2023

Pacific Northwest Streamflow Data Landscape: A Report from the 2022 Streamflow Data Roundtables

Kendra E. Kaiser
Boise State University

Publication Information

Kaiser, Kendra E. (2023). *Pacific Northwest Streamflow Data Landscape: A Report from the 2022 Streamflow Data Roundtables*. Boise State University. https://scholarworks.boisestate.edu/geo_facpubs/805

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A report from the 2022 Streamflow Data Roundtables

Kendra E. Kaiser, PhD, Department of Geosciences, Boise State University

BOISE STATE UNIVERSITY

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This research was funded by the U.S. Geological Survey Northwest Climate Adaptation Science Center under Grant/Cooperative Agreement No. G20AC00439-A. Special thanks to Vanessa Fry (Idaho Policy Institute, Boise State University, and Darcy Widmayer (Northwest Climate Adaptation Science Center) for their feedback on the report and all participants of the roundtable discussions (Appendix 1).

Preface

This project was funded by the U.S. Geological Survey Northwest Climate Adaptation Science Center to catalog the location, temporal extent and purpose of non-USGS streamflow datasets. As part of this project, roundtable meetings convened local, state and federal agencies, and nonprofits to explore the complexity of gathering and integrating the identified datasets and identify issues surrounding data-sharing across organizations.

This report synthesizes discussions from each of the state roundtable discussions convened in the spring of 2022, and highlights common challenges and needs across the region. Additional information from organizations not able to be present at the meetings were added after one-on-one discussions with organization members.

Information gathered through these discussions highlights the importance of streamflow data, multitude of data purposes, the need for additional data, and support for data management and quality assurance.

Acronyms & Definitions

(FAIR) Finable, Accessible, Interoperable, Reusable: The FAIR guiding principles for scientific data management emphasize the need to improve our ability to find, access, and reuse data using computational systems.

Metadata: Information that describes primary data, such as the date and time of collection, methods and other information that is important for another user to properly reuse the data.

Streamflow Gage: Continuous monitoring location that measures streamflow directly (e.g. cubic feet / second (cfs)), or indirectly (e.g. stage height, ft).

(QAQC) Quality Assurance and Quality Control: A combination of methods to error check, clean and validate raw data such that its quality can be ensured so it can be used for its intended purpose.

Executive Summary

Streamflow data are critical for decision-makers from local to regional scales who are responsible for an array of topics ranging from real-time water management to long-term water resources planning. The largest source of high-quality streamflow data is the U.S. Geological Survey (USGS). In the Pacific Northwest (PNW: Idaho, Oregon, Washington), the USGS operates 723 streamflow gaging stations. Through the Streamflow Catalog project, the Idaho Policy Institute distributed a survey to capture the range of organizations collecting streamflow data in the PNW and basic information about their streamflow networks and data collection (Kaiser et al., *in review*). While this survey did not capture all data providers, it estimated that there were about 2,000 non-USGS streamflow monitoring locations across the region. In conjunction with this effort, we engaged with PNW organizations operating streamflow gaging networks to coalesce metadata about these datasets into a centralized Streamflow Data Catalog, which captures 2,661 continuous streamflow monitoring locations and 30,557 miscellaneous measurement locations from 32 organizations (Kaiser et al., 2023). In combination with these data collection efforts, we convened roundtable discussions in each state to gain additional insight into the challenges that organizations are facing and to identify priorities in regard to improved quality and accessibility of streamflow data. These roundtable discussions captured input from local and state government agencies, non-profits, and federal agencies.

Summary of challenges identified

- The degree to which organizations use standard streamflow data collection protocols, quality assurance procedures and structured databases is generally limited by time, expertise, and financial resources
- Streamflow data collection efforts are highly dependent on available funding which can vary from year to year, making maintaining long-term data streams vulnerable to economic fluctuations
- While the USGS maintains the highest standard of data quality, few organizations are able to meet all of these standards
- Many organizations are increasingly adopting higher data quality standards and highlight the variability of data quality over time (e.g., historic datasets may have higher uncertainty)
- Each PNW state has significantly different organizational structures and associated mechanisms for funding, management and collection of streamflow data

Regional Priorities

- Tiered data quality standards with associated training materials that are accessible outside of the USGS
- Identification of the major streamflow data gaps and how additional locations would benefit specific needs
- A mechanism to integrate data from small data providers into one database or platform
- Additional mechanisms for standardization of data collection, particularly in the field
- Improved models of streamflow in small streams and ungaged basins

Regional Streamflow Data

Regional streamflow data providers (e.g. federal agencies) were present at multiple roundtable meetings, and have also provided information about their data collection in separate meetings. This section summarizes information gathered from data providers at federal agencies about how their agencies collect and use streamflow data.

U.S. Geological Survey (USGS)

The USGS Office of Quality Assurance in Reston, VA, develops techniques, policies and manuals. There is a data management team at each water center that includes data managers and a data chief. Between these resources hydro technicians are trained to follow USGS policies and procedures and each water science center has a surface water quality plan that cites techniques and methods reports. Their quality assurance and quality control (QAQC) method has 3 tiers, first data is analyzed to check for obvious errors, another technician approves the data and the data is later audited for long term consistency. The USGS Water Mission Area (WMA) is working on code to evaluate the amount of time it takes for the water science centers to approve records and to identify data gaps and outliers. The water data management software that the USGS uses (Aquarius) enables efficient data quality checks. The USGS has been increasing the amount of in-house training, but has also created some virtual training that are publicly available online (Appendix 2).

Automated quality control can be done on stream discharge measurements that are taken with specific instruments. When using an acoustic doppler current profiler (ADCP) the Qrev software does quality checks, filtering, and estimates uncertainty, thus improving consistency across users (Muller, 2020). FlowTracker 2 is a wading discharge measurement instrument that also assesses quality in real time, including the signal-to-noise ratio, standard error of velocity, and the number of spikes filtered from the data (SonTek, 2019). The USGS is also evaluating how to measure low flows by determining gage height at zero flow and the Washington Water Science Center has been tracking progress of that effort.

The USGS hosts data through two primary repositories, the National Water Information System (NWIS, waterdata.usgs.gov/nwis?) and ScienceBase (sciencebase.gov/catalog/). There is a rigorous process to get data into NWIS and the only external data USGS hosts here is "furnished" data from a collaborator who follows the Surface Water Technical Procedures (USGS, 2017) and has measurements validated by the USGS by collecting intermittent measurements (USGS, 2016). When studies are funded by other sources, those cooperators

may follow other QAQC standards which means they may not have as rigorous of a quality assurance protocol (QAP). There are efforts underway to evaluate how to get streamflow data that follows other QAQC standards available on public websites, but specific guidance on how to do this or if this will be implemented is not yet available. ScienceBase is a digital repository that has a wide variety of data from across the USGS, allowing for various levels of QAQC and data management structures. While this repository is widely used, there is no way to geographically visualize datasets and it can be cumbersome to compile disparate datasets.

USGS has done a comparison of various methods to evaluate operator inaccuracy (Hundt and Blasch, 2019) and are interested in assessing where the biggest errors occur in various methods. The USGS has recently named the Willamette as the fourth Integrated Water Science Basin. This will focus resources on data collection, research and modeling to provide high-quality, real-time information about the water quality and quantity in the basin.

U.S. Bureau of Reclamation (USBR)

The **USBR** relies heavily on USGS data to assess inflow into reservoirs, namely to maintain space in the reservoirs for flood control. In dry years they are monitoring the entire system to determine if the minimum flow levels are being met across each region. This includes monitoring NRCS, NOAA and AgriMet sites as input into water supply forecast models. The USBR also works with irrigation districts to maintain their water monitoring infrastructure in some basins. While they facilitate this data collection, the data is private, so QAQC and data management is up to the individual organization. Identifying drought as a hazard is one mechanism to draw attention to the need for additional gaging stations, particularly in low-order streams and could encourage organizations like USBR to build new gages.

U.S. Forest Service (USFS)

Region 4 of the **U.S. Forest Service (USFS)** collects miscellaneous streamflow measurements for individual projects largely to comply with the Endangered Species Act and to mitigate litigation. They have an in-stream flow team in Idaho that maintains gages and rating curves focused in the Sawtooth Mountains and the Salmon-Challis National Forest. They note that this data is largely on hard copies, all internally stored, and distributed across the individual forests. The PacFish/InFish Biological Opinion Monitoring Program (PIBO) is one effort to monitor stream and riparian habitats to support aquatic conservation strategies, this program has collected incidental streamflow measurements since 1998. During any given field season

information is collected at close to 450 randomly selected watersheds throughout the intermountain west.

Natural Resource Conservation Service (NRCS)

The **Natural Resource Conservation Service (NRCS)** runs the SNOTEL network and the water supply forecasting program for the western US. They use existing data to develop and test various models (e.g. seasonal streamflow forecasts). Capturing antecedent watershed conditions (e.g. soil moisture) is critical for modeling aquifer conditions where surface water - groundwater connections are high, such as in the Cascades. They maintain additional climate stations, such as the soil climate analysis network (SCAN), although some of this data does not yet have a sufficiently long data record to be used in their modeling efforts.

State Streamflow Data Sources & Use Cases

Data collection responsibilities vary widely across the region. Most states have a primary water resources agency, but there are also multiple other state and local organizations that collect streamflow data. This additional data is not integrated with the primary state streamflow data, generally due to resource limitation from the primary state agency to provide training, ensure data collection standards and perform QAQC. This lack of integration make it difficult to provide **Findable, Accessible, Interoperable and Reusable (FAIR)** water data (Wilkinson, 2016)

The organizations also use a range of data management software, meaning that integration of data across states post-collection may be particularly challenging. Additionally, the organizational structures and planning documents that support water data management are highly variable, for example, Oregon developed a 100-year water vision in 2020 (OWV Water Vision). In Idaho, the primary planning documents are the Idaho Water Plan (IWRB, 2012) with a sustainability section that was added in 2016 (IWRB, 2016), and the Idaho Drought Plan (IWRB, 2001). In 2018 the Washington Legislature passed the Streamflow Restoration Act (RCW 90.94) to support watershed planning in 15 priority basins.

Here, we summarize information gathered in each state roundtable. Water data uses included water supply and regulation, recreation, restoration project design and monitoring, maintenance of in-stream flows, managed aquifer recharge, model development and testing, fisheries management, water quality, infrastructure design and climate change modeling.

Idaho

The primary streamflow datasets in Idaho outside of the USGS are from the Idaho Department of Water Resources (IDWR), Idaho Power, Idaho Department of Environmental Quality (IDEQ) and irrigation entities. Various Idaho nonprofits gather streamflow data to support their missions, The Henry's Fork Foundation is a nonprofit that works in the upper Snake River basin, while The Nature Conservancy and Trout Unlimited work on efforts across the state. Cities also gather streamflow data, but we did not have any city representatives in attendance at the Idaho roundtable discussion.

The **Idaho Department of Water Resources (IDWR)** uses streamflow data for a range of operational purposes. Their streamflow data is primarily related to water rights accounting and water allocation. This streamflow data (often collected to estimate reach gains) is used for groundwater model calibration which is of particular importance for conjunctive management. IDWR requires that irrigation districts provide streamflow measurements for regulatory enforcement, while irrigation districts collect additional streamflow measurements throughout their system Return flows from irrigation are also important to provide a general understanding of the system and model calibration, while some irrigation districts use this information it is not used for regulatory enforcement. They use their streamflow data to assess managed aquifer recharge, namely in the East Snake Plain Aquifer for the Eastern Snake River Plain Aquifer Comprehensive Aquifer Management Plan (cite). They also use streamflow data in conjunction with the Office of Species Conservation and the Water Transactions Program for salmonid in-stream habitat improvement.

The Idaho Water Resources Board is composed of 8 governor appointed members that are charged with formulation and implementation of the state water plan and financing water projects and operation of programs that support the state water resources. This has included creating comprehensive basin plans in 10 basins and comprehensive aquifer plans in 3 locations, a state water resources inventory (IWRB, 2010), and recently have compiled a list of priority regional water sustainability projects.

The **Idaho Department of Environmental Quality (IDEQ)** also monitors streamflow across the state. This includes time series data as well as miscellaneous measurements through their Beneficial Use and Reconnaissance Program (BURP). The BURP program has been collecting information about surface waters and biological and habitat data since 1993. Environmental Management System

The **Henry's Fork Foundation (HFF)** is a non-profit that seeks to promote healthy fish populations, water quantity and quality in the Henry's Fork and South Fork Snake River Watersheds. They use streamflow data to evaluate water supply for irrigators and for recreational flows. Their data collection efforts facilitate local irrigation district water management. Fine scale, real-time information about diversions can save significant amounts of water, particularly with the use of remotely controlled head gates for real-time operations. The HFF provided the non-federal match for a WaterSMART grant to install additional monitoring locations. This additional gaging is not necessarily relevant for water rights accounting, but precision within 20 cfs is significant for management of the system. In addition to management of the system, the HFF uses streamflow data for model calibration, particularly for local groundwater models. While additional gages will always be of interest to irrigators, full USGS gages are cost prohibitive, particularly on canals which only run for about 3 months of the year.

The Nature Conservancy (TNC) uses relevant science to determine where they should work and how to prioritize watersheds to do conservation projects. They are interested in determining locations that are important to conserve both now, and 50-100 years from now, to increase climate resilience. They use existing, publicly available, and internally derived model output to prioritize projects such as where to do land protection projects, restoration projects and water transactions. In their Resilient Watershed work seeks to demonstrate nature-based solutions and remove barriers for their adoption. This work is often opportunity driven, but they could use more modeling to facilitate identifying viable options. They use streamflow data to determine where additional in-stream flows are needed, to facilitate project design, identify which tributaries within a watershed are the most important (measurable and significant impact), monitor results of projects, and to understand systems as a whole to get an idea of how different policies will work. Projects often occur in locations that people think are important, so there are already stream gages in them. At the national scale TNC is working on a map of functionally connected and resilient freshwater systems to identify streams and rivers that can maintain aquatic biodiversity and ecological functions through a changing climate (https://crcs.tnc.org/pages/freshwater).

Multiple long term research watersheds in Idaho have streamflow data that are collected and maintained by the universities. Boise State University has been measuring streamflow and other environmental variables at Dry Creek since 1999. The Reynolds Creek Experimental Watershed was established in 1960 and is managed by the Northwest Watershed Research Center and has ongoing research projects by multiple institutions.

Irrigation districts across the state collect streamflow measurements in their canals and drains. Some of this data is reported to local watermasters and shared with the IDWR. These stations are often located at rated structures, some have real-time monitoring and others are measured weekly for water management purposes. These data are proprietary, but could be particularly useful for understanding how both water use and return flows are changing.

ID Data Management, Quality Assurance & Quality Control (QAQC)

IDWR uses USGS streamflow measurement standards and weir rating structures. They have compliance requirements for measurement devices which are independently produced. Site selection is a major challenge for IDWR, and there are a few instances when they have had to move gages which can cause problems with data legacies. They note that while a given measurement location may not be ideal for gaging it may be more ideal for minimizing inflows which is critical as their primary use of water data is for water rights management.

When operating stream gages in conjunction with irrigators, the HFF either uses a rated weir, or creates a rating curve all at once, they then make measurements throughout the season to double check the rating curve. They note that the in-stream locations they monitor are challenging to rate, where possible they start with the old USGS rating curves and then slowly add to them, but this is particularly tough at low flows when ice is prohibitive. They use an ADCP and generally follow USGS procedure (e.g. making 4 passes with less than 5% error). They note there are many choices to be made when setting up the ADCP, so while there is good precision, there are still biases present in the data. For example, they have made measurements with different instruments at a given site which makes it very clear how difficult it is to make accurate estimates. Two organizations would need to make measurements at the same time to evaluate accuracy and associated uncertainty. They do add a statistical prediction interval around their data which helps quantify that uncertainty, this is documented in their code and SOPs. Funding through their WaterSmart grant provided the resources to make their data and workflows FAIR. They check the edge settings on the ADCP, the raw data and check for consistency from week to week and month to month. At the end of the season they check the correlation between neighboring gages and reservoir data as well as stream temperatures (to determine if the site is frozen). They look at the data a 3rd time to look across years for multi-year correlation.

Oregon

The Oregon Water Vision outlines major state water priorities which follows from their second Integrated Water Resources Strategy (Mucken & Bateman, 2017). This strategy includes a thorough description of the current water challenges in the state, and one of its many recommended actions is coordinated inter-agency data collection, processing and use in decision making. These strategic plans highlight the advanced planning and coordination that is occurring in Oregon. The Oregon legislature has asked for a water data portal which has led to the development of the Water Core Team, a leadership team created to discuss issues and needs across the state. This team was developed to integrate water resources across the natural resources' cabinet, ODFW, and the health authority. The following organizations are key contributors to water data in the state.

The **Oregon Water Resources Department** (OWRD) has a large gage network (over 200 sites), some of which have records since the early 1900s (some of which were operated by the USGS prior to 1990). They have recently been appropriated funding for new stream gages and the water resources group is growing. They have several basin studies that are starting or are underway and have been reaching out to watermasters to identify where new gages are needed. These basin studies are a mechanism to evaluate the basic functioning of a basin to quantify the components of the water budget. The data is used internally for regulation and water management, and their water availability program. Through this program they determine if water is available for future water rights or storage rights. The peak flow program is used for flood flows, and they contract with the Oregon Department of Transportation to create reports for bridge building and culvert sizing. Through the OWRD Water Use Reporting Program some of the major points of diversion are reported monthly, but it is possible that the rating curves are not updated regularly in the irrigation districts. The irrigation districts usually contract with Farmers Conservation Alliance for their stream gaging purposes (contact to talk about QAQC and methods).

The **OWEB STREAM Team** is "an inter-agency effort to facilitate collaborative and coordinated planning, monitoring and communication of water-related data". This includes the OWRD, ODFW, DEQ, OWEB grantees, and to a lesser extent the Department of Agriculture and the Department of Forestry. Their monitoring map shows locations that are actively being monitored in a given calendar year to help "identify opportunities to use monitoring resources more effectively". OWEB gathers this information from grantees and other agencies early in the year with a goal of having all information updated by the end of May so that agencies can use current information while planning. A critical component in development of this tool was

creation of a controlled vocabulary for integration of information across organizations. In addition to being useful for planning, this tool is a mechanism to facilitate conversations about monitoring across organizations. OWEB fosters and provides training and technical resources to their grantees who are required to submit their data which is then uploaded to AQUAMS and the EPA database.

The **Oregon Watershed Councils** are independent organizations that were initially created in 1999 largely due to the decline of Coho Salmon. Each of the Watershed Councils has a board of directors that is representative of interests in each watershed and are largely born out of grassroots efforts. If a Watershed Council collects streamflow data using funds from an OWEB grant they are required to report that data, often to ODFW if it is related to fish, or to DEQ if it is water quality. This data is used for surface water groundwater modeling, to evaluate project effectiveness, shallow groundwater recharge and managed aquifer recharge.

The Walla Walla Watershed Council is conducting a bi-state flow study in which the irrigation districts are addressing in-stream flows, but overall they do not intervene with regulation. Over time the Watershed Council has taken over maintaining a few gages from Washington and when funding is available they will return those gages back to them. They generally get funding from OWEB for two years and match that funding with money from the Bonneville Power Administration and have also sought funding from the DEQ 319 program or funding through the municipalities for water rights. These studies are used for operations so that the irrigation districts can make sure sufficient bypass flows are being met in the Walla Walla basin. They are performing ongoing trend monitoring because there are water supply issues there, while the water is allocated there they are a neutral party that supplies information for planning.

The Coos Watershed Association also uses their streamflow data for monitoring project effectiveness, monitoring fish impediments to determine appropriate flow ranges, and for use in a hydrodynamic model for various efforts including culvert and bridge sizing (Eidam, et al., 2021) . The general public also uses their data for fishing and recreational purposes.

The **Oregon Department of Fish and Wildlife** collects streamflow data to evaluate if in-stream flows are being met, and to set emergency regulations for low-flow. Streamflow estimates are useful to help determine when to sample for fish, even a point measurement can be helpful when their only other information is the NHD or the PROSPER model. This data is also used to predict run sizes for returning salmon and evaluate out-migration conditions.

Oregon State University runs the Long-Term Ecological Research forest HJ Andrews, is developing Elliot State Forest, and the Watershed Research Cooperative performs paired watershed studies at Hinkle Creek, Trask Watershed and Alsea Watershed. These research sites examine how various timber harvesting practices impact streamflow, water quality, aquatic habitat and fish. The HJ Andrews website has a page dedicated to data management, metadata data release and access policies, and they have additional resources on information management. This includes annual training and outreach to graduate students, IGERT, and Eco-Informatics Summer Institute students (HJ Andrews webpage). The core of their information management system is the long-term data repository, the Forest Sciences Data Bank which began in 1983 and is supported by the Andrews LTER in coordination with the USFS PNW Research Station and the OSU College of Forestry (Stafford et al 1984).

OR Data Management, Quality Assurance & Quality Control (QAQC)

OWRD follows the USGS protocols as much as possible, they send employees to USGS trainings and do side by side measurements to confirm they are following the technique accurately. OWDR might only get to each gage every 5 years to update their rating curves, while the USGS gets to sites every year, or 3-5 years once levels even out. Their internal protocol is to have the field staff collect data, the data is put into WISKI and reviewed by hydrographers, and then finalized for long term storage. State agencies note that they have legitimate capacity concerns, while OWRD recently opened multiple positions, they have been short staffed for some time. With the additional staff they are anticipating bringing in, they hope to also do long-term analysis for QAQC purposes. They use WISKI for their back end data management as well as a SQL database for public facing data access.

ODFW largely collects point measurements and they follow USGS protocols, such as the number of measurements to take at a given location. They also have some semi-permanent stations where they measure stage height. The rating curves for these locations likely haven't been updated since they were originally created. It was noted that installation of staff gages can be challenging, the ideal installation conditions are rarely met which decreases the accuracy of measurements.

The **watershed councils** are independent organizations, so while many may base their streamflow measurement SOPs on USGS protocols, implementation is likely variable across the state. In the Walla Walla Basin they take duplicate measurements about every 6 weeks, independent measurements at their telemetered sites every 6 months and every 3 months for stand alone sites. They document any changes at the site (vegetation, scouring) and at the end

of the year they review and confirm stage measurements, stage-discharge curves and discharge data. These protocols have improved over time with their first SOP developed in 2013 and updated to align with the USGS in 2018. They have bought instrumentation based on USGS requirements, do concurrent measurements with OWRD and trainings with the USGS. They noted that their second tier of QAQC is time consuming and that data prior to implementation of 2013 SOPs is of lower quality. In the Coos watershed, they also follow USGS SOPs, but don't have someone to do concurrent measurements with. They engage with ODWR on procedures and do review data at the end of the water year. The software used for data analysis across watershed councils is variable, some use WHISKY, but it can be cost prohibitive.

While there were no watermasters present for the meeting, there are some that are very engaged with the other organizations working in their districts and are interested in improving their data.

The **Department of Environmental Quality** does not often use flow data, but the total maximum daily load (TMDL) program does. The Oregon DEQ AQUAMs database can accept streamflow data, they generally don't measure streamflow, if they do it is for integrated reports or through volunteer monitoring groups. While it is a valuable clearinghouse of data, there is limited built-in quality control, and data analysis is beyond the capacity of the system. Additionally, data entry is dependent on passing internal quality control and capacity for someone at DEQ to enter the data. Watershed councils and volunteer groups that work with DEQ do their own data QAQC and then submit it data to AQUAMS. The **Oregon Water Data Portal** is being developed by the DEQ and is in the pilot phase. They will be building out the effort this year.

Additional State Data Repository and Projects

The Oregon Water Map Viewer is a tool to explore various water related geospatial data. The beta version can produce a water report that aggregates information within a given area of interest to provide administrative information (e.g. water districts, watershed councils, OWRD regions), average monthly precipitation, water quality impairments, groundwater concern rating, stream temperature, surface water availability, dams, OWRD monitoring locations and other relevant sources of information. The Walla Walla Water 2050 Strategic Plan is another regionally relevant project.

Washington

Washington Department of Ecology (ECY) has an extensive streamflow database that is available online with about 80 sites, some of these stations have over a 20 year record (cite website). Interestingly, at one point ECY had close to 200 active gages, but that number dropped to 65 active gages after the 2008 economic crisis. When determining which gages to cut they sent out a survey to identify which gages had the most interest. Many of the newer sites are associated with tribal water quality issues. Funding for these sites largely comes from appropriated funding from the state and some funding from tribes. The majority of these sites are for fisheries management, and are also used as control points for in-stream flow rules, in support of TMDLS, for recreational interests and interested citizens, and in coordination with a few tribes for other water quality standards. Almost all of the locations also have stream and air temperature, but they note that the air temperature may not be reliable because the thermistor is often located near the station and the radiant heat may be affecting the values.

Washington Department of Fish and Wildlife (WDFW) has ongoing streamflow data collection with the main purpose of streamflow gaging being for monitoring and support of the fisheries. Much of this data and metadata is high quality after 2013, but prior to that (back to 1980s), the location data and other metadata might not be very clear or sufficient for re-use. The Water Science team also monitors trust water transactions where water is put into trust and the ecology team manages and assesses the benefits for fish. Effectiveness of this management tool is challenging to evaluate because baseline data is rarely available since the WDFW does not know where the transaction is being brokered until after it occurs. In these situations they use other data as proxies, or calibrated process based models (e.g. VIC from UW).

Streamflow data is also used by WDFW when creating climate adaptive infrastructure, for example, determining sediment transport during high flows, or appropriate culvert sizing. Minimum instream flow requirements can be useful when prioritizing these projects, but it is hard to determine if streams are meeting requirements, or in need of restoration, when they do not have historical data. They also use streamflow data to develop climate and development baselines to inform rural water development, such as evaluating the impact of new wells, or to differentiate between existing variability in streamflow versus climate impacts.

The **National Park Service (NPS)** collects a variety of aquatic data that is stored in Aquarius, but there is often a backlog of data. The degree to which NPS employees use it is variable, and is dependent on organizational bandwidth. They collect continuous temperature data and measure streamflow at a few sites in Mt. Rainier National park in conjunction with geohazard

warnings. In North Cascade National Park they monitor aquatic habitat and cold water refugia for various climate change modeling efforts. They are currently working on a standard operating procedure (SOP) for publishing data, otherwise data availability is dependent on the project. They work with hydroelectric power companies when relicensing comes up, Seattle City Light with regards to reservoirs and other monitoring efforts, Lake Chelan, Puget Sound Energy and Bonneville power (Electron Dam on the Upper Pullup). They have recently started working with the McCaw tribe on collecting some streamflow data as well.

Pierce County Public Works has a water management and monitoring program, they collect both continuous and synoptic streamflow measurements and maintain a few weather stations which are stored in a data portal. The two main purposes of their monitoring efforts are for capital improvement projects (CIP) and for water quality monitoring and management. Streamflow is used to run HEC-RAS for flood control and CIP. They use streamflow to calculate loads for TMDL requirements and National Pollutant and Discharge Elimination System (NPDES) compliance. They use both internal and state grant funding to manage these projects and associated data collection, but find themselves limited in their ability to go through multiple phases of QAQC.

In Washington, the Water resources program manages all of the water rights and adjudication in the state and their drought coordination team may be a valuable resource. Washington State University also does some water quality and streamflow monitoring in a few small watersheds in eastern Washington.

WA Data Management, Quality Assurance & Quality Control (QAQC)

ECY collects streamflow data using USGS methods, but they monitor many smaller streams where the USGS standards are not always functional. Maintaining long term sites is challenging as channel locations change. They use the QRev and FlowTracker software for field QAQC and also have a peer review program between co-workers to review individual flow measurements. They have two people that manage the QAQC for all the long term monitoring including managing the rating curves and continuous records. This process is very time consuming and often creates a backlog of updated measurements to be posted online due to time and resource limitation.

A centralized data repository for **WDFW** would be beneficial because much of the existing streamflow data is project-based so it is hard to know what data is where. Their data collection is funded by pass-through funding or grants through ECY, and data is often submitted into the

Environmental Information Management (EIM) database. The WDFW only has internal SOPs for tracer studies and dilution gaging, so while there is a general ECY quality assurance plan (QAP), one that is specific to streamflow gaging would be helpful. QAQC methods in the field may become more common, there are instances of using Survey123 forms for streamflow measurements, these methods of standardization may be of particular use to smaller organizations. Within the organization, data management may not be a high priority, and there is likely a general lack of understanding of FAIR and how to record relevant metadata.

Pierce County had similar challenges in that project data collection is often siloed, and various units may not know what all is going on in other organizations. Prioritizing data QAQC is challenging given how time consuming it is and that there is only one person to do it. The county did pay USGS hydrology technicians to provide training to staff at one point in time, and they have internal QAPs that cite USGS SOPs. They have a variety of project specific data, but a big limitation is development of rating curves. Additionally, they are often measuring low flows, which makes it difficult to meet the current USGS standards because they cannot get enough sections across small channels. Given that the measurements are often auxiliary to other environmental measures like benthic sampling, the accuracy is not as important as when streamflow data is being used more broadly. They do have the capacity to construct quality control methods within their data management system (WISKI), but additional mechanisms to QAQC data collected would be helpful, yet they are resource limited in this endeavor.
In addition to having quality streamflow data, quality geospatial data is really important for wider usability. Pierce county collects coordinates with the StreamTracker2, and Survey123 can mark a location, generally within 30 feet. They use a GPS with an antenna when they collect benthic data, but the surveying team is not always a part of every effort. Additional information like street names, or which tributary a measurement is on would be beneficial for snapping information to the NHD.

Regional Data & Training Needs

Streamflow Modeling

In general, while there are existing streamflow modeling tools and resources (CIG VIC, UW Climate Adaptive Culverts), improved models of streamflow in small streams would facilitate various management actions. Managers note the high uncertainty in smaller streams where infrastructure is being replaced (because of existing fish barriers) and the need for mechanistic models that would help prioritize restoration efforts and support watershed planning. For

example, when considering the viability of a given restoration project it is important to know if upstream reaches contain good habitat and that they can supply a sufficient amount of water. Other ongoing NW CASC funded research is working to spatially align stream temperature data with discharge and fish data to conduct a vulnerability assessment for a group of fish species under future climate scenarios. The Bureau of Reclamation has developed basin-wide climate forecasts (RMJOC-II, 2020) in addition to their SECURE Water Act Report to Congress about the Columbia River Basin, which highlights how collaborative efforts like Upper Deschutes River Basin Study can bring together diverse stakeholders in addition to developing additional model output and data (USBR, 2021).

Training

While the USGS does have various training mechanisms, they might not be easily found or accessible (e.g. lengthy written documents). The USGS does have some publicly available training videos (HydroTube, Hydroacoustic Webinars), but many training opportunities are only available to USGS employees (e.g. Hydrologic Data Advisory Committee website; Scientific and Technical Employee Development Training Website). Making training more widely available and accessible could increase the quality of streamflow data collected by non-USGS entities across the country.

In Oregon, OWRD provides the largest repository of streamflow data in the state, but they do not have a mechanism to integrate data from other sources (such as the watershed councils or other small organizations). OWRD has considered providing training programs, but are limited by staff time and equipment to train with. OWEB provides and fosters training to grantees using a range of sources (OWEB, Field & Technical Guides). In Idaho, water masters and irrigation districts gain streamflow monitoring training through programming that was developed and hosted by the Idaho Water Users Association. Using existing professional societies that engage streamflow data providers will be a valuable mechanism to distribute training materials once developed.

QAQC

Additional mechanisms for standardization of data collection, particularly in the field, would be useful (e.g. data templates, Survey 123, automatic QAQC with ADCPs or FlowTrackers). Participants highlighted the importance of geospatial accuracy, and while a permanent marker of where measurements occur is ideal, they note that reference locations are hard to manage, particularly in urban environments. A significant limitation to managing and quality controlling

data for many of these organizations is human resources. Participants brainstormed alternative mechanisms to facilitate auditing other groups' data to increase level of QAQC. A baseline set of QAQC procedures with minimal best practices would be beneficial for those gathering data, particularly in a short format like a "cheat sheet". Since small organizations are time and resource limited, filtering through nested pages and long documents creates a barrier to collecting good data. Information that details when data quality decreases substantially would highlight to smaller organizations which procedures are relevant for their data uses. This could be something like a "Techniques & Methods Report'' where it describes how much your confidence in a measurement goes down if you don't do a given step (e.g., Hundt and Blasch, 2019). An additional point was raised that not all data needs to be the quality of USGS data. This leads to the question of: what data accuracy is actually necessary and feasible for non-USGS data providers? Guidance on what questions various levels of data quality can answer would help identify the rigor needed by an individual organization.

Data Management, Availability & Metadata

Mechanisms that organizations use to manage their data is highly variable, particularly across organization size (Kaiser et al., 2023). This parallel effort to compile metadata for non-USGS streamflow monitoring locations found that there are about the same number of active, continuous monitoring locations across the Pacific Northwest operated outside of the USGS as in the USGS (588 non-USGS and about 600 USGS). This **Streamflow Data Catalog** is likely the largest cross-organizational set of streamflow metadata available, yet significant monitoring gaps remain (Figure 1). Assessing streamflow gaging gaps and identifying which locations would be the most valuable to improve our monitoring biases will be important as we increase our gaging network for both management and modeling efforts.

While there are other regional monitoring efforts that are not captured by the catalog, such as the **Pacific Northwest Aquatic Monitoring Program** which has 16 intensely monitored watersheds, no streamflow data is publicly available on their website (https://www.pnamp.org/). Of the known monitoring locations, critical metadata such as start and end dates, or methods and instrumentation are lacking. Creating standardized metadata templates that capture information about streamflow monitoring (even when it is secondary to other data) and

identifying ways to distribute them effectively will be critical to future data harmonization.

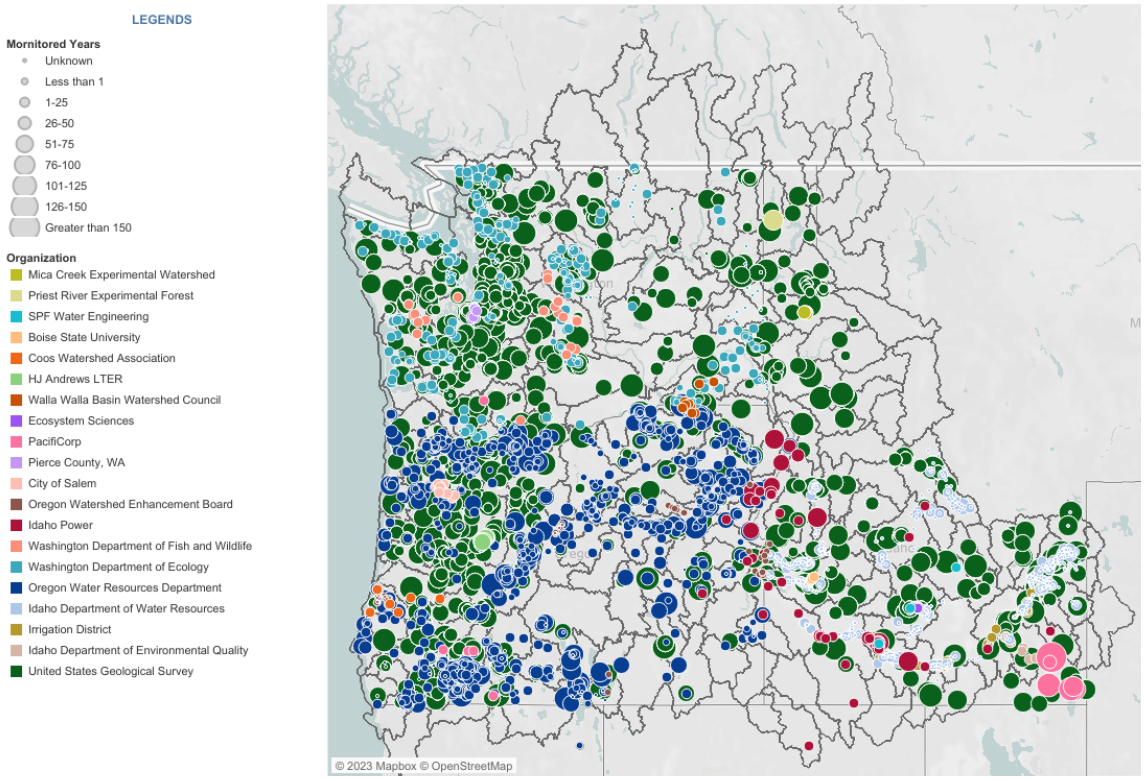

Figure 1: Pacific Northwest Streamflow Data Catalog online data interface. This shows all known continuous monitoring locations across 32 organizations in the region. https://tableau.usgs.gov/#/views/Streamflow_Catalog/Introduction?%3Aembed=y&%3AisGuestRedirectFromVizportal=y

Conclusions

This report provides context for the current lack of and need for shared data standards, and improved archiving and access to water data across organizations. Creating venues for water data providers across sectors and organizations to discuss data management best practices will increase our capacity to create FAIR water data.

Examining the Strengths, Weaknesses, Opportunities and Threats (SWOT) of these findings provides a structure to analyze how we can strategically advance this work while taking into consideration internal (strengths and weaknesses) and external (opportunities and threats) factors.

This SWOT analysis was conducted to evaluate the Pacific Northwest Streamflow Data Landscape and provides objective information about the strengths and weaknesses of our current data, data management and accessibility as well as the opportunities and threats to improving streamflow data across the region. This SWOT analysis can inform future decision-making and how we can strategically engage across agencies and organizations.

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Appendices

A1 Participants

Washington Attendees: Scott Groce (Pierce Co.), Shu Hui Dun (Pierce Co.), Carol Falkenhayn Maloy (Pierce Co.), Monica Ponce-McDermott (Pierce Co.), Austin Jennings (Pierce Co.), Jim Shedd (Washington Department of Ecology), Kris Jaeger (USGS), Nicholas Sutfin (USGS), Tristan Wiess (Washington Department of Fish and Wildlife), Julie Padowski (Washington State University), John Yoder (WSU, Water Research Center), Carmen Welch (National Park Service), Jon Roca (USBR)

Oregon Attendees: Spencer Swaske (ODFW), Rich Marvin (OWRD), Sean Fleming (NRCS), Audrey Hatch (OWEB), Mark Stewart (USGS), Tara Patten (Walla Walla

Watershed Council), Adam Stonewall (USGS), Dan Brown (DEQ), Freelin Reasor (Coos Watershed Council), Luke Adams (Walla Walla Watershed Council)

Idaho Attendees: Kyle Blasch (USGS), Dave Evetts (Data Chief, USGS), Jon Rocha (USBR), Konrad Hafen (USGS), Rob vanKirk (Henry's Fork Foundation), Neil Crescenti (The Nature Conservancy), Colin McKeel (IDWR); Sean Vincent (IDWR), Nathan Welch (TNC); Corey Loveland (NRCS)

A2 USGS Streamflow Monitoring Training Resources

Hydroaoustic training	https://hydroacoustics.usgs.gov/training/index.shtml	in-person
STED Training Website		Internal USGS Access Only
Surface Water Techniques	https://pubs.usgs.gov/fs/2007/3099/	On-demand [Broken links]
Water Science School	https://www.usgs.gov/special-topics/water-science-school	
Discharge Measurements at Gaging Stations	https://pubs.er.usgs.gov/publication/tm3A8	Techniques & Methods Docs
Stage Measurement at Gaging Stations	https://pubs.usgs.gov/tm/tm3-a7/tm3a7.pdf	Techniques & Methods Docs
Computing Discharge Using the Index Velocity Method	https://pubs.usgs.gov/tm/3a23/pdf/tm3-a23.pdf	Techniques & Methods Docs