Rivers of Colorado Water Watch Network

1989 - 2020

2021- Present

Study Design
1989 – 2021

Revision History

All Sections and SOP's revised and finalized 8/31/2020	Barb Horn, RW Program Manager, 1989-2019
Revised for RW CDIP Program	Barb Horn April 2021
Revised for RW CDIP Program	Michaela Taylor 2021

This SOP document and all supporting documents are updated annually at a minimum or whenever a procedure or operation changes. This information in this SOP document is the primary location for this content. In a few cases primary content will live in a subdocument, which is referenced in this SOP. Therefore, changes to this SOP document need to be made in the following documents as well:

Document	Responsibility
QAM – TOC in text and document Embedded in Appendix	CPW RW Program Manager
QAPP - – TOC in text and document Embedded in Appendix	CPW RW Program Manager

Subdocument Table of Contents are mapped to SOP Chapters and specific SOPs in the Master Document Map SOP. Thus, changes to subdocuments that contain primary SOP content (Sample Plan, Hit List, Database Application User Manual for example) need to be referenced back and updated in the relevant SOP

COLORADO RIVER WATCH NETWORK
Study Design Story
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d. **Identification of Niche**

Data is just facts and statistics collected for reference or analysis. Data is not information of value or an asset without a context, purpose and path that connects purpose and a technical design that collects right data at the right time and place with the right method to answer posed questions. Often you have a question you are trying to answer; like is my water safe to drink? How do you know what to collect where? Who do you want to do what with the data and what information do they need where, when, with what methods and quality? Collecting data is hardly the end, all that data has to be managed in a way it can be verified, secured and available. Data remains data until it is translated into information through analyses, simple or robust and available (read delivered or communicated) to those who take action on that information. Then evaluation needs to occur to understand if monitoring questions were answered, if not why not, what should be adjusted? Were desired results, outcomes or impacts achieved or progress made? This is how success stories are collected, curated and create a sustainable program.

A Study Design or Monitoring Plan is the blue print or strategy put in place to generate the quality of data needed to answer the questions being asked to achieve desired results, impacts or outcomes. Without a Study Design or Monitoring Plan that integrates four key elements (1.who/why, 2.technical, 3. information and 4. evaluation plans to the degree of formality and rigor for desired results, outcomes or impacts) is just monitoring for the sake of monitoring. Monitoring for monitoring sake is not sustainable nor does it generate measurable results beyond outputs such as number of stations, results or people trained to sample. A Study Design or Monitoring Plan tells the data user what you are doing, why and how, level of quality and what you are not doing, your niche. It tells them everything they need to know to evaluate if the data and information can be used for their purposes or not. It provides a program credibility, transparency and a way to measure results. It is a best management practice or an industry standard to help communicate and share data effectively and widely. A Study Design can be formal or informal, simple or complex, there is no one particular way. However, addressing all elements, even if a particular element is not needed in a design, tells the user that you thought about it and made a decision it was not needed and why, that is credible. Below is the River Watch Study Design.

1. **Overview of Organization** (*Informs what information is necessary about the entity monitoring to provide the reader, potential data users and decision makers context for the results, outcomes and impacts the monitoring program is designed to produce. This will vary by program, maybe different for each monitoring program. If the monitoring program is a regional collaboration or stakeholder group this might include all members as well as the stakeholder group*).

   a. **Parent Organization**

   Rivers of Colorado Water Watch Network ("River Watch") is a volunteer monitoring, citizen and community science program primarily funding and sponsored by Colorado Parks and Wildlife (CPW). Colorado Parks and Wildlife is a state agency under the Colorado Department of Natural Resources, which includes Divisions of Water Resources, Water Conservation Board, Forestry, Mining, Oil and Gas and State Trust Lands. CPW is charged with providing conservation of wildlife and habitat in balance with providing recreational opportunities for Coloradans (cpw.state.co.us).

   In Colorado, wildlife is managed under Department of Natural Resources, Colorado Parks and Wildlife. **Water quantity** and associated water rights legislation, policies and laws are administered by the Division of Water Resources. Programs, funding and resources to assist water quantity management fall under the Water Conservation Board. **Water quality** management, legislation, policies and laws of the Clean Water Act, Safe Drinking Water Act, Hazardous Materials Act, etc. fall under the responsibility of the Colorado Department of Public Health and Environment, specifically the Water Quality Control Division (WQCD). The Clean Water Act is overseen by the Colorado Water Quality Control Commission (WQCC).

   CPW is comprised of five branches, Wildlife (water, aquatic and terrestrial), Field Services (Game Wardens and Park Rangers), Financial Services, Information and Education and Research, Policy and Planning. The agency is the largest DNR Division with 1000 plus employees spread statewide. The River Watch Program has resided under the Wildlife Program Branch in the Water Unit. CPW staff in the Water Unit work closely with the WQCD and WQCC, often more intimately than with the Wildlife Commission.

   b. **Location**

   CPW headquarters is 6060 North Broadway in Denver, Colorado. The agency has four regional offices in each quadrant of the state, NW is Fort Collins, NE is Grand Junction, SW is Durango and SE is Colorado Springs. CPW also has numerous decentralized area offices, hatcheries, state wildlife areas and state parks.

   c. **Vision and Mission**

   CPW is charged with balancing the conservation of our wildlife and habitat with the recreational needs of our state. The Future Generations Act passed in 2018 provides specific goals designed to help us achieve that balance. Our agency mission is critical and relevant to all Coloradans, and we need the support of all Coloradans in fulfilling this critical work.

d. Constituents.

CPW's constituent are the citizens of Colorado.

e. Strategic Plan.

CPW's current Strategic Plan (2019) has five goals with objectives listed that River Watch contributes to and bullet statements regarding that contribution.

Goal I | Conserve wildlife and habitat to ensure healthy sustainable populations and ecosystems. (Objectives B5, B6, D14, D15, E16, E17 for WQ restoration)

- Provides leadership in and among WQ community
- Science based decisions, helping STEM in youth, underserved communities, informal
- Protect and restore aquatic habitat, data/CWA/stewardship/ match, etc.
- Provide monitoring of invasive, new/rare species of macroinvertebrates

Goal II | Manage state parks for world class outdoor recreation. (Objective C13)

- Working with parks and partners who work with parks and RW together, other WQ monitoring at parks)

Goal III | Achieve and maintain financial sustainability. (Objective B and C8)

- Collaborate and partner to find $ outside CPW, w/ partners have raised about $50,000 per year, provided over $600,000 in match past 30 years for groups doing restoration work
- Keep asking if can restore funding to Fed Aid and free up cash for other CPW efforts
- Created and working on Communication Relevance Matrix (products and information to CPW sectors to communicate work, value, outcomes, resources, etc.)

Goal IV | Maintain dedicated personnel and volunteers. (Objective C10, C11)

- Training plan and training transition for RW PM and my position
- Invite relevant section staff to our events, attend theirs' cross training/communication (Education, Aquatic, Research, Vol, regional, area, state parks,)
- Longest term volunteer participation

Goal V | Increase awareness and trust for CPW. (Objective A1, A3, A4, B5, B6, C1, C2)

- Include CPW priorities in RW communication, WQ efforts
- Conduct surveys for volunteers, data users, etc.
- Include CPW management information in RW training and material
- Social Capital CPW gets from RW, non-traditional audiences, statewide, reaches minority, underserved, diversity
- Adaptive management is NON regulatory and shows CPW working in locally alongside communities meeting them where they are working issues neither of us can tackle alone (
- Communication of WQ issues, solutions, only going to be more important in future

Goal VI | Connect people to Colorado's outdoors. (Objective A1, A3, A4, A5, A6, D13, D14, D17, E20)

- Include in RW training, material

- Vol source of income, outreach, support,
- Stewardship—by default in statewide schools reach

In summary, River Watch is a strategy CPW uses to fulfill its strategic plan and specific initiatives. Information on the current version of those strategies and River Watch's contribution contact the CPW River Watch Program Manager. River Watch provides these primary products and services for DNR and CPW:

- Water Quality Information, chemical, biological and physical habitat.
- Water Resource Management Influence, Education and Information.
- Cost Savings and Operation Efficiencies.
- Social Capital
- Personal Relations
- Hunter, Angler and Park Pass Recruitment

f. Program Goals and Initiation Story

River Watch has two equally weighted goals:

1. **Collect high quality data for use in water quality decision processes (Baseline monitoring).**
2. **Provide a hands-on real science experience for volunteers to understand and value river ecosystems.**

River Watch started in 1989 to address large data gaps in 700,000 stream miles in water quality decision processes, primarily in the Clean Water Act. CPW partners with a nonprofit to implement the program and works closely with their sister agency, Colorado Department of Public Health and Environment (CDPHE) and their Water Quality Control Division (WQCD) who implements Colorado's Clean Water Act. The program provides about $3000 in monitoring equipment, training and support to volunteers who monitor rivers in their community for _chemical_ (field, metals and nutrients) monthly, _biological_ (macroinvertebrates) and _physical habitat_ parameters. All program elements are designed to produce high quality data and a meaningful experience. All participants are required to attend a four day training to be certified, participate in an annual site visit for annual certification, use only provided equipment and chemicals and sign an annual agreement with performance criteria we measure, for example. All field and laboratory protocols match or are more prescriptive than CDPHE. Staff perform an annual evaluation in each of the nexus areas people (schools, staff, partners, etc.), science (methods, standard changes, regulations, workflows, information products, etc.) and purpose (funding, strategic changes, results, outcomes or impacts, etc.). This has kept the program relevant and consistently funded for 30 years.

River Watch's slogan is "**_Real People doing Real Science for a Real Purpose_**". The program's foundation is about relationships and bringing the nexus of these three areas together. This is described further on the River Watch Standard Operating Procedures Chapter 1 (provide a reference). Volunteers are about 85% schools (6th grade to college, all types of schools) and 15%

adult groups (individuals, watershed groups, towns, districts, etc.). Average participation for teachers is seven years, many serving twenty plus years and we have fourth generation volunteers.

River Watch focuses on rivers but the database does contain some lake, reservoir, ditch, wetland and other data types. Data is available via coloradoriverwatch.org, uploaded annually to data portals Colorado Data Sharing Network and the National Water Quality Portal, downloaded by CDHPE for their annual basin data call, and in a machine readable, discoverable format with an accessible api. CPW has a research section with underutilized laboratory capacity that River Watch took advantage which provides metal and nutrient analyses at sufficient detection limits for Clean Water Act decisions.

In 2020, River Watch's 30th anniversary, over 95,000 volunteers have been trained. River Watch as one of the largest data sets in the National Water Quality Portal (USGS and EPA's data repository), with 700 plus stations covering 550 plus rivers and serving about 120 active groups annually. Success stories are collected and part of the communication plan to turn into consumable products and is as important as data generated by the program.

g. **Structure**

i. **Where and who make decisions about monitoring purposes, data uses, users, targeted decision makers, data objectives, data quality objectives and information needs.**

River Watch's primary *monitoring purpose* is baseline monitoring which is equivalent to condition monitoring, asking the question about the health or condition of the river and over time is that condition changing. A refinement of baseline or condition monitoring is to determine if the way in which we or wildlife use our rivers is in any way impairs the physical, biological or chemical elements of a waterway. This is monitoring purpose is called a use assessment, identifying how rivers are used and assessing if that use is attained. This is in essence the monitoring purpose of the Clean Water Act asking if our nations waters are fishable and swimmable (uses) and providing states and tribes with funding and guidance to implement various programs, like standards and monitoring to assess use attainment. Baseline monitoring over sufficient space and time will identify uses in rivers that are have high quality and need protection, uses in rivers with low quality with impaired uses and need restoration and rivers where uses are in threat or showing degradation. All of these situations shift data the purpose of River Watch data from baseline to a study design that seeks to refine impacts or the effectiveness of protection and restoration strategies implemented.

Data collected for the purposes of baseline / trend/ use assessment that evolve into impact and or effectiveness can be used in a range of data uses. For River Watch those *data uses* include education, engagement, and research and resource management. The very same dataset, due to River Watch's technical and information design, provide data for all the above monitoring purposes and data uses.

The data must be used by specific users to achieve desired program results, outcomes or impacts related to program goals. The information needs of those users in the context with monitoring purposes and *data uses* direct and inform River Watch data quality objectives. River Watch produces data of sufficient quality, including meta-data and quality control and assurance data,

to be used in Clean Water Act decision making processes, CPW management, other water managers and volunteers. Specific data quality objectives for field, metals, and nutrient, macroinvertebrate and physical habitat parameters are characterized in the RW Standard Operating Procedures (SOP) and associated Quality Assurance Project Plan (QAPP).

The *primary data users* are those responsible for implementing the Colorado Clean Water Act, specifically the Colorado Department of Public Health and Environment, Water Quality Control Division and Commission. River Watch engages different sections of the CWA with its capacity and Study Design, including data used for 305b Report (state of the waters), 303d (impaired waters and associate total maximum daily loads restoration strategy), 319 (nonpoint source projects and associated monitoring) and standards development. River Watch mirrors the WQCD's field and laboratory methods as well as assessment methods which provides the criteria for our technical design (what is collected, when, where, how-data quality and data management) because this meets data quality needs of our targeted decision makers and their decision processes.

Secondary monitoring purposes, data uses and data users include objectives of CPW biologists, researchers, staff and then the volunteers. In addition, other water managers, Environmental Protection Agency, nonprofits, industry, academia and individuals utilize the data.

River Watch Staff, led by the CPW River Watch Program Manager, identifies and determines program monitoring purposes, data uses, users, targeted decision makers and associated data objectives, data quality and information needed to answer monitoring questions that best serve CPW's mission. These decisions are not made in a vacuum however. The Program Manager works with vendor staff, CPW staff, CDPHE, volunteers, other data users and partners in an annual evaluation to adjust these elements and associated technical, information and evaluation designs.

ii. **Where and who make decisions about what and where to monitor, sample analyses and data management.**

River Watch Staff, led by the CPW River Watch Program Manager, identifies and determines the program technical design, which includes what, when, where to monitoring and how to meet data quality and information needs of targeted decision makers. This includes data management of raw data as well.

These decision are 100% driven by information provided by identifying River Watch's monitoring purposes, data uses, users, targeted decision makers and associated data objectives, data quality and information needed to answer monitoring questions that best serve CPW's mission. It is the data quality and information needs of our targeted decision makers that drive the technical design.

The Program Manager works with vendor staff, CPW staff, CDPHE, volunteers, other data users and partners in an annual evaluation to adjust these elements each year.

River Watch has and does generate a large amount of data per year. CPW has invested in a data management system, documented standard operation procedures and benchmarks that ensure data is managed via best management practices. This investment is critical to River Watch's

success. The data volunteers generate, including meta-data and quality assurance data, have to managed and verified in sufficient rigor and quality to be used for our monitoring purposes. That rigor will vary with each program.

Our data management system has evolved over time and developed into its own data management plan, a subset document of this study design. River Watch data is machine readable, discoverable and available for data hubs to access. This ensures the data will live on long after collection and be used over and over, which is a data management best management practice in the community and a program goal.

iii. **Where and who makes decisions about data analyses, making recommendations or conclusions, what information products will be created, how they will be reported and delivered and data management of those products.**

River Watch Staff, led by the CPW River Watch Program Manager, identifies and determines the program technical and information design, this section's topic. This includes data management of information products.

These decision are 100% driven by information provided by identifying River Watch's monitoring purposes, data uses, users, targeted decision makers and associated data objectives, data quality and information needed to answer monitoring questions that best serve CPW's mission. It is the data quality and information needs of our targeted decision makers that drive the technical and information designs.

The Program Manager works with vendor staff, CPW staff, CDPHE, volunteers, other data users and partners in an annual evaluation to adjust these elements each year. Our targeted decision makers include CDHPE, CPW biologists and volunteers who have the same monitoring purpose, data uses, monitoring questions and data objectives as we do. They want these information products:

- Verified raw data (to combine with other data or to conduct their own analyses)
- Analyzed data (metrics reproduced by anyone like average, max, min, percentiles)
- Interpretation (what does analyses say)
- Success stories about data and human ROI's (Program results, outcomes and impacts)
- Program Performance (of our QAPP basically)
- Program Statistics (program outputs)

River Watch as several information products and processes that create and deliver these depending on the audience. They include data uploads to CDSN, NWP and to CDPHE directly, watershed reports, newsletter/blasts, specific campaigns, stewardship awards, performance reports, systematic reporting, presentations, surveys and others. More detail is provided in further sections. Every information product is linked to respective decision maker/audience/user, data use, monitoring purpose and program ROI's. This is what enables our program to maximize evaluation, produce measurable results and document success. The also affords the program external credibility, transparency and sustainability which increases impact.

iv. **Where and who conducts overall monitoring program evaluation, answers monitoring questions and individual program elements.**

River Watch Staff, led by the CPW River Watch Program Manager, identifies and determines the program technical information and evaluation design, this section's topic. This includes evaluation of individual processes such as sample collection, analyses or data management as well as evaluation of the overall monitoring program and study design to answer monitoring questions, achieve data and data quality objectives, results, outcomes and impacts as wells as move closer to water vision.

These decision are 100% driven by information provided by identifying River Watch's monitoring purposes, data uses, users, targeted decision makers and associated data objectives, data quality and information needed to answer monitoring questions that best serve CPW's mission.

The Program Manager works with vendor staff to create Program Standard Operating Procedures for the entire program, study design, sample collection, analyses, volunteer management, data management, information management, funding, relationship and communication management. Documentation is key. Specific SOP's are developed and updated that contain relevant workflows, benchmarks, work flows and critical information to produce consistent results.

Volunteers are the work horses, collecting samples using River Watch equipment, chemicals and protocols. They are evaluated annually via their performance report and a site visit. Annually River Watch staff review threats, opportunities, changes and challenges in all vectors, people, science and purpose. External changes with teachers, schools, vendor, CDPHE and other partners. Internal changes with CPW staff, needs, funding, etc. Changes in regulations, standards, procedures, technology, etc. Evaluation of program performance criteria in specific work flows, benchmarks, workloads, equipment, etc. This is all integrated and program adjustments are made and prepared to be implemented in July each year.

v. **Funding (related to monitoring program)**

Funding for the agency comes from three primary sources, federal aid available to this type of agency, license revenues and a portion of state lottery dollars for specific uses. Colorado Parks and Wildlife is an enterprise agency in the state which means it generates its own revenue versus receiving revenue from the state general or tax funds. CPW receives literally one dollar from the state general fund. CPW's overall funding is comprised of fees (hunting, fishing, passes, stamps, tags, etc.) which fund specific programs and staff such as district wildlife managers and park rangers. Other sources of funding include federal aid administered by USFWS that is only available to state wildlife agencies for designated uses. Likewise CPW receives Colorado Lottery dollars for designated uses only and has other partnerships with other federal, state, local entities that include grants, donations and other funds, again for specific purposes.

River Watch funding for the first decade was Wallup Breaux Federal Aid, which is a tax on the manufacturers of fishing and boating equipment administered by the USFWS for Wildlife

Agencies divided up based on a number of fishing licenses sold formula sold. Most of the these funds are used to provide fishing access like boat ramps, however a limited portion can be used for angler recruitment and aquatic education, requiring a 30% match. River Watch was considered both angler recruitment indirectly and aquatic education and volunteers provided that in-kind match. Volunteers consistently provided more match than was available to fund and this is the case still today.

During the second decade of the program CPW mixed funding sources with the Colorado Lottery funds. The Colorado Lottery funds, a portion of which is allocated to CPW for wildlife land acquisition, education and other specific categories. **As of 2019 CPW funds River Watch solely via lottery dollars**.

h. Budget (related to monitoring program)

Historically the annual program budget is about $225,000. This includes all operating costs (equipment, shipping, analyses, supplies, training, temporary and contract staff). CPW permanent staff salary is not included in this budget.

i. Staffing (related to monitoring program)

To implement River Watch and provide full time permanent staff to manage volunteers, diversify and expand funding as well as program elements, CPW partners with a nonprofit through a five year request for proposal state approved process. CPW provides the scientific expertise, study design, data management, data delivery, laboratory analyses and equipment while the vendor provides the volunteer management, training, sample processing, and equipment inventory and entry data management. This approach provides the program and volunteers with consistent support necessary to produce consistent quality data as well as opportunities to expand the program in volunteer size, geographic coverage, parameters and impact. CPW's partner vendor has consistently contributed annually $50,000 or more to the program, provided 2-4 dedicated full time staff and the ability for volunteers to expand their efforts into areas CPW cannot.

j. Partners (related to monitoring program)

Key partners to implement River Watch besides actual volunteer groups and primary vendor is the Colorado Department of Public Health and Environment, Water Quality Control Division (WQCD) and Commission. This is the Clean Water Act agency. Three divisions within the WQCD, standards, assessment and protection all collaborate with River Watch. CPW staff; CPW Research, Aquatics, Education sections and Regional staff are also key partners. Connections and relationships with the Colorado Education system, National entities that drive Clean Water Act changes, water quality database portals, monitoring and analyses methods and Citizen Science or Volunteer Monitoring are also key partners.

k. Program Benefits

Program benefits to Colorado citizens or participants include:

- aquatic resource habitat and wildlife restoration and protection, including native species and retain healthy biodiversity for animals and humans

- Identification of new macroinvertebrates and locates of invasive species

- more recreational and stewardship opportunities

- development of protective aquatic life standards

- educated and inform voters

- Students have received credit, payment, scholarships, awards, service learning

- More students in STEM, especially underserved and non-traditional CPW audiences

l. **How Can I Find More Information or Get Involved?**

Go to: coloradoriverwatch.org

2. Program Design: The Who and Why Design (Module 2)

a. Why Monitor?

Monitoring can tell us how well a river is functioning and if it is healthy or at risk. Understanding how monitoring fits into the bigger picture is essential in implementing a River Watch monitoring program. One way to assess the health of an aquatic ecosystem is to categorize monitoring parameters into three areas **chemical**, **physical**, or **biological**. The River Watch program measures parameters in each of these three categories. When assessing the health or status of a system, like your body or a stream, you want to measure the **stress, exposure** and **responses** to possible pollutants. A comprehensive watershed monitoring plan would incorporate all six of these elements as much as resources allow. River Watch includes indicators in all three media's and for stress, and response to organisms. Exposure is difficult to measure being very resource intensive and not scalable. In directly, exposure limits drive water quality standards to protect uses such as drinking water and aquatic life.

Furthermore, all three areas can be a stressor, exposing harm to organism who live or use the river and they are indicator species. Exposure causes a response in these species. That response can be **chronic** or **acute**. To characterize or quantify exposure a monitoring program's study design will include ways to measure **magnitude, frequency and duration** of exposure to determine if it is at a level to cause a chronic or acute impact. That impact will also depend upon the organism, the size, age, species, ability to move, time of year, path of exposure (ingestion, physical, etc.). **Magnitude** is the degree of exposure above a threshold, large or small. **Frequency** is how often the organism is exposed, every day or once year or once a life time. **Duration** is how long an exposure occurs, if every day maybe all day or only for five minutes, if once a year for one day, etc. If the exposure is of sufficient magnitude, frequency and duration and the organism dies, that is considered an **acute exposure** (often high magnitude, not frequent and short duration think of being in the building during the 1986 Chernobyl nuclear plant breakdown). If

the exposure cause anything from a skin condition to death, that is considered **chronic exposure** (lower magnitude, very frequent and longer duration think second hand smoke). Clean Water Act standards include an acute and chronic level when data is available.

Monitoring stressors provide information on stressors and exposure. Conclusions may or may not support the same conclusion if monitoring response communities exposed to those stressors. The response community would include monitoring the plants, animals and/or humans directly. Humans are difficult to monitor directly but patterns if disease, sickness or other conditions, can be monitored, that is the science of epidemiology. Bacteria like E.coli provide an indicator of health and is often the parameter used to protect recreation standards in many states clean water acts. All waters have **bacteria** to break down organic material for food like your stomach, some are good and some are harmful like some cyanobacteria. **Aquatic vegetation** can be an indicator for excess nutrient loading as an example along with chlorophyll and direct measurements of phosphorus and nitrogen. **Macroinvertebrates are effective indicator species** because they spend most of their life cycle in the water, live a year or less, are not that mobile relative to fish, easy and feasible to collect, occupy diverse habitats, have diverse life cycles, are not artificially managed, differ in their tolerance to different pollutants (stressors) and respond to human disturbances in predictable ways. **Fish** are also good indicators as they are further up the food chain, reside in different habitats, do have different tolerances to pollutants and their response is predictable for some human disturbances. However, fish are more expensive and difficult to collect, there are fewer of them and they can be managed (stocked, etc.). Each biological community provides a unique line of evidence for impairment or health that adds to information from chemical and physical habitat monitoring.

Examples of a chemical indicator include pH, dissolved oxygen or cadmium. An example of a physical habitat indicator includes amount of flow, stream width and depth, bank stability and substrate composition. An example of a biological indicator includes fish, macroinvertebrates, algae, daphnia and bacteria. An example indicator of a stress could be chemical pollutants or toxicant substances such as the heavy metal cadmium. An example indicator of exposure would be to test the exposure of an organism to a specific pollutant as laboratory experiments often do to produce a concentration that kills 50% of the organisms, called the LC50. An example indicator of a response is to measure the community structure of an aquatic system such as the species composition of the macroinvertebrate community or a diversity index. River Watch includes indicators in all three media's and for stress, and response to organisms. Exposure is difficult to measure being very resource intensive and not scalable. In directly, exposure limits drive water quality standards to protect uses such as drinking water and aquatic life.

Biological Integrity is where the chemical, physical habitat and biological components and in their healthy condition overlap, see the Venn diagram below. Stressors in any area can result in stress to another area as they are all connected. Stresses include pollutants (chemical), physical habitat (flow for e.g.) or biological (invasive species for e.g.). You can identify a stressor in one area and identify possible stressors in other areas. For example, a physical habitat stressor such as poor riparian and bank condition perhaps due to overgrazing or bike path causes the bank to

slough into the river, resulting in a chemical stressor, sedimentation which then buries substrate, macroinvertebrate and spawning habitat impacting those biological communities. The exposure to the stressor is covered in detail in metals section. Response is measuring the actual plant, animal or human condition, in response to being exposed to a stressor.
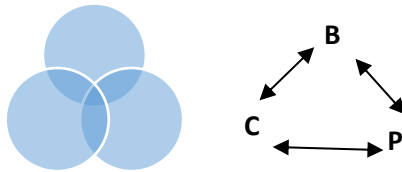
Environmental Protection Agencies' top three pollutants for the nation are nitrogen, phosphorus and sediment. In Colorado, due to the precious metal mining legacy the top pollutant is metals. For metals, nutrients and sediment, it is important to distinguish the difference between *natural/background and human caused (anthropogenic) reversible* and *pollution and pollutant*. These things occur naturally and are often needed. It is the role of streams to carry sediment from eroding mountains to the ocean and that sediment often carries necessary nutrients for organism. As rivers flood they bring in more nutrients and flush out the system and move material downstream. These become pollutants when they exceed a threshold, biological or physical. Pollution is the introduction of harmful materials into the environment. Those harmful materials are called pollutants. Pollutants can be natural, like volcanic ash or man-made like plastics, pesticides or hormones. A river that receives too much sediment for its discharge, hydrology and physical capacities will "fill up" in sense and sediment becomes a pollutant causing pollution (impact). Same with metals and nutrients.

Following how a pollutant behaves and changes as it enters the soil, water or air is called *fate and transport*. Many chemicals, like pesticides, break down into numerous pollutants as part of fate and transport, and that one product produces 17 pollutants to monitor and analyze. A metal may change form and become bioavailable or unavailable. This presents an additional challenging for monitoring as well as developing policies that protect all beings.

Systems have varying degrees of what is natural or background levels occurring based on many factors, region, elevation, geology, climate, etc. Human uses over time introduce often in an unnatural way or rate, metals, nutrients and sediment, in this example and that is called an anthropogenic source. Different systems have different capacities to *assimilate* and process these exposures or additions, just like humans. The Clean Water Act attempts to minimize impacts from human sources and has many programs to protect and restore waters. The primary philosophy is that if a human source can be "fixed" it will be. In some cases, the system cannot be returned to its natural or previous condition and that is termed irreversible and efforts focus on reaching the 'new' potential, even if altered from natural. In some cases the altered condition can be perceived as better than the natural condition. For example, some braided flashing streams or ephemeral (don't flow all year) streams are altered into contained cold water, year

round flows that support trout. Or some rivers are dammed and now support a reservoir fishery. These may be irreversible changes. Restoration strategies have to discern between these areas.

Monitoring is a necessary component in understanding the function and health of river ecosystems, but only a means to an end, not the end. Monitoring generates **data**, numbers, ratings, and descriptions, but that data still needs to translation into **usable information,** used by decision makers, even if that decision maker is you, for a desired action, change, impact or result. The decision and actions taken because of the information generated by the data is the end. In order to have your monitoring efforts produce a measurable result you start with end in mind, what is the desired action, result or change and work backwards to what you do not know and data will help you answer. These questions are often called monitoring objectives.

Steps to identifying the monitoring objectives include, who will use the data, how they will use the data, what decision they are trying to make, and what information needs generating to make those decisions. Information needs of the data user, decision maker and uses that should determine what, where, when, and how the data is collected. As well as the quality of the data and how rigorous the data collection needs to be.

Finally, a plan to manage the monitoring results (hear data management) and translate the data into information (information products) is essential. This includes a plan to implement the monitoring, managing raw data, performing data analysis, derive findings, interpret the results, make recommendations, and deliver the results to data users. Then circulate back, evaluate and adjust the monitoring plan (questions asking, what, when, where, how, data quality, etc.).

Together the steps and approaches listed above make up the bigger picture of an effective study design or monitoring plan and thus monitoring program. Many of the components of an effective monitoring program (or watershed assessment) are in place with the River Watch program for the participants.

b. Why Citizen Science or Volunteer Monitoring?

Citizens were the original scientists in the 1600's, those that had time and resources. The term "scientist" was coined by an English philosopher and historian of science William Whewell in1834, and was assigned to a woman, Mary Somerville to distinguish what she was doing versus men. Being a scientist wasn't a profession until the mid to late 18th century and it was in this era that pushed the pendulum from curious community members to the opposite realm. In this era the primary power behind science became controlled by institutions and remains that way today. Data is primarily available to, disposed by, generated by, some expert, some agency or process for a privileged few. Science and power has become elitist, exclusionary and sometimes ineffective. This inequity rises to the surface when the institutions do not have the resources to be everywhere all the time doing everything in face of all the threats to our waterbodies. It is this gap that motivates citizens to act to protect and restore waters in their back yard because their daily quality of life is impacted.

Citizen science democratizes the power structure behind resources and information to gather data, analyze it and make decisions or take action. It can be seen by agencies as a great resource or a threat, either to their power or to their ability to "handle" more. Citizen Scientist can provide data across geographic and temporal scales that agencies will never have sufficient resources. The volume of data Citizen Scientist can collect is greater than any one agency alone. And the quality if data can be rigorous, thorough and high for compliance and enforcement or simple and like observational data and everything in-between. Citizens can be in charge of the entire project from study design to implementation to evaluation or involved in different aspects taking on different roles.

River Watch would not exist without its volunteers. No other agency or entity would "fill" the data or stewardship role River Watch fills. We are able to target the right type of volunteer, provide the right role and level of engagement that leverages their time in sample collection, field analyses and stewardship, one of the most expensive elements in monitoring. Volunteers stay on average 10 years in the program, some their entire teaching career and we have 3rd generation volunteers.

c. Keepers of Study Design (who is/should be involved and/or responsible)

CPW River Watch is responsible for program design, documentation, implementation and evaluation. This position does not perform all tasks but is the keeper of the information.

A master document road map provides a list of all program documentation, subdocuments, their outlines and purposes, all **Standard Operating Procedures** and a matrix of who is responsible for each document. This is updated annually with relevant documentation. Standard Operating Procedures are the standard ways in which a work flow, task or responsibility is to be completed. However simple or complex, formal or informal, in the field and laboratory but also for data, volunteer and overall program management create credibility, reproducibility, transparency, cost efficiencies for a program as well as provide the path to generate consist data quality.

d. Water Vision (what want for waterbodies, watershed that is a uniting theme guiding the study design - can be small and focused or large and general)

River Watch has the same vision as the Clean Water Act for all state waters, that they are fishable and swimmable. Specifically, River Watch has a vision that all native and desired aquatic life are sufficiently protected to be available for biodiversity, healthy and resilient ecosystems. Secondarily that where managed as such water quality is sufficient to support recreational opportunities.

e. **Monitoring Program Desired Results Outcomes and Impacts**

The ROI's for achieving River Watch's two primary goals include:

- Aquatic Life Uses met as defined by Colorado Clean Water Act (CWA), where possible obtain outstanding waters designations, list impaired waters, help delist waters that

or impaired but restored, help develop water quality standards where can (zinc, cadmium, macroinvertebrates)

- Assist local groups monitor to restore or protect their watershed by being a River Watch volunteer, using the network, providing match or identifying clean up targets, often through the 319 Non-Point Source Program

- Create and informed citizenry that actively protects or restores rivers where every they may live and if in Colorado make informed on water use issues

- Help teachers and students engage in real science and water management

- Occasionally provide data for other monitoring purposes beyond use support or condition/baseline, such as research.

i. **Who makes what decisions to achieve above?**

CPW River Watch Program Manager oversees those decision being made, consulting with CPW Strategic Plan, Leadership, key internal stakeholders, Colorado Department of Public Health and Environment, volunteers and other key watershed managers.

ii. **What information and activities do they need to make desired decision/action?**

Colorado CWA and the WQCD provides the elements of a technical design what needs to be sampled, when, where and how, data quality in field and laboratory for both chemical and biological samples. This information is provided in their methods documents available on line or by contacting staff.

WQCD only has three staff members to sample the entire state so they rely on third party data. WQCD has stated from 20-30% of their data each basin hearing is River Watch, at some locations it is the only data. As such WQCC typically samples only every other month, sometimes quarterly and/or high-low flow only.

River Watch baseline sample frequency is monthly for field and metals, high-low flow for nutrients and once a year for macroinvertebrates and physical habitat assessment. River Watch emulates all chemical field and laboratory methods and documents deviations, as well as changes in respective SOP's.

River Watch maintains the following to document methods:

- This Study Design is a subdocument to the larger River Watch Standard Operating Procedural Manual (internal document), which documents all aspects of the program from philosophy, structure, training, sample collection, processing, analyses, data management, data analyses, data to

information products and delivery and evaluation. All specific SOP are located in this document, 11 Chapters, each chapter is its own document.

- Sample Plan and Hit List – subset of larger document to provide volunteers instructions.

- Quality Assurance Manual and Quality Assurance Project Plan – Former is for CPW's larger research laboratory and the latter for the River Watch Project

- Data Management Plan – for all aspects of managing River Watch's voluminous data, including a Data FAQ Summary (external), database application user and developer manual (internal).

- About 25 tracking tools to document, track, report and evaluate various work flows from a samples birth to death, volunteers, meta-data and equipment (internal).

iii. **What assumptions and resources are being made?**

Assumptions each and every year to implement River Watch include:

- Funding is sufficient to maintain core River Watch (serving 140 groups sampling about 350 stations per year for field, metals, nutrients, bugs and physical habitat, plus quality assurance, training, site visits, data management and delivery and evaluation).

- Qualified vendor is in place as partner and all staff adequately trained.

- Laboratory equipment function and perform consistent and with quality.

- Volunteers renew their annual agreement. If not equipment is reclaimed.

- Annual evaluation of changes in education system, costs, Clean Water Act standards or regulations, field or laboratory technology are assessed and program adjusted, changes documented.

iv. **Start a Logic Model to document Study Design's Monitoring Program.**

See River Watch's Program Logic Model at XXX.

f. **Scope Inventory**

i. **Physical Inventory ***

River Watch's scope is statewide. In our site selection with volunteers we prioritize these basic factors, safety, year round and long term access (public not private land), if a water quantity gauge exists, if there is an existing abandoned station and meaning for CPW, WQCD or the volunteer.

To meet our data objectives, information needs of our targeted decision makers, answer our monitoring questions and achieve our ROI's, River Watch does not need a physical inventory of every waterbody we monitor. However, we train and invite our volunteers to learn as much as they can about the water body they are monitoring as a volunteer.

ii. **Information Inventory* (uses, economic, social, classifications, condition, regulations, existing monitoring or data)**

The WQCD on their website has listed all aquatic life uses for all segments in basin documents by Water Body Id, or WBID. These are segments the WQCC creates where uses change in order to administer the CWA, like discharge permits.

The Colorado Data Sharing Network and EPA's National Water Quality Portal can help determine existing stations or data. However, since River Watch has stewardship and educational goals and our monitoring frequency is greater than any other entity, River Watch data rarely collects where data exists, if it does it complements the existing frequency.

iii. **Human Inventory* (history, cultural, community values, threats, perceptions, stakeholders, power and influence)**

River Watch as a program doesn't need this element to meet our data objectives, information needs of our targeted decision makers, answer our monitoring questions and achieve our ROI's, River Watch does not need a physical inventory of every waterbody we monitor. However, we train and invite our volunteers to learn as much as they can about these elements in their water body they are monitoring as a volunteer.

g. **Map of Data Pathways (All combinations of Purpose, Data Use, Users and ROI's)**

i. **List all Assessment Types - All Combinations of Monitoring Purpose/Reason plus Use**. River Watch as six unique combinations of data purpose, data use, users and results, outcomes and impacts. All are served by collected using the same Technical Design, but have some different Information Designs.

Purpose	Use Support/Condition (baseline	Impact	Use Support/Condition (baseline	Use Support/Condition (baseline)	Use Support/Condition (baseline)	Use Support/Condition (baseline)
Data Use	CO CWA Assessment Hearings	CO CWA NPS Program	CO CWA Standards Process	Stocking, species removal, invasive species mgnt, restoration target, hatchery mgnt	Volunteers WS Management Decisions, restoration, protection, designations	Water Management Planning, protection, restoration, use decision
Data Users	WQCC-Assessment and Standards Unit	WQCC-Protection Unit	WQCC-Assessment and Standards Unit	CPW Biologist, Researchers, Hatcheries, Parks	Volunteer organizations	Local Water Managers
Results, Outcomes & Impacts	Aquatic Life uses attained, Id impaired or restored and delisted	Project restoration data and match,	Development of standards	Healthy biodiverse aquatic communities & habitat, more rec opportunity, productive hatcheries	Healthy biodiverse aquatic communities, rec opportunity	Healthy biodiverse aquatic communities, rec opportunity in local community
	Clean available water, impaired on restoration path	Restored water			Informed citizenry More students in STEM	Informed citizenry
Monitoring?	Are Aquatic life uses met?	Are Aquatic life uses met?	Are standards protective of Aquatic life?	Are Aquatic life uses met?	Are Aquatic life uses met?	Are Aquatic life uses met?
Information Product	Verified raw data (not analyzed)	Verified raw data (not analyzed)	Verified raw data (not analyzed)	Verified raw data (not analyzed), watershed assessment reports	Verified raw data (not analyzed), watershed assessment reports	Verified raw data (not analyzed), watershed assessment reports

ii. **Monitoring Questions per Assessment Type**

River Watch's primary monitoring question is the same as the CWA, are our waters meeting aquatic life uses, as defined by Colorado CWA? That is a Use Support data purpose. The data is used in several processes all providing different mechanisms to our ultimate ROI's, healthy, diverse, resilient aquatic communities for quality of life, recreation and subsistence.

When we discover a use is not supported using baseline technical study design, we modify our technical study design in that specific watershed to answer monitoring questions, "what is the extent of pollutant/stress/contamination, where is the source" – an impact purpose. Once that is complete and a restoration action has happened, we change technical design to monitor the effectiveness (of restoration, change in regulation, ceased discharge, etc.), all the while continued to implement the baseline technical design.

iii. **Information needs and data quality objectives.**

The WQCD via the CWA processes provide River Watch both the technical and information design for their decision process. The WQCD wants raw, verified data as they combine all data of known quality into their assessment and processes. As such we export River Watch data to three places and make it available on our website, to the National Water Quality Portal, Colorado Data Sharing Network and CDHPE specific upload formats when requested. Their information needs provide the technical and information design. This also fills the information needs for many some CPW staff, other water managers and some volunteer groups.

The decision we want WQCC to make are to protect waters meeting aquatic life uses, assign outstanding waters to those above standards and to place segments not meeting aquatic life use into restoration strategies. These are a data uses and management actions. See the information inventory summary.

Assessment Type: Use Support + Regulatory	User (Step 3): WQCD and WQCC 305b and 303d process, annual basin focus or hearing	Uses/Decision (Step 3): If on 305b-restore/assessed, if not get on 303d/other to restore, if un-assessed, get assessment scale refined

Monitoring question (step 4):__1_ of _3_: Are waters in the state meeting their uses- on the segments data is available, are all streams assessed, if a use is not being met or a criteria exceeded is that segment listed on the states 303(d) Impaired list or in another restoration strategy process-how can River Watch Help (iterative)?

Info Need:	Decision Maker _1_: WQCD	Decision Maker 2: RW if not on 303d
Decision Make?	If on 305b-restore/assessed, if not get on 303d/other to restore, if un-assessed, get assessment scale refined, if not on 303d where is it, can we help?	Take impaired segment and see if can work w/ local group
Key processes, natural/political?	Current data, hydrologic cycle, minimum data elements, follow states data call format/timing, 303d listing methodology-study design, etc.	Follow up after each basin hearing to determine assessed, and 303d to see results
Key Indicators needed, in what media?	Use same set WQCD does, chemical suit, bugs, physical habitat, photo – see WQCD and then our Operation Procedures which include SOP's	
Where do they need it from (key locations, political, historical, etc.)?	Provide where we have volunteers, which is more often than not where no one else is monitoring, if is, still meets education goals—anywhere can get or data exists, basin of focus	
Benchmarks and references they use, criteria, metrics, indexes, statistics, etc.?	Co CWA standards, numeric and narrative	
What frequency/duration (length of record) does information need to be?	Require 4-6 samples, we do monthly at least, last 5 years,	
How "good" does it have to be (peer reviewed, certain methods, etc.) be?	We do 20% QA above required 10%, have QAPP, produce annual performance report, presentation to WQCC	
Methods are they using, need you to use, field/lab	methods field/lab same, doc, detect limits—Our SOP matches theirs	
What acceptance/performance criteria do they use?	In 303d/305b guidance, participate in modifying those guidance's to make sure data can be submitted	
Information needs to be included besides data or information, meta data?	Have required meta data, org, station information, methods, detection limits match	
Will you deliver, raw data, analyzed, interpreted, conclusions,	Raw	

recommendations, where will you exit?		
Do they need you to analyze, interpret, conclude or recommend	No	
Is the decision made? Process, formal, legal, rigorous, opportunities	Informal to provide data, just answer data call by deadline, Rulemaking hearing formal, but do participate	
Do they need the information, format?	normalized, in STORET too, relational database allows us to provide large dumps or specific water body data dumps	
Will it be delivered, mail, meeting, hearing, orally, etc.?	Sent when the do August data call – email now, can get from STORET or website, but have not been	
Is the decision made?	Yes, 1st part, annual basin hearing use our data as part of overall review, every 2 years is the 303d hearing, use our data there, and for Monitoring and Evaluation list primarily	See above comments
Do they need the data or information at what frequency?	Prefer data 5 years old or less but use all if that is not met, 6x year, most chemical parameters—data dump every August for basin of focus, every other year for 303d statewide	
Will deliver the data and then evaluate if decision was made and role of information?	CPW staff, RW coordinator	

Volunteers and other CPW staff do not want raw data. Their information needs include wanting to know what the data means, an assessment and interpretation. To fulfill this information need River Watch provides a summary of each hearing, how the data was used and the result, produces small watershed reports using only River Watch data and the same protocols as used in the CWA assessments, and provides resources for volunteers to use other existing analyses and visualization tools (like National Water Quality Portal, Colorado Data Sharing Network, EPA's How is my waterway?).

The decisions we want others and volunteer groups to make is to engage in restoration or protection actions for the river in their community. This is a planning, advocacy data use.

Our education goals are similar, we want volunteers to understand the value and function of rivers in the natural and managed world and their role and opportunities to advocate for healthy rivers. Healthy defined by Colorado Clean Water Act.

River Watch is a data acquisition program not a data interpretation program. All resources and training go into collecting high quality data, providing resources for the volunteer and user to analyze the data through their own lens, for their own

empowerment and purposes. That is what CPW does with the data to fulfill aspects of its mission.

iv. How Answer Monitoring Question, Ambiguous Terms

River Watch's primary monitoring question, 'are aquatic life uses met?' is answered routinely each year in specific water bodies during the WQCC's basin and impaired stream hearings and in the basin we produce watershed reports. "Meeting" uses is defined in the Colorado Clean Water Act.

v. River Watch Information Blueprints per Assessment Type- Communication Tool

Assessment Type: Use Support and Regulatory	Use(r): WQCC and WQCD 305b and 303d CWA processes	Use(r) / Decision (s): If on 305b-restore/assessed, if not get on 303d/other to restore, if un-assessed, get assessment scale refined
Monitoring Question: _1___ of__3__: Are waters in the state meeting their uses- on the segments data is available, are all streams assessed, if a use is not being met or a criteria exceeded is that segment listed on the states 303(d) Impaired list or in another restoration strategy process-how can River Watch Help (iterative)?		
Information Blueprint #	**Your response**	
1. Watershed Vision and Desired Outcomes this is design to help	All people have access to clean water for basic uses. All people understand the role, value and function of water ecosystems for all life and make decisions that preserve a healthy use relationship.	
2. Scoping Inventory needs related to Assessment Type	Focus on basin WQCD focuses on, try and select sites w/ gauges, above/below, long term access, no data or complimentary data – decide this at RW training for this objective, collectively adds up for State and this objective	
3. Existing data or monitoring efforts that are of quality to use here	See above, WQCD will be using all qualified data for decision	
4. Targeted Decision Makers	WQCD 305b and 303d CWA processes, River Watch for another review if impaired segment does not make 303d list OR assessment scale could be refined	
5. Technical info needed by Decision Makers (what, where, when, how, raw data mngt):	Chemical suit, bugs, phys hab – aligned methods, detection limits, etc., where we have volunteers works, we collect more than required 12/year, need raw data, delivered in August data call, normalized, for 305b, only new data, not entire database.. For RW, get volunteers to sample and/or work w/ local group restore.	
6. DQO's and QA/QC needed	Got from WQCD protocol methods manuals	
7. Decision makers needs for analyses (summaries, illustrations, metrics, indexes, statistics, etc.)	Raw data, plus meta data- minimum data elements required by STORET	
8. Decision Maker Benchmarks	Colorado WQ Standards, narrative and numeric	
9. Decision makers needs for interpretation, conclusion or recommendations (assessment	None—however do know what they do and why their frequency of collection is what it is, for e.g., take 85 percentile of parameter x, compare to standard, etc.	

protocol, criteria, method, process, statistical hypothesis):	
10. Communication & Delivery needs of Decision-maker, organization/others	Data call in August for basin of focus, and every other year, recent data statewide for 303d hearing
11. *Monitoring question* is met when XYX…..":	Annually, Basin of focus hearing, use assessment, classifications and segmentation are reviewed and adjusted, every 2 years 303d list is updated and so is CO monitoring /evaluation list, we review results, adjust monitoring plans—thus measurable result here is this annual evaluation/process
12. Monitoring System Product:	Database-, annual hearing results. For Volunteer audience we do our own WS report, but that would be on its own blue print with many of the same answers above, the INFORMATION design is different because volunteers (most) don't want raw data, they want the "is my river okay" analyses, we take the results of the hearing process and report it but also do our own analyses w/ their data mimicking the WQCD analyses.
13. Evaluation Date	After each basin and 303d hearing (June and March). A result of this process has allowed us to find a niche in helping implement monitoring for new standards (temp), developing new criteria (zinc for sculpin), and restoration plans (monitoring/evaluation 303d list in CO)
14. Assumptions and External Factors	RW structure, support remains in place and functioning, Changes in CWA standards or methods, we change too, but may take a transition period.
15. Definitions for ambiguous terms:	"Healthy" for us means meeting aquatic life use, and other CWA uses. "Restoration" means work that restores the quality for the use impacted.
16. Ball Park Estimate of $	RW currently can analyze 12 dissolved and total metals, 6 nutrients for $35 sample, Bugs $150 pre-processed. Upstart training equipment is about $1000, annual support is about $350.

h. Volunteer Management

River Watch has a robust volunteer management program, managing 140 groups annually since 1989. The documentation for all volunteer management elements is a spread out in the River Watch Standard Operating Procedures manual various chapters, including recruitment, training, expectation, testing and certification, evaluation, retention, recognition, outreach and communication and termination While this is not a subdocument it could be.

The top three common challenges by volunteer monitoring groups across the nation are volunteer recruitment, retention and getting data used. River Watch as none of these challenges and never has. There is a waiting list for groups to participate. Average program participation is 7 years for teachers, 10% have stayed 15 plus years, some their entire teaching career. We have 4th generation volunteer teachers now. Volunteers on average donate annually the equivalent of 2.5 full time employees and drive enough miles to journey from Denver and NYC and back twice.

The WQCC has been using our data for 30 years, all over the state in same decision processes they use their own data. The data has been challenged and where appropriate retained and where not deleted. No entity ever will produce a perfect data set, the key is to ensure best practices are in place to catch data of insufficient quality.

River Watch takes volunteer management as serious as generating high quality data. That intent and responsibility is passed on to each volunteer. Each volunteer signs an annual contract with performance measures for both entities and must attend the initial training to get equipment. Once in they have a spot secured as long as the sample or communicate with the team, this is all part of expectation management. It is an investment that if implemented well will reap. It is imperative to have feedback loops that identify what is important to volunteers, keep them engaged and informed and communicates that they matter.

3. **Technical Design:** The What, When, Where, Data Quality and Management, (Module 3). Per Assessment Type or your own organizing unit.
   a. **Water Body Type(s)**
   River Watch monitors primarily running water, brooks, and streams, rivers large and small. Rivers is our strategic focus, given these factors:
   - Legacy mining makes metals in rivers a top state pollutant priority over nutrients and sediment, this is a key data gap
   - Our volunteer base, which is 85% sixth grade to high school and 15% adult groups, of whom many live on or near one of Colorado's 770,000 river miles
   - Accessibility to and technology of sampling of rivers versus lakes is easier
   - What our resources and capacity can provide and maintain consistently
   - A direct tie to CPWs mission exists with rivers in a way that groundwater and some reservoirs does not

   All of these drive our capacity to produce the quality and quantity of data needed by our decision makers to use we want for the purpose we want to achieve ROIs. While lakes, reservoirs and groundwater all have data gaps too, we cannot fulfill those like we can for rivers. Data does exist for ditches, adits, inlets, outlets, hatcheries, wells, wetlands and some lakes, it is not the program focus.

   b. **What (Indicators, Benchmarks, etc.) and why?**
   The Colorado CWA provides our technical design. See below table.
   Volunteers collect field parameters, ship metals, nutrients and macroinvertebrates to CPW laboratory. Macroinvertebrates are given to a certified taxonomist to identify to species where possible. Volunteers conduct an annual physical habitat assessment.

Indicator	Frequency	Method	Lower Report Limit	Method Detection Limit
pH	monthly	Meter, probe for fresh water	0.1 S.U.	0.1 S.U.
Temperature	monthly	Celsius thermometer	1.0 unit	1.0 unit
Dissolved Oxygen	monthly	SM 421.B	0.5 mg/l	0.5 mg/l
Phenol/Total Alkalinity	monthly	EPA 310.1	0.1 mg/l	0.1 mg/l

Indicator	Frequency	Method	Lower Report Limit	Method Detection Limit
Total Hardness	monthly	SM 314 B	0.1 mg/l	0.1 mg/l
Aluminum	monthly	EPA 200.15 (ICP)	10 ug/l	2.1 ug/l
Arsenic	monthly	EPA 200.15 (ICP)	10 ug/l	5.8 ug/l
Calcium	monthly	EPA 200.15 (ICP)	100 ug/l	18.6 ug/l
Cadmium	monthly	EPA 200.15 (ICP)	0.5 ug/l	0.18 ug/l
Copper	monthly	EPA 200.15 (ICP)	1.0 ug/l	0.5 ug/l
Iron	monthly	EPA 200.15 (ICP)	10 ug/l	5.2 ug/l
Magnesium	monthly	EPA 200.15 (ICP)	200 ug/l	91 ug/l
Manganese	monthly	EPA 200.15 (ICP)	5 ug/l	2.4 ug/l
Lead	monthly	EPA 200.15 (ICP)	3 ug/l	2.4 ug/l
Potassium	monthly	EPA 200.15 (ICP)	200 ug/l	100 ug/l
Selenium	monthly	EPA 200.15 (ICP)	5 ug/l	2.4 ug/l
Indicator	**Frequency**	**Method**	**Lower Report Limit**	**Method Detection Limit**
Sodium	monthly	EPA 200.15 (ICP)	200 ug/l	100 ug/l
Zinc	monthly	EPA 200.15 (ICP)	5 ug/l	2.6 ug/l
Ammonia	High/Low Flow	EPA 350.1	0.01 mg/l	0.004 mg/l
Nitrate-Nitrite	High/Low Flow	EPA 353.2	0.02 mg/l	0.01 mg/l
Total Phosphorus	High/Low Flow	EPA 365.1 and .3	0.005 mg/l	0.0009 mg/l
Chloride	High/Low Flow	EPA 325.1	1.0 mg/l	0.17 mg/l
Sulfate	High/Low Flow	EPA 375.4	0.5 mg/l	0.2 mg/l
Total Suspended Solids	High/Low Flow	Standard Methods	4 mg/l	1.0 mg/l
Macroinvertebrates	Annually/Fall	See RW Sample Plan – bugs ID'd by taxonomist, Dnet, 4, 60 sec kicks, sandy/rocky methods	NA	
Physical habitat	Annually/Fall	Micro for bug kick, macro both banks assessed	NA	
Field quality assurance samples	20% plus 2 unknowns/yr	80-120% recovery Except pH 96-104%	NA	
Laboratory	20% according to machine protocol	Function(test)	NA	

c. **Where and why?**

River Watch uses the following criteria to select stations and has a detailed SOP around selection, meta-data for each station and managing them:

River Watch's scope is statewide. In our site selection with volunteers we prioritize these basic factors, safety, year round and long term access (public not private land), if a water quantity gauge exists, if there is an existing abandoned station and meaning for CPW, WQCD or the volunteer.

River has two Access applications that help 'assign' a value or weight to each station for planning, documentation and to provide management "justification" for each the resources to monitor each station. These applications provide each station with a set of identifiers:

- CPW priority (a native species site for example)
- In at WQCC CWA basin hearing that year
- On the Impaired Stream list
- Other priorities
- Existing data or not

Based on that weight, a report provides a list of River Watch stations and their score against all possible sites/segments in the WQCC's database. The companion application can run a cursory exceedance analyses and determine if any sites are exceeding aquatic life standards and CPW can take further action to in the CWA process for those locations.

These processes have served for 30 years to fill a data gap and provide relevant data in time and location for the CWA processes

d. **When and why?**
River Watch sampling frequency per parameter is listed in the previous table. For most CWA decisions only data from the previous five years is used, unless none other exists. However, River Watch's data objective is baseline data into geologic time, to produce that war and peace novel, not an abridged version or one page of that novel. The WQCD's sampling plan is based on maximizing limited resources to create the minimal scientific quality data. The result is a rotating basin sample schedule that at best collects samples for 1-2 years bimonthly. Quarterly is next and often is high and low flow only. About 40 sites per year are long term meaning sampled every year. Most WQCD stations are lower down in a watershed and if that site is meeting standards then they claim all segments and tributaries above are as well. River Watch aims to fill in the gaps the above sample design leaves open in space and time. In addition, to retain volunteers, engagement has to be at a critical significance. Sampling less frequent than we do, given our volunteer base, we lose engagement (samples), performance issues arise and we do not meet our goals. Every monitoring program has to figure out the balance for themselves.

e. **(W)how will meet data quality objectives, site access, transportation, safety, sample delivery?**
River Watch as a **Quality Assurance Manual (QAM)** for our research laboratory that provides the procedures and protocols at a high level that all projects in the CPW laboratory must meet. Each individual project has a more specific set of protocols and procedures for sample preparation, collection, handling, analyses, security, data management and validation, safety, training and all measures that provide checks for precision and accuracy in these areas. Project purpose, data uses and objectives drive the quality of data needed. This document is a **Quality Assurance Project Plan (QAPP).** Elements of Study Design and the QAPP are transferred to a Sample Plan just for volunteers. The QAPP tells data users others the data quality being generated by this project. **That provides project credibility, transparency and the data can be used again and again**. These are subdocuments to the

larger River Watch Standard Operating Procedures manual, which contains all parent content and all specific SOPs. Laboratories and other programs consider SOP proprietary. Colorado River Watch Standard Operation Plan first level Table of Contents is in the appendix of this document. Second or third level TOC or entire sections are available upon request.

The WQCC provides the data quality objectives, field and laboratory methods for River Watch. We meet those where we can and where we can't we document why and what is done. In some cases our data quality methods are more stringent than the WQCC's. When River Watch started, we took the WQCD's Quality Assurance Project Plan (QAPP) and made it our own, then gave it back to the WQCD and said, "If data was given to you with these protocols, would you use it?" The rest is history, for 30 years.

River Watch has a robust quality assurance and control plan and philosophy that is embedded in every aspect of the program, including training, outreach and evaluation. For example River Watch:

- Does 20% QA samples for example when industry standard is 10%.
- Validates 100% of data entry whereas industry standards are 10%.
- Uses the same equipment, training and protocols for all volunteers regardless of age, affiliation or background.
- Won't add parameters unless the data can produce a measurable result that can be demonstrated back to the volunteer.
- Makes data management, documentation and evaluation top program priorities.
- Has 25 tracking tools that track individual work flows through out our monitoring program and are each an SOP.

f. **Data Management for Raw Data (Data Management Plan Part 1)***

River Watch generates and enormous amount of data, which would be useless if not managed, just number and not available to anyone. River Watch strives for industry best management practice or **FAIR principles**. FAIR means data is findable, accessible, interoperable and reusable. Can others find it? Once found is it accessible? Can it be used in a variety of platforms, software and the like is interoperability. And is it resale beyond the original data purpose and that makes a data set and asset, living on long after original use. Reusability is tricky though and requires data generators provide meta-data (information about the data such as units, dates, station location, sample preservation, methods, analytical detection limits, etc.), monitoring purpose and objectives, methods (technical design) and quality assurance and control information for others to determine if this data is appropriate for their use. **Data that meets FAIR principles provide data of a known quality, an asset to be used long after the original intent.**

River Watch started in 1989 before the desktop computer and lab results came back on paper, so if we can do it so can you. We didn't jump to where we are now, we had a systematic approach coupled with a commitment to get it right that directed each decision and each system. We went from a Dbase application (new "Excel or Lotus or QPro" was not enough) to a sequel server application to a new sequel application. It meant investment and letting go of control on one level to gain it on an entirely new level.

We have a data management plan with associated SOPs for all database functions, as well as a database application developer document, user manual and all our code is owned and secured in an equity account. All are available upon request.

We got there by following and addressing these areas.

i. **Data Inventory.** Identify all data generating. Include Meta- data and quality assurance data.

Our data management plan has a full inventory of all the data, meta-data and quality assurance data we generate and how it is managed. Including all chemical, biological and physical habitat results, meta and QA data, information on volunteer organization, training, certification, equipment and organization performance.

To develop our management system we mapped all data collecting from birth to death and document work flow of what happens along the way. This is what we documented for a vendor to build the system we have.

1. How is data generated
2. Entered
3. Validated, verify, edit and delete
4. Lab and Field integration
5. Quality assurance integration
6. Data integration from other sources
7. Reporting requirements

River Watch database application manages all our meta-data, results from field and laboratory, equipment and reporting. We use ancillary tools managed what the system can't (no system will ever do it all, quit trying) and other applications to deliver the data other than verified data.

ii. **System Support**

River Watch's SOP covers the following elements that apply to all offices and applications, including who is responsible for various system aspects. The Developer document is for our system vendor. The User Manual is for staff and covers system functions from A-Z and serves as SOP"s for the application itself.

1. Characterize data elements relationships, data schema
2. Hardware, software, data and code ownership
3. Best Management Practices (back up, naming conventions, treatment of null, below method detection, etc.)
4. System roles, responsibilities, evaluation
5. Plan to update and upgrade including functions wish list so when funding is available the scope of work is too.

4. **Information Design: Data to Information through Analyses, Interpretation, Reporting and Communication (Module 4). Per Assessment Type or your own organizing unit.**
   a. **Data Analyses, Interpretation, Conclusions and/or Recommendations**
   b. **Information Products and Data Management**
   c. **Delivery and Communication of Data and Information**

River Watch has two primary Assessment Types, Use Support and Regulatory and Use Support and Advocacy/Planning. Data Users and decision makers for the first purpose are the WQCC, CPW staff and water managers. These data users want raw/verified data to put into their own assessment applications, do their own analyses, interpretation and recommendations that come in the form of a WQCC Hearing, stocking or fishery management decision or planning a restoration or protection project.

As such River Watch has invested our database application the ability to export ready to go formats to import to the National Water Quality Portal, the Colorado Data Sharing Network (same data schema) and specific WQCD data call formats (similar data format). We know what meta-data, fields and information are required but also helpful for other data users to "know" the quality of our data. We purposefully make our data machine readable, available and discoverable on these sites so it will be used over and over- appropriately, as baseline data is meant to useful for a long time.

We have annual processes to evaluate changes in reporting requirements, methods, data base changes to keep up with changes our data users need so we stay relevant. We have mini-user manuals to document the process and provide SOPs for these uploads (AQWMS and EDAS for our macroinvertebrates). These include steps and protocols specific to our data to execute the upload. Any application we build or use we document how to use it, that is a best management practice.

In summary, the information product for this monitoring purpose, data use and specific users is to deliver raw, verified data, no analyses, interpretation or conclusions. Delivery is via the River Watch database application imports to specific data portals that these data users access for their targeted data calls.

For our second Assessment Type, the primary data users are volunteers and citizens. For these users, River Watch does conduct an analyses and interpret the data. The resulting information product are watershed assessments by river segments condensed into a report. We use the exact same assessment template (Excel spreadsheet) that the Water Quality Control Division (WQCD) uses in their CWA use support assessments. These templates have the Colorado CWA standards for all regulated pollutants embedded and divided into their management segments called Water Body IDs (WBID).

The only difference between a River Watch assessment report and a WQCD report is that the River Watch reports use only River Watch data so the volunteer can see directly what their data

story is in this context. Whereas the WQCD assessment will combine all data of sufficient quality for a WBID to analyze. The WQCD does not generate a lengthy report but instead identifies segments that are meeting their uses and reports those on a biannual basis in their required CWA Section 305(b) reports and all segments not meeting any use in their Section 303(d) impaired waterbodies list. Those segments on the impaired list have access to specific funds to help restore their condition to meet the uses, that process involves developing total maximum daily loads for pollutants causing impairment. WQCC has a separate regulation and hearing process for these segments.

River Watch calls their assessment watershed reports. The assessment protocols are in the Colorado CWA regulations. This is a legal or regulatory assessment and we use this to also bring in a biological and scientific assessment as part of our education ROI. For example, the biological definition for acute exposure is a high concentration, which occurs one time and is short in duration that results in death of an organism. However, the regulatory definition of acute exposure is to identify the 85th percentile concentration of pollutant and that percentile cannot exceed an ambient concentration more than three times in one year. Perhaps you can see how a monitoring design would generate sufficient data at the right place and time to capture an acute exposure—or not. To learn more about Colorado CWA please refer to tutorials on the River Watch website.

These watershed reports are simple, basic analyses and visualizations to convey identify exceedances and convey basic concepts and critical thinking skills for our volunteers and specifically students. Often in our high tech world, people equate fancy and complicated with necessary, precise or providing more – and some do, but it is not always necessary or true. Any data analyses, visualization or other tool will only produce as valid of a result as the quality of the data going in.

In summary, the information product for this monitoring purpose, data use and specific users is to deliver a simple analyses of data against CO CWA standards using the WQCD assessment protocol. Delivery is via the an application on the River Watch website that provides the report and data used in the report. Analyses includes chemical, biological and physical habitat data when it exists. Reports are updated on a rotating basis that follows the WQCC's CWA rule making hearings. Basically, the watershed is in each corner of the state has a hearing every five years.

Finally, these watershed reports are also the last data validation step, reviewing data in context with legacy data, looking for outliers, patterns and other stories. These reports are a key part of our volunteer retention, recognition, engagement and message to demonstrate the difference they make.

Evaluation of this River Watch Information Design is doable because a data pathway exists from purpose, use, user's information needs and delivery. We are able to evaluate and report data used, decisions made that align with our desired results, outcomes and impacts. It is a slow, relatively boring process and even results are mundane compared to taking down a dam or

stopping an illegal discharge. That does not take away from the impact. For every river we provide sufficient, data of a known quality, that data has to be used to protect the existing uses as per the CWA. Often no change is a success, meaning that river may not be impaired and is not degrading because we provided data (it is protected). Those stories are often untold and are in addition to all segments we find data that indicates an impairment and puts that segment on a path to restoration. The nature of the CWA focuses the majority of resources on problems to fix and less resources on rivers and lakes that are healthy and need protection so they do not degrade into impairment.

As part the River Watch larger SOP document and subdocument Data Management Plan, the SOPs, roles, responsibilities and documentation of these processes are in our Outreach Chapter and How to produce WS Reports manual, available upon request. These SOP's include tutorials and a data/information management plan for managing and delivering raw data to portals as well as generating and updating watershed reports.

5. **Evaluation Design: Will This Work and How Will We Know? (Module 5) Who Will Do What?**
   a. **Effectiveness Evaluation of Monitoring Program/Effort Design of Evaluation**
      i. **Final Data Pathways and Assessment Types*.**
      ii. **Final Roles and Responsibility Matrix and Scale.**

If a program never answers its monitoring question, never evaluates if the data collected indeed made progress on desired results, outcomes or impacts how does one know it is effective or not just collecting data for the sake of data? Evaluation is what generates success stories and measurable results even IF the data didn't answer the monitoring question or results were not achieved. Progress was made on what is not necessary perhaps or identifies what is not a limiting factor for progress. Monitoring is not always and exact science, but and iterative science. Evaluation is the number one missing element in most programs and provides credibility, transparency and success stories needed for funders, relevancy and progress.

River Watch covers this programmatically in great detail in the larger SOP, master document. Here is a summary of River Watch evaluation processes (not associated with evaluating results, those are specific SOPs in the data birth to death workflows). In essence River Watch as an evaluation process for each part of their slogan "Real people doing real science for a real reason"

- Program dashboard is reviewed quarterly that has program metrics and benchmarks used for contract but also tracking
- Bimonthly a leadership team (from CPW and vendor) meet to check in on all elements of program from leadership view, including communication
- Monthly the River Watch Team report status, review problems and upcoming preparation needed, a master standard activity matrix is used as agenda
- Each spring we take the program apart and review these items:
  - Changes, opportunities and threats in Educational field (since 85% of volunteers are teachers and school groups)
  - Changes, opportunities and threats in CWA Regulatory field

- o Changes, opportunities and threats in CPW operations, funding, mission
- o Changes, opportunities and threats for vendor (shipping, etc.)
- o Volunteer feedback (site visits, survey, training needs, etc.)
- o Tracking tools and workflow benchmarks (changes needed)
- o Equipment needs
- o Staff workload, work flow, benchmarks, communication
- Annually
  - o Vendor report on contract outputs, challenges, recommendations
  - o Program Performance Report is generated and posted (has performance report on River Watch QUAPP actions, includes program outputs and outcomes)
  - o Each Volunteer Annual performance report, including performance on quality assurance samples
  - o Data FAQ, RW Study Design and other public documents updated
  - o Documentation updated (all relevant SOPs, subdocuments, tracking tools turned over for next year, Sample Plan, website content, etc.)

b. Answering Monitoring Questions

River Watch answers our monitoring questions every year in the CWA hearing when segments are assessed for aquatic life uses. If they are not, they are put on the impaired list or another restoration strategy. In some cases more data us required and we place those sites high in our priorities.

c. Final Documentation

Documentation of a Study Design is underrated and assists in transitions, credibility, transparency, reproducibility, cost efficiencies and tells others what you are doing and not doing, i.e. your niche.

River Watch has a master document spreadsheet that illustrates all program documentation, sub documentation, purpose, outlines and responsibility. The Program Manager uses this to track documentation. All SOP's have the same format and location of documents are identified, as well as who drafted and who updated document.

River Watch invests and believes in documentation and as such credibility is not an issue. Below is a list of River Watch documentation. Many of these, if not most, do not change much once created.

i. River Watch Standard Operating Procedures

Mother content for all other documents. Internal use but available upon request. Each chapter covers an area of the program and has associated SOPs, sub documentation, forms, datasheets and the like, all stored in a known location (hard or electronically).

ii. Master SOP Sub documents
1. River Watch Study Design (this document)
2. Quality Assurance Manual
3. Quality Assurance Project Plan

iii. Additional Manuals
1. ICP User Application Manual

2. Database Developer Manual
3. Database Application User Guide
4. AWQMS and EDAS upload Manuals (annual export to data hubs and answer WQCC data calls)
5. GAP and WQSTDS applications manuals

iv. **Reports (available on website, sent out, integrated into volunteer correspondence, social media, etc.).**
1. Volunteer Performance Report, including Unknown Results
2. Annual Program Performance Report
3. Watershed Reports for CWA segments
4. Data FAQ

v. **Additional Documentation**
1. Each River Watch SOP is its own document, but stored with its respective chapter
2. Tracking Tools
3. Datasheets, forms, contracts, decision tools
4. Spreadsheets, calendars, matrixes, check lists, resources, photos, and support material

d. **Identification of Niche**

River Watch has claimed out a territory and performed well in protecting that role. Even in areas where others are sampling they are not serving the stewardship educational role. Where groups are doing education, they are not generating or using the avenue of generating real science in the same field and scope as River Watch.

We sample in locations, frequencies and for baseline indicators that would not exist otherwise and no other entities produce. Other entities, WQCD, USGS, EPA, local efforts may sample for the same indicator but locations, frequencies or duration are fewer or shorter term then River Watch's study design. We fill an identified data gap.

Entities have compared our data to USGS, EPA, state and other data and the results are positive. In many cases the results have been the same and collection was in collaboration. In other cases River Watch data was not used, not because the data was bad, but because the data purpose and use did not match. That is comparing apples to oranges and claiming the apple is bad because it is not an orange. Sometimes the difference is in the field other times in the lab.

In other cases River Watch data was found to be in error or the USGS was in error, as an example. This has been very rare. That data was removed from all databases. This is a good thing, which means we have systems in place that find errors because they will and do exist. We explain this in more detail in our data FAQ, when you combine data from different sources, best management practices need to be in place to vet the actual DATA not the data generator.

Part of River Watch's niche and success is the volume of data citizen scientist can generate over space and time, would not others wise exist. And when you have that volume it is more challenging to throw it out versus a smaller data set. Citizen scientist

are democratizing who gets to generate and own data and that is a good thing for the future of our rivers.

If River Watch did not exist, there is no other agency, entity or organization that could fill the equivalent monitoring frequency, spatial coverage or parameter coverage. It is too expensive. River Watch leverages volunteers in the community with laboratory capacity, agency mission and partnerships to execute the program.

Rivers of Colorado Water Watch Network

Standard Operations Plan

April 2021

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5.5 Metals

5.6 Nutrients

5.7 Macroinvertebrates

5.8 Physical Habitat

5.9 Summary What RW Program Manager Needs to Know

6.0 Data Quality Objectives <mark>Follow a piece of data from collection to reporting/use</mark>- most of this content will go into QAM or QAPP Or be referred to there)

6.1 Data Quality Objectives (Matrix)

6.2 Project Management

6.3 Data Generation and Acquisition (see relevant sections above)

6.4 Reporting, Assessment and Oversight

6.5 Data Review and Usability

6.6 Summary What RW Program Manager Needs to Know

7.0 Database Management Standard Operating Procedures

7.1 RW Database Management Plan

7.2 RW Data Inventory Mapping

7.3 Application Management Functions

7.4 RW Data Pathways

7.5 RW Data Exports and Delivery

7.6 RW Database System Elements

7.7 What the RW Program Manager Needs to Know

7.8 Summary What RW Program Manager Needs to Know

8.0 Data Analyses and Reporting Standard Operating Procedures

8.1 RW Study Design – How Answer Monitoring Questions

8.2 Information Products

8.3 Summary What RW Program Manager Needs to Know

9.0 Webpage

9.1 CPW and RW Websites

9.2 CPW Site Map

9.3 RW Site Map

9.4 Watershed Report Application

9.5 Summary What RW Program Manager Needs to Know

10.0 Outreach, Products (Information Products) and Services

10.1 Volunteers (contract, calendar of correspondence, training, feedback, troubleshoot, hardship, SV, station photo, group profile)

10.2 CPW

10.3 Data Users

10.4 Products & Services (for Organization, Volunteers, Data Users)

10.5 Summary What RW Program Manager Needs To Know

11.0   Program & Monitoring Evaluation (not results evaluation)

  11.1 Surveys & Evaluations (training, SV, CDPHE Assessments, NWP updates, etc.)

  11.2 Inventory and Equipment Needs

  11.3 Data Quality Objectives – Methods, Work flows

  11.4 Station Status

  11.5 Operation & Capacity Adjustments

  11.6 Annual Program Performance Report

  11.7 Summary What RW Program Manager Needs To Know

Supporting Key Subdocuments

  A list for each Chapter

Appendices – SOP's for Each Chapter