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Estimating the Value of Public Water Data

John Gardner,* Martin Doyle,*,** and Lauren Patterson**

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Author Affiliation
* Nicholas School of the Environment, Duke University
** Nicholas Institute for Environmental Policy Solutions, Duke University

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Review
This working paper has not undergone a formal review process. It is intended to stimulate discussion and inform debate on emerging issues.

SUMMARY

Public water data, such as river flow from stream gauges or precipitation from weather satellites, produce broad benefits at a cost to the general public.

This paper presents a review of the academic literature on the costs and benefits of government investments in public water data. On the basis of 21 studies quantifying the costs and benefits of public water quantity data, it appears that the median benefit-cost ratio across different economic sectors and geographic regions is 4:1. But a great deal of uncertainty attends this number; very few studies empirically quantify or monetize the costs, the benefits, or both of water information with sound economic methods, and no studies have quantified the value of water quality information.

This review is part of an ongoing effort by the Nicholas Institute of Environmental Policy Solutions at Duke University and the Aspen Institute to develop the foundations of an Internet of Water by quantifying the potential value of open and integrated public water data.

INVESTING IN PUBLIC WATER DATA

There is growing interest in water data, particularly in expanding the use of existing public water data through increased data integration and sharing. A recent dialogue series held by the Aspen Institute found that although many water managers agree there is value in an integrated water data system, they consider the absence of quantified benefits to be a significant barrier to building political support for and investment in making public water data open and shareable. Governments could make investments in water data and information—as they have in other public goods—to reach the socially optimal outcome. However, without evidence of the value of water information, decision makers will likely remain skeptical about the return on that investment (Jeuland et al. forthcoming).

Valuation of public data, particularly with robust benefit quantification methods—is conceptually and logistically difficult. The value of information should be measured against a counter-factual, that is, relative to a baseline of outcomes absent the information.[1] Rigorous, empirical studies of the benefits and costs of public water data that do so are rare (Jeuland et al. forthcoming).

QUALITATIVE REVIEW OF STUDIES POINTS TO THE VALUE OF WATER DATA

Research databases were scanned for academic and peer-reviewed studies that quantified a benefit-cost ratio for public water data. The resulting articles were screened for relevance and from them information about the type of data (i.e., sector, region) was extracted and coded.[2] This approach provides a snapshot of the value of public water data—although a preliminary and empirically weak one.

The studies in this meta-analysis generally focused on specific types of information (e.g., hydrologic, ecological) or sectors (e.g., agriculture, hydropower). The meta-analysis consisted of 29 estimates of benefit-cost ratios from the 21 articles identified in the academic literature, government reports (e.g., U.S. Geological Survey, Office of Management and Budget), inter-governmental agencies (e.g., the World Bank), and NGOs. All but one of these studies accounted for both costs and benefits of water information.[1] Stallings and Fread (1997) provided costs as the annual budget of the U.S. National Weather Service (NWS) during the year in which the benefits were estimated.

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[1] The three key steps of valuation are identifying, quantifying, and monetizing impacts (Boardman and Boardman 2008). Quantification is conceptually challenging because the impact of additional information stems from improvements in management decisions. Without investments in additional water information, managers would make decisions with available information. The value of collecting, analyzing, and disseminating additional information must be measured as the extent to which more-informed management decisions improve outcomes relative to a (unobserved) counterfactual, or baseline—what would have occurred without additional information. Researchers must estimate the counterfactual using models, expert opinions, and empirical economic methods (e.g., before-after studies, cross-section studies, differences-in-differences comparison, natural experiments, or randomized control trials). Impacts can be monetized using market or shadow prices. For example, researchers often estimate the value of hydro-met information on the basis of avoided damages, natural hazards, or increased revenues from improved efficiency (WMO 2015). Estimates often rely on expert opinions of preventable costs or predicted revenues. Alternatively, researchers can estimate the value of information using decision-making models that assume users optimize their behavior in response to new information and measure increased outcome (e.g., additional crop yield or lower risk of flood damages).

[2] If a range of benefit-cost ratios was presented, the mean of those estimates was used.

IDENTIFIED COSTS AND BENEFITS OF PUBLIC WATER INFORMATION

The costs associated with public water information broadly include collection, analysis, dissemination, and use. Collecting water data requires designing, installing, operating, and maintaining a network of environmental sensors and research stations. These water quantity and quality data must be cleaned and analyzed, which requires investments in information technology, data management, and training of scientists and managers. Dissemination costs include publishing information online and in print and holding meetings and workshops for users. Use costs largely stem from education and training expenses (Jeuland et al. forthcoming).

Many studies have outlined the potential economic benefits of public water information (see Table 1 and appendixes A and B for a list of benefits and studies, respectively). Water information enables governmental agencies, non-governmental organizations, private companies, and individuals to make evidence-based decisions about both short- and long-term management operations and planning. This information is beneficial to many sectors, including agriculture, energy production, hydropower, forestry, manufacturing, mining, tourism and recreation, and water service provision (Table 1).

The benefits of public water data can be very simply categorized on the basis of improved design of infrastructure (roads, bridges, irrigation structures, dykes, reservoirs, mine-tailing ponds), flood and storm avoidance, and sustainable resource management (Azar 2003). Flood and storm avoidance is a frequently cited and quantified benefit of water quantity information across all sectors. For example, forecasting flood magnitude and geographic extent helps private and public industries protect infrastructure and assets. Sustainable resource management is most beneficial to the daily operations of hydropower, agriculture, forestry, or any industry that directly depends on water to generate products and revenue.

Table 1. Sectoral benefits derived from public water information

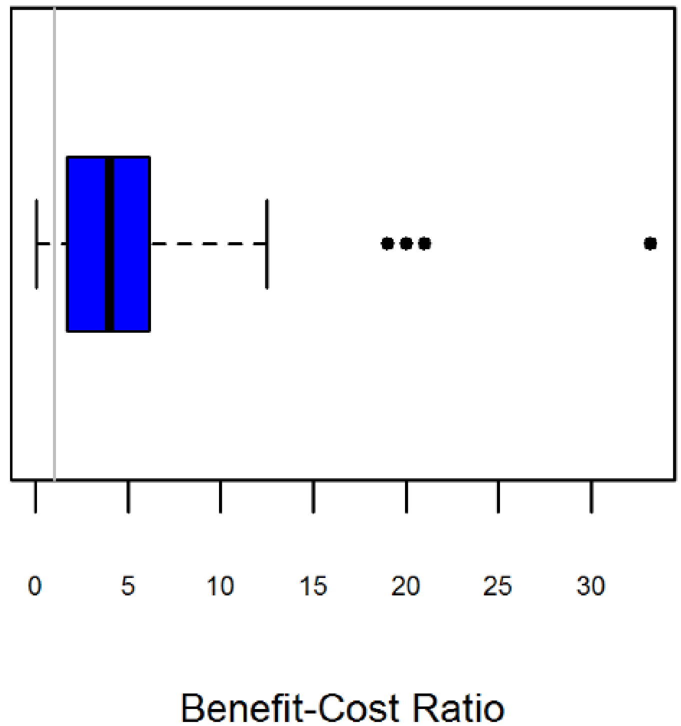
Sector/type of information	Water quantity information (meteorological and hydrological data)	Water quality information (ecological and chemical data)
All sectors	Reduce costs from uncertainty by increasing managers' ability to plan more efficiently and respond more quickly to water availability and use issues (Jeuland et al. forthcoming)	Reduce costs by decreasing the likelihood and scale of expensive threats (e.g., chemical spills/leaks, harmful algal blooms, decaying infrastructure) Reduce costs by identifying more efficient and precise ways to treat quality problems and comply with government regulations
Agriculture (irrigated and non-irrigated)	Increase revenue by improving planting and irrigation decisions to increase yields or product quality (Jeuland et al. forthcoming)	Reduce costs through more efficient (less) use of fertilizer
Energy production	Reduce cost and increase revenue by improving planning and production decisions (e.g., by knowing the amount of energy needed to transport water to meet demand) (Copeland 2017)	
Forestry	Increase revenue by improving planning and operations decisions about planting and harvesting (e.g., information about groundwater/soil moisture helps managers project biomass growth and operate efficiently)	Water information facilitates a secondary market for water quality (e.g., foresters can earn revenue by selling water quality credits earned by planting of trees to decrease surface water temperature)
Hydropower production	Reduce costs by optimizing the design of hydropower facilities; stream gauging data in the Columbia River led to $153 million in hydropower revenue (NRC 2004) Reduce costs by improving reliability and avoiding operations shutdowns	Reduce costs of complying with environmental regulations by improving dam releases to maintain viable fish populations downstream
Manufacturing and industry		Reduce costs by improving operations to precisely address recycling, reuse, and release contaminants

Sector/type of information	Water quantity information (meteorological and hydrological data)	Water quality information (ecological and chemical data)
Mining	Reduce costs and increase production by optimizing planning and operations on the basis of water availability information and flood/weather forecasting	
Transportation	Reduce costs by optimizing planning for shipping/logistics industry; trucking alone loses $3 billion a year from inclement weather (Marquis 2012)	
	Reduce costs by optimizing barge operation	
Tourism and recreation	Increase revenue through using information (e.g., lake/stream levels, snowpack for skiing) to improve planning and attract tourists to recreation; the market value of water in the Delaware River Basin for recreation is ~$2.2 billion (Kauffman 2011)	Reduce costs of treatment through early identification of pollution to maintain fisheries and public safety
	Reduce costs by using information to improve risk planning for floods and other disasters	
Water service provider	Reduce costs by optimizing operations and disaster planning with improved weather and flooding forecasts; streamflow gauging data has saved $50 million in avoided flood damages (NHWC 2006); the value of a UK water monitoring network for water planning and flood defense was estimated at ~$25 million (Walker 2000)	Reduce costs of treatment by using information to quickly identify and effectively respond to pollution and leakages
	Reduce costs and increase revenue by monitoring water delivery and consumption to optimize supply/demand operations decisions, improve reliability, understand user behavior, plan water and wastewater treatment (improved projections reduce spending on excess capacity) (GWI 2016)	Reduce costs of treatment by using information to improve source water protection, which is often less expensive than traditional treatment

QUANTIFIED AND MONETIZED COSTS AND BENEFITS OF PUBLIC WATER INFORMATION

The median benefit-cost ratio of water information was 4 (n = 29), with a range of 0.04 to 33 (Figure 1). Overall, 86% of analyses reported that the benefits of public water information exceeded the costs.

Figure 1. Benefit-cost ratio estimates for 29 benefit-cost ratios

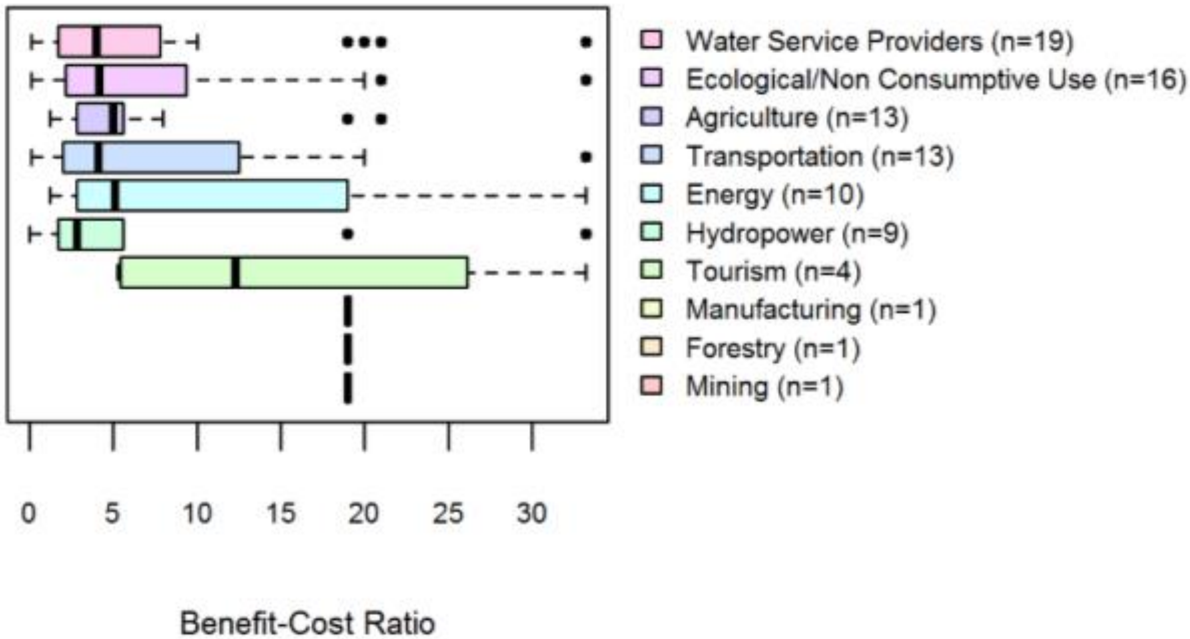


Note: The gray line represents a benefit-cost ratio of 1. The box represents the inter-quartile range, or the middle 50%, of values. The black line in the box is the median value, the whiskers represent values outside the inter-quartile range, and the circles represent outliers.

The literature survey turned up only studies on water quantity information (e.g., hydrometeorological data from precipitation and river gauges, hydrological forecasting). No studies quantifying the benefit-cost ratio for public water quality data were found.

The majority of the studies combined economic benefits across two or more sectors (69%); the remaining studies (31%) focused on a specific (i.e., single) sector. The sectors most commonly represented in these studies were water service provision (66%), ecological and non-consumptive use (55%), agriculture (45%), and transportation (45%). The median benefit-cost ratio ranged from 3.9 (hydropower sector) to 19 (manufacturing) (Figure 2). However, there were not enough data to quantify the relative benefits of water information in several sectors, and only one study included the manufacturing, mining, and forestry sectors.

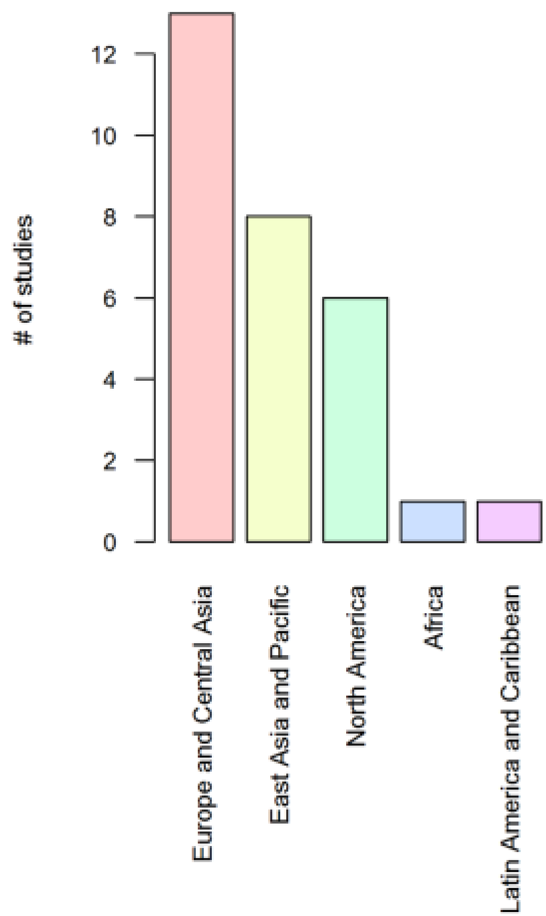
Figure 2. Benefit-cost ratio across sectors



Note: The number of benefit-cost estimates within each sector (n) is shown in the legend on the right. Many values are counted multiple times because estimates for multiple sectors were aggregated in the same study.

The studies were largely clustered within three geographic regions: Europe and Central Asia (45%), East Asia and the Pacific (28%), and North America (21%). Only one study from Africa and Latin American (Figure 3) was found.

Figure 3. Number of studies represented across global regions



INTERPRETATION

Water information is a public—non-rival and non-excludable—good. As such, it is necessary and important for public agencies to provide ongoing investment in it. The analysis presented here shows that public investment in water information is a good investment: its economic benefits generally outweigh the costs. But because the academic literature does not comprehensively or consistently quantify or monetize these costs and benefits, significant uncertainty and speculation about them exist.

Many of the reviewed studies also suffer from methodological shortcomings:

- Very few studies include the full costs associated with generating and utilizing additional public water information. User costs and transactions are not often reflected in benefit cost-ratios (Jeuland et al. forthcoming). Those ratios are likely too high when full costs are not captured.
- The value of additional public water information appears not to have been estimated using a rigorous experimental or quasi-experimental design. Very few studies measure the benefits vis-à-vis a synthetic counterfactual (Jeuland et al. forthcoming). The World Meteorological

Organization's (2015) assessment of the value of meteorological and hydrological services and Cordery and Cloke (1992) work on the value of streamflow data are notable exceptions. Counterfactuals are often estimated by extrapolating from historical outcomes, which may not be pertinent (Jeuland and Whittington 2014).

- Benefits from additional public water information are often based on hypothetical physical and hydrologic models that predict, rather than empirically measure, changes in outcomes. For a good example, see the Adeloye (1996) model for estimating the value of streamflow data. Actually utilizing additional information to make more informed management decisions may require advanced analytical tools that many users lack, thus calling into question the predicted benefits (Jeuland et al. forthcoming). In addition, benefits and costs are currently estimated from model outputs rather than real-world outcomes—in many cases, use of water data is captured through download numbers.
- Very few studies monetize the value of improvements in operations and planning from additional public water information. It is unclear whether, or how, better information has quantitatively improved or optimized infrastructure performance or potentially reduced the costs of design and construction.

Beyond these limitations, there is no information on the value of water quality information, specifically the benefit-cost ratio. Yet, there is high potential for growth in water quality monitoring due to the rapid development of sensor technology, along with growing interest and deployment of markets for water quality trading (e.g., nitrogen trading among water treatment plants). Just as water quantity data increases the odds that floods and other water-related disasters can be avoided, water quality monitoring could prevent costly spills and water quality hazards. However, the value of water quality information depends, to some degree, on regulation (e.g., the Clean Water Act, the Safe Drinking Water Act) that sets numeric standards for water quality or for the ability of water users (e.g., water treatment plants) to make use of new streams of data to improve operational efficiency.

TRENDS IN WATER DATA AND INFORMATION

Several broad trends in water data may affect the value of public water information. First, water data are increasingly collected by private entities (and typically not publicly shared) because of the decreased costs associated with data collection and increased recognition of the value of water data. This effort has been enabled by the rapid improvement in technology and sensor development. There are likely strategic incentives to not share water data as well as incentives to avoid potential regulatory implications.

Second, and in contrast, scientific, NGO, and government institutions are attempting to make water data more open and easily accessible (GWI 2016). For example, the U.S. federal government established the Open Water Data Initiative, which seeks to integrate fragmented data from across the nation into one open water web to facilitate "innovation, modeling, data sharing, and solution development." Similarly, the non-profit Consortium of Universities for the Advancement of Hydrologic Science is developing hydroinformatic tools for sharing and synthesizing data. With the rise of big data, empirical information will increasingly play a role in decision making for individuals, companies, and governments.

APPENDIX A: BENEFIT-COST RATIOS

	Agriculture	Energy	Forestry	Hydropower	Manufacturing	Mining	Transport	Tourism	Non-Consumptive Use	Water Service Provision	Region	Benefit-Cost Ratio
Adams et al. 2003	X										Latin America and Caribbean	2.90
Adeloye 1996				X							Europe and Central Asia	0.04
Anaman and Lellyett 1996									X		East Asia and Pacific	4.17
Azar et al. 2003	X	X	X	X	X	X	X	X		X	North America	19.00
Black et al. 1999		X		X			X	X	X	X	Europe and Central Asia	33.22
Herschy et al. 1991	X			X					X	X	Europe and Central Asia	2.30
Considine et al. 2004		X									North America	2.39
Cordery and Cloke 1990	X			X						X	East Asia and Pacific	5.00
Cordery and Cloke 1990							X		X	X	East Asia and Pacific	20.00
Cordery and Cloke 1992							X		X	X	East Asia and Pacific	0.10
Cordery and Cloke 1992							X		X	X	East Asia and Pacific	0.80
Cordery and Cloke 1992	X			X						X	East Asia and Pacific	1.70
Cordery and Cloke 1992							X		X	X	East Asia and Pacific	2.00
Cordery and Cloke 1992							X		X	X	East Asia and Pacific	4.00
Frei et al. 2010	X	X									Europe and Central Asia	5.00
EU Met Statistics 2014	X	X							X	X	Europe and Central Asia	21.00
Gray 2015							X		X		Europe and Central Asia	12.50
Lazo 2009									X		North America	6.18
Lazo 2015											Africa	1.78
Leviakangas et al. 2007	X	X					X		X	X	Europe and Central Asia	4.13
Leviakangas et al. 2009	X	X					X	X	X	X	Europe and Central Asia	5.24
McMahon and Cronin1980				X			X				North America	1.30
National Hydrologic Warning Council 2006	X	X							X	X	North America	1.23
Perrels et al. 2013	X	X		X			X	X	X	X	Europe and Central Asia	5.58
Stallings et al. 1997	X	X		X			X		X	X	North America	2.82

Walker 2000										X	Europe and Central Asia	0.80
Walker 2000										X	Europe and Central Asia	1.70
Walker 2000	X										Europe and Central Asia	8.00
Walker 2000										X	Europe and Central Asia	10.00

APPENDIX B: QUANTITATIVE STUDIES ON THE COSTS AND BENEFITS OF PUBLIC WATER INFORMATION

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Nicholas Institute for Environmental Policy Solutions

The Nicholas Institute for Environmental Policy Solutions at Duke University is a nonpartisan institute founded in 2005 to help decision makers in government, the private sector, and the nonprofit community address critical environmental challenges. The Nicholas Institute responds to the demand for high-quality and timely data and acts as an "honest broker" in policy debates by convening and fostering open, ongoing dialogue between stakeholders on all sides of the issues and providing policy-relevant analysis based on academic research. The Nicholas Institute's leadership and staff leverage the broad expertise of Duke University as well as public and private partners worldwide. Since its inception, the Nicholas Institute has earned a distinguished reputation for its innovative approach to developing multilateral, nonpartisan, and economically viable solutions to pressing environmental challenges.

Contact

Nicholas Institute, Duke University
P.O. Box 90335
Durham, North Carolina 27708

1201 Pennsylvania Avenue, NW
Suite 500
Washington, D.C. 20004

Duke Marine Lab Road
Beaufort, North Carolina 28516

919.613.8709 phone
919.613.8712 fax
nicholasinstitute@duke.edu
www.nicholasinstitute.duke.edu