Technology Adoption at Public Agencies

Identifying Challenges and Building Opportunities to Modernize Public Water Data Infrastructure

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Summary

Modernizing public agency water data infrastructure depends not only on technology adoption, but also an organizational and cultural evolution in how data are managed, shared, and deployed for decision-making. The Duke Internet of Water (IoW) Technology Adoption Program (TAP) was designed to address both aspects of water data modernization for public agencies. The program includes introduction to and training on available technologies and close engagement with public agency staff and leadership to facilitate the organizational transformation needed to adopt modern technologies and approaches. This report details efforts by the Duke IoW team to identify the challenges public agencies face when modernizing their water data infrastructure and recommends a roadmap for technology adoption at public agencies based on nationwide surveys and interviews, best practices identified by public interest technologists, and the principles of modern data infrastructure. The report also includes a pilot case study from the New Mexico Water Data Initiative and resources for public agencies to pursue their own initiatives.

INTRODUCTION

In the United States, water data are collected by a variety of public agencies, each with their own data standards, formats, platforms, and sharing protocols. There is variability not only among different states, but also among public agencies within the same state, and even departments within the same public agency. This data fragmentation makes it difficult for potential users to find the data sets they need, and once they've been found, to standardize them so they can integrate with other data sets. As a result, decision-makers are often forced to make judgments without the benefit of a complete picture of their water resources (The Aspen Institute 2017).

To build an accurate water picture, public agencies need to modernize their water data infrastructure. **Modern water data infrastructure is an integrated system of information technologies, which includes common standards, formats, and tools designed to make water data easy to find, access, and use.** Modern water data infrastructure does not necessarily have to be *new*, nor does it have to be *open*. Rather, modern data infrastructure is optimized to meet the needs of all users. In some cases, the newest technology may not be the most accessible. The rapid pace of digital innovation and environmental change causes users' needs to change rapidly as well. Modern water data infrastructure is designed to adapt to these evolving needs.

The following is the result of Technology Adoption Research Project conducted by the Internet of Water (IoW) team, part of the Water Policy Program (WPP) at Duke University's Nicholas Institute for Energy, Environment & Sustainability. The project follows 18 months (2019–2021) of pilot engagements and focus groups conducted by the Duke IoW team. The project was developed to improve understanding of the current state of public agencies' water data infrastructure and how modern technology is adopted at those agencies. Targeted research about technology adoption at public agencies is needed given their unique characteristics, structures, and processes.

Over the course of the project, the Duke IoW team conducted a survey and follow-up interviews with the following goals:

- Assess the current state of water data infrastructure at public agencies

- Learn more about the process of technology adoption within public water agencies

- Document the successes and challenges of technology adoption

- Develop an adoption curve to visualize the technology adoption transition in public agencies

In collaboration with the Water Data Exchange of the Western States Water Council, the American Water Resources Association, the American Water Works Association, the Association of Clean Water Administrators, the Association of State Drinking Water Administrators, and the Environmental Council of States, the Duke IoW team administered a 23-question survey via listservs and social media outlets, followed by in-person interviews of participants. The results revealed technology adoption challenges unique to public agencies and highlighted the need to develop clear, actionable solutions to those challenges and targeted initiatives to help public agencies implement those solutions.

> **Notable Terms**
>
> **Digital or data transformation:** A fundamental change in how organizations think about, collect, and manage data, resulting in the modernization of data into a service rather than a single-use product.
>
> **Technology adoption:** The implementation of the technological systems necessary to modernize an organization's data systems.
>
> **Modernization:** To bring a process, organizational structure, regulation, or mission up to a current standard. While standards evolve over time, modernization does not necessarily mean *new*. Modernization also does not mean *digital*, as there are some processes that are not accessible or improved by digital formats (for example, services for populations without easy access to the internet). It is also important not to equate modern with *permanent*, as truly modern systems are those that resilient to contextual changes. A modern system should constantly reassess how well it responds to the changing context around it. This adaptability makes modern systems simple, usable, useful, reliable, and resilient.

PROJECT SUMMARY

The Duke IoW team has ongoing collaborative projects with partners in four states: California, New Mexico, North Carolina, and Texas. This collaborative work provided an opportunity for us to observe how public agencies in these states adopt new technology and, in particular, the challenges they face when doing so. We also conducted several focus groups to talk directly with a diverse range of public agency employees from across the U.S. about their experiences working with data in their agencies, challenges or barriers to improving water data infrastructure, the benefits and successes of modernization efforts, and their recommendations for how their agencies can modernize.

To date, there has been little research exploring technology adoption by public agencies, and even less about those agencies that work in water management. This often contributes to misunderstandings and potentially ineffective proposals for solutions. An informal literature review conducted for this project in 2021 located few articles associated with technology adoption for public agencies in the water sector. Of 75,572 articles on technology adoption, 3,615 were specific to the water sector and 524 were specific to public agencies. Ultimately, only 23 articles addressed technology adoption among public agencies in the water sector. In many of those articles "technology adoption" focused on issues such as technical equipment and laboratory procedures. In addition, most articles on technology adoption for public agencies were international in scope, limiting their relevance to challenges faced by public agencies in the United States. The few articles that focused on the United States. were regionally specific and, therefore, not representative of national demographic distributions (see the Recommended Reading and Bibliography sections).

While there is a wealth of information on technology adoption across sectors and geographic scales, there has been very little work to understand how technology adoption in public agencies in the United States can improve the data infrastructure for water management. Given the dependence of effective water resource management on reliable, accessible, and usable data,

more effort is needed to (1) understand the status of data infrastructure in public agencies, (2) document the specific challenges public agencies face when modernizing data infrastructure, and (3) develop proposed solutions and policy interventions to support such efforts.

CHALLENGES FOR PUBLIC AGENCIES

The COVID-19 pandemic has exposed many challenges regarding public agency technology adoption and modernization that the emerging field of public interest technology is addressing. Research into public interest technology provides important lessons learned and insights that can be applied to the water sector (see the Recommended Reading section).

Through the IoW start-up period (2017–2020), the Duke IoW team's engagement with public agency leaders and staff, as well as scholars in the field of public interest technology, revealed challenges associated with technology adoption in public agencies. These are rooted in four causes:

(1) Lack of demand: In the private sector, a demand signal, powered by the market, indicates a desire for modernization. In the public sector, no such demand signal exists to drive action. Instead, the driver of action is the need to deliver the "public good" in a manner that is effective and efficient.

(2) Necessary transparency: The private sector is not necessarily better at technology development. When the private sector makes a mistake or fails at technology development, it is not public knowledge. However, in the public sector, transparency requires that attempts and failures are public knowledge, often leading to questions surrounding the appropriate use of public funds. Therefore, public agencies and the people who lead them are often risk-averse and incentivized to maintain the status quo.

(3) Competing priorities: Private organizations can identify and focus on a priority based on a market-driven mission. This mission can change over time in response to changing conditions or the intention of donors. In contrast, the missions of public agencies are often established in law and frequently more expansive than those of private organizations. This can create competing priorities that make cross-agency coordination and efforts to centralize data management difficult.

(4) Generational conflict: Public agencies often have multiple generations of technology under one roof. This causes cultural conflicts and often results in resistance to technology adoption and modernization within and between agencies. Today's systems are not only built upon legacy technologies, but also the thinking that created them.

For data infrastructure modernization efforts to be successful at public agencies, it is critical that technical frameworks and implementation plans are developed within the contexts, capacities, and capabilities of the agencies involved. Modernization efforts require coordination across the divisions of the public agency and should be carried out in accordance with typical organizational structures.

SURVEY RESULTS

The Duke IoW team and collaborating partners administered a 23-question survey (See Appendix B for survey questions) via listservs and social media outlets. The survey received 143 responses from public agency employees (federal, state, local, and tribal) representing each of seven broad geographic regions within the United States (Figure 1).

The survey captured responses from a variety of agency types, including water quality, water quantity, water planning, water rights and permitting, water pricing, water conservation, and others (e.g., water supply, enforcement, fish and wildlife), with the majority from water quality agencies (Figure 2).

Respondents also identified their role in working with data within their agency. These roles included data collection, modeling and visualization, decision-making based on water data, data management, and data requests. Within these roles, respondents were asked to categorize their experience working with data in their agency. Relatively few described their working experience with data as "excellent;" however, experiences with data collection as well as modeling and visualization were largely described as "good." Decision-making using data was described by roughly 60% of respondents as somewhat difficult, while nearly 90% of respondents described requesting water data as "somewhat difficult" or "difficult" (Figure 3). Difficulties with data-driven decision-making and requesting water data (particularly in cross-agency circumstances) also surfaced in the follow-up interviews as key areas for improvement.

Figure 1. Percent of respondents by region
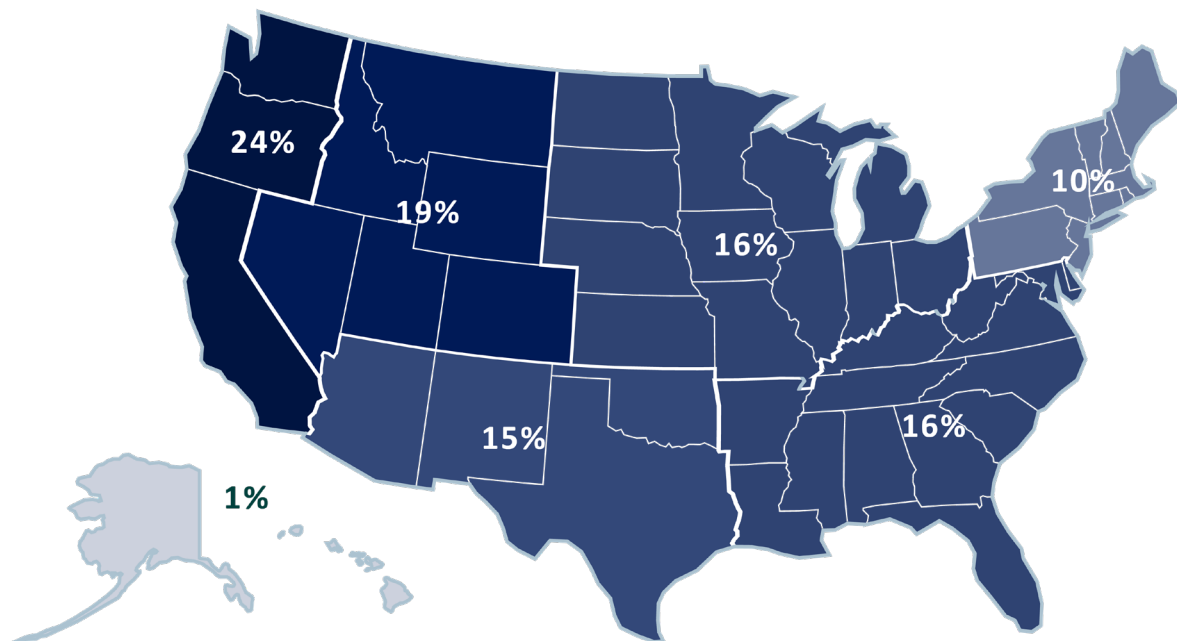
Note: In this graphic we show the percentage of participants located in each U.S. census region. The number of respondents per region are as follows: Northeast: 13, Southeast: 22, Midwest: 21, Southwest: 20, Rocky Mountains: 25, Pacific: 32, Noncontiguous: 2.
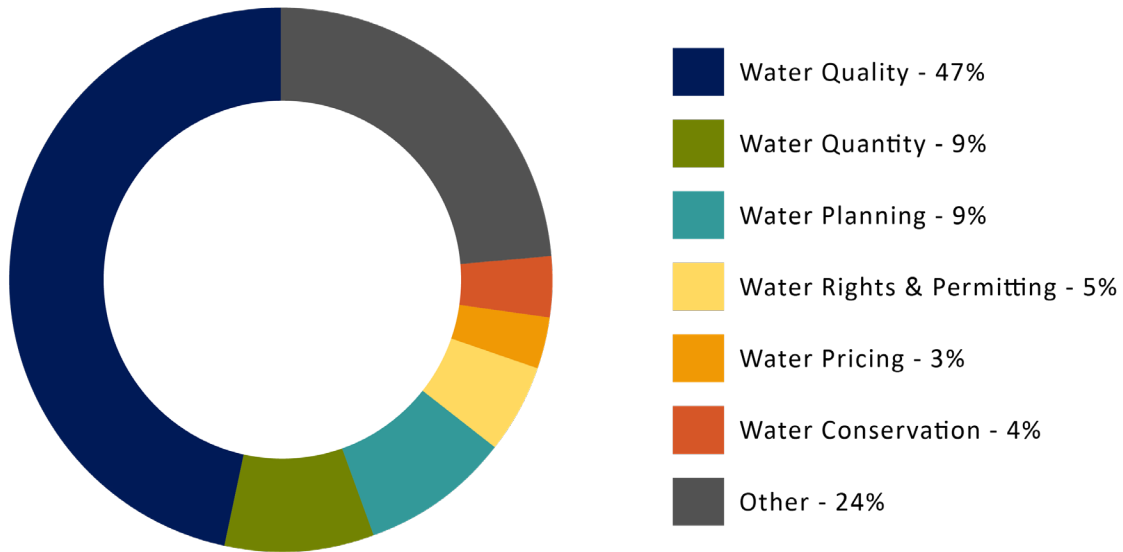
Figure 2. Agency roles

- Water Quality - 47%
- Water Quantity - 9%
- Water Planning - 9%
- Water Rights & Permitting - 5%
- Water Pricing - 3%
- Water Conservation - 4%
- Other - 24%

Figure 3. Described experience working with water data

RESPONDENT'S ROLE

- Collecting Water Data
- Data Modeling and Visualization
- Making Decisions based on Water Data
- Managing Water Data
- Requesting Water Data
- Other
- None

PERCENT OF RESPONDENTS

Legend:
- Excellent
- Good
- Somewhat difficult
- Difficult
- Very difficult
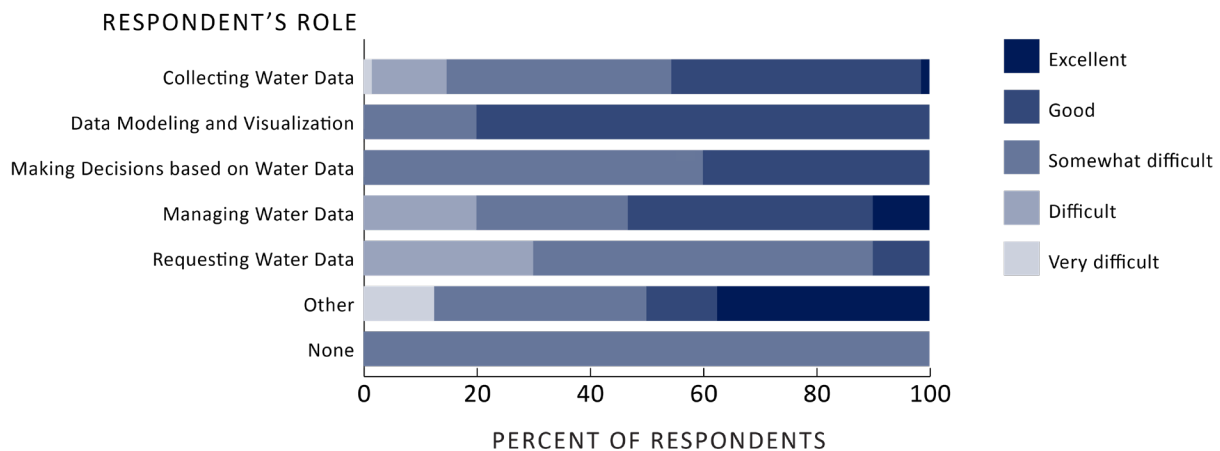
Note: We have broken out participants' self-described experience working with water data at their agencies by their job roles as related to data collection, management, or use.

Survey respondents were asked to consider their agency's water data infrastructure within a technology adoption curve (Figure 4).

This curve was developed initially by the Duke IoW team and later evaluated for accuracy using survey responses that compared how respondents classified their agency on the curve versus how they described the characteristics of their agency's water data infrastructure. For these survey questions, to comply with best practices in survey design, respondents were given seven choices:

Figure 4. Technology adoption curve

| STAGE 1	STAGE 2	STAGE 3	STAGE 4
• Most data are collected in paper formats and stored in filing cabinets	• Most data are collected in digital formats and stored on local computers	• Most data are collected in digital formats and stored in a shared database/s	• Data are collected in digital, machine-readable formats and stored in a shared database
• Staff manually access and compile data	• Staff manually access and integrate data	• Staff access data through one or more databases and manually integrate data	• Staff access and integrate data through APIs
• Staff can not create data visualizations or analytics	• It is difficult for staff to create data visualizations and analytics	• It is difficult for staff to create data visualizations and analytics	• Staff can easily create data visualizations and analytics
• Data are not standarized	• Data are not standarized	• Data may not be standarized across divisions or agencies	• Data are standarized across divisions and agencies
• Data quality is not documented	• Data quality is documented in an unstandarized way that is not legible to those outside the division or agency	• Data quality is well-documented	• Data quality is high and is well-documented
• Staff cannot integrate their data with data from other divisions or agencies	• It is difficult for staff to integrate their data with data from other divisions or agencies	• It is difficult for staff to integrate their data with data from other divisions or agencies	• Staff can easily integrate their data with data from other divisions or agencies
• It is difficult to share data across or between agencies	• It is difficult to share data across or between agencies	• It may be difficult to share data across or between agencies	• It is easy to share data across or between agencies

(a) Stage 1: Most reports and data are collected using paper formats and stored in file cabinets. Agency staff manually access and compile data upon request. Data are fragmented. Data are collected across many divisions within an agency and there is little ability to share data between divisions or agencies, and little knowledge of data collected by other divisions or other agencies.

(b) Somewhere between Stage 1 and Stage 2.

(c) Stage 2: Outdated data infrastructure and software exist, including local data servers that must be maintained by local staff. Data are not accessible from outside the agency. Data are fragmented and nonstandardized (e.g., variation of units, data names, etc. used within the agency).

(d) Somewhere between Stage 2 and Stage 3.

(e) Stage 3: A data infrastructure exists that allows for data sharing; however, the data are not always standardized or machine-readable. There is no easy method for creating visualizations and analytics. There may be duplicative systems across agencies, but they are not linked to each other.

(f) Somewhere between Stage 3 and Stage 4.

(g) Stage 4: A modern data management system exists that includes the ability to extract data from the system and conduct data visualization and analytics.

The curve was evaluated for how well the stages represent levels of data infrastructure at public agencies by comparing how respondents ranked their agency versus how they described the characteristics of their agency's water data infrastructure. Using this guideline, the responses matched the categories as defined in the technology adoption curve. Overall, most respondents placed their agency between Stages 2 and 3 on the technology adoption curve with minimal variation across geographic regions (see Figure 5).

Respondents were also asked to consider barriers to movement along the technology adoption curve. Respondents were asked to select from the following categories:

(a) Funding

(b) Legal barriers

(c) Agency leadership

(d) Lack of capacity

(e) Access to resources

(f) Lack of understanding of available technologies

(g) Lack of clarity about the value created by deploying improved data solutions

(h) Data security

Figure 5. Average stage on technology adoption curve by region
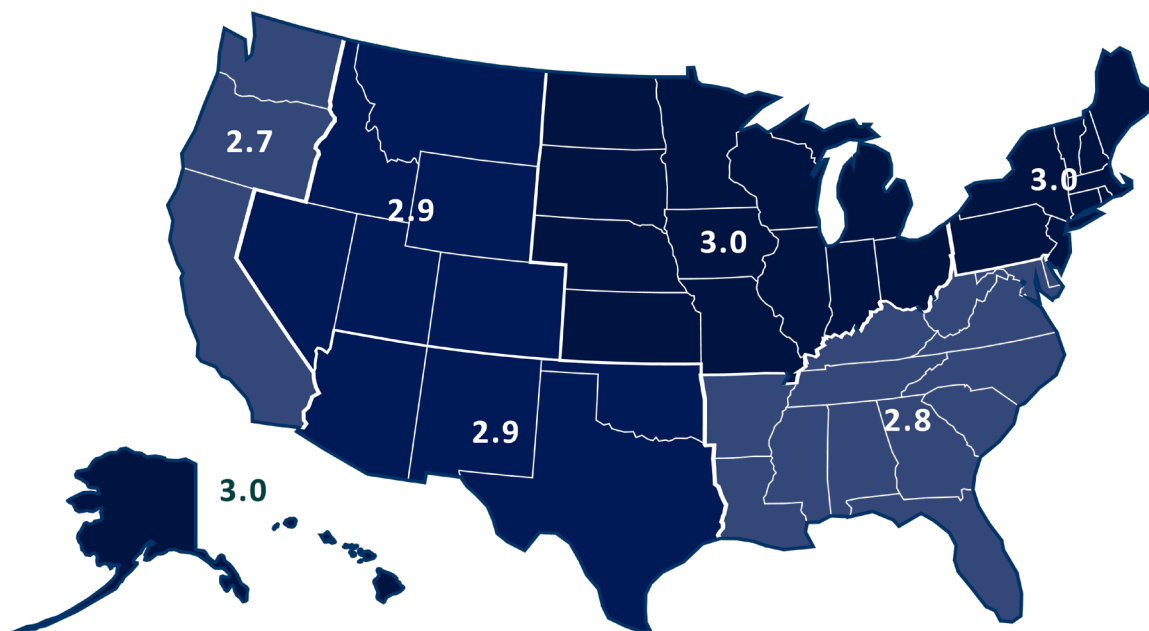
Note: The number of respondents per region are as follows: Northeast: 13, Southeast: 22, Midwest: 21, Southwest: 20, Rocky Mountains: 25, Pacific: 32, Noncontiguous: 2.

The overwhelming barrier to data infrastructure modernization, according to respondents, is funding (75%). Interviews with respondents were able to examine this finding in more detail, revealing that not only is lack of funding the root of most capacity issues, but the promise of funding can also serve as an important incentive to pursue data modernization efforts. Respondents also commented on additional barriers not indicated among the choices provided in the survey (responses a–h above). These included:

- Cross-agency collaboration, particularly across counties, states, or other administrative boundaries

- The need to support old applications while moving to modern technology

- Difficult bureaucratic processes, such as requests from IT departments, to adopt modern software

- High turnover among agency employees

- Inefficient existing technologies

- Resistance to the adoption of modern technologies

Topics such as resistance to change, lack of capacity, and high learning curves also surfaced in the interviews and were classified as cultural barriers, such as:

- Interviewee 1: *"I think it's probably more change resistance. I think there's a couple of people who understand it and care to see a change, but a lot of the people are just not eager to see change."*

- Interviewee 2: *"…it's hard when the benefits aren't tangible to them, you know what I mean? Like, here's all this extra work you have to do, or doing things, maybe not extra work, it gets harder or it's different. You have to learn, you know, it's out of your comfort zone and there's not really a, like, they don't see a benefit to that. So, I guess that's trying to like find ways to point to like, hey, this will make your job easier. And here's how."*

- Interviewee 3: *"When I talk about, you know, data management strategies or best practices in-house, I think that the people who aren't necessarily familiar with that world, you know, they might get a little bit intimidated and say, okay, well, that's going to be a whole other skill set I have to learn. They automatically, I think their head jumps to coding. They jump to language learning. They say I don't have time for this. Like, I know Excel, I know my data processing. This works for me. They think they don't have time to invest in a learning curve. And I think maybe this is what I need to learn to communicate better, and, I think, the people who are working on this might need to communicate better is: you don't need to learn anything necessarily like in the command line or anything like that in order to manage your data more effectively."*

When asked about helpful "next steps" to aid their agency in moving along the technology adoption curve, responses were concentrated primarily in two categories: identifying funding and technical support (Figure 6).

Figure 6. Respondents' recommendations for next steps for data modernization at their agencies

NEXT STEPS TO DATA MODERNIZATION
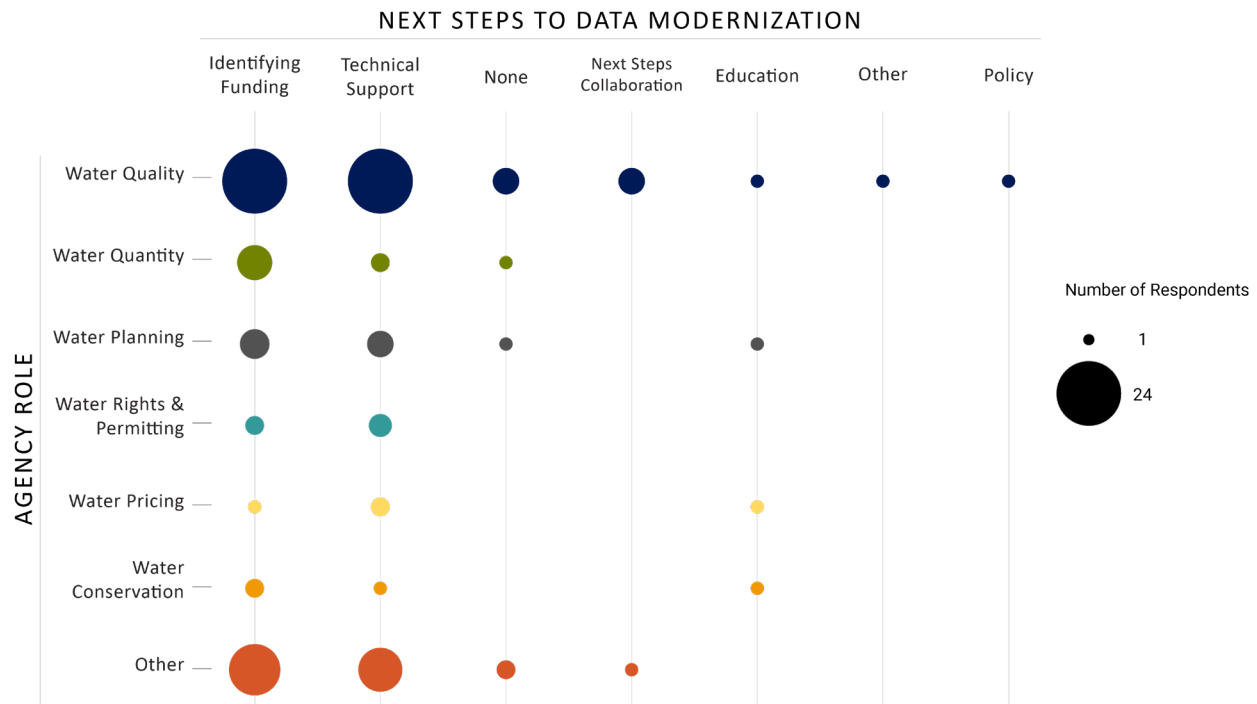
Note: Respondents' recommendations have been broken out by their agency's role.

INTERVIEWS

In addition to the survey, members of the Duke IoW team conducted interviews with 16 volunteer participants from the survey (see Appendix C). A content analysis of these interviews revealed themes of inefficient systems and cross-agency challenges, exacerbated by procurement processes, but also illuminated the benefits of increased efficiency within agencies that have invested in modernization efforts.

Interviewees cited five technology tools commonly deployed in their agencies: Oracle, SQL, Microsoft Excel, Microsoft Access, and Esri's ArcGIS. In many cases, these systems have been in place for 10 to 20 years and are frequently the source of many inefficiencies in their work with data. Outside of these legacy systems, interviewees cited poor procurement procedures via contractors that put structures in place that agencies are either unable to upgrade or to change systems that were never configured to meet their data needs.

- Interviewee 4: *"And so they recognize the need to build up this capacity … And I think our direct managers are aware that's critical as well. But I think historically there has absolutely been this tradition of, okay, you need a database, we don't have time to build it for you. So, hire a consultant to do it, but then only the consultant knows how to manage it. And so, then the database dies after, you know, three or four years. And either way, building these little databases, whether it's internally or externally, you're not getting the cross-agency function or consistency that you need for this to be kind of a long-lasting culture change or really effective."*

In addition to procurement issues, barriers to cross-agency collaboration were a common theme throughout the interviews.

- Interviewee 5: *"You don't necessarily know where to go to get the data you're looking for. You kind of have to ask around and find who's the steward of that data and then ask them for it. And then you get emailed an Excel file. And, so, there's, like I said, there's not version control because you're not necessarily pulling data from a database. You know, you're asking someone for this data set and that might be a different person than my colleague asked three weeks ago for the same data."*

- Interviewee 6: *"One of the challenges is there's just a real lack of interagency communication. I'll go a step further, not just electronically, but verbally. Communication as a whole is a real challenge. People are always talking, but it's sometimes you're not even sure that you have the right people involved, so it would be nice to have a network of databases as reference."*

Ad hoc systems were often described by interviewees as a mechanism to deal with the lack of investment in data infrastructure. These systems were often developed in-house by an employee with coding skills; however, these ad hoc systems contribute to systemic fragmentation and limit cross-agency interoperability, producing wide disparities in agency infrastructure. While a few "lucky" agencies had an employee who could code, many others lacked that internal capacity.

- Interviewee 7: *"I would describe it as a free-for-all of everyone just kind of making what they need to make the wheels go round."*

- Interviewee 8: *"I think that it's just a really hodgepodge approach and that, you know, that makes things difficult for us. It makes things difficult for the state. It makes things difficult for the public. You know, there are the inconsistencies, that's not great, you know, it hampers decision-making, you know, like if we're trying to make really big decisions, how can you do that?"*

But for those agencies who have implemented modernized data infrastructure, even for only a few, specific projects, the benefits are clear. The benefits most often cited by interviewees related to employee efficiency, which translated to dollars saved. For example, one interviewee described his agency's struggles to fulfill Freedom of Information Act (FOIA) requests. Initially, the agency received 200 to 300 FOIA requests per year. After implementing a public-facing tool for data delivery that allows the public to directly access the requested data requested, the agency now only fields about five FOIA requests per year, for a savings of 400 to 600 staff hours annually. Another agency employee described the impact of her agency's modernization: *"We have not ever undertaken an audit to, to like, quantify that time savings. But data reporting is so much smoother now … And then when you need to dig deeper, it's so much easier to be able to pull out exactly what you need … I would say that it's probably cut the time for report prep by maybe a third to a half."*

The following observations and lessons learned emerged from synthesizing the survey, interviews, and readings.

OBSERVATIONS AND LESSONS LEARNED

(1) ***"You can't bring knowledge, products, or services to a fight over incentives"*** (**Andrew Do**)**.** Incentives remain a critical barrier to modernization efforts. Regulatory measures, while effective in the short term, can be limited in their effectiveness for sustained, long-term change. Incentives provide the necessary resources to establish modernization programs, ensure their sustainability by building internal capacity, and provide tangible examples of the benefits of modernized water data infrastructure (often measured by more efficient use of employee time). Sharing these examples within and across agencies can inspire cultural change among both agency staff and leadership.

(2) **Ad hoc solutions increase data fragmentation across agencies.** Cross-agency interoperability is a critical barrier that prevents agencies from "seizing the moment," particularly in response to crises. An overreliance on single files that are held by individuals and individually requested, with little version control across agencies and little or no agreement on data and metadata standards, creates difficult or near-impossible circumstances for cross-agency data sharing and integration. This often leads to the development of ad hoc solutions for individual agencies and divisions that do not integrate with other systems, increasing the fragmentation of both data and resources.

(3) Agencies need less innovation and more operationalization. There is less need for innovation and more need to operationalize technologies that currently exist. An emphasis on innovation has meant fewer resources focused on implementing systemic change through improved processes as compared to single-platform solutions. It is important to distinguish the meaning of *modern* in these contexts. *Modern* means to bring current standards, processes, and organizational structure to the management of an organization and its data. It does not mean *new* or *digital*. Modern systems evolve over time and are responsive to changes in agency needs, mission, and context; therefore, as needs change the technology changes, and these criteria must be regularly reassessed. An emphasis on process means asking questions about what kind of data collection, management, and integration processes exist, what kind of processes are needed, and what technologies are appropriate to address these needs.

(4) Not all legacy systems are bad. Some systems are not improved with data modernization; therefore, it is important to preserve what is working and make efforts to integrate these systems into a modern workflow. Additionally, digitization of paper records (commonly considered a major component of legacy systems) should occur in a measured, strategic manner that focuses on prioritized documents of high use or need.

(5) Integrated data requires leadership and accountability. There must be an "owner" (a single decision-maker/traffic controller) that ensures cross-agency compliance and the establishment of standards. Examples include a chief data officer or a compliance officer that oversees data modernization across agencies and divisions and ensures external contracts adhere to established principles. Too often, public agencies rely on contractors to make critical decisions around data infrastructure, divorcing technological development from the agency context, and resulting in technologies that are less responsive to the changing needs of the agency. Investment in expertise and management not only enhances coordination, but also reduces inefficiencies by eliminating unintegrated ad hoc solutions, allows for resource sharing where appropriate, and supports a holistic approach to systems management.

(6) Effective policy and procurement practices are key. The United States spends an estimated $200 billion per year for federal and state IT services; many describe the results as old, difficult-to-access systems that often fail when needed. However, technology, or the lack of it, is not the issue. The problems arise from people, policy, and procurement issues. This requires (a) addressing the challenges with cultural conflicts across agencies and between leadership and staff, (b) implementing meaningful policy that supports modernization and the sustainable maintenance of data infrastructure, and (c) creating procurement processes that are responsive to the challenges of data infrastructure and technology adoption. These three issues are often intertwined. For example, an overreliance on contractors has meant software and existing infrastructure cannot be easily upgraded or refined with existing agency resources. This reduces human capacity, in terms of new technology expertise, within the agency to respond to needs as they arise and evolve. Effective procurement processes respond to the often rapidly changing nature of technology adoption and support agency capability while avoiding over hiring at the agency staff level.

RECOMMENDATIONS

Best practices in the fields of digital transformation and public interest technology, lessons learned from community and public agency engagement during the start-up period of the IoW project, and the survey and interviews conducted during the Technology Adoption Research Project provide the basis for the following recommendations. These recommendations are for public agencies at all levels who wish to undergo modernization of their water data infrastructure.

- **Identify and provide incentives for data modernization.** Because human capacity, digital infrastructure, and financial resources are limited at public agencies, an important mechanism for water data infrastructure modernization is to tie grant or other funds to the development of and compliance with standards for improved accessibility, interoperability, and modernization of public agency water data infrastructure. This includes grant programs offered by federal agencies but should also incorporate grants provided through philanthropic and other nonprofit organizations. Documentation of standards and best practices for data modernization should be provided to grantors as guidance for award requirements. While cultural barriers will not be resolved with incentives alone, the application of funds toward modernization can provide in-house demonstrations that can be persuasive to resistant leadership, particularly when they result in improved employee efficiency. Agency leadership can also use these demonstrations to champion water data modernization and urge policy-makers to develop sustainable funding sources for these initiatives.

- **Connect information delivery with policy outcomes.** While leaders often tout "data-driven decision-making," participants in the study and start-up period engagements struggled to provide evidence of decisions directly informed by data. This may be the result of cultural or behavioral processes in which decision-makers, who have historically not had access to information delivered in meaningful ways, continue to fall back on their traditional decision-making methods. To understand how data inform decision-making, agencies need to make clear avenues of information delivery accessible to decision- and policy-makers, then seek out and compile evidence about how their data modernization efforts have directly improved or informed decisions. These findings will promote further support of data modernization, as those tasked with resource allocation will also directly benefit from the modernization process.

- **Resolve issues with procurement processes.** Guidelines should be developed for agency procurement contracts to ensure that contractors follow modern data principles, meet agency needs for sharing and interoperability, and build in plans for sustained maintenance and maturity of systems.

- **Identify leaders for cross-agency compliance and establishment of standards.** Executed contracts should be overseen by a project lead, as described in the Observations and Lessons Learned section. Invest in modernization and technology adoption training for water leaders. Communication and training programs designed to inform decision and policy-makers about how to interpret and understand data, apply data to decision-

making, and appreciate the need for and power of modern data infrastructure will narrow the cultural divide between different generations of technology, equip leaders with the knowledge they need to engage with their agency staff about modernized data infrastructure, and remove much of the resistance and fear over technology adoption. Modeled after the Harvard Evidence for Policy Design program (EPoD 2022), the IoW Technology Adoption Program (TAP) deploys teams to states for in situ training on water data modernization and technology adoption training. Funding for this program comes from a combination of public grants and philanthropic funds.

OPERATIONALIZING TAP

The challenges outlined are not insurmountable. This assessment does not mean that public agencies need to be more like private organizations. Instead, public agencies can approach technology adoption with a greater level of intentionality to overcome the barriers and develop data infrastructure systems that are sustainable over time.

The goal of the IoW TAP is to provide education and training for both management and staff to implement technology adoption in their public agency. In situ training for public agencies

- facilitates agency-wide consensus on the need for modernization,

- identifies obstacles and challenges to modernization, and

- enables the high-impact behavioral and cultural change necessary to improve data use for water resources management.

More broadly, the adoption of modern water data infrastructure will make it easier for local governments and water users to report their data with minimal effort, enable state governments to manage and integrate those data, and empower water managing entities across sectors and scales to use public data to make informed, evidence-based decisions.

Recommended Criteria for Successful Partnerships

Partnership with the IoW Coalition[1] will be most effective when public agency or state partners achieve the following:

- Identify a project lead or chief technology officer

- Determine three to five agencies or agency divisions (in larger states) willing to participate in the TAP process

- Adhere to IoW Principles (IoW 2021b; Appendix A)

- Maintain a sufficient baseline of digital water data holdings (i.e., not requiring digitization)

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[1] The IoW Coalition is a group of organizations working together with federal, state, and local government partners to build foundational water data infrastructure across the United States and create a community of people and organizations using water data to make better decisions. The IoW Coalition is coled by five nonprofit organizations: the Lincoln Institute of Land Policy's Center for Geospatial Solutions, Duke University's Nicholas Institute for Energy, Environment & Sustainability, the Consortium of Universities for the Advancement of Hydrologic Sciences, Inc., the Water Data Collaborative, and the Western States Water Council's Water Data Exchange.

While all of these criteria are not required to be in place, such efforts from public agency partners are a good indicator of interest and commitment to modernization and, as such, an indicator of long-term success and sustainability.

IMPLEMENTING TAP

The IoW TAP process is best considered as a two-phase process. Phase 1 focuses on broad organizational cultural and behavioral transitions for adopting modern data infrastructure. The result of Phase 1 is an implementation plan that considers the current organizational data infrastructure, capacity and capability needs and limitations, end goals, and potential funding requirements and sources. Phase 2 focuses on the transition from the implementation of the plan as outlined in Phase 1 to the adoption of modern water data technologies and infrastructure and includes ongoing support.

Along the technology adoption roadmap (see Figure 7), Phase 1 consists of steps 1–6 with a transition period during steps 7–8. Phase 2 consists of steps 9–12.[2]

Roadmap for TAP

To initiate a partnership with the IoW Coalition and begin the TAP process, public agencies should contact the IoW Coalition via internetofwater.org. Once the U.S. Environmental Protection Agency pilot program for data sharing projects is established, authorized by the 2021 Infrastructure Investment and Jobs Act (IIJA), states will also be able to express interest in participating in TAP through an application to their state pilot program. The IoW Coalition will provide agency partners with information on TAP to review and discuss during an initial consult.
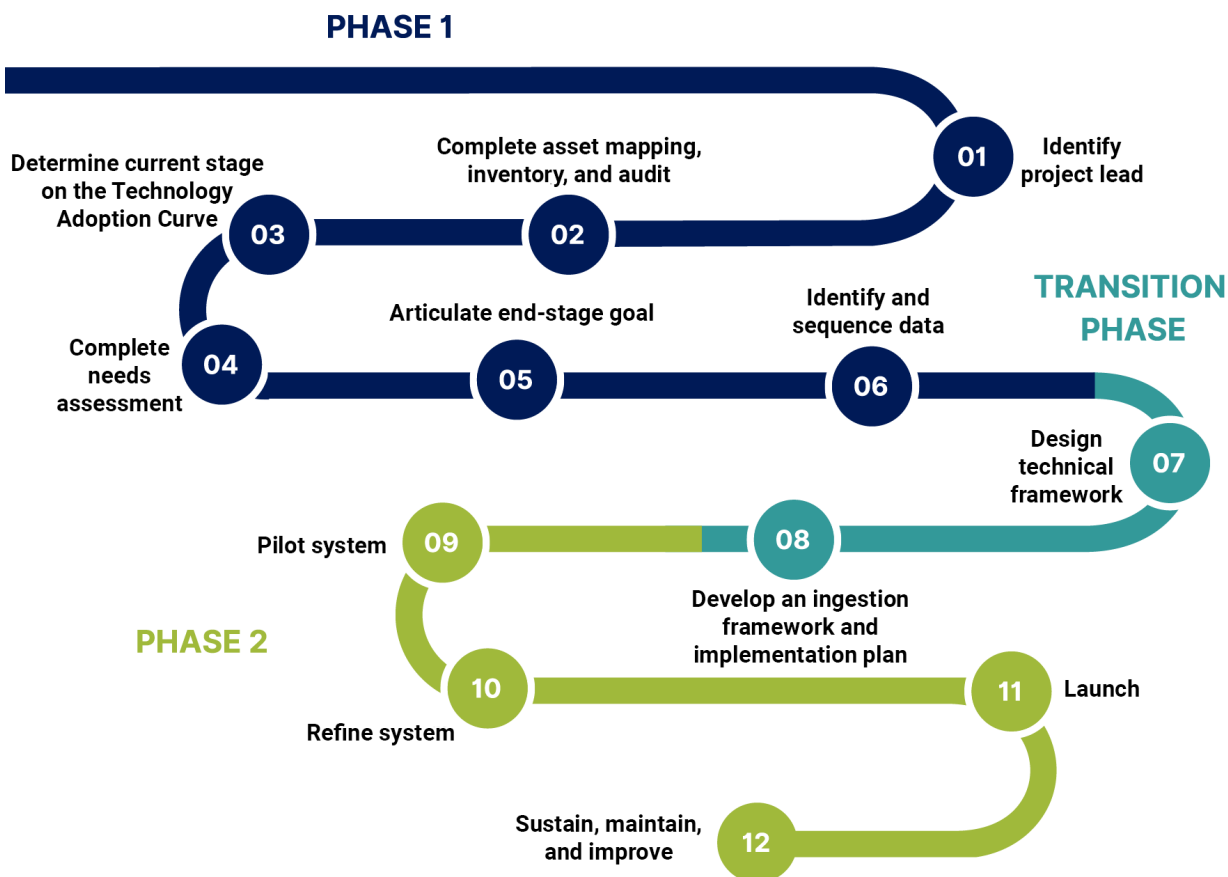
Phase 1
Methods for In Situ Engagement: Using Open Space Technology to Empower Change
The philosophy that guides the IoW TAP in-person engagement sessions is Open Space Technology (OST), a self-managed, participatory process specifically designed to address organizational change and one that "thrives in situations in which there is a diverse group of people who must deal with complex and potentially conflicting material in innovative and productive ways" (Owen 2008). Because of its ability to empower all participants, OST is an ideal philosophy for IoW TAP.

In OST engagements, participants identify the topics to be addressed, then self-select to work in small groups with the flexibility of moving from one group to another. The purpose of the small working groups is not necessarily to provide solutions, though suggestions for solutions are welcome, but instead to gain a better, more nuanced understanding of the topic and suggest a path to a solution. As groups report out, it becomes easier to prioritize and identify who should be responsible for taking the topic further.

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[2] The roadmap incorporates best practices for data ingestion, adapted from private industry (See Snowflake [2022], Striim [Kutay 2021], and Qlik [2022]), and incorporates agile development guidance from the U.S. Digital Services Playbook (CIO Council n.d.). Additionally, the roadmap outlined in this report represents public agency–specific guidance developed during the IoW's pilot studies and the observations and lessons learned from this report, all in accordance with the IoW Principles.

Figure 7. Technology adoption roadmap

Note: A step-by-by roadmap for technology adoption at public agencies. The phases shown on the roadmap are described in more detail in following paragraphs.

The information gained during the in situ engagement will form the basis of the implementation strategy. This is a critical step in creating strategies that both address the appropriate challenges and do so within the organization's context and capacity (see Appendix D, Planning and Conducting Open Space Technology Engagements).

Phase 1 Steps (Approximately 12 Months, Including Transition Phase)

(1) **Step 1: Identify project lead**

    (a) Assign project lead(s) responsible for the implementation of the water data modernization effort. The person(s) should have technical project management experience and appropriate knowledge of water data to navigate engagements with users and stakeholders.

(2) **Step 2: Complete asset mapping, inventory, and audit**

    (a) Conduct asset mapping to understand the different skills, capacities, and capabilities of different teams across agencies or agency divisions. Understanding in-house capacity is important to create an efficient, effective, and sustainable

modern data infrastructure. As part of this process, the IoW TAP team[3] will meet with state or agency executives and IT staff separately to discuss the status of data infrastructure, barriers, and needs, and to assess willingness to modernize.

(b) Conduct an inventory of current systems and platforms. (See the IoW's Water Data Inventory guidance [IoW 2022a]). The inventory will help the state or agency to determine data availability, location, status of existing data (digital or nondigital), and agency assets for modernization (software and hardware requirements). The time commitment for the data inventory is dependent upon designated employee time, fragmentation of the current system, and the size of the participating state or agency.

(c) Fundamental questions during this process are: What does the existing system look like? What technical skills currently exist within the agency? What capacity do those with technical skills have to devote to modernization efforts?

(3) Step 3: Determine current stage on the technology adoption curve

(a) Determine current agency or state location along the technology adoption curve (Figure 4).

(4) Step 4: Complete needs assessment

(a) Conduct internal engagement regarding barriers or challenges to movement along the technology adoption curve and identify internal and external resources that could be allocated to the modernization effort. This assessment will include a survey distributed to agency leadership and staff by the IoW TAP team to gather foundational information about state or agencies needs in preparation for the in-person engagement session.

(b) Meet to review the results of the survey and design the in-person engagement session. This meeting should include the state or agency lead, the IoW TAP team, and key representatives from participating agencies or agency divisions.

(5) Step 5: Articulate end-stage goal

(a) Set an end-stage goal on the technology adoption curve. This determination should be based on the starting point, needs assessment, and agency capacity and capability, as identified in previous steps of the roadmap. For example, not every agency will move directly to Stage 4. It is important to identify a realistic end-stage goal for data modernization.

(6) Step 6: Identify and sequence data

(a) Engage with agency or division leadership and IT staff. The IoW TAP team will travel to the participating state or agency to facilitate a one-day, in-person

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[3] The IoW TAP team includes staff from both Duke University's Nicholas Institute for Energy, Environment & Sustainability and the Lincoln Institute of Land Policy's Center for Geospatial Solutions. The IoW TAP team's work in Phase 1 is led by team members at Duke, while Phase 2 is led by team members at Lincoln.

engagement session. The evening prior to the engagement, there will be an informal meet and greet with the IoW TAP team, project lead(s), and identified agency or division leadership and IT staff. The engagement session will use an OST format to facilitate open and honest discussion (see Appendix D). The IoW TAP team will administer surveys to participants before, during, and after the in-person engagement to evaluate the stakeholder process.

(b) Develop a strategic plan to identify and sequence data to be incorporated into a newly modernized data infrastructure, considering digital and nondigital legacy data.[4]

Transition Phase Steps

(7) **Step 7: Design technical framework**

(a) Follow the IoW technical framework, which defines specifications and implementation for data modernization.[5]

(b) Develop a technical framework informed by the engagement and needs assessment (Step 4), responsive to the current location on the technology adoption curve as well as desired end stage (Step 5), and in line with data standards, metadata standards, and the software needs and acquisition plan (Step 6a).

(8) **Step 8: Develop an ingestion framework[6] and implementation plan**

(a) Develop a data ingestion process based on the data architecture, the volume of data to be ingested, and the frequency of data ingestion. A data ingestion framework articulates these processes, as well as any integration challenges (such as data compatibility and standardization), required for successful data modernization.

(b) Generate an implementation plan based on issues identified, solutions presented, and priorities set during the in-person engagement session that articulates an organizational strategy for the execution and sustainability of the data

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[4] Not all legacy data need be digitized; therefore, data sets of most need should be prioritized. In addition, data sets that are commonly shared internally or externally should be prioritized for incorporation into a newly modernized infrastructure to address issues of version control and challenges with cross-agency collaboration.

[5] IoW technical framework: (1) Metadata is published on the web, ideally in compliance with best practices for data on the web from W3C (2017). (2) Data is available for download in bulk and/or application programming interface (API) in open, nonproprietary formats. (3) To the extent possible, bulk download data formats and/or APIs will follow community-standard patterns (e.g., OGC standards [OGC 2022]), metadata will be included with data and of sufficient quality for users to make judgments as to what purposes the data is fit for use, and data content will reference publicly available definitions, controlled vocabularies, and data standards appropriate to the data's subject matter. (4) Data will be published and identified with version records and made available (to authorized users) so that workflows can be reproduced. (5) Open-format data content standards and data exchange or API standards for similar kinds of data should reference community, national, or international standards where practicable (see *IoW Data 101 Guidebook* [IoW 2021a]).

[6] A *data ingestion framework* is a process for transporting data from various sources to a storage repository or data processing tool. See Snowflake (2022).

modernization effort.[7] In collaboration with project lead(s), the IoW TAP team will develop the implementation plan, including a roadmap, and potential funding mechanisms.

(c) Incorporate state or agency feedback. This period is a cycle of feedback and revisions between the IoW TAP team, project lead(s), and other participating partners. The IoW TAP team will administer a survey to participants after delivery of the final implementation plan to evaluate the process.

Phase 2
Methods for Technology Development and Adoption: The IoW Service Center

The U.S. Digital Services (USDS) Playbook provides a general framework and best practices for the implementation of a technology adoption program once the first phase of social-behavioral change is complete (CIO Council n.d.). In addition to the generalized USDS framework, however, long-term and sustained adoption relies on individualized technical assistance to help public agencies implement new technologies within the context of their legacy systems. Person-to-person, ongoing support is critical to address the evolving needs of public agencies and sustain employee engagement during the transition phase.

Specifically, direct technical assistance is needed to (a) introduce and explain specific data standards and (b) assist in the implementation of those standards within state agencies to fully realize the goal of digital transformation. This step is also essential to ensure that technologies adopted by states use common standards and approaches and result in data sets that are interoperable with others from state and federal agencies.

Finally, states require technical assistance to ensure their water data sets are accessible to authorized users, including the general public for public data sets. In each state, technical assistance for implementation is generally needed for a period of one to three years. The IoW Initiative at the Center for Geospatial Solutions at the Lincoln Institute of Land Policy is designed to provide this service. Beyond that, the IoW Coalition will provide ongoing webinars, trainings, and best practices through the IoW Peer-to-Peer Network.

Phase 2 Steps (approximately 12–24 months)

(9) **Step 9: Pilot system**

(a) Engage with users and stakeholders to assess the usability, functionality, and efficiency of the modernized system.[8]

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[7] An implementation plan consists of an engagement strategy, long-term care and maintenance plan for the resulting systems or products, privacy restrictions and guidelines, funding requirements, associated staffing needs, and monitoring and evaluation strategy for impact assessment.

[8] This recommendation is in accordance with agile development best practices (see *U.S. Digital Services Playbook* [CIO Council n.d.]).

(10) Step 10: Refine system[9]

    (a) Refine the system based on feedback and lessons learned from the engagement in Step 9.

    (b) Return to Step 9 to further refine.

(11) Step 11: Launch

    (a) Promote the system through internal and/or external communications and trainings to ensure that it is widely adopted by agency staff.

(12) Step 12: Sustain, maintain, and improve

    (a) Perform routine maintenance to ensure the system is sustained over time.

    (b) Evaluate the newly modernized system, measuring and articulating impact and identifying opportunities for improvement at intervals defined in the implementation strategy.

CASE STUDY: NEW MEXICO WATER DATA INITIATIVE

New Mexico Water Data Act

With the passage of the Water Data Act in 2019, New Mexico became a national leader in addressing water and climate challenges by prioritizing a statewide collaborative approach to modernizing water data.[10] The goal of the Water Data Act is to make finding water data simple by coordinating data integration efforts across multiple state agencies and working with regional and federal data providers. The Act established the New Mexico Water Data Initiative (NMWDI), which refers to the collaborating team effort and project convened by the New Mexico Bureau of Geology and Mineral Resources and involves state directing agencies, including the New Mexico Office of the State Engineer, New Mexico Interstate Stream Commission, New Mexico Environment Department, and New Mexico Energy, Minerals and Natural Resources Department.

The legislation requires communication and collaboration among these agencies and others collecting or managing water data for the state. Other key partners and supporters currently include the Healy Foundation, the Internet of Water Coalition, Sandia National Laboratories, the U.S. Bureau of Reclamation (WaterSMART program), and the Thornburg Foundation. The NMWDI is a reliable model for other, similar initiatives because it required cross-agency collaboration, funded a lead agency, incorporated stakeholder engagement, and resulted in a public-facing platform to facilitate data integration and interoperability.

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[9] Steps 9 and 10 articulate an iterative process for engagement and refinement. These steps should be repeated until the new system or product meets user expectations.
[10] NMSA 1978, § 72-4B

Budgeting for Water Data Modernization in New Mexico

The initial state funding provided for the NMWDI was $110,000 for years one and two of the initiative. This funding was supplemented by philanthropic contributions and federal grant programs. The estimated cost for years three to five is an additional $500,000 annually to fully support an IT and operations team with up to four full-time dedicated staff who will develop and maintain the cyberinfrastructure and connections to data producers and users. The six other agencies named in the Water Data Act also requested funding. Their funding requests varied significantly depending on existing agency capacity, existing data infrastructure, and the volume of data managed by the agency. Initial investments to modernize data infrastructure for these agencies averaged $410,000, and recurring annual costs averaged $421,330.

In September, 2022 the NMWDI released a new plan for the continued implementation of the New Mexico Water Data Act entitled *2022 Plan: New Mexico Water Data Initiative* (NMWDI 2022). The plan states that they "estimate that state agencies will require a combined annually recurring budget of $2.65 million, with other non-recurring costs of approximately $6.5 million over the next 5 years, to fully implement the Water Data Act. Additional state funding may be addressed through an IT special appropriation (C2 request), while state agencies are also working to build funding through grants and programs related to water data." Updates can be found on the NMWDI website.

Introducing TAP

Since 2019, the NMWDI has made substantial progress—building collaborations, working groups, and data catalogs and implementing data standards. And yet, there is significant work ahead to complete the digital transformation of New Mexico water data. Currently, the efforts of the NMWDI focus on communications between and within agencies, implementing water data plans at each agency, developing success stories, offering a range of support for agency-specific needs, improving data literacy, building a water data community, and providing opportunities for data users to share feedback. As part of these efforts, the NMWDI partnered with the Duke IoW team to launch a TAP pilot in September 2022, focused on identifying and addressing organizational barriers to data modernization.

The goal of the IoW TAP engagement with the NMWDI was to provide in situ training for participating agencies to:

- Promote meaningful dialogue across New Mexico water agency leaders related to modernizing data collection, storage, access, and security

- Identify key issues and obstacles related to data infrastructure modernization

- Establish prioritized data modernization strategies for each agency

- Learn lessons from the New Mexico pilot program that can be applied to other states' modernization initiatives

More broadly, facilitating the final stages of adoption of modern water data infrastructure will make it easier for New Mexico's local governments and water users to report their data with minimal effort, enable state governments to manage and integrate those data, and empower water

managing entities across sectors and scales to use public data to make informed, evidence-based decisions. The information gained during the in situ engagement establishes the basis for future planning and next steps for the statewide initiative. This is a critical step to create strategies that both address the appropriate challenges and do so within the participating agencies' context and capacity.

Sample Meeting Agenda

Morning Agenda (begin 9 a.m.)

- Kick-off—why we are here

- Survey feedback and discussion

- Introductions and overview of Open Space Technology methodology

  - Theme identified: How do we modernize data infrastructure to serve both our citizens and our agencies?

  - Participants identify and display topics, for example:

    - What specific data sets need to be prioritized for digitization and/or standard practice

    - How to make it easier to fulfill FOIA requests

    - How to digitize water rights so people know who owns water, and where

    - What is needed to create a data dashboard for easier visualization and decision-making

    - What data security issues need to be managed

    - Data transparency—issues and concerns

  - Participants select concurrent sessions to attend

  - Meetings are organized and held

Afternoon Agenda (conclude 5 p.m.)

- Report-outs of morning meetings

- Intra-agency meetings to synthesize insights from the morning session and prioritize commitments

- Agency report-outs

- Next steps and meeting end

Preengagement Survey

A 20-question survey was distributed to all staff of the five New Mexico water agencies, as outlined in the 2019 New Mexico Water Data Act (see Appendix E). Before the TAP engagement, 165 participants completed the survey. Survey respondents represented a diversity of agency roles, with the majority representing water rights and permitting, water quality, and water quantity (Figure 8).

The majority of individual respondents were responsible for managing water data, making decisions based on water data, and replying to public requests for data and information (Figure 9).

While the majority of respondents indicated that employees carry out much of the data collection for their agency (52%), a significant number indicated that consultants (26%), or certified, trained community members (10%) carry out data collection. Much of this data is stored in structured tabular form, such as in Excel spreadsheets or an Access database (39%), while nearly as much is stored in unstructured formats, such as Word documents or PDF files (31%).

Data sharing methods are somewhat varied, but largely consist of direct communication (25%), online website applications or web forms (24%), interactive web maps (16%), or public repositories, such as the Water Quality Exchange (WQX) (12%) (Figure 10) with the primary audience being the public, followed closely by regulators and decision-makers (Figure 11).

To determine their agency's current location on the technology adoption curve (see Figure 4), respondents were asked a series of questions regarding the ease of working with data in their agency and asked to place their agency's status along the curve. The survey measured respondent perceptions of working with data in their division as well as within their agency. More than 60% of respondents indicated that working with data in their agency is either "difficult" or "somewhat difficult" while only 46% indicated difficulty in working with data within their own division. Overall, respondents placed their division and agency on the technology adoption curve either between Stages 2 and 3 or in Stage 3.

Figure 8. Agency role
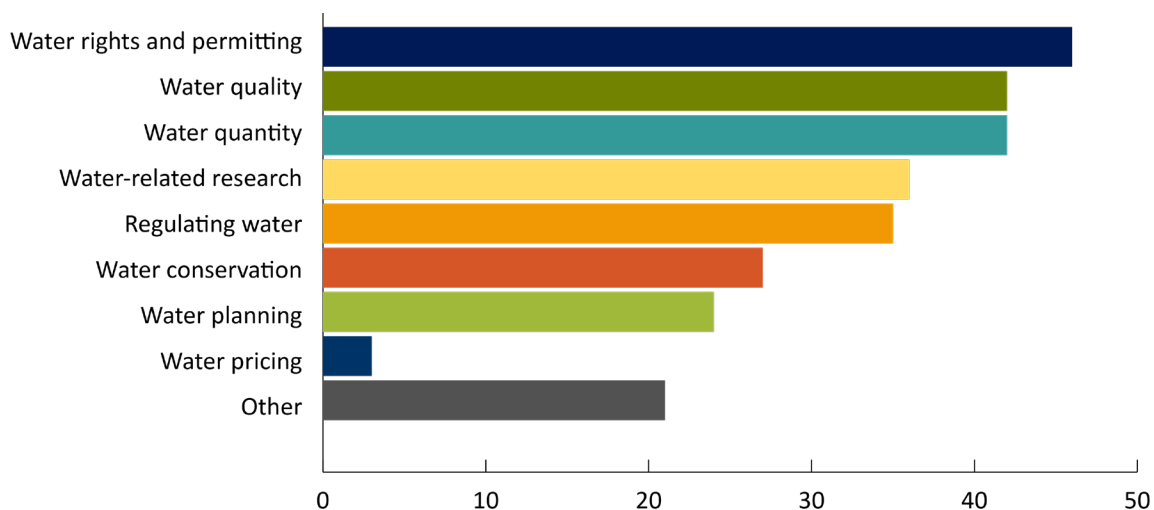
Figure 9. Participants' roles related to data collection, management, and use at their agencies
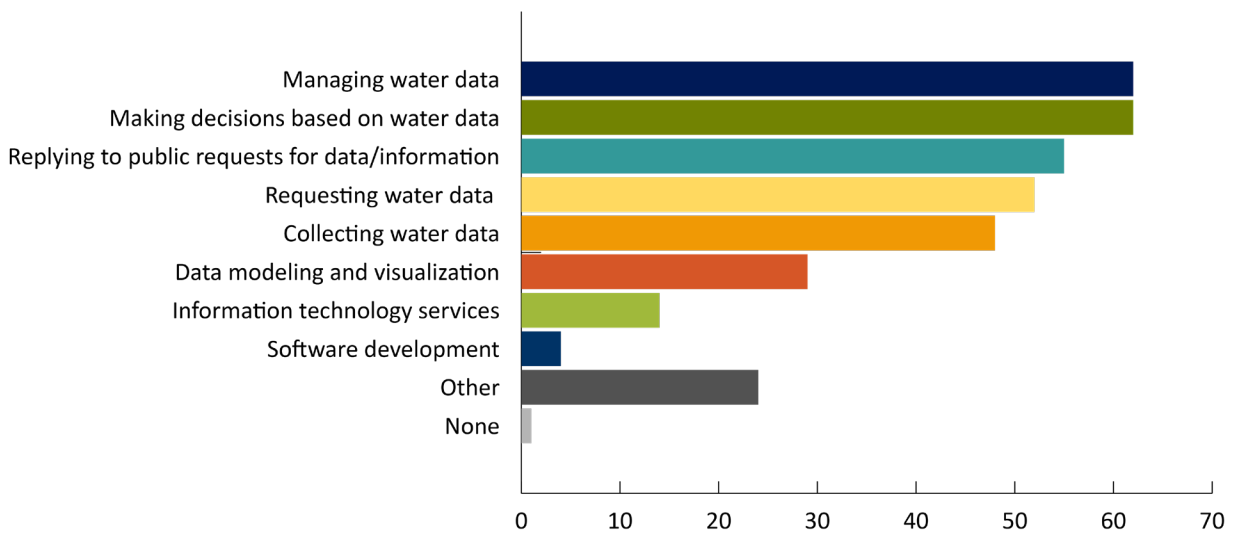
Figure 10. Data sharing methods
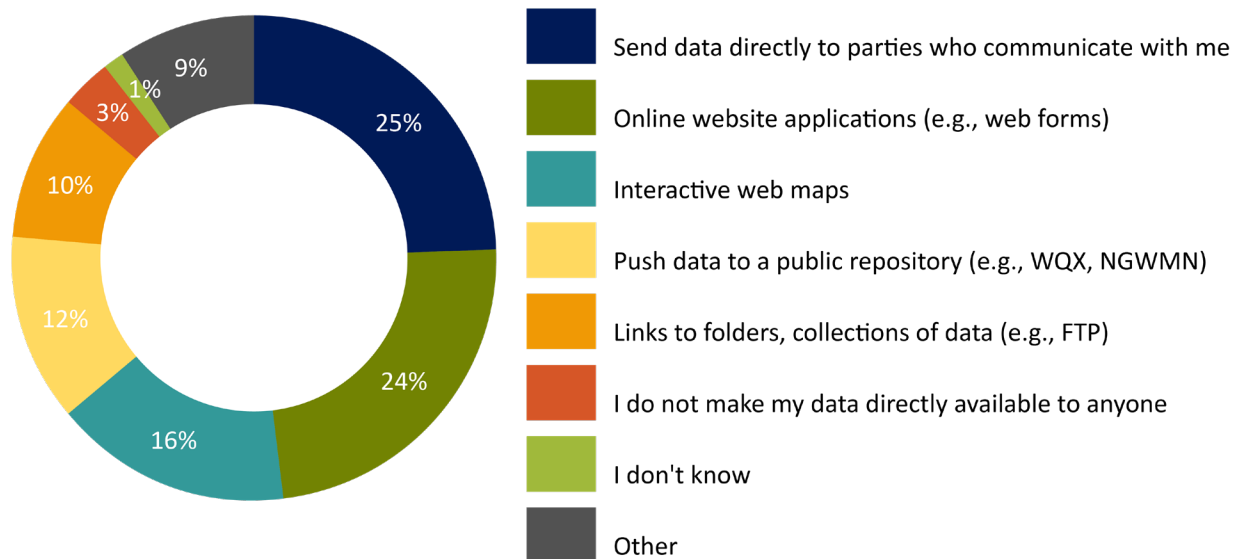
Funding and organizational capacity consisted of half, or nearly half, of respondents' noted barriers to modernization as well as their priorities for next steps (Figure 12).

Finally, participants were asked to comment on what they would change about how their agency or division manages water data. These comments were classified into 11 categories, as follows:

- Centralization: Combining multiple data platforms or management systems into a single system

Figure 11. Intended audience for data

Figure 12. Participant recommendations for future work for their agency and their agency division

- Legacy data or systems: Updating legacy data systems

- Standardization: Standardizing data across divisions or agencies

- Capacity: More staff time or training

- Discoverability: Making it easier to find data

- Data entry: Improving data entry systems

- Collaboration: Increasing interagency or inter-division collaboration

- Data extraction: Improving data extraction systems

- Funding: More funding to implement data infrastructure modernization

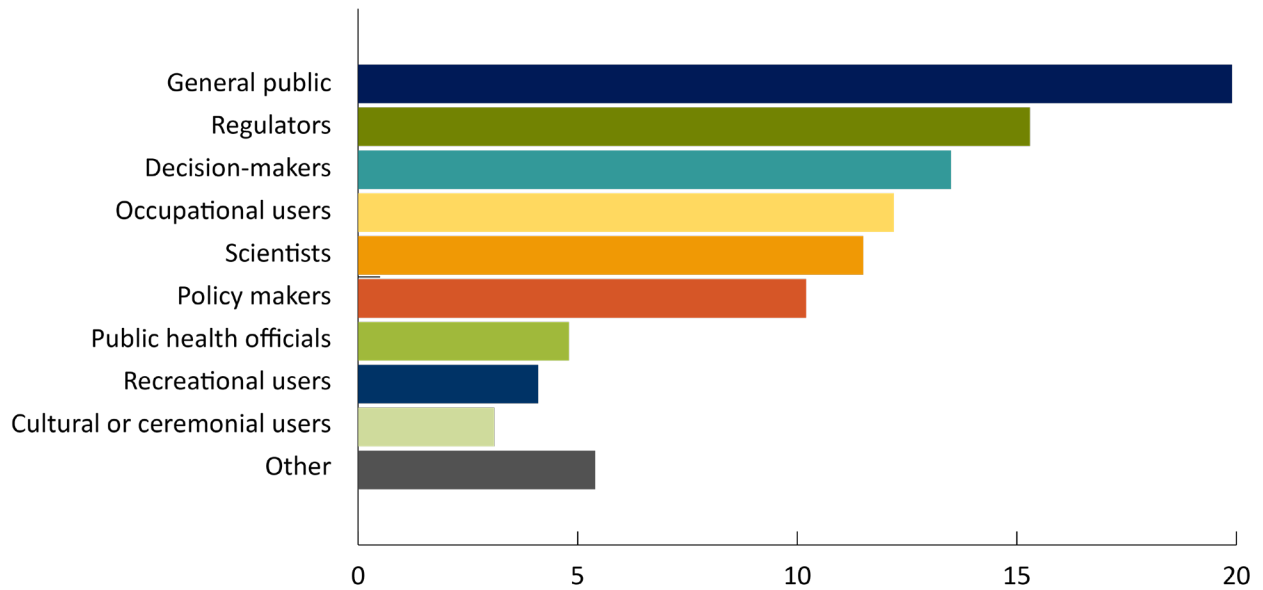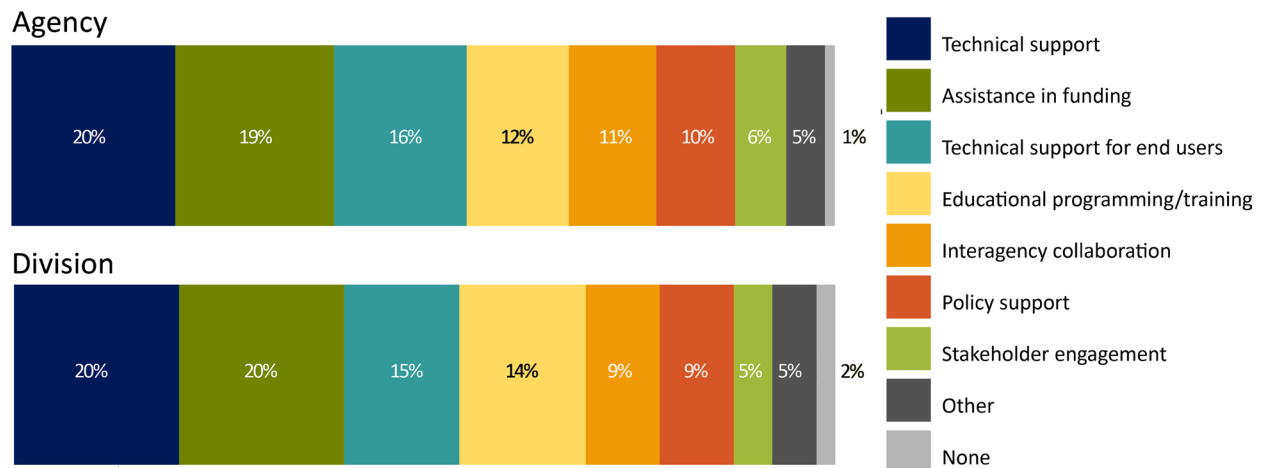- Data visualization/analytics: Enabling data visualization and analytics

- Other

Based on the categorization of responses, participants would prefer an agency-wide centralized system for data, division and agency-wide attention to updating legacy data systems, division and agency-wide attention to data and metadata standards, and an increase in capacity across both agency and division (Figure 13).
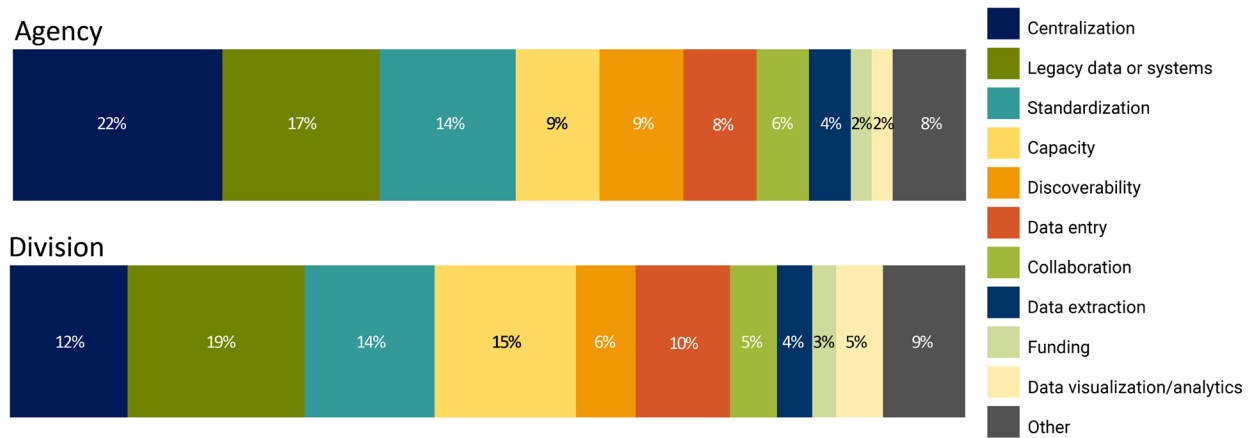
The survey responses provided valuable information entering the in-situ engagement. During the engagement, participants introduced six topics for discussion: the development of "killer apps;" data integration; data integrity, management, and standardization; vision and leadership; turning data into information, knowledge, and wisdom; and legacy data. Participants self-organized into cross-agency working groups based on these identified topics, and produced a report-out that outlined the following:

- Problem or opportunity statement

- Why the topic is important

- Various perspectives and differing opinions on the topic

- Recommendations or conclusion (it is important that participants be specific [i.e., "collaborate more" is conceptual, not specific])

- People or agencies who may take the topic further (if appropriate)

Participants were then asked to convene based on their affiliated agency to reflect on the lessons learned from the cross-agency collaboration and establish next steps for their agency in modernizing their water data infrastructure. Based on the cross-agency report-outs and the agency-specific report-outs, the following recommendations were made:

- **End reliance on paper data.** Cease acceptance and production of paper data to reduce the growing burden of legacy data through the adoption of electronic data collection and management requirements for electronic data submission, electronic forms, and the requirement for third-party vendors to submit data in electronic formats.

- **Diversify funding mechanisms for water data modernization.** Use mechanisms such as updating and increasing fees; reduce agency reliance on the legislature for funds to support water data modernization.

- **Review and update procurement and hiring practices.** Review and update practices that trap agency resources in proprietary software, refine contracting requirements to reflect overall data modernization efforts, and recruit and retain a workforce with the appropriate data skills.

Figure 13. Participant comments about recommended changes at their agency and within their agency division

Agency

Centralization 22%	Legacy data or systems 17%	Standardization 14%	Capacity 9%	Discoverability 9%	Data entry 8%	Collaboration 6%	Data extraction 4%	Funding 2%	Data visualization/analytics 2%	Other 8%

Division

12%	19%	14%	15%	6%	10%	5%	4%	3%	5%	9%

Legend:
- Centralization
- Legacy data or systems
- Standardization
- Capacity
- Discoverability
- Data entry
- Collaboration
- Data extraction
- Funding
- Data visualization/analytics
- Other

- **Focus on API development.** Prioritize building services, like APIs, that facilitate the accessibility and integration of data across agencies.

- **Increase education and guidance from NMWDI.** Provide guidance on appropriate data and metadata standards as well as education on how divisions and agencies can connect with the NMWDI catalog and services.

Evaluation of Pilot

To conclude the in situ engagement, each participant was asked to name a single word or phrase that described their experience with the engagement. Figure 15 is a representation of these closing thoughts and demonstrates an overall positive view of the engagement.

Additionally, the in situ engagement was followed by a survey distributed to all participants. Most of the workshop participants, 21 of the 31 in total, completed the survey. Overwhelmingly the feedback was positive, with 100% of responding participants satisfied with the communications and preparations leading up to the workshop and feeling that they could talk openly and honestly about the issues facing their agency or division. All respondents reported that they felt the workshop was a good use of time. Furthermore, all but one respondent said they would not only use the information from the workshop to inform planning and activities in their agency or division, but also that they could have a positive effect on their agency or division's water data modernization efforts because of their participation in the workshop.

Participant confidence in their agency or division's ability to fulfill the recommendations generated in the workshop was overall positive but varied. Sample comments included:

- *"Our agency can move forward as long as it has the financial and human resources to support the effort."*

- *"I believe we will get there, but competing priorities slow the process."*

- *"I am confident my group is on the right path, and this gave us great ideas on how to proceed."*

- *"9/10 because we discussed realistic recommendations like improving data collection with electronic forms which help toward larger goals like reducing the use of paper."*

- *"Our team was able to arrive at a common understanding as to the functions of our respective divisions in relation to water data services. We are not as siloed as we thought, and we have both producers and consumers of data products in our department. Having our Deputy involved was a great help in understanding the issues and how the data modernization effort fits into operations going forwards."*

Overwhelmingly, the need to be able to implement the recommendations outlined during the engagement focused on acquiring increased financial and human resources. However, there were several who indicated a need for increased education and staff buy-in: *"We need more education on what the water data act means for the rank and file. Leaders will come and go, but how the movement forward needs to be conducted by informed people."*

Next Steps

Participating agencies were provided the opportunity to review the engagement summaries as well as the agency commitments and recommendations, and to provide corrections or feedback. This feedback has been incorporated into a report submitted to the NMWDI leadership.

At the time of this report's publication, it was recommended that a six-month follow-up meeting among participants be convened to capture post-workshop reflections and progress-to-date from each agency toward their stated commitments and recommendations. It was also recommended that a one-year follow-up meeting be convened.

MOVING FORWARD: IMPLEMENTING IOW TAP UNDER THE IIJA

The Technology Adoption Research Project revealed a strong desire for data infrastructure modernization within state agencies that manage water resources across the United States. It also illuminated significant barriers that have prevented many of these agencies from implementing large-scale data modernization projects in the past. The IIJA, signed into law on November 15, 2021, commits $55 billion to modernize America's water infrastructure. As part of that investment, the federal government authorized funds for the U.S. Environmental Protection Agency to provide grants to pilot projects aimed at more easily sharing information on water quality, water infrastructure needs, and water technology between state and local agencies. The law states that the "Internet of Water Principles developed by the Nicholas Institute for Environmental Policy Solutions"[11] should guide these efforts. This funding would help state agencies overcome one of their most substantial barriers to data infrastructure modernization: a lack of funding.

The IoW TAP aims to help state agencies overcome the other barriers revealed by this research through individualized engagement and guidance. The IoW Coalition also supports state agencies as they work towards modernization through a variety of resources and tools (IoW 2022b, 2022c). Our goal is a future where decision-makers at all levels can access the data and information they need to adapt to water challenges and ensure sustainable, equitable, and resilient management of our nation's water resources. We believe that to achieve better water management, you must first have better water *data* management.

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[11] Now called the Nicholas Institute for Energy, Environment & Sustainability.

Figure 14. Participants' closing thoughts

Data
Literacy

REFRESHING

Learned a lot

ABOVE THE LINE

Encouraging HELPFUL

STRONG RELATIONSHIPS

FASCINATING Informative

Educational Eye-opening

CAUTIOUSLY OPTIMISTIC Positive

Common Cause VALIDATING

ILLUMINATING Common Needs

Enlightening NEW AND OLD

Integrating Minds REVEALING

WEALTH OF IDEAS

Reassuring

RESOURCES

Recommended Reading

Bellotti, M. 2021. *Kill it with Fire: Manage Aging Computer Systems (and Future Proof Modern Ones)*. San Francisco: No Starch Press.

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APPENDIX A: IOW PRINCIPLES

(1) Water data are essential for efficient, equitable, sustainable, and resilient water planning, management, and stewardship.

(2) Modern data infrastructure increases the usefulness of water data and enables its broadest possible application.

(3) All water data produced for the public good should, by default, be findable, accessible, interoperable, and reusable (FAIR) for public use or authorized users.[12]

(4) Security and privacy risks associated with sharing data can be mitigated using mechanisms for tiered access for authorized users.

(5) Commonly accepted data, metadata, and exchange standards should be adopted by water data producers to promote interoperability, efficiency, sharing, and secondary uses of data.

(6) Control and responsibility over data are best maintained by data producers.

(7) Data producers are responsible for sharing data of known quality and documenting essential metadata; data users are responsible for determining whether data are appropriate for specific purposes and uses.

(8) Federated, distributed systems of interoperable public water data generally provide scalability and flexibility to meet the diverse needs of data producers and users.

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APPENDIX B: SURVEY QUESTIONS

Name: _____

Email Address: _____

    (1) Can we contact you for an interview to further discuss data technology at your agency?

        (a) Yes

        (b) No

    (2) Do you work at a state agency?

        (a) Yes

        (b) No

    (3) In which geographic region is your state/agency located?

        (a) Northeast (Pennsylvania, New York, New Jersey, Connecticut, Massachusetts, New Hampshire, Vermont, Rhode Island, Maine)

        (b) Southeast (Maryland; Delaware; Washington, DC; Virginia; West Virginia; Kentucky; Tennessee; North Carolina; South Carolina; Georgia, Florida; Alabama; Mississippi; Louisiana; Arkansas)

        (c) Midwest (Ohio, Indiana, Michigan, Illinois, Iowa, Wisconsin, Minnesota, North Dakota, South Dakota, Missouri, Nebraska, Kansas)

        (d) Southwest (Oklahoma, Texas, New Mexico, Arizona)

        (e) Rocky Mountains (Montana, Idaho, Wyoming, Colorado, Utah, Nevada)

        (f) Pacific (Washington, Oregon, California)

        (g) Noncontiguous (Alaska, Hawaii)

    (4) My agency's primary role regarding water resources is focused on:

        (a) Water quality

        (b) Water quantity

        (c) Water rights

        (d) Water planning

        (e) Water conservation

        (f) Water pricing

        (g) Other (please specify)_____

(5) At my agency, my role involves the following (select all that apply):

    (a) Collecting water data

    (b) Managing water data

    (c) Requesting water data (from within my agency or from other agencies)

    (d) Making decisions based on water data

    (e) None

    (f) Other (please specify)_____

(6) At my agency, working with data is best described as:

    (a) Very difficult (data is highly fragmented and not digitized, located mostly in paper format)

    (b) Difficult (data is highly fragmented and often digitized but is located in reports or PDFs that are difficult to access)

    (c) Somewhat difficult (data is somewhat fragmented and/or somewhat digitized but not standardized; data is available in Excel or CSV formats)

    (d) Good (data is mostly or completely digitized, minimally or not fragmented, and is either standardized or stored in a central repository)

    (e) Excellent (data is fully digitized, not fragmented, standardized, easily accessible, machine-readable, and stored in a central repository)

(7) Which statement best describes your agency's current position on water data? Please explain.

    (a) My agency is comfortable with its current data tools and infrastructure

    (b) My agency is interested in pursuing tools and technology to improve data management, access, and use

    (c) My agency currently or has recently implemented projects and new technology to improve data management, access, and use

    (d) Please explain_____

(8) What was the catalyst behind starting data improvement projects? Select all that apply.

    (a) Internal demand (e.g., rising need for improved data infrastructure from within the agency)

    (b) Legislative demand (e.g., state policy determines data standards, legislators require improved quality of or access to data, etc.)

(c) Constituent demand (e.g., pressure from constituents for improved access to or quality of water data)

(d) Demand from other agencies (e.g., other agencies required access to or use of my agency's data, increased need or demand for collaboration between agencies)

(e) Other (please specify)_____

(9) What challenges or barriers does your agency face regarding improving data infrastructure and management? Select all that apply.

(a) Funding

(b) Legal barriers

(c) Agency/leadership approval

(d) Lack of organizational capabilities to deploy improved data solutions

(e) Access to resources (e.g., training, technology)

(f) Lack of understanding of available technologies

(g) Lack of clarity on value created by deploying improved data solutions

(h) Data security concerns

(i) None

(j) Other (please specify) _____

(10) What next steps would be most relevant to your agency? Select all that apply.

(a) Assistance identifying funding

(b) Technical support (setting up databases/systems, data digitization/ standardization)

(c) Technical support for end users (dashboards and visualizations)

(d) Educational programming or training

(e) Policy support

(f) Interagency collaboration

(g) Stakeholder engagement

(h) None

(i) Other (please specify)_____

Technology adoption curve

STAGE 1	STAGE 2	STAGE 3	STAGE 4
• Most data are collected in paper formats and stored in filing cabinets	• Most data are collected in digital formats and stored on local computers	• Most data are collected in digital formats and stored in a shared database/s	• Data are collected in digital, machine-readable formats and stored in a shared database
• Staff manually access and compile data	• Staff manually access and integrate data	• Staff access data through one or more databases and manually integrate data	• Staff access and integrate data through APIs
• Staff can not create data visualizations or analytics	• It is difficult for staff to create data visualizations and analytics	• It is difficult for staff to create data visualizations and analytics	• Staff can easily create data visualizations and analytics
• Data are not standarized	• Data are not standarized	• Data may not be standarized across divisions or agencies	• Data are standarized across divisions and agencies
• Data quality is not documented	• Data quality is documented in an unstandarized way that is not legible to those outside the division or agency	• Data quality is well-documented	• Data quality is high and is well-documented
• Staff cannot integrate their data with data from other divisions or agencies	• It is difficult for staff to integrate their data with data from other divisions or agencies	• It is difficult for staff to integrate their data with data from other divisions or agencies	• Staff can easily integrate their data with data from other divisions or agencies
• It is difficult to share data across or between agencies	• It is difficult to share data across or between agencies	• It may be difficult to share data across or between agencies	• It is easy to share data across or between agencies

(11) Using the above chart, please identify which stage best represents your agency.

    (a) Stage 1: Most reports and data are collected using paper formats and stored in file cabinets. Agency staff manually access and compile data upon request. Data are fragmented. Data are collected across many divisions within an agency and there is little ability to share data between divisions or agencies, and little knowledge of data collected by other divisions or other agencies.

    (b) Somewhere between Stage 1 and Stage 2.

    (c) Stage 2: Outdated data infrastructure and software exist, including local data servers that must be maintained by local staff. Data are not accessible from outside the agency. Data are fragmented and nonstandardized (e.g., variation of units, data names, etc. used within the agency).

    (d) Somewhere between Stage 2 and Stage 3.

    (e) Stage 3: A data infrastructure exists that allows for data sharing; however, the data are not always standardized or machine-readable. There is no easy method for creating visualizations and analytics. There may be duplicative systems across agencies, but they are not linked to each other.

    (f) Somewhere between Stage 3 and Stage 4.

    (g) Stage 4: A modern data management system exists that includes the ability to extract data from the system and conduct data visualization and analytics.

(12) Please select the benefits of your agency's investment in a modern water data infrastructure. Select all that apply.

    (a) Reduced employee time on data requests

    (b) Reduced employee time on data processing

    (c) Improved operations and decision-making to achieve agency mission (effective identification of challenges and solutions)

    (d) Decreased costs (associated with data storage or software)

    (e) Increased interagency collaboration and/or communication

    (f) Better public communication and stakeholder engagement

    (g) Reduced employee time on reporting

    (h) Better ability to advocate for agency mission support

    (i) None

    (j) Other (please specify)_____

(13) Which of the following best describes how data are collected and stored at your agency?

    (a) Most data are collected in paper formats and stored in filing cabinets

    (b) Most data are collected in digital formats and stored on local computers

    (c) Most data are collected in digital formats and stored in a shared database(s)

    (d) All data are collected in digital, machine-readable formats and stored in a shared database(s)

(14) Which of the following best describes how staff access data at your agency?

    (a) Staff manually access and compile data

    (b) Staff access data through one or more databases and manually integrate data

    (c) Staff access and integrate data through APIs

(15) Which of the following best describes data visualization and analytics at your agency?

    (a) Staff cannot create data visualizations or analytics

    (b) It is difficult for staff to create data visualizations and analytics

    (c) Staff can easily create data visualizations and analytics

(16) Which of the following best describes data standardization at your agency?

    (a) Data are not standardized

    (b) Data may be somewhat standardized across divisions or agencies

    (c) Data are standardized across divisions and agencies

(17) Which of the following best describes data quality at your agency?

    (a) Data quality is not documented

    (b) Data quality is documented in an unstandardized way that may not be legible to those outside the division or agency

    (c) Data quality is well-documented

    (d) Data quality is high and is well-documented

(18) Which of the following best describes how data are integrated at your agency?

    (a) Staff cannot integrate their data with data from other divisions or agencies

    (b) It is difficult for staff to integrate their data with data from other divisions or agencies

    (c) Staff can easily integrate their data with data from other divisions or agencies

(19) Which of the following best describes how data are shared at your agency?

    (a) It is difficult to share data across divisions or agencies

    (b) It may be somewhat difficult to share data across divisions or agencies

    (c) It is easy to share data across divisions or agencies

APPENDIX C: INTERVIEW GUIDE

Interview Details

Project: Internet of Water Agency Technology Adoption Curve	**Date:**

Interviewer(s):

Interviewee:

Interview Guide

Validate the Interviewee Profile

- We would like to record this interview, with your permission. We will not share this recording—this is only for our internal purposes. Do I have your permission to record?

- Can you quickly walk us through your background and experience?

- What is your agency's primary role regarding water resources? Water quality, water quantity, water rights, water planning, etc.?

- What are your direct experiences working with data at your agency?

Explore their Data and Technology Experience

- Describe a typical project for you or your agency that involves data management.

- What kind of technologies, frameworks, or other methods has your agency implemented for working with data? Note: get to the workflow—follow step-by-step data process.

- For these technologies, did your agency purchase the technologies or do you develop and maintain them in-house?

- How standard are these processes across different departments? Is it the same across different data types, such as groundwater versus water quality?

- How would you describe the ease or difficulty of working with data in your agency?

- What do you believe are the barriers or challenges to water data modernization in your agency? When there have been improvements, what were you able to do and why?

- Where, if applicable, has ambition for improving data infrastructure come from? Pressure from external data users (e.g., constituents or legislators)? Internal data users or managers? Department chairs?

- If your agency has implemented new technologies or processes, what was the benefit to the agency or to outside users?

- Do you have a sense of how other people perceive the data you share? Its quality, standardization, how easy it is to work with, etc.? Who generally asks for data from your agency or department?

- In the survey, you were asked to place your agency along the technology curve. Do you access data from other agencies? What's wrong with it? Why is it difficult to integrate with your agency's data—where would you put those agencies on this curve?

- You indicated your agency was at *X* stage. What do you think it would take to move your agency to the next stage?

Lessons Learned

- What lessons or advice do you have for your agency peers on the topic of working with or managing water data?

- Are there resources that would be helpful for your agency in improving and modernizing your water data infrastructure?

APPENDIX D: PLANNING AND CONDUCTING OPEN SPACE TECHNOLOGY ENGAGEMENTS

Open Space Technology Engagement Planning

Because Open Space Technology (OST) is fully participatory and does not impose a structure on the meeting, there is very little preparation needed to develop a formal agenda. Instead, preparations focus on securing the appropriate space and supplies and encouraging participation from those who are interested and engaged in the overall topic.

Creating an invitation for participation should follow a simple format. It is important to keep the invitation brief but provide enough information to encourage participation. As there is no formal agenda created in the OST format prior to the engagement, there will be no attachments necessary. Consider the following format for an invitation:

- Theme (issue): Stated in ten words or less

- Background: Brief highlights and questions to be addressed

- Logistics: When, where, and how including information on meals provided and/or transportation, if needed

- Promises: Summary of expected outputs from the meeting

To successfully carry out OST engagements, it is important to locate a space large enough to facilitate participants sitting in circles, both for the kickoff session of identifying topics and for the concurrent meetings that will occur afterward. Additionally, supplies such as easels with pads and markers will be required for each concurrent session and the general participation kickoff meeting.

Getting Started

Participants may not be familiar with the OST process. Therefore, it is important to lay the groundwork at the outset of the meeting. Typically, this consists of the following:

(1) **Welcome.** The lead person or a trusted voice should welcome participants to the engagement and introduce any outside facilitators.

(2) **Focus the group.** The facilitator should take this time to actively focus the group. For example, instead of immediately joining the group, walk around and encourage everyone to take note of who is present, draw their focus on what is set to be accomplished.

(3) **State the theme.** Clearly state the purpose of the meeting. Avoid long histories or any kind of presentations. Think of this step as a "destination check" and use it as a moment to inspire participation. Remember that empowerment messaging has more impact than consequences (catastrophic) messaging. Something like: "By the end of this process we will have…."

(4) **Describe the process.** Now that the audience is curious about what is happening,

describe the process: "In case you are curious about how we are going to get from here to there, it is called Open Space Technology. It has been developed over many years, starting in 1985, and has been used all over the world with groups large and small. You will be surprised by how simple it is and how it always seems to work! You might be wondering how we are going to accomplish our goals today. It is quite simple. In just a little while, I'm going to ask each one of you who cares to—and not everyone has to—identify the issues or opportunities related to our theme for which you all have an interest and passion in addressing. Don't just consider ideas that you think others are interested in. This is your chance for anything goes that is important to you and pie-in-the-sky ideas."

(5) Open the marketplace. Topics of discussion are recorded for concurrent meetings.

(6) Get out of the way!

OST is driven by four principles and one law. The four principles are: (1) whoever comes are the right people, (2) whatever happens is the only thing that could have, (3) whenever it starts is the right time, and (4) when it's over, it's over. The only law is the law of two feet. This means that if at any time during the concurrent meetings, participants find they are neither learning nor contributing, they can move to another concurrent meeting.

While the lack of structure of the meeting may be intimidating, the positive outcomes and results of unstructured, participatory engagement have been long referenced in research and are especially useful in potentially contentious situations or in situations in which difficult change is required. For these reasons, TAP will be modeled after the OST approach and philosophy.

For more information, see Owen (2008).

APPENDIX E: NEW MEXICO TAP PREENGAGEMENT SURVEY QUESTIONS

(1) Please select your agency:

    (a) New Mexico Bureau of Geology and Mineral Resources

    (b) New Mexico Environment Department

    (c) New Mexico Office of the State Engineer

    (d) New Mexico Energy, Minerals, and Natural Resources Department

    (e) New Mexico Interstate Stream Commission

(2) Which division, bureau, or group do you work in within your state agency?

(3) My agency's primary role regarding water resources is focused on (select all that apply):

    (a) Water quality

    (b) Water quantity

    (c) Water rights and permitting

    (d) Water planning

    (e) Water conservation

    (f) Water pricing

    (g) Water-related research

    (h) Regulating water

    (i) Other (specify) _____

(4) At my agency, my role involves the following (select all that apply):

    (a) Collecting water data

    (b) Managing water data (databases, data entry)

    (c) Requesting water data (from within my agency or from other agencies or data providers)

    (d) Making decisions based on water data

    (e) Data modeling and visualization

    (f) Information technology services

    (g) Software development

    (h) Replying to public requests for data or information

(i) None

(j) Other (specify) _____

(5) Who collects data for your agency (select all that apply)?

(a) Employees

(b) Interns

(c) Certified, trained community members unaffiliated with your agency (e.g., crowdsourced, NGOs)

(d) Data is submitted or reported by consultants or industry

(e) Other (specify) _____

(6) What is the frequency at which the data you use are collected?

(a) Daily

(b) Weekly

(c) 2–3 times per month

(d) Monthly

(e) Annually

(f) Irregular

(g) All of the above

(h) Other (specify) _____

(7) What is the format of the data your agency collects?

(a) Unstructured text: Word, PDF

(b) Unstructured media: Images, video

(c) Structured tabular: Excel, Access

(d) Flat file: comma (CSV) or tab-delimited file

(e) Other (specify) _____

(8) What is the format of the data you use:

(a) Unstructured text: Word, PDF

(b) Unstructured media: Images, video

(c) Structured tabular: Excel, Access

(d) Flat file: comma (CSV) or tab-delimited file

(e) Other (specify) _____

(9) How do you or your agency currently make data available to other parties?

  (a) I do not make my data directly available to anyone

  (b) Send data directly to parties who communicate with me, such as by IPRA or email

  (c) Links to folders, collections of data (e.g., FTP)

  (d) Push data to a public repository (e.g., WQX, NGWMN)

  (e) Interactive web maps

  (f) Online website applications (e.g., web forms)

  (g) I don't know

  (h) Other (specify) _____

(10) Who do you believe owns the data collected by your agency, division, bureau, or group?

  (a) The individuals or agency who collects the data

  (b) The individuals or agency that finances data collection

  (c) The individuals or agency that manages and stores the data

  (d) The public whose tax dollars pay for the collection, storage, and maintenance of data

  (e) Other (specify) _____

(11) Who is the primary audience for the data you use or the data that your agency collects? (select all that apply)?

  (a) General public

  (b) Recreational users

  (c) Occupational users (industry, agriculture, etc.)

  (d) Cultural or ceremonial uses

  (e) Public health officials/regulators

  (f) Decision-makers

  (g) Policy-makers

  (h) Scientists

  (i) Other (specify) _____

(12) For what purpose does your agency or division collect data (select all that apply)?

    (a) To inform decision-making

    (b) To comply with regulations

    (c) To respond to requests by constituencies

    (d) To respond to requests by elected officials (nonregulatory)

    (e) To be eligible for certain types of funding, unique opportunities (e.g., disaster response funding)

    (f) Other (specify) _____

(13) At my agency, working with data is best described as:

    (a) Very difficult (data are highly fragmented and not digitized, located mostly in paper format)

    (b) Difficult (data are highly fragmented and often digitized but located in reports or PDFs that are difficult to access)

    (c) Somewhat difficult (data are somewhat fragmented and/or somewhat digitized but not standardized. Data are available in Excel or CSV formats)

    (d) Good (data are mostly or completely digitized, minimally or not fragmented, and are either standardized or stored in a central repository)

    (e) Excellent (data are fully digitized, not fragmented, standardized, easily accessible, machine-readable, and stored in a central repository)

(14) What challenges or barriers does your AGENCY face regarding improving data infrastructure and management (select all that apply)?

    (a) Funding

    (b) Legal barriers

    (c) Agency leadership approval

    (d) Lack of organization capacity to deploy improved data solutions (e.g., staff time or skill)

    (e) Access to resources (e.g., training or technology)

    (f) Lack of understanding of available technologies

    (g) Lack of clarity on value created by deploying improved data solutions

    (h) Data security concerns

    (i) None

    (j) Other (specify) _____

(15) What next steps would be most relevant to your AGENCY? (select all that apply)?

    (a) Assistance in funding

    (b) Technical support (setting up databases/systems, data digitization and standardization)

    (c) Technical support for end users (dashboards and visualizations)

    (d) Educational programming or training

    (e) Policy support

    (f) Interagency collaboration

    (g) Stakeholder engagement

    (h) None

    (i) Other (specify) _____

(16) What challenges or barriers does your DIVISION, BUREAU, or GROUP face regarding improving data infrastructure and management (select all that apply)?

    (a) Funding

    (b) Legal barriers

    (c) Agency leadership approval

    (d) Lack of organization capacity to deploy improved data solutions (e.g., staff time or skill)

    (e) Access to resources (e.g., training or technology)

    (f) Lack of understanding of available technologies

    (g) Lack of clarity on value created by deploying improved data solutions

    (h) Data security concerns

    (i) None

    (j) Other (specify) _____

(17) What next steps would be most relevant to your DIVISION, BUREAU, or GROUP (select all that apply)?

    (a) Assistance in funding

    (b) Technical support (setting up databases/systems, data digitization and standardization)

    (c) Technical support for end users (dashboards and visualizations)

    (d) Educational programming or training
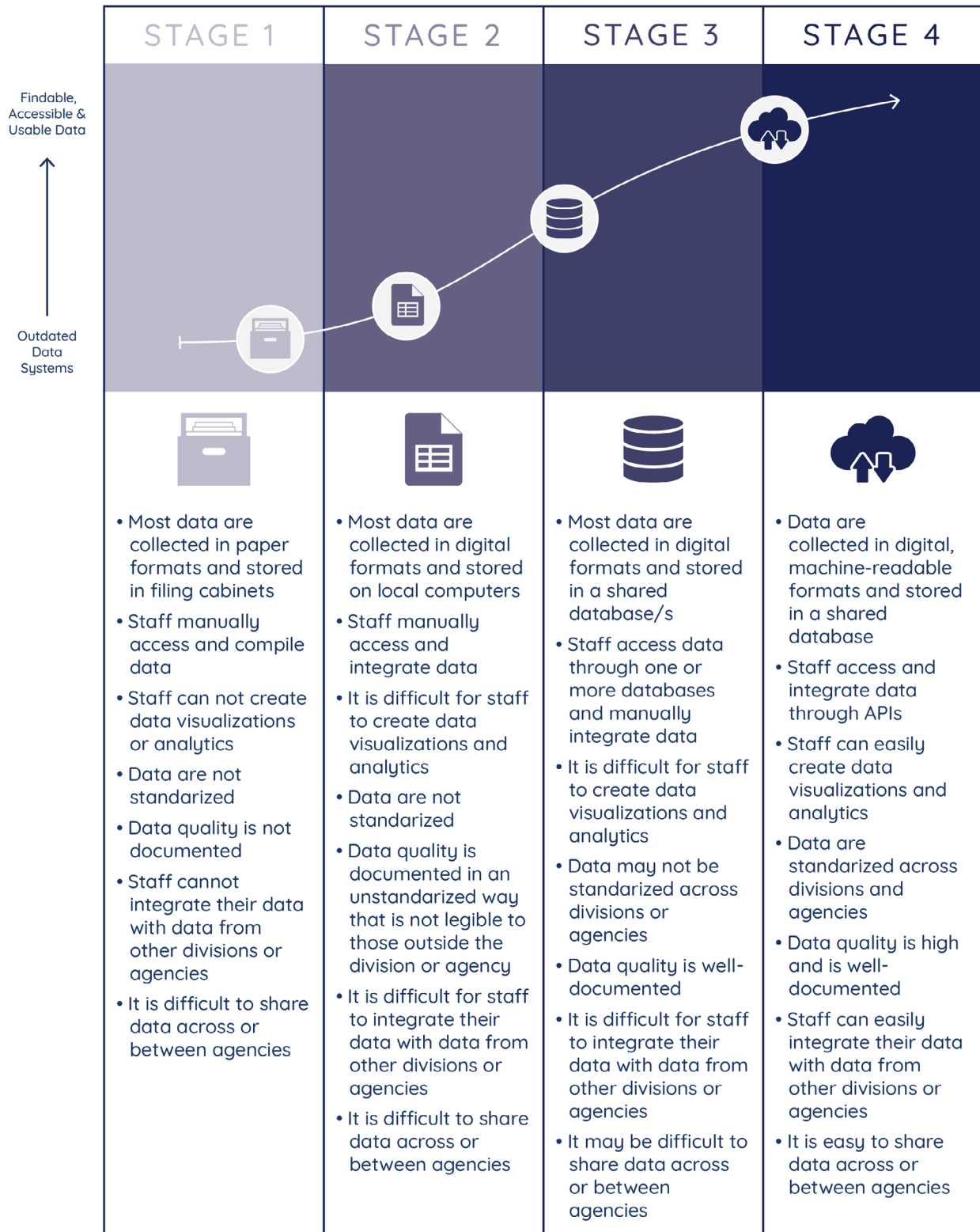
(e) Policy support

(f) Interagency collaboration

(g) Stakeholder engagement

(h) None

(i) Other (specify) _____

Use the diagram below [p. 52] to answer the questions that follow about your agency AND your division, bureau, or group within your agency.

(18) Using the chart, please identify which best represents your AGENCY:

(a) Stage 1: Most reports and data are collected using paper formats and stored in file cabinets. Agency staff manually access and compile data upon request. Data are fragmented. Data are collected across many divisions within an agency and there is little ability to share data between divisions or agencies, and little knowledge of data collected by other divisions or other agencies.

(b) Somewhere between Stage 1 and Stage 2.

(c) Stage 2: Outdated data infrastructure and software exist, including local data servers that must be maintained by local staff. Data are not accessible from outside the agency. Data are fragmented and nonstandardized (e.g., variation of units, data names, etc. used within the agency).

(d) Somewhere between Stage 2 and Stage 3.

(e) Stage 3: A data infrastructure exists that allows for data sharing; however, the data are not always standardized or machine-readable. There is no easy method for creating visualizations and analytics. There may be duplicative systems across agencies, but they are not linked to each other.

(f) Somewhere between Stage 3 and Stage 4.

(g) Stage 4: A modern data management system exists that includes the ability to extract data from the system, data visualization and analytics capabilities for decision-making, and is machine-readable.

Technology adoption curve

STAGE 1	STAGE 2	STAGE 3	STAGE 4
• Most data are collected in paper formats and stored in filing cabinets • Staff manually access and compile data • Staff can not create data visualizations or analytics • Data are not standarized • Data quality is not documented • Staff cannot integrate their data with data from other divisions or agencies • It is difficult to share data across or between agencies	• Most data are collected in digital formats and stored on local computers • Staff manually access and integrate data • It is difficult for staff to create data visualizations and analytics • Data are not standarized • Data quality is documented in an unstandarized way that is not legible to those outside the division or agency • It is difficult for staff to integrate their data with data from other divisions or agencies • It is difficult to share data across or between agencies	• Most data are collected in digital formats and stored in a shared database/s • Staff access data through one or more databases and manually integrate data • It is difficult for staff to create data visualizations and analytics • Data may not be standarized across divisions or agencies • Data quality is well-documented • It is difficult for staff to integrate their data with data from other divisions or agencies • It may be difficult to share data across or between agencies	• Data are collected in digital, machine-readable formats and stored in a shared database • Staff access and integrate data through APIs • Staff can easily create data visualizations and analytics • Data are standarized across divisions and agencies • Data quality is high and is well-documented • Staff can easily integrate their data with data from other divisions or agencies • It is easy to share data across or between agencies

Findable, Accessible & Usable Data

Outdated Data Systems

(19) Using the above chart, please identify which best represents your DIVISION, BUREAU, OR GROUP:

(a) Stage 1: Most reports and data are collected using paper formats and stored in file cabinets. Agency staff manually access and compile data upon request. Data is fragmented, collected across many divisions within an agency with little ability to share data across the agency, little knowledge of data collected by other divisions, or from other agencies.

(b) Somewhere between Stage 1 and Stage 2.

(c) Stage 2: Outdated data infrastructure and software exist, including local data servers that must be maintained by local staff. Data are not accessible from outside the agency. Data are fragmented and nonstandardized (e.g., variation of units, data names, etc. used within the agency).

(d) Somewhere between Stage 2 and Stage 3.

(e) Stage 3: A data infrastructure exists that allows for data sharing; however, the data are not always standardized or machine-readable. There is no easy method for creating visualizations and analytics. There may be duplicative systems across agencies, but they are not linked to each other.

(f) Stage 4: A modern data management system exists that includes the ability to extract data from the system, data visualization and analytics capabilities for decision-making, and is machine-readable.

(20) If you could change one thing about how your AGENCY collects, stores, or uses data, what would it be?

(21) If you could change one thing about how your DIVISION, BUREAU, or GROUP collects, stores, or uses data, what would it be?

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Nicholas Institute for Energy, Environment & Sustainability

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