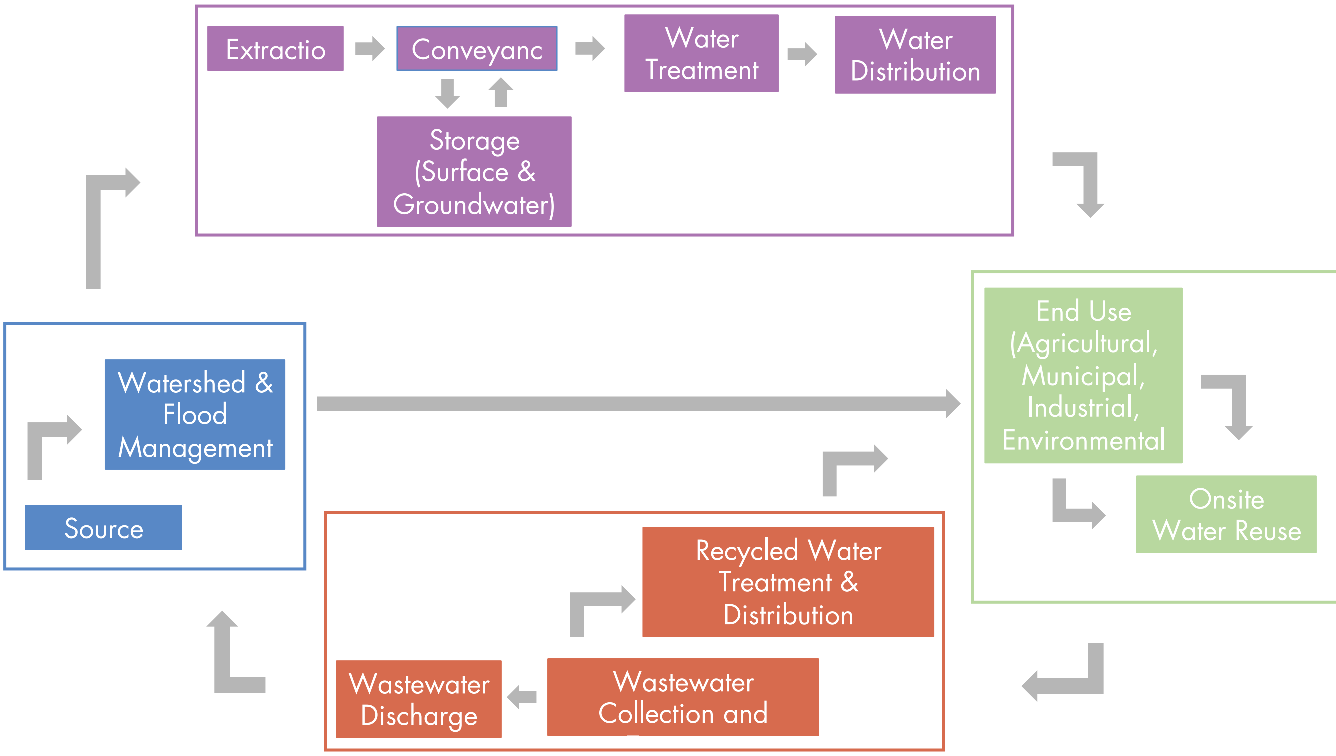
Methodologies and tools have been developed to better account for the energy used in water systems and water used by energy systems. Figure 4 presents a flow diagram for assessing the energy inputs of water systems and is applicable to a broad range of water sources, from local and imported surface supplies to groundwater, ocean desalination, water recycling, and rainwater harvesting. It has been used as the basic approach to calculate the energy intensity of water supplies by several entities in the United States and in other countries and forms the basis of an open-access computer model, called The Water-Energy Simulator, created by the Pacific Institute and the Bren School at the University of California, Santa Barbara (Cooley and Wilkinson 2012).

Water use efficiency improvements also typically reduce overall energy consumption, such as lower energy requirements for water pumping, treatment, and end use (with less pollution and water use related to energy production as a result) and reduced water and wastewater infrastructure capacity and processing requirements (Wilkinson 2015). In response to the ongoing drought, California instituted mandatory drought restrictions in 2015 that reduced urban water usage by nearly 25 percent compared to 2013 levels. Spang, Holguin, and Loge (2018) found that water conservation mandates reduced electricity use by 1,830 GWh, 11 percent greater than the savings from the efficiency programs run by all the investor-owned utilities in California combined, and reduced greenhouse gas emissions by 524,000 metric tons of carbon dioxide equivalents (see Figure 5).

Figure 4.

Flow Diagram of Energy Inputs to Water Systems.

Purple Shows Pre-Use Management, Green Shows Water Use and Potential Reuse, Red Shows Post Use Management, and Blue Shows Natural Systems. Grey Arrows Denote Water Flows



Source: Adapted from Wilkinson 2000; CEC 2005

Energy production through hydropower generation is also an important component of the water-energy nexus. Hydropower generation is highly dependent on in-stream flows, and decisions that affect flows can have a dramatic impact on hydropower production (Gleick 2015). For example, during the 2001 drought in Washington State and nationwide energy crisis, the Columbia Basin Project diverted large volumes of water from the Columbia River upstream of hydroelectric dams, reducing downstream energy production. Cohen, Nelson, and Wolff (2004) suggest that "during dry years, when power costs are high and agricultural commodity prices are low, the value of this energy potential may be large enough for voluntary fallowing programs to pay farmers more than they could earn growing low-value crops and still have enough money left to purchase environmental flows."

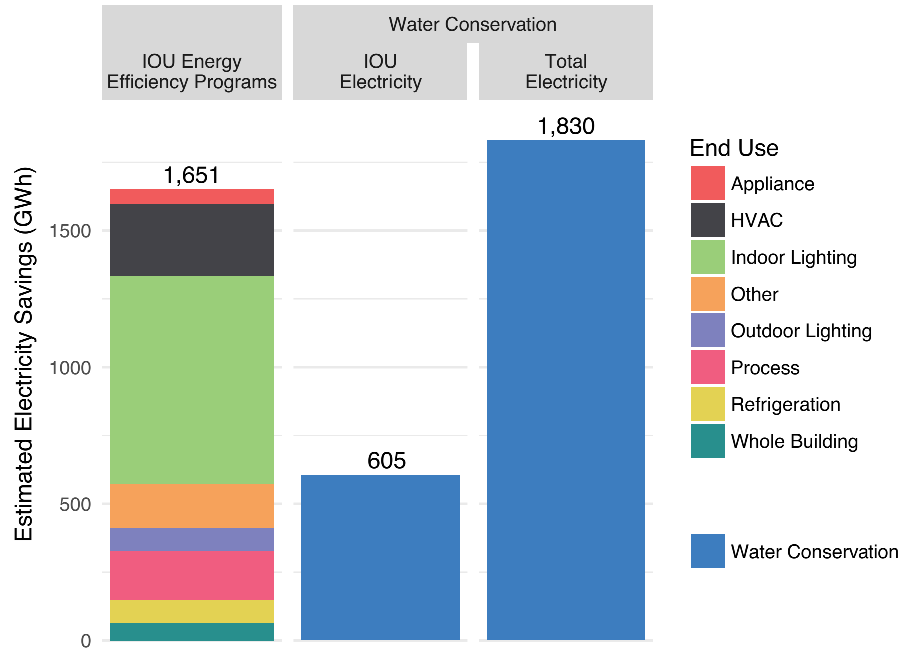
LAND AND ENVIRONMENT

Water is directly connected to land and the environment, including habitat and biodiversity; air quality and greenhouse gases (GHGs); and soil health and agricultural sustainability. Research on ecosystem services has advanced dramatically over the past several decades, and there is a growing body of literature on indicators and

Figure 5.

Estimated Electricity Savings from Statewide Drought Water Conservation Mandate Compared to Investor Owned Utility (IOU) Efficiency Programs

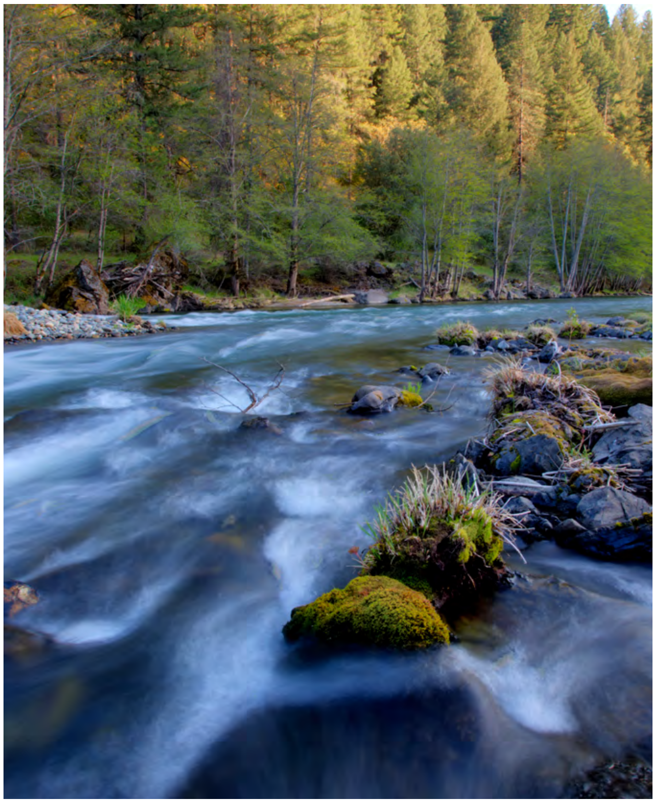
Source: Spang, Holguin, and Loge (2018)



metrics for assessing the benefits and trade-offs of water management projects. Many land and environment benefits can be quantified, such as the impacts of water projects on GHG emissions and capture or the capture of other contaminants. While environmental economists may differ in their methods for monetizing or evaluating these benefits, there are many indicators and metrics that can help determine the net benefits and negative impacts derived from water management projects.

Healthy aquatic ecosystems depend on adequate water quality and water flows. Water management strategies that improve water quality through environmental remediation can enhance or protect ecosystem health. For example, industrial wastewater treatment reduces contaminant concentration or loading, which can be readily quantified and often monetized. Similarly, stormwater management often focuses on reducing contaminant loading to nearby waterways through active or passive treatment. The International Stormwater Best Management Practices (BMP) Database provides data on the efficacy of particular stormwater practices for reducing contaminant loads and can help to quantify the expected water quality benefits of these projects (International Stormwater BMP Database, 2018). In addition, water supply projects can affect surface water ecosystems or groundwater-dependent ecosystems, especially through impacts on in-stream flows and groundwater recharge. By ensuring adequate quality and quantity of water in environmental flows, water management strategies can support healthy habitats and biodiversity.

Land management practices, such as reforestation, are increasingly recognized for the potential benefits to water management, especially water supply and water quality, in addition to the many established benefits to habitat and biodiversity. A recent study from Earth Economics found that forests in Pierce County, Washington improve water storage in soils and groundwater and improve water quality, while also sequestering carbon, providing habitat, and reducing soil erosion (Van Deren et al. 2018). Similarly, sustainable agricultural land management practices can also provide benefits through provision of ecosystem services while improving soil organic matter and water holding capacity. Foley et al. (2005) developed a conceptual



Source: Bureau of Land Management

In addition to providing habitat and sequestering carbon, healthy forests can provide a large number of benefits for water management. Increasingly, water managers are investing in protecting forests to protect water supply, improve water quality, and reduce flooding.

framework for examining ecosystem services provided by cropland. This work was expanded by the California Department of Food and Agriculture Science Advisory Panel to define 13 categories of services or benefits provided by agriculture (Gunasekara 2013), including pollination services, biodiversity, and wildlife habitat.[1] These benefits, when characterized, can be compared to any costs of agriculture in each of these areas to determine net benefits and beneficiaries.

1 These benefit categories include wildlife habitats; nutrient cycling; food, fiber and fuel production; recreation and culture; soil structure, formation and fertility; biodiversity conservation; water cycling; atmospheric gas/climate regulation; water quality; pest control; and pollination services.

There is a strong relationship between water and energy, and by extension, the air pollutants derived from energy generation. The air pollutants released depend on the energy generation method and fuel source (e.g., coal, natural gas, hydropower, and solar), although GHGs and criteria pollutants are of particular concern. As discussed in the energy theme above, water and energy are strongly linked and thus water management decisions have dramatic impacts on energy consumption and related GHGs and air pollutant emissions. For example, Kavvada et al. (2016) demonstrates that the location and elevation of decentralized and centralized non-potable water reuse systems dramatically influence overall energy consumption and GHG emissions. In addition, many agencies and organizations have adopted GHG emission reduction targets, and there are a variety of water management strategies available that can help meet those targets.

We acknowledge that not all impacts to ecosystems are readily apparent. For example, water reuse can impact aquatic ecosystems positively and negatively in different ways. Many utilities are seeking water reuse strategies to reduce effluent and allow them to reduce or eliminate wastewater discharge to surface waters, thereby improving local water quality (Bischel et al. 2012). In addition, water reuse can provide an additional source of water that can reduce water withdrawals or imports. However, these types of changes to a water system can impact other aspects of the watershed. For example, water reuse projects may reduce historic releases of treated wastewater effluent to nearby surface water and impact aquatic ecosystems either positively or negatively. In some cases, water reuse can reduce water availability for instream flows and downstream users (Zoltay, Kirshen, and Vogel 2007). In others, the water quality improvements from reduced effluent are beneficial to downstream ecosystems. The complexity of many water systems can present a challenge to determining the net impact of projects on ecosystem health; however, defining the many positive and negative impacts can allow for more transparent comparisons among strategies.

RISK AND UNCERTAINTY

There are a variety of risks and uncertainties associated with water management, and they can be related to environmental and socioeconomic conditions as well as technological and human performance. Water investments, for example, have a variety of known and unknown risks that can affect the ability to attract financing, the rate of return, and the overall viability of a project. Known risks can include changes in construction or operating costs compared to proposed costs or a project yield that is less than expected. These known risks are often accepted as part of project development. However, less traditional water management strategies often have risks that are not as well characterized. As a result, project developers may avoid new projects due to the real and perceived risks while accepting the known risks associated with more traditional projects.

For example, water systems traditionally have been highly centralized, although there is new interest in more distributed systems. There are additional risks associated with distributed systems compared to centralized systems, such as increased public health risks and the real or perceived risks of reliability of these systems (Institute for Sustainable Futures 2013). However, distributed water systems can provide multiple benefits that may outweigh the change in risk, including resource recovery, enhanced resilience, flexibility to meet new demand, corporate sustainability, and healthier ecosystems (Charting New Waters 2014). A systematic analysis of trade-offs and benefits can help to identify, compare,

Source: Sharon Wills, iStock

Distributed rainwater capture, like the rain tanks pictured here, can help to reduce stormwater runoff and provide water for landscaping or other non-potable uses.

and incorporate risk and uncertainty into a fair comparison of water management options.

Risk also comes from uncertainty in water planning. Water demand forecasting is used to estimate the future water demand needed within a particular service area, and inaccurate forecasts present a substantial risk to water suppliers. On the one hand, overestimating demand can lead to costly investment in unneeded infrastructure and water supply sources, with higher water bills and potential environmental impacts. Yet, underestimating future water demand could contribute to water supply shortfalls, temporary increases in water bills, or the imposition of emergency cutbacks (Heberger, Donnelly, and Cooley 2016). Development of more robust scenario planning tools and closely monitoring water use trends can help agencies to more accurately forecast future demand. In addition, there are water management strategies that can help to reduce uncertainty and associated risk of, for example, stranded assets or water shortfalls. Water conservation and efficiency programs (and the resulting reduction in water demand) can reduce or eliminate the need for new water and wastewater treatment, storage, and transport infrastructure, thus reducing the risk of future stranded assets (Dziegielewski 1999; Alliance for Water Efficiency, American Rivers, and Environmental Law Institute 2011).

Increasingly, the private sector recognizes the risks water poses to their business activities and the importance of identifying and mitigating those risks. For example, water scarcity can halt industrial production because there is not enough water available. Likewise, a contaminated water supply may require additional investment and increase operational costs for pre-treatment. Increasingly, companies are performing water risk assessments to understand and mitigate their risk, using, for example, the World Resource Institute's Aqueduct Water Risk Atlas and the World Wide Fund for Nature's Water Risk Filter. In general, these tools help users identify water risk "hot spots" around the world and are followed up with more detailed local assessments, where appropriate. A growing number of companies are implementing a range of measures, such as building onsite reuse systems and improving access to water and sanitation to nearby communities, to mitigate water risks and help enable more sustainable management of shared freshwater resources.

PEOPLE AND COMMUNITY

Water management strategies can provide a wide range of benefits to people and communities, such as human health and well-being, aesthetics, reduced crime, reduced urban heat island effect, economic security, recreation and appreciation for culture and art, among many others (Andersson-Sköld et al. 2018; Abdullah and Blyth 2016; Bonnet et al. 2015; Driscoll et al. 2015; Kondo et al. 2015). We group these benefits into three broad categories: local economy, health and safety, and community resilience.

Water management practices can support economic activity within a community, including increasing access to jobs, property values, and sustainability of local businesses (Odefey et al. 2012; Moore et al. 2013). In Philadelphia, for example, investment in green stormwater infrastructure (GSI) has had a dramatic effect on the local economy within just five years, resulting in significant job creation, more tax revenue, and higher property values (Sustainable Business Network of Philadelphia 2016). Because GSI projects are typically smaller than traditional grey-infrastructure projects, smaller, locally-based firms can more easily secure contracts for the work, supporting local jobs and businesses.

These benefits are not limited to Philadelphia or to GSI. The Green Remediation approach, developed by the US EPA, demonstrates how incorporating sustainability principles into the remediation of contaminated sites can reduce project cost, provide additional property use opportunities, and strengthen local economies (US EPA 2008). By remediating land to support additional uses, such as business or recreation, green remediation projects can increase economic gain for landowners. For example, an engineered wetlands system was installed to remove gasoline from contaminated groundwater in Casper, Wyoming, allowing for site redevelopment with an office park and recreational facilities, including a kayak park and golf course (US EPA 2008). In Fort Worth, Texas tree plantings were used to promote biodegradation of contaminates impacting the soil and shallow groundwater. Eventually the land was transferred to the community for use as open space, enhancing local recreation (US EPA 2008).

In addition to supporting the local economy, water management can improve the health and safety of communities, including mitigating the urban heat island effect, reducing crime, increasing recreational opportunities, and improving public health. For example, strategies that reduce impervious surface and increase green space can provide significant reduction in urban heat island effect, improving human health and reducing water demand for irrigation (Vahmani and Jones 2017; U.S. EPA 2014).[2] In addition, green stormwater infrastructure has been shown to reduce crime from narcotics manufacturing and burglaries near the project sites (Kondo et al. 2015) and can be designed to increase bicycle and pedestrian safety (Hjerpe and Adams 2015).

Water management strategies can affect community resilience, defined here as access to basic needs for a community to thrive, including access to safe and affordable water, social networks, nutritious food, educational opportunities, and cultural and recreational resources. Water affordability is a growing concern in communities across the United States, and water management choices can have a dramatic impact on the cost of water. Water management strategies can have a dramatic impact on the capital and operating costs of water utilities, and thus the affordability of water service. For example, a study by the Alliance for Water Efficiency found that water conservation and efficiency reduced water rates in Tucson and Gilbert, Arizona by 11.7 percent and 9.0 percent, respectively, due to the avoided cost of water investments in the system, including infrastructure to deliver and treat water and wastewater (Mayer 2017b, 2017a). Additional research from the Water Research Foundation suggests there is an economic case at the utility level for retrofit programs for water-efficient devices, especially for low-income customers (Cromwell et al. 2010). The researchers cited a program in Austin, Texas, which saved a larger volume of water at a lower cost for the utility by providing high-efficiency toilets to low-income customers for free as compared to rebate programs for higher-income customers (Beecher, Chesnutt, and Pekelney 2001).

Source: J. Bryson, iStock

Communities can integrate important benefits into water management strategies, such as supporting a community garden with captured rainwater. These projects can improve access to nutritious foods and green space, educational opportunities, and recreation.

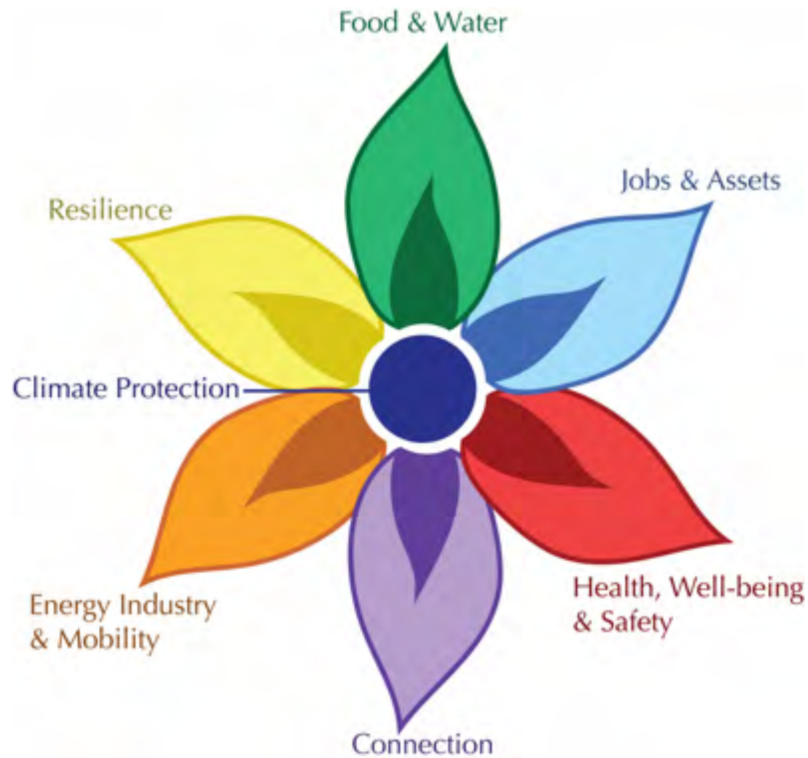
Watershed protection, for example, can preserve significant cultural and spiritual resources, including for Native American Tribes. The value of cultural resources are usually not included

2 The urban heat island effect refers to the heat caused by urban areas with little to no vegetated or shaded spaces.

Figure 6.

Climate Interactive Framework for Long-Term, Whole-System, Equity-Based Reflection Tool for Examining the Multiple Benefits of Investment in Climate Solutions

Source: Sawin (2015)



in economic analyses (Stallman 2011) because the value of these resources differs among communities and even among individuals within a community. Thus, it is essential to engage with communities to better understand impacts on cultural resources and to then incorporate that information into decision making (USBR, SAWPA, and Kennedy Communications 2013).

EQUITY AS AN ESSENTIAL LENS

There is growing recognition that water planning and management decisions must incorporate equity considerations. Equity is defined here as the just distribution of costs and benefits among stakeholders. While equity is often cited as a benefit of specific water management strategies (e.g., US EPA 2017; CA DWR 2015), we contend that management strategies are not inherently equitable or inequitable. As Heckert and Rosan (2016) argued, water management projects can support equity "only if there is an intentionality about how funds are distributed, which communities are priorities, how partners are chosen and cultivated, and which types of projects are implemented in which neighborhoods." For this reason, equity is not considered a "benefit theme" within the multi-benefit framework, but rather an essential consideration that should be incorporated into all categories.

Examining the benefits and ensuring a fairer distribution of benefits and costs among impacted stakeholders is a key component for advancing equity, regardless of the project that is selected. Climate Interactive's Framework for Long-term, Whole system, Equity-based Reflection (FLOWER) tool offers a means for examining the distribution of benefits within a project or initiative through a worksheet (Figure 6; Sawin 2015). For all benefit themes identified, the petals are shaded towards the center if the benefits tend to accrue to those who are already well off or shaded at the perimeter if the benefits are specifically targeted to vulnerable or marginalized groups.

For example, the FLOWER tool was applied to understand the role of regenerative farming in addressing climate change and the resulting human displacement and migration (Edberg 2018). Regenerative farming is a new approach to agriculture and land use that focuses on improving soil health and water retention, and using crop rotation, agro-forestry, and rotational grazing to sequester carbon. It has recently been considered as a strategy for reviving local economies in Guatemala and other communities experiencing population displacement due to a lack of economic opportunity, violence, and environmental degradation (Cummins 2017). When applying the FLOWER tool to regenerative farming in Guatemala, the outer petals were shaded (for targeting marginalized and vulnerable populations) in the Climate Protection, Food & Water, Job & Assets, Health, Well-Being, & Safety, and Connection categories. The tool can be used to describe and advocate for this practice by focusing on the multiple benefits that are provided, as well as the benefits that can positively impact marginalized communities. Similarly, equity should be discussed within the multi-benefit framework as the distribution of the potential benefits and trade-offs from water management strategies.

SECTION 4. METHODS FOR CHARACTERIZING AND INCORPORATING MULTIPLE BENEFITS

In Section 3, we described connections between water management strategies and various benefits, which we grouped into five broad themes. This information can help to identify the benefits and trade-offs of a water project, program, or policy (step 1 of the framework). In this section, we examine approaches for characterizing benefits and trade-offs (step 2 of the framework), including those focused on specific benefits as well as those that integrate accounting across benefit categories. For the purposes of this report, we use the following terminology:

- **Benefit-specific approaches** are methods and tools best suited to account for or quantify the value of specific benefits and costs within themes (e.g., land and environment or energy). Traditional modeling approaches that examine a specific physical phenomenon, such as pollutant reduction or flood flows, are included in this category, including water quality, hydrologic, and hydraulic modeling. Qualitative assessments, such as stakeholder ranking, may also be used to assign values to specific metrics.
- **Integrating approaches** are systematic, qualitative, or quantitative approaches that facilitate consolidated accounting of benefits, costs, and/or trade-offs across benefit categories. The three commonly-used integrating approaches discussed in this section include benefit-cost analysis, multi-criteria decision analysis, and systems modeling.

In most instances, a comprehensive analysis requires a combination of benefit-specific and integrating approaches to account for the full range of benefits and costs associated with a water project, program, or policy. There are often multiple ways to assess or quantify a given benefit, albeit with trade-offs in accuracy and precision, and the approach selected will depend on the time, resources, and data available. We examine here several examples of integrating and benefit-specific approaches and provide some of the pros and cons of the approaches.

BENEFIT-SPECIFIC APPROACHES

Benefit-specific approaches seek to quantify the value of specific benefits or costs associated with the five themes outlined in step one. In this section, we discuss several key benefit-specific approaches, including ecosystem services analyses, risk and impact assessments, and life cycle assessments.

Ecosystem Services Analysis

Ecosystem services analysis seeks to quantify the benefits humans derive from the natural environment and functioning ecosystems. Ecosystem services analysis, which can encompass all classes of ecosystems (e.g., aquatic, forest, agroecosystems), divide ecosystem services into four classes: provisioning, regulating, supporting, and cultural services (Millennium Ecosystem Assessment 2005).[3] Many ecosystem service analyses translate these services into economic values. For example, the value of sediment retention in watershed headwaters may be estimated as a combination of the cost of removing sediment from source water at downstream water treatment plants, the value of fish available to harvest when

3 Provisioning services include food production and water supply. Regulating services are those that limit or mitigate the impact of natural and anthropogenic phenomenon, such as floods, droughts, or pollution. Supporting services include ecosystem processes, such as nutrient cycles and soil formation. Cultural services include the spiritual and recreational value of nature.

Source: Dan Roizer, Unsplash

Ecosystem services are defined as the many benefits that ecosystems provide to people, such as pollination or carbon sequestration. Water management strategies often impact ecosystem services, and the benefits and trade-offs can be characterized through ecosystem services analysis.

sedimentation of downstream habitat is avoided, and other relevant factors. Grêt-Regamey et al. (2017) identifies more than 30 examples of tools and applications of ecosystems services analysis.

In many ways, ecosystem services analysis is an evolution of benefit-cost analysis (BCA) that grew out of recognition of a need to better account for the multiple benefits provided by functioning ecosystems. The outputs from an economically-oriented ecosystem services analysis can serve as inputs into a more traditional BCA or serve as a stand-alone assessment. Where ecosystem services analysis excels is in providing a methodological approach for assessing connections between functioning ecosystems and a diverse range of more tangible societal benefits. While useful for inclusion in economic assessments, this framing has been criticized as neglecting the intrinsic or aesthetic value of ecosystems, leading to recent reframing around the concept of "Nature's Contribution to People," which are intended to be more inclusive (Pascual et al. 2017; Díaz et al. 2018).

Nonetheless, ecosystem services analysis is a mature tool for systematically assessing the magnitude of a host of environmental benefits. Many of the common tools used for ecosystem services analysis are spatially-explicit, bio-physical models (Bagstad et al. 2013; Vigerstol and Aukema 2011; Grêt-Regamey et al. 2017). This structure allows for the systematic assessment of factors, such as the spatial distribution of benefits across beneficiaries and impacts of changing watershed hydrology. Benefits and costs (or portions thereof) that cannot be linked back to ecosystem function are not included in ecosystem services analysis. Ecosystem services analysis can be a useful tool for systematically accounting for a range of otherwise difficult-to-quantify benefits in the water and land and environment themes (Table 1).

The Natural Capital Project, a partnership between Stanford University, the Chinese Academy of Sciences, the University of Minnesota, World Wildlife Fund, and The Nature Conservancy, promotes collaborations with scientists and decision makers throughout the world to demonstrate the benefits provided by ecosystems, and provides resources for advancing projects that protect people and the natural environment. The Natural Capital Project developed an ecosystem services modeling tool, called Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) that models ecosystem services under different scenarios and helps to identify trade-offs of those services among alternative management strategies (Sharp et al. 2018). The

Table 1.

Advantages and Disadvantages of Using Ecosystems Services Analysis (ESA) to Assess Multiple Benefits and Costs Associated with Water Investment Decisions

Advantages	Disadvantages
Many successful examples of the use of ESA to inform decisions and greater inclusion of environmental benefits	Difficult to incorporate qualitative/intangible factors
Successful utilization of ESA analysis to facilitate payment for ecosystem services between uncommon stakeholders	Distinctions between services, functions, and processes are not made in a consistent way (Jax 2010)
Online databases for finding relevant studies estimating value of ecosystem services	Careful attention required to avoid double counting
Well-developed tools for conducting analysis (some tools have more than a decade of history and many publications)	Limited evidence of lasting impacts on governance and broader inclusion in decisions beyond the specific decision(s) targeted by the analysis
Tools available for analysis at multiple scales (e.g., local, regional, national)	Cultural services not as well integrated into existing tools as other classes of service
~50 percent of current tools identified can be used across generic contexts (Grêt-Regamey et al. 2017)	

data and mapping components have allowed users to adequately demonstrate the magnitude and beneficiaries of ecosystem services, leading to more informed discussion on connections and trade-offs between environmental protection and societal advancement (Ruckelshaus et al. 2015).

The US EPA's National Ecosystem Services Classification System (NESCS) framework classifies end products of environments that are specific to human uses (US EPA 2015). In the NESCS classification scheme and valuation framework, the benefits are determined based on what holds value for society through either use value (defined as preferences for goods or services that are associated with or derived from direct use or contact) and non-use value (defined as preferences for goods or services that are not associated with or derived from direct use or contact, such as existence of tropical forests even if one has never visited them) (US EPA 2015). Frameworks such as this can help to determine the ultimate value of benefits to land and environmental categories.

Risk and Impact Assessment

Risk assessments are widely used to set regulations and assess the impact of a broad range of policies, programs, and projects on human health, the environment, and the economy. Each of these topics is typically addressed independently in health risk assessments, environmental risk assessments, and economic risk assessments. Risk assessment seeks to systematically characterize the hazard being evaluated, response to the hazard, and impacts associated with that exposure. Risk assessments can provide valuable information for understanding the climate risk associated with water management strategies, as well as the human health risks.

Impact assessments are closely related to risk assessments. As a requirement for many state and federal funding programs, environmental impact assessment (EIA) is perhaps the most widely used form of impact assessment. The National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) require the use of EIA to assess the environmental consequences of a project relative to alternatives. The EIA process was designed to ensure that environmental impacts are included in project decision making, but only specific types of projects are covered under NEPA/CEQA requirements. In addition, decision makers required to perform an EIA are not required to select the most environmentally favorable alternative. A summary of the advantages and disadvantages of using risk and impact assessments to assess multiple benefits and costs can be found in Table 2.

Examples of risk and impact assessments and tools include:

Health

- Health impact assessment
- Quantitative microbial risk assessment

Environment

- NEPA/CEQA Environmental Impact Assessments
- Ecological risk assessment
- Environmental justice assessments (integrated across risks)

Economic

- WWF Germany's Water Risk Filter
- Ecolab's Water risk monetizer
- World Resources Institute's Aqueduct

Traditional health, environment, and economic risk assessments are typically conducted as independent assessments. However, the US EPA's recent Sustainability Framework acknowledges that such an approach can limit consideration of multiple benefits, including the social, environmental, and economic trade-offs. The Sustainability Framework provides guidance on ways to better incorporate these considerations into existing risk assessment approaches. These approaches can provide extremely detailed accounting across a range of metrics within the scope of the assessment (e.g., differential rates of bladder cancer across demographic groups attributable to different regulatory decisions; die-off of certain fish species in response to different regulatory decisions).

Life-Cycle Assessment

Life-cycle assessment (LCA) aims to quantify the life-cycle environmental impacts of a product or project as a function of the material flows required to produce that output.[4] Starting with the final output (e.g., operational wastewater treatment plant), inputs such as water, energy, raw materials, and pollutant releases are quantified at each stage of the product/project. These results are then systematically tabulated to calculate the total inputs required to produce the final output. The quantity of each of the inputs is translated to a common metric such as energy, GHG emissions, or nitrogen pollution associated with the production of each unit of the output. This approach allows for comparison of the environmental (or other) impacts across projects using a common unit of measure. LCA has been used extensively to compare the energy and GHG emissions of different water and wastewater treatment approaches, bioenergy production, water conveyance, and many related topics (Stokes and Horvath 2009; Stokes-Draut et al. 2017; Chen, Ngo, and Guo 2012). There are many publicly-available LCA tools, including Water-Energy Sustainability Tool (WEST), Wastewater-Energy Sustainability Tool (WWEST), Water Supply Evaluation Tool (WaterSET), Economic Input-Output LCA, and openLCA. A closely related concept of particular relevance to the water sector is water footprint

4 The concept of life-cycle assessment is strongly related to cradle-to-grave/gate/cradle, ecologically based LCA, emergy/exergy, eco-efficiency analysis, and water footprint analysis..

Table 2.

Advantages and Disadvantages of Using Risk and Impact Assessment to Assess Multiple Benefits and Costs Associated with Water Investment Decisions

Advantages	Disadvantages
Already widely conducted (to varying degrees) as part of water infrastructure projects, setting regulations (e.g., recycled water treatment/quality standards)	Scope usually limited to impact on a single outcome or outcome class (e.g., incidence of asthma, impacts on endangered species, specified classes of environmental outcomes)
Systematic approach to characterizing risk and impact	History of omitting or incompletely accounting for impacts on vulnerable populations (e.g., disadvantaged communities, reservation lands)
Helpful for prioritizing projects across multiple sites (e.g., environmental remediation), evaluating differential risk within a region	Data on specific health or environmental effects, response at different levels of exposure, etc. are often unknown (particularly for many chemicals)
Quantitative determination is typical output	Data limitations can require use of proxies (chemicals/microbes expected to behave similarly in the environment as the contaminant of interest)
Well-established analysis methodologies	May not adequately capture differential impacts on sub-populations, classes of ecosystems
Probabilistic/likelihood outputs (health and ecological risk assessments) helpful for understanding likely range of outcomes	Complex analyses and outputs make it challenging to effectively communicate risk and translate risks into understandable contexts
Can (but do not necessarily) account for cumulative effects, exposure from multiple sources	May not account for system-level interactions
Helpful for planning and preparing for future conditions (e.g., increased water scarcity)	Widely varying opinions on acceptable risk, value of avoided risk among stakeholder groups

analysis (Hoekstra 2017). Water footprint analysis seeks to quantify the water embedded in a product over the course of its lifecycle. In all instances, well-defined system boundaries are critical for transparency, analysis feasibility, and avoiding double counting of inputs. The advantages and disadvantages of using LCA methods to assess multiple benefits and costs are summarized in Table 3.

The core LCA concept of the functional unit is well aligned with multi-benefit thinking. Functional units are focused on the core objective of the project/product (e.g., pounds of nitrogen removed, gallons of water treated) rather than the output itself. This approach fosters consideration of alternatives through its acknowledgement that there are often multiple pathways to achieving the same outcome. LCA has traditionally focused on climate-related metrics (e.g., reductions in CO2, GHG) but has evolved to include a broader range of metrics such as water consumption and nutrient pollution. Likewise, sub-fields of LCA, such as ecologically-based LCA, have evolved to incorporate a broader range of environmental indicators. LCA can be used to quantify many environmentally-oriented benefits in multiple benefits/costs accounting. However, accounting for a large number of benefits with LCA would be prohibitively complex or time-consuming for many projects.

Table 3.

Advantages and Disadvantages of Using LCA to Assess Multiple Benefits and Costs Associated with Water Investment Decisions

Advantages	Disadvantages
System-level assessment of the environmental impacts of a project/product (including connections to the broader US economic system)	Not possible to convert every input into quantitative value
Translation to common unit helps facilitate even comparison	Output units limited (e.g., energy, CO2, GHG)
Useful for comprehensive accounting for climate-related impacts	Data uncertainty/regional variation in conversion factor from input to output units
Well-defined system boundaries explicitly define what is included/not included	Analyst-defined system boundaries necessarily limit the scope of inputs considered

INTEGRATING APPROACHES

Benefit-Cost Analysis

BCA is a broadly accepted and utilized approach for comparing projects and assessing the costs of a policy, program, or project relative to the benefits it provides (Birol, Karousakis, and Koundouri 2006).[5] BCA translates direct and (sometimes) indirect benefits and costs of a project into a monetary value to allow for summation and direct comparison of benefits relative to costs. Some state and federal programs require applicants to conduct benefit-cost analyses as part of their funding requirements (CA DWR 2008a; US Army Corps of Engineers (USACE) 2000), and they are a routine element of regulatory analysis. The level of detail incorporated in these analyses varies widely.

At the most basic level, BCA incorporates only direct economic costs, such as the cost of the installed infrastructure, value of crops, or other products generated by the project. Historically, environmental and social values have been excluded from or incompletely incorporated into BCA. However, improving methods and availability of data for quantifying these sometimes indirect or intangible values have increased the inclusion of additional benefits and trade-offs. Triple bottom-line approaches to BCA and incorporation of life-cycle costs are starting to better incorporate social and environmental values (Garcia and Pargament 2015; Birol, Karousakis, and Koundouri 2006). Examples of tools and applications incorporating these concepts include US EPA GI Wiz tools, Center for Neighborhood Technologies Green Values Calculator, guidelines for preparing economic analyses of recycled water projects (CA DWR), and Flood Rapid Appraisal Model (CA DWR 2008b).

The appropriate method for measuring benefits and costs depends on the nature of the benefits and costs considered. Typical quantification methods for different benefits are summarized in Table 4 (California Department of Water Resources 2008a). Further details on each of these methods are provided in the DWR guidelines and numerous other references (California Department of Water Resources 2008a; Birol 2006).

In principle, the BCA methodology is capable of comprehensive accounting for the full range

5 Benefit cost analysis (BCA) is closely related to triple bottom line BCA, cost analysis, and life-cycle cost analysis.

Table 4.

Water Management Benefit Measurement Methods.

Benefit Measurement Methods	Water Management Purposes							
	Water supply	Water quality	Hydropower	Flood damage reduction	Navigation	Recreation	Ecosystem restoration	Fisheries
Revealed Willingness to Pay								
Market Prices	X		X					X
Productivity	X	X	X		X			X
Hedonic Pricing							X	
Travel Cost						X	X	X
Imputed Willingness to Pay								
Reduction in Costs	X	X		X	X	X	X	X
Alternative Costs	X	X	X	X	X	X	X	X
Expressed Willingness to Pay								
Contingent Valuation	X					X	X	X
Contingent Choice	X					X	X	X
Benefit Transfers	X	X	X	X	X	X	X	X

Source: From CA DWR (2008a)

of benefits and costs associated with water investment decisions. Triple bottom line BCA is used to quantify and monetize the social, environmental, and economic benefits and costs of water management strategies over time. BCA has the significant advantage of being broadly utilized and, in some instances, is a statutorily required component of water project planning. However, several common challenges can limit the full realization of this approach. Some key advantages and disadvantages of BCA are summarized in Table 5.

The City of Philadelphia Water Department used a triple bottom line approach to compare options for controlling Combined Sewer Overflow (CSO) events. The analysis compared traditional grey infrastructure for CSO controls (e.g., storage tunnels) with alternative LID options (e.g., tree planting, permeable pavement, green roofs) and examined benefits and external costs for the options in a number of categories, including

Source: Bonnie J., iStock

The City of Philadelphia is a national leader in implementing green infrastructure and advancing consideration of multiple benefits.

Table 5.

Advantages and Disadvantages of Using Benefit-Cost Analysis to Assess Multiple Benefits and Costs Associated with Water Investment Decisions

Advantages	Disadvantages
Widely accepted and sometimes required by funders	Not all benefits and costs can be translated to a monetary value
Monetary terms of inputs and outputs are clear and simple to conceptualize, given that economic considerations are a core component of most water-related decisions	Translation of environmental and social values to monetary terms can be controversial
Can encourage critical thinking and evaluation of trade-offs between alternatives	Lack of available data relevant to the specific project context
Value transfer methodologies help translate data across contexts	Lack of objectivity of organization conducting analysis can skew results/scope of variables included
Established methodologies for accounting for direct, indirect benefits/costs, option, and values	Different results for different beneficiaries are possible
	Scenario(s) analyzed must be tightly defined to avoid double counting
	Comparing the distribution of benefits/costs among beneficiaries requires multiple analyses with each analysis scoped around each beneficiary group
	Not naturally suited to assessing spatial variation in the distribution of benefits and costs

recreational opportunities, aesthetics, urban heat island effect, water quality, energy savings (or usage), and air quality. The benefits were quantified and monetized using a variety of methods, including willingness to pay for water quality, avoided costs for health services, and recreation "user days." When multiple benefits were included, the assessment found that a 50 percent implementation LID development option would provide 20 times more than a 30-foot tunnel, i.e., $2.8 billion in total present value compared to $122 million, respectively (Stratus Consulting, Inc. 2009). The benefits of LID included more than $520 million in additional recreational activities, $1.1 billion in reduction of heat stress mortality, and $130 million in green collar jobs.

Multi-Criteria Decision Analysis

Multi-criteria decision analysis (MCDA) is a broad approach for explicitly evaluating the trade-offs of multiple conflicting criteria in decision making. It has been used extensively in the water sector (e.g., IWRM Decision Support Systems) and more broadly in transportation, conservation, and other fields. Applications of MCDA include Envision, California Integrated Regional Water Management Plans (IRWMP), and Climate Interactive's multi-solving tools (e.g., FLOWER Multiple-Benefit Tools). MCDA can range from a simple normalized sum of criteria scores to complex integration with systems modeling. The level of detail and types of criteria incorporated in MCDA vary with the decision being made, analytical approach, data available, and resources available. At its most basic level, MCDA consists of the following steps (Velasquez and Hester 2013; Hajkowicz and Collins 2007; National Research Council 2011):

1) **Define the problem**: A clearly defined problem, analogous to the decision being made, is critical for identifying alternatives and relevant analysis criteria in later steps;

2) **Identify stakeholder interests and sub-interests**: Enumerate key concerns of stakeholder groups, and assign weights to interests and sub-interests based on stakeholder input and other relevant sources (if appropriate);
3) **Identify alternatives**: Enumerate range of project alternatives that would address the problem identified in step 1;
4) **Build a decision framework**: Identify which interests and sub-interests each alternative contributes to (e.g., a rain garden over clay soils or a confined aquifer may not contribute to groundwater recharge, but may still contribute to water quality or stormwater management goals);
5) **Rate the alternatives**: Assess the degree to which each alternative contributes to linked interests and sub-interests; and
6) **Conduct multi-criteria analysis**: Score the alternatives to make recommendations.

The degree to which multiple benefits are incorporated into MCDA depends on the strength of the stakeholder engagement process and the willingness of project leadership to account for such factors. Stakeholders (broadly conceived) define which interests and sub-interests are important and relevant to the problem (decision) being addressed. With standard MCDA, only one problem can be addressed at a time, but multiple options for addressing that problem can be incorporated as alternatives. For example, a utility that has identified a need to increase water supply could evaluate conservation and efficiency programs, recycled water, and increased groundwater withdrawals side-by-side with MCDA. The California IRWMP program uses MCDA to assess the benefits and trade-offs of different water management projects and to allocate funding. Distribution of benefits across beneficiaries can be incorporated via weightings of interests, but doing so requires intentionality. A summary of the advantages and disadvantages of using MCDA to assess multiple benefits is included in Table 6.

Envision is a multi-criteria decision support tool developed by the American Society of Civil

Table 6.

Advantages and Disadvantages/Limitations of Using MCDA to Assess Multiple Benefits and Costs Associated with Water Investment Decisions

Advantages	Disadvantages
Does not necessarily require extensive technical capacity	Heavily influenced by subjectivity of stakeholders consulted in the process
Allows comparison across a shared framework	Stakeholder interests can be omitted if they are not included in process from beginning
Possible to make assumptions and weighting transparent and understandable by broad populations	Does not inherently account for system-level impacts/feedback unless combined with system dynamics modeling
Alternative or complimentary to economic approaches	Transparency of process not a given, requires intentional effort
Specific emphasis on incorporating both economic and non-economic values	Identifying and compensating for stakeholder and analyst biases is extremely challenging
Can incorporate qualitative and quantitative, uncertain/incomplete information (common of most environmental and social data available)	Challenging to account for uncertainty

Engineers (ASCE), American Public Works Association (APWA), and the American Council of Engineering Companies (ACEC) that assists design teams, infrastructure owners, policy makers, and NGOs in incorporating sustainability practices into a wide variety of infrastructure projects, including water treatment systems, dams, landfills, bridges, and more. The Envision framework defines 60 criteria, or “credits,” that include economic, environmental, and social impacts that should be considered when determining the sustainability of a project. These credits are divided into five categories: Quality of Life (e.g., stimulate sustainable growth and development), Leadership (e.g., foster collaboration and teamwork), Resource Allocation (e.g., reduce energy consumption), Natural World (e.g., preserve species biodiversity), and Climate and Risk (e.g., prepare for long-term adaptability).

Envision has been used to inform decision making on projects throughout the U.S. and has helped to increase long-term reliability and resilience, reduce negative impacts on ecosystems and neighboring communities, improve long-term financial savings for landowners, and improve overall community livability and aesthetics (Institute for Sustainable Infrastructure 2017). By fostering collaboration on the design, process, implementation, and operation and maintenance of projects, Envision has helped projects realize the full potential of long-term benefits, thereby improving system resiliency and increasing awareness on best sustainability practices. The first facility to earn an Envision Project Award was the William Jack Hernandez Sport Fish Hatchery in Anchorage, Alaska. The 141,000 square-foot facility has water recirculation technology that reduced energy use by 88 percent from baseline usage and currently uses only 5 percent of the fresh water volume and energy compared to conventional hatcheries (Institute for Sustainable Infrastructure 2013).

Source: Dan Cook, U.S. Fish and Wildlife Service

The William Jack Hernandez Sport Fish Hatchery in Anchorage, Alaska can produce more than 6 million sport fish per year. These fish are released throughout Alaska and account for over $20 million per year in economic activity for local communities.

Systems Modeling

Systems modeling is a generic term for models quantifying relationships and feedback between system components. Such models may be used to inform decisions but also for exploring emergent properties, such as system resilience to drought or climate change. This class of models can include optimization models, socio-hydrologic models, eco-hydrologic models, socioeconomic models, economic-engineering models, and other permutations of combined hydrologic, ecologic, and economic modeling. A summary of the advantages and disadvantages of systems modeling is included in Table 7.

In the water sector, systems modeling began with water allocation modeling but has since evolved to incorporate the effects of social, economic, and environmental variables on system function (Global Water Partnership 2013). Socio-(hydrologic, ecologic, and economic) modeling (and various permutations thereof) have become popular within the water sector for exploring system level impacts and feedback. For example, these models could be used to explore the relationship between water conservation activities and in-stream flows. Likewise, this approach could be used to assess the impacts of farmer perceptions of their use of recycled water and subsequent impacts on surface or groundwater withdrawals. Due to the complexity and data intensity of these models, most begin as research projects. However, there are examples of models which have been adopted by state or federal agencies and have made significant contributions to decision-making processes. Some examples of systems models currently being used to inform decision making include the CALVIN hydro-economic model, Regional Hydro-Ecological Simulation System, Spatial Hydro-Ecological Decision System, and US EPA Watershed Management Optimization Support Tool (WMOST).

In principle, systems modeling goes beyond simple benefit accounting to systematically explore the interrelationships and feedback between system components. Such an approach can help identify the degree to which a given benefit is actually realized by given beneficiaries. Many models are spatially-explicit, which provides insights into spatial variation in the realization of benefits as well. However, data availability and model complexity remain barriers to the inclusion of certain benefits in systems modeling. Given the uncertainty of many inputs, modelers often take a probabilistic approach when assigning ranges of input values.

Systems Modeling Example: WMOST, developed by the US EPA, is an IWRM modeling tool designed to evaluate and determine the least-cost combination of various water resource management options. The tool helps water resource managers to evaluate the economic and environmental costs and benefits, as well as trade-offs and additional benefits, of an array of water resource management projects including, but not limited to, stormwater, water quantity, wastewater, LID, and land conservation.

WMOST is available publicly online and guides users through a step-by-step process. The user specifies watershed characteristics, potential management practices, and management strategy goals, and the program then optimizes management options and identifies the least cost combinations. Version 2 of WMOST, developed in

Table 7.

Advantages and Disadvantages of Using Systems Modeling to Assess Multiple Benefits and Costs Associated with Water Investment Decisions

Advantages	Disadvantages
Greater level of accuracy and precision than qualitative assessments	Requires highly technical expert knowledge to develop models
Quantify feedback between system components (e.g., economic impact of drought on agricultural production)	Requires substantial input of good quality data
Many incorporate spatial analysis to assess relationships and trade-offs between or across regions	Communicating complexity of models in an understandable way is challenging
Well suited to quick iteration across a range of water management, climate, and hydrologic scenarios	Often the range of included benefits/costs is limited, creating trade-offs between model complexity and assessment comprehensiveness
Modeling is inherently systematic, with defined inputs and outputs	

2015, further improves the tool by incorporating several new modules. The Baseline Hydrology and Stormwater Hydrology modules assist users in obtaining hydrologic time-series data for pre-assessment purposes, and the Flood Damage module assists users in incorporating flood damage costs within the optimization. WMOST Version 3, developed in 2018, improves the tool even further by considering water quality, whereas previous models only considered water flows. Additionally, version 3 incorporates a CSO module that considers the minimization of CSO occurrences within the optimization process. Through utilization of WMOST, water managers can determine the most cost-effective management scenario that considers both economic and environmental impacts while still reaching the water resource management goal.

INCORPORATING MULTIPLE BENEFITS INTO EXISTING FRAMEWORKS

Several frameworks have been developed to advance water management, and more recently frameworks are increasingly integrating economic, environmental, and social benefits into decision-making processes. Some of these are focused on water, whereas others simply incorporate water-related benefits (e.g., FLOWER Multi-Benefits Toolkit and US EPA Sustainability Assessments). Some of the water-focused frameworks include:

- Triple Bottom Line Accounting;
- Integrated Water Resources Management (IWRM);
- Adaptive Water Management;
- Integrated Water Management;
- Sustainable Cities;
- One Water/Cities of the Future; and
- US EPA Integrated Municipal Stormwater and Wastewater Planning Approach.

While our research on incorporating multiple benefits into decision making is in its early stages, we have explored several existing water management frameworks that can potentially integrate multiple benefits more broadly. Here, we describe opportunities for incorporating broader benefits and costs into two frameworks (IWRM and One Water), to describe avenues for future work.

Multiple Benefits and Integrated Water Resources Management

Since the adoption of the Dublin Principles in 1992, IWRM has become a dominant paradigm in water resources planning and management (United Nations 1992; Global Water Partnership 2017). IWRM is commonly defined as “a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.” (Global Water Partnership 2017). It is broadly accepted as a best practice for water management, with 98 percent of countries in 2012 reporting that they had an IWRM plan somewhere along the continuum from under development through fully implemented (UNEP 2012). The Global Water Partnership IWRM ToolBox provides a searchable database of more than 500 case studies, fact sheets, methods, and other documents useful for understanding how IWRM projects have incorporated or accounted for benefits and costs (Global Water Partnership 2018). However, the primary focus of IWRM is achieving collaborative management within a basin, and it emphasizes policy and governance mechanisms needed for stakeholders to collaboratively manage water resources. IWRM is focused on process and explicitly agnostic about the pathway followed to reach the desired end state.

Incorporating a systematic approach for

identifying and evaluating multiple benefits through collective management in the IWRM process could significantly advance consideration of these benefits in decision making throughout the world. The inclusion of specific benefits and costs is not explicitly addressed in IWRM, though there seems to be an implicit assumption that inclusion of relevant benefits and costs will occur organically if relevant stakeholder groups are meaningfully engaged throughout the basin planning process. Future work will focus on how the multi-benefit framework can support inclusion of a broader range of benefits and trade-offs in IWRM.

Source: Pixabay

The San Francisco Public Utilities Commission provides drinking water, wastewater, and energy services to 2.7 million customers in San Francisco and the surrounding Bay Area. They have adopted a One Water approach through their own OneWater SF vision to help examine their services more holistically and develop projects that can provide multiple benefits.

Multiple Benefits and One Water

The One Water approach, developed by the US Water Alliance and implemented by several organizations throughout the United States, focuses on projects that can meet multiple objectives, and thus provide additional benefits among water entities. The One Water approach emphasizes the interconnectedness of water systems and recognition that all water has value.[6] More specifically, One Water is defined as an approach that "views all water – drinking water, wastewater, stormwater, grey water and more – as resources that must be managed holistically and sustainably. Doing so builds strong economies, vibrant communities, and healthy environments." (US Water Alliance 2016).

Through this approach, One Water has significantly advanced work on multiple benefits by guiding entities to develop regional partnerships and integrate planning efforts among water-related entities. Multiple benefits are explicitly identified as a key component in the One Water approach. Which benefits are included and the level of analysis required for understanding these benefits is left to the discretion of the implementing organizations. For example, the San Francisco Public Utilities Commission (SFPUC) has adopted a One Water approach to managing its drinking water and wastewater services, while also considering ecosystem and community needs (San Francisco Public Utilities Commission 2019).

Inclusion of the full range of benefits associated with a project or program requires intentionality. Even with a One Water approach, institutional mandates and funding constraints can limit the degree to which multiple benefits are incorporated into water management decisions. However, there are opportunities to leverage existing project or program requirements in creative ways through the One Water approach, increasing awareness and intentional consideration of multiple benefits.

6 Similar concepts, such as integrated water management, regenerative infrastructure, water sensitive urban design, integrated resource planning, and integrated regional water management, are also gaining prominence.

SECTION 5. CONCLUSIONS AND NEXT STEPS

Communities throughout the United States are advancing water management strategies that achieve multiple benefits, from complete street projects that create safe transportation options for all users and reduce pollutant runoff to water efficiency programs that reduce water and energy demand while increasing in-stream flows. While many government agencies, businesses, and others acknowledge the value of multi-benefit approaches, there is no standardized methodology for systematically identifying and evaluating the benefits of water management strategies. As a result, the full range of benefits and costs are not routinely included in water management decisions.

To advance the consideration of multiple benefits and costs in water management, the Pacific Institute and Professor Bob Wilkinson of the University of California, Santa Barbara launched an initiative to develop, build consensus around, and promote the uptake of a framework to embed the multiple benefits of water projects into decision-making processes. This initiative has three distinct phases. The goal of Phase 1 was to develop a draft framework and process for evaluating water projects by engaging a diverse set of stakeholders representing government, businesses, NGOs, investors, and decision makers. During Phase 2, we will be working with stakeholders to apply the framework to specific water management decisions, such as optimizing green infrastructure locations, evaluating the return on investment for water reuse, or developing an integrated water strategy. Phase 2 will allow us to refine the framework and develop resources to assist users in implementing the framework. Finally, in Phase 3, we will focus on embedding the framework into policy and planning. This report represents the culmination of Phase 1 of this work and includes a proposed framework for examining multiple benefits and trade-offs of water management.

CONCLUSIONS

We have developed several key conclusions and recommendations for integrating multiple benefits into water management decisions.

1. **Expanding the types of benefits and trade-offs considered in water management decisions can help broaden support for a policy or project; leverage resources from partners; minimize adverse and unintended consequences; increase transparency; and optimize the investment of time, money, and other resources.**

While many government agencies, businesses, and non-profit organizations acknowledge the importance of multiple benefits, the full range of benefits are not routinely considered in analysis because we lack (1) a consistent definition of multiple benefits, and (2) tools and resources to adequately identify them. To address these challenges, we have developed a three-step process to support more deliberate consideration of benefits and trade-offs in water management decisions: (1) identifying benefits and trade-offs across five broad themes; (2) characterizing benefits using quantitative and qualitative metrics; and (3) incorporating that information into decision-making processes.

Integrating the full range of costs and benefits into water management decisions can help to incentivize action towards those options that provide the greatest net benefits. For example, the City of Philadelphia compared options for controlling CSO events by assessing the triple bottom line. The analysis compared traditional grey infrastructure for CSO controls (e.g., storage tunnels) with alternative LID options (e.g., tree planting, permeable pavement, green roofs) and examined effectiveness of each option as well as associated co-benefits (wetlands creation, air quality improvements, electricity demand, reducing urban heat island effect, and more). When additional benefits were included, LID increased the economic value of the investment by a factor of 20 compared to traditional grey infrastructure alone: from $122 million to $2.8 billion (Stratus Consulting, Inc. 2009). The benefits from LID included more than $520 million in additional recreational activities, $1.1 billion in reduction of heat stress mortality, and $130 million in green jobs. Implementing either option would require a significant investment, but examining a broader suite of benefits allowed the city to select the option that would maximize the value of its investment.

2. Stakeholder engagement is essential for identifying and prioritizing benefits and trade-offs.

Throughout our research and discussions, water managers in the public and private sector stressed the importance of engaging with stakeholders to successfully identify and implement projects with multiple benefits. This process is not without challenges, such as the potential to delay projects. However, when effectively involved in the decision-making process, community members and agency stakeholders can drive projects that incorporate multiple benefits and reflect their needs and values. The multi-benefit framework may be able to assist water managers with stakeholder engagement by providing a platform for transparent and open discussions on the project goals, broad benefits and beneficiaries, and trade-offs. In addition, the overall decision-making process is likely to benefit from stakeholder engagement through, for example, better communication with the public and support for the outcomes; financial support and improved relationships with partner organizations; and a smoother regulatory process (Jeffery 2009; Mitchell 2013; Alliance for Water Stewardship 2014).

For example, in 2005, Tucson Water formed the Community Conservation Task Force (CCTF) to develop recommendations for conservation programs based on costs and benefits to both the utility and the customer. In 2006, CCTF prepared a report on the benefit-cost ratios of 48 different conservation measures from three different perspectives: the utility, participants, and from a combined perspective (Tucson Water 2017). By forming a stakeholder group tasked with including the community perspective, decision makers engaged with stakeholders, motivating them to consider a broader range of potential benefits and beneficiaries.

3. Equity should serve as an essential lens for evaluating water management strategies.

Water management projects are not intrinsically equitable or inequitable. Instead, equity is defined as the just distribution of benefits and trade-offs among stakeholders. For this reason, equity is not considered a "benefit" within the multi-benefit framework, but rather, it is a lens that should be applied to all benefits. In most decisions, benefits and costs cannot be distributed equally among stakeholders, and there will be communities, agencies, or ecosystems that benefit more or are harmed more than others. In order to advance equity, water managers and decision makers must identify stakeholders that are impacted by a decision, both positively and negatively, and work toward ensuring that the same stakeholders are not consistently receiving all the benefits or incurring all the costs. Examining the distribution of the proposed benefits and costs to a range of stakeholders through an equity lens in the initial project scoping can help promote a more transparent discussion about impacts to various stakeholders.

4. Multi-benefit projects can advance collaboration among stakeholders and facilitate innovative funding opportunities.

Water management and infrastructure will require significant investment in order to address climate change, aging infrastructure, population growth, and environmental degradation. Funding for investments in water management remains a major challenge across the country. An explicit focus on multiple benefits provides an opportunity to more efficiently plan, implement, and fund projects that simultaneously meet multiple objectives. The prospect of incorporating new financial partners (i.e., co-financing) into water management projects is one of the strongest motivations for examining multiple benefits. Significant effort is needed to support partnerships and co-fund projects that meet multiple objectives.

Multi-benefit projects can facilitate partnerships within and between cities, organizations, businesses, and NGOs that improve regional planning and project development. While these may not always result in co-funding, there are substantial benefits to building partnerships among entities. In southeast Oklahoma, the Altus Chamber of Commerce advocated for partnerships around multi-benefit water investments and regional planning efforts. During a major drought, representatives from agriculture, cities, regional agencies, and a nearby military facility came together to address water supply reliability concerns in the region (Gorke 2018). The Chamber of Commerce recognized that water reliability was essential for the economic well-being of local industries and communities. Thus, the Chamber of Commerce was able to build partnerships among regional planning and water management programs that accounted for different water users throughout the region, including programs for improved water use efficiency by all sectors and solutions that enhance the community livability through restoration and revitalization of a local reservoir to attract recreation and tourism (Duane Smith & Associates 2018).

5. Expanding the definition of the problem and the scope of the analysis will help to better integrate additional benefits and trade-offs into water management decisions.

One of the keys to examining multiple benefits is carefully defining the water management challenges that are being addressed and expanding the analysis to include a broader range of potential benefits and beneficiaries. The boundary or scope of the decision-making process determines the relevant stakeholders, geography, and benefits and costs considered within an analysis – what's in and what's out. Setting a scope that is too narrow runs the risk of ignoring important impacts that could alter the type of project pursued. On the other hand, expanding the scope of the analysis can increase the complexity of the project, resulting in a decision-making process that is too time and/or resource intensive. For example, a water supply agency may conclude that a stormwater capture project is not cost effective if it distributes the entire cost of the project over the amount of water that project yields and ignores other benefits, such as flood management and water quality, provided by the project. If these additional benefits are included, stormwater capture becomes significantly more cost-effective. If the scope is expanded to include additional benefits, the water manager can more fairly compare projects and provide decision makers with adequate information to maximize investments in water management.

Brainstorming tools, such as mind maps, can help organize benefits across themes, assess relationships, and define analysis boundaries. Mind maps, such as those developed through Coggle or MindMup, visually display the relationships among projects and potential benefits or trade-offs. Similarly, presentation tools, such as Prezi, can help to demonstrate complex relationships among benefits and trade-offs. The Pacific Institute developed a mind map using MindMup to demonstrate the relationship between sustainable landscape features and potential site-level and community-level benefits or trade-offs (Cooley et al. 2019).

NEXT STEPS

We are currently embarking on Phase 2 of this work and are seeking to improve and advance the framework through test cases, development of resources, and policy innovation. For this effort we are working to:

- Refine the multi-benefit framework based on real-world water management decisions and stakeholder input;
- Develop and provide online resources for analysts, decision makers, and advocates to identify and examine the multiple benefits of a broad range of water management strategies; and
- Examine methods and tools for qualitatively and quantitatively characterizing benefits to assist with specific water management challenges.

We are implementing the multi-benefit framework through several test cases. The framework currently provides a theoretical approach to identifying and quantifying multiple benefits and costs of water management strategies. Our goal in Phase 2 is to refine and advance the framework by applying it to real-world management decisions and assessing its usefulness in encouraging consideration of multiple benefits.

During Phase 3, we will identify pathways to embed multi-benefit analyses and resultant information in policy and investment decision-making, such as promoting uptake of the framework in funding proposal requirements and in integrated water management planning at the local, state, and federal levels. Ultimately, we believe that having a systematic framework will increase the usefulness and uptake of the existing multi-benefit data and allow for wider development of multi-benefit tools.

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Appendix A

CONVENING ATTENDEES

The conclusions and views expressed in this report are the responsibility of the authors and do not necessarily represent the views of the convening attendees below.

MULTI-BENEFIT CONVENING (LOS ANGELES)

Rucker Alex, AECOM
Mike Antos, Santa Ana Watershed Project Authority
Corinne Bell, Natural Resources Defense Council
McKenzie Bradford, University of California, Santa Barbara
Fernando Cazares, Trust for Public Land
Mark Gold, University of California, Los Angeles
Max Gomberg, California State Water Board
Roger Gorke, US Environmental Protection Agency
Adel Hagekhalil, Los Angeles Sanitation
Steve Hobbs, The Conservation Fund
Kelsey Jessup, University of California, Los Angeles
Cynthia Koehler, WaterNow Alliance
Andy Lipkis, TreePeople
Paul Liu, Los Angeles Department of Water and Power
Caryn Mandelbaum, Leonard DiCaprio Foundation
Jeff Mosher, Carollo Engineers
Gregor Pastch, 2nd Nature
Tracy Quinn, Natural Resources Defense Council
JR De Shao, University of California, Los Angeles
Lisa Shibata, The Walt Disney Company
Wing Tam, Los Angeles Sanitation
Deven Upadhyay, Metropolitan Water District of Southern California
Rafael Villegas, Los Angeles Department of Water and Power

MULTI-BENEFIT CONVENING (MINNEAPOLIS)

Gary Belan, American Rivers
Fawn Bergen, Intel Corporation
Marcus Bush, Metropolitan Council of the Twin Cities, MN
Mama Lila Cabbil, People's Water Board
Marc Cammarata, Philadelphia Water Department
Paula Conolly, Green Infrastructure Leadership Exchange
Trina Downer, University of Michigan, Flint and activist for indigenous rights
Kristen Evans, The Nature Conservancy
Erin Hagan, University of California, San Francisco
Jean-Ann James, Turner Foundation
Susan Kaderka, National Wildlife Federation
Cynthia Koehler, Water Now Alliance
Dee Korich, City of Tucson
Jen Kostrzewski, Metropolitan Council of the Twin Cities, MN
Pat Lando, Recode, Landscape Architect
Melodee Loyer, City of Tucson
Sharlene Leurig, Texas Water Trade
Jessie Martin, Earth Economics
Katie Mika, City of Los Angeles
Sam Paste, Metropolitan Council of the Twin Cities, MN
Asia Philbin, Marana Water
Emily Resseger, Metropolitan Council of the Twin Cities, MN
Sarah Richards, Cynthia and George Mitchell Foundation
Matthew Ries, DC Water
Taj Schottland, Trust for Public Land
Doug Shaw, The Nature Conservancy
Brigid Shea, Travis County, TX
Catlow Shipek, Tucson Water
Jennifer Walker, National Wildlife Federation
John Wells, Retired

Appendix B

EXAMPLE SCOPING QUESTIONS FOR INCLUSION OF MULTIPLE BENEFITS

These questions explore common issues affecting the inclusion of multiple benefits and costs into project scopes. They are a synthesis of observations of successful multi-benefit projects and interviews conducted with policy makers, regulators, project implementers, and other key stakeholder groups.

PROBLEM IDENTIFICATION AND DEFINITION

- What are the core problem(s) being addressed with this water management decision/investment? What blind spots exist that could influence problem definition?
- What types of engagement will be most effective for soliciting meaningful feedback from relevant stakeholder groups? At what stages?
- What factors motivated action towards solving this problem (e.g., regulatory compliance, system resilience)?
- What is the desired/required outcome(s) from solutions to this problem?
- What stakeholder groups are most invested in this problem? Who is missing from the discussion?
- What benefits/costs are of greatest importance to these stakeholder groups?
- Are there benefits/costs that are not being included, but may be of importance to non-involved stakeholder groups?

SCREENING (ASSESSING LEVEL OF EFFORT AND EXISTING SUPPORTING RESOURCES)

- What level of detail/information is needed to make an informed decision?
- What level of effort is possible within time/budget constraints?
- What are key priorities regarding the inclusion of additional benefits within these constraints?
- When making this decision, what planning/regulatory requirements (e.g., CA IRWMP, NEPA/CEQA, CBA) and/or assessment methods (e.g., water quality modeling, ecological assessment) are already being used that include certain additional benefits or costs?
- What additional benefits and costs are already being considered through required assessment methods?
- Where are there gaps?
- At what stage(s) in the process do these assessments occur?
- Can better coordination of existing assessments help identify additional project-related benefits?

SCOPING TO FACILITATE CHARACTERIZATION AND ACCOUNTING OF MULTIPLE BENEFITS

- Who are the primary beneficiaries being considered?
- What benefits and costs are most important to include in this analysis? Why?
- What additional analyses will need to be conducted to include the full range of relevant benefits and costs?
- What options are available for funding these additional analyses?
- What geographic region(s) are included? Why?
- What timescale is appropriate for this analysis? Why?

Appendix C

INTERVIEW FINDINGS AND PARTICIPANTS

GOALS OF INTERVIEWS

1. Complement the literature review with greater practical understanding of multi-benefits within water investments and how they are implemented (what data sources are used, what tools are most valuable).
2. Elucidate areas of greater and lesser certainty in multi-benefit valuation literature.
3. Gain greater practical understanding of decision making on water investments and the degree to which multiple benefits are considered.

QUESTIONS

1. What benefits are associated with water investment projects? (Based on list, sent in advance.) Are there benefits that are missing or are there ones that you would remove?
2. What data sources are available for evaluating these benefits?
3. How are multiple benefits incorporated into decision making?
4. What are the drivers and barriers to incorporating multiple benefits into decision making?
5. Is there anything else you would like to share?

MAJOR FINDINGS

1. Decision-makers are discussing multiple benefits in many different contexts, from the one water frameworks to Food-Energy-Water nexus, climate resilience frameworks, and integrated park design. Examining multiple benefits frameworks from different sectors can provide insights into additional benefits and a structure for communicating those benefits.
2. Engaging with stakeholders is the key to developing and implementing successful projects.
   a. Engaging stakeholders from the beginning of the process through implementation and maintenance can build trust and a common language for advancing shared goals.
   b. Water managers can build relationships with stakeholders by entering into discussions willing to listen and learn.
   c. Stakeholder consensus is necessary for determining effective metrics for decision making and providing weighting schemes for desired outcomes.

d. Consider potential stakeholders beyond those traditionally involved. For example, people who work in operations and maintenance can provide invaluable insight into implementing innovative projects. In addition, engagement with emergency response and public health experts can ensure sufficient protection for the public.

3. Incorporating additional benefits and trade-offs is a challenging but necessary part of decision making in order to maximize the net benefits of projects.
   a. Multiple benefits should be included systematically. Often, multiple benefits are discussed at the end of decision making as part of justifying selected projects. Instead, a broad range of benefits should be discussed throughout the decision-making process.
   b. Social and environmental justice and equity components must be considered in the analysis, including: gentrification, climate resilience and justice, equitable access to services, and others.
   c. Risk and reputation are important considerations for water agencies and municipalities that can be incorporated into decision making.
   d. Many benefits are interrelated, and care should be given to incorporating the non-linear relationships between benefits.

4. Several key drivers were highlighted during the interviews that helped to motivate consideration of multiple benefits.
   a. Local leaders play an essential role in driving consideration of multiple benefits in decision making. These leaders can include local officials, public agencies, environmental groups, or business coalitions.
   b. Innovative financing can help to motivate consideration of multiple benefits and can help to overcome capital and O&M financing challenges.
   c. Regulatory compliance can serve as a motivator for incorporating multiple benefits to solve multiple problems efficiently. Or, regulatory silos can serve as a challenge for examining additional benefits. In both cases, regulation can provide an impetus for considering broader benefits while stakeholder engagement and leadership can help to develop successful relationships and projects.

INTERVIEW PARTICIPANTS

We would like to thank those involved in the interview process for their time and insights, including:

Ken Barenklau, University of California, Riverside
Marcus Bush, Metropolitan Council of the Twin Cities, MN
Fernando Cazares, Trust for Public Land
Stephanie Craighead, Philadelphia Parks and Recreation
Martha Davis, formerly Inland Empire Utilities Agency
Mark Gold, Institute for Environment and Sustainability, University of California, Los Angeles
Kathy Jacobs, Center for Climate Adaptation Science and Solutions, University of Arizona
Kelsey Jessup, University of California, Los Angeles, Luskin School of Public Affairs
Esther Lev, Wetlands Conservancy
Avery Livengood, Philadelphia Water Department
Anastasia Loukaitou-Sideris, University of California, Los Angeles, Luskin School of Public Affairs
Peter Mayer, WaterDM

Kelli McCune, Sustainable Conservation
Laura Meadors, Apple Inc.
Irene Ogata, Tucson Water
Sarah Olivier, Trust for Public Land
Jennifer Ruley, City of New Orleans
Candice Rupprecht, Tucson Water
Kelly Sanders, University of Southern California and One Water LA Advisory Board
Beth Sawin, Climate Interactive
Taj Schottland, Trust for Public Land
Kurt Schwabe, University of California, Riverside
Doug Shaw, The Nature Conservancy
Brigid Shea, Travis County (TX) Commissioner
Duane Smith, Duane Smith & Associates
Shannon Spurlock, Denver Urban Gardens

The views expressed in this report are solely those of the authors and may not reflect the opinions of those interviewed.

Appendix D

BENEFITS AND TRADE-OFFS CITED

Through our literature search and interviews, we identified more than 100 unique benefits and trade-offs. These benefits and trade-offs were then categorized within these themes. Here, we include examples of benefits or trade-offs for each theme.

Water

- Water quantity or volume
- Flood (water timing)
- Water quality (surface, ground, estuary, ocean, and drinking water quality)

Energy

- Energy for water extraction, conveyance, and distribution
- Energy for water treatment
- Energy for wastewater collection, treatment, and disposal
- End use energy for heating water or heating and cooling buildings
- Energy production through hydropower

Land and Environment

- Habitat and biodiversity
- In-stream flows
- Air quality
- Greenhouse gas emissions
- Carbon sequestration
- Soil health
- Agriculture
- Resource recovery

People and Community

- Local economy
- Community resilience (access to basic needs, social networks, and nutritious food)
- Health and safety
- Recreation
- Urban heat island effect
- Educational opportunity
- Water affordability
- Aesthetics

Risk and Uncertainty

- System resilience (ability of system to withstand extreme events or changing climate)
- Water supply reliability
- Stranded assets
- Reputational risk
- Regulatory compliance

Pacific Institute
654 13th Street,
Preservation Park
Oakland, California 94612
510.251.1600 | info@pacinst.org
www.pacinst.org

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