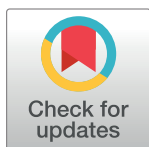OPINION

Water data for water science and management: Advancing an Internet of Water (IoW)

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Introduction

In the face of climate change, natural resource and environmental quality managers around the world face increasing pressure to manage water carefully and ensure its quality for sustainable water supplies, sanitation, and public health. These managers require information derived from water data—including administrative records, as well as results from environmental measurement, monitoring, modeling, analysis, and assessment. However, data production is distributed across a fragmented system of natural resource and environmental governance across sectors and jurisdictions within and between countries. This fragmentation means that data are collected for different purposes across different scales, and stored and published in innumerable formats and platforms. While these data are often made public, their staggering heterogeneity makes them difficult to find and use beyond the primary purpose for which they were collected [1]. Thus, analysts spend more time finding, cleaning, and formatting data than on analysis. In addition to these technical issues, the cultures of agencies that manage public water are generally wary of opening, sharing, and reusing water data, because of a lack of incentives as well as perceived costs and risks to privacy, security, and sovereignty [2].

The challenge of water data management, therefore, presents a classic public goods collective action problem, since the benefits of good water data management accrue primarily to secondary users rather than the data producers themselves. While some cost and risk concerns can be addressed with modern data infrastructure, a broad shift in norms and behavior across public agencies and utilities will be essential to enable the technical transformation necessary to maximize the power of water data.

Efforts to date

Since the early 2000s, organizations within the federal government, state agencies, and academia have attempted to address certain aspects of the water data challenge, and from 2009 to 2019, significant technical and policy progress has been made in the United States. Technical progress accelerated with development and implementation of WaterML [3], a technical standard for representing time-series water data, and the initiation of the Water Data Exchange (WaDE) project of the Western States Water Council to enable the exchange of water planning, water use and water allocation data among public agencies and the general public [4]. The Obama Administration created policies to improve open data, including the Open Water Data Initiative [5], which led to improved access to federal agency water data by encouraging data-as-a-service models [6], and the Public Access to Research Results policy [7], to increase

the accessibility of publications and digital data produced by federal funding recipients. Subsequently at the state level, both California and New Mexico passed legislation in 2016 [8] and 2019 [9] respectively, to provide policy incentives for improving water data openness, access and use.

Internationally, the World Water Data Initiative is being led by World Meteorological Organization (WMO) to organize the data necessary to realize and monitor progress towards the UN Sustainable Development Goal 6 on water. Thus far, this initiative is accelerating the sharing of hydrometeorological data. This may be because hydrometry is in high demand for weather and flood forecasting and its sharing is perceived by agencies as less risky for water management and reputation than data about water pollution, use, and services.

In October 2021, the WMO Congress approved a sweeping new Unified Data Policy, that provides a comprehensive update of the policies guiding the international exchange of weather, climate and Earth system data, including hydrology, between the 193 Member states and territories of WMO. Data on these topics is shared through the data centres comprising Global Terrestrial Network for Hydrology, including the Global Runoff Data Centre (stream gauging), GEMStat (global water quality samples), and many others.

In addition, the intergovernmental Group on Earth Observations (GEO), a voluntary partnership of national governments and Participating Organizations hosted by the WMO, established the GEO Global Water Sustainability project [10]. This informal agreement among partners from inside and outside the UN system has helped mobilize resources from the World Bank and other sources to advance international water data sharing and integration projects in Latin America, the Congo Basin, and elsewhere.

While these efforts are valuable, their data are not necessarily published in findable, accessible, interoperable, reusable manner, and there is no way to seamlessly interact with the data published across these systems. Moreover, these efforts around hydrometry are not integrated with efforts around water and sanitation infrastructure such as the Joint Monitoring Programme.

The way forward: An Internet of Water

All of the above activities have advanced open water data with foundational technical tools and policies that have led to some shifts in behavior in the United States and globally. To date, however, they have not attempted to address the broad incentive challenges facing states and the many thousands of non-governmental organizations and local agencies that manage water data. Moreover, while some global networks exist as mentioned above, there is no domestic network in the U.S. for bringing these water-related institutions together and encouraging the adoption of interoperable technical standards across the network.

It this context, a gathering of water policy experts, water users, and water data practitioners convened by the Aspen Institute in 2017 confirmed that the fragmentation of public water data limits their utility for decision-making, and called for "an Internet of Water" to address this challenge, and established an initial set of principles for doing so [11]. The Internet of Water project began as a start-up at Duke University in 2018 to knit earlier efforts together, providing the community, infrastructure, and incentives for a new culture of data modernization and openness and to make data findable, accessible, and usable to all.

The Internet of Water Principles were updated in 2021 [12] and referenced in the Infrastructure Investment and Jobs Act of 2021, which includes a new US Environmental Protection Agency grant program that will initiate state-based water data sharing pilot programs [13]. This program will improve incentives for water data modernization, by tying financial resources for data infrastructure to following guidance for data sharing.

While the Internet of Water project currently focuses on the United States, it is in dialog with related efforts in other countries, promoting the same standards and practices where applicable. Water data sharing has made significant progress in Australia, where the Bureau of Meteorology has been charged since 2007 with organizing, standardizing, and serving water data sourced from many organizations [14]. In the European Union, the INSPIRE directive requires member states to implement a variety of data and data sharing standards for geospatial information, including about water and infrastructure. The directive came into force in 2007, and implementation is ongoing and incremental [15].

Following a three-year start-up phase that demonstrated integrated water data in four states and built supporting technologies, the Internet of Water project is expanding into a growth phase led by a multi-sector coalition, with a mission to advance the modernization of public water data infrastructure in the United States. The growth phase may include an international scope if funders, sponsors, and collaborators can be identified. If new financial incentives are provided by the US Congress, the Internet of Water is poised to effect the long-needed cultural shift in public agencies to achieve equitable, sustainable, and resilient water management and stewardship enabled by shared and integrated water data.

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