Data-Driven Decision Platform for Sacramento River Real-Time Water and Fishery Coordination

Final Report

May 31, 2018

Executive Summary

Protecting and restoring the endangered Winter Run Chinook Salmon in the Sacramento River is a challenging endeavour. Winter Run populations remain severely compromised despite concerted efforts over many years to improve conditions for the species. The U.S. Bureau of Reclamation's (Reclamation) operation of Shasta dam to maintain flow and temperature conditions in the Sacramento River is and will continue to be a primary focus of Winter Run management. The primary goal of this project was to test the hypothesis that more open data paired with more advanced analysis and visualization tools could improve decision-making regarding Shasta Dam operations for Winter Run. Fully achieving this goal required that the following objectives be met:

1) Active participation by key stakeholders in the decision-making process around Shasta operations for Winter Run management.
2) Acquisition of key data from stakeholders and affiliated data managers.
3) Development of a user-designed, open source platform capable of analyzing and visualizing key data to support the decision-making process.
4) Adoption of the platform by Reclamation and use as the primary tool for decision-making.
5) Comparison of the effectiveness of decisions supported by the platform relative to previous decisions made without the platform.

The entire scope included in the work plan proposed for this project was completed. More specifically, objectives one through three were fully achieved during the project. However, Reclamation has not yet fully adopted the platform developed during this project for decision-making, which prevented objectives four and five from being fully achieved. This project began to test its central hypothesis by demonstrating that the transparency, accessibility, interactivity, and timeliness of information important to decision-making can be improved with more open data and improved analysis and visualization tools. However, without full adoption and use by Reclamation, the extent to which the efficacy of decisions can improve with respect to outcomes for water management and Winter Run recovery remains unclear.

While the hypothesis could not be fully tested during the first phase of this project, the objectives achieved, lessons learned, and unexpected benefits realized to date are notable. First, this project established a new forum with full stakeholder participation where the benefits of more open data to decision making for Shasta operations and Winter Run management were discussed and significantly advanced. Next this project unlocked access to previously unavailable data and established connections between several emerging open data tools. Most visibly, this project produced a user-designed web application called SHOWR (Shasta Operations for Winter Run - https://flowwest.shinyapps.io/showr/), a fully functional, open source web application that expands access to and transparency around the key data used to support decision-making for Shasta operations and Winter Run management. It is yet to be determined whether Reclamation will ultimately use this application to support their decision-making. But it is anticipated that the next dry year (both of the Water Years during this project were relatively wet which made most of the Shasta operations decision-making relatively simple) will greatly increase the value of SHOWR to Reclamation and potentially motivate their adoption of the tool.

This project also resulted in several key lessons learned. There is now improved understanding among stakeholders and data managers about the technical steps and specifications that must be followed to facilitate effective data acquisition and use in an open source, open data platform. In addition, the iterative web application design process used in this project provided a very useful template to guide design of open source data-driven decision support tools for water resources and aquatic ecosystem management. This new template illustrates a balance between efficiency, user-experience, aesthetics, and context likely to be required in any open water data decision support tool. Finally, an improved understanding of the time, technical, and

communication requirements essential to user adoption of open data tools emerged through this project.

This project also yielded some unexpected benefits. Perhaps the most important benefit was the development of new open source software required for the back end technology infrastructure supporting SHOWR. The new CDECRetrieve open source software application was posted to the open source code repository GitHub and by the end of the project had been downloaded and installed over 1,000 times. This has already resulted in other water managers, including staff at the California Department of Water Resources, developing their own open data-driven decision support tools and thereby expanding the open data "ecosystem" needed in California water management.

Several next steps will build on the momentum and successes of this project to further adoption of more open data and improved analysis and visualization tools for water management. First, the Sacramento River Settlement Contractors will continue to maintain and expand functionality of SHOWR while using it to inform their participation in Shasta operations decision making over the next year. Next, the Reclamation Information Sharing Environment program has expressed interest and potential ability to take on SHOWR hosting beyond the next year and already has the technical infrastructure in place to do so. Finally, SHOWR is a "use case" being evaluated by the implementers of the Open and Transparent Water Data Act (AB-1755) and will be used as a test bed to help guide AB-1755 implementation.

Project Summary & Status

The grantee for the *Sacramento River Real-Time Water and Fishery Coordination* project is the Sacramento River Settlement Contractors (SRSC), being coordinated by the Glenn Colusa Irrigation District (GCID). The primary project objective is to integrate diverse streamflow, water operations, fishery, and water quality data into a single, open data application that facilitates data-driven and timely decision making related to temperature management on the Sacramento River, primarily for Winter Run Chinook Salmon. The beta version of the platform reported on in the June 2017 Interim Report (known at the time as the Minimum Viable Product, or MVP) has been replaced by a redesigned web application called SHOWR (Shasta Operations for Winter Run). This section provides a detailed description of the development of SHOWR, including the organization of key data used in SHOWR. The current version of the web application can be accessed online at https://flowwest.shinyapps.io/showr/.

SHOWR Development

Figure 1 illustrates the major steps in the creation of the SHOWR web application. SHOWR is designed to provide open data access, visualization, and analysis capabilities for decision-making around implementation of the Reasonable and Prudent Alternatives (RPA) from the Biological Opinion for the Long-Term Operations of the Central Valley Project. Development began in January 2017 during a meeting of the Technical Committee (see Agency Participation section) formed to advise on data, functionality, visualizations, and other aspects of the platform. The first iteration of SHOWR was called a Minimum Viable Product (MVP), which for consistency in documentation is now referred to as SHOWR version 0.1. An MVP is a new data product developed with sufficient features to satisfy early adopters.

The primary intent in creating an MVP was to get a product in front of users as soon as possible. It was expected that this would allow more focused conversations more quickly around a prototype product as opposed to theoretical constructs. The MVP was developed as a web application using the R and RShiny web development framework. This “front end” architecture allowed development of an application with high portability, maintainability, and extensibility. The MVP used Amazon Web Services (AWS) for its “back end” architecture because of its broad accessibility, on-demand use capabilities, and affordable pricing. The Technical Committee reviewed and approved both the front-end and back-end architectures. Over the first few months of the project, a small subset of reservoir operation, temperature, flow, and fisheries data was added to the MVP and used to guide iterative refinement the MVP through discussions with the Technical Committee around data, functionality, and decision-making needs. The MVP phase of development was completed in the Spring of 2017.

A large workshop attended by the SHOWR development team, Technical Committee members, public agencies, private water districts, non profit organizations, and philanthropic organizations kicked off the second phase of SHOWR development in the Summer of 2017. The goal in this phase was to migrate SHOWR to version 0.5, which was referred to as the Beta Version of SHOWR. The primary objectives in this development phase were to integrate new data, streamline the back end infrastructure, and optimize the user experience through design improvements and increased application speed. To this end, much of the development effort in this phase switched from front end to back end. More specifically, the development work for SHOWR 0.5 focused on creating a set of logic that would make serving data from raw sources to the web application as streamlined as possible.

To achieve this, a database was designed with features selected to solve the unique challenges associated with integrating highly variable data from disparate sources. The SHOWR back end uses a PostgreSQL database, Python scripting (including database specific Python libraries), and several services from AWS including S3, RDBS, and EC2. The full source code for the backend components of SHOWR is available at https://github.com/FlowWest/shodb. SHOWR 0.5 development concluded at the end of 2017.

The final phase of SHOWR (SHOWR 1.0) development began in January 2018. In this phase, the focus of development shifted back to front end, user facing issues in the web application. Development work on SHOWR 1.0 included aesthetic design improvements, metric refinements and additions, visualization improvements, and addition of substantial new contextual information intended to guide new and infrequent users in more effective use of SHOWR. A “feature freeze” was also implemented in this phase of development, during which no additional features were created from scratch, rather existing features were refined and improved. The full source code for the SHOWR 1.0 shiny web application is available at https://github.com/FlowWest/showr-application.

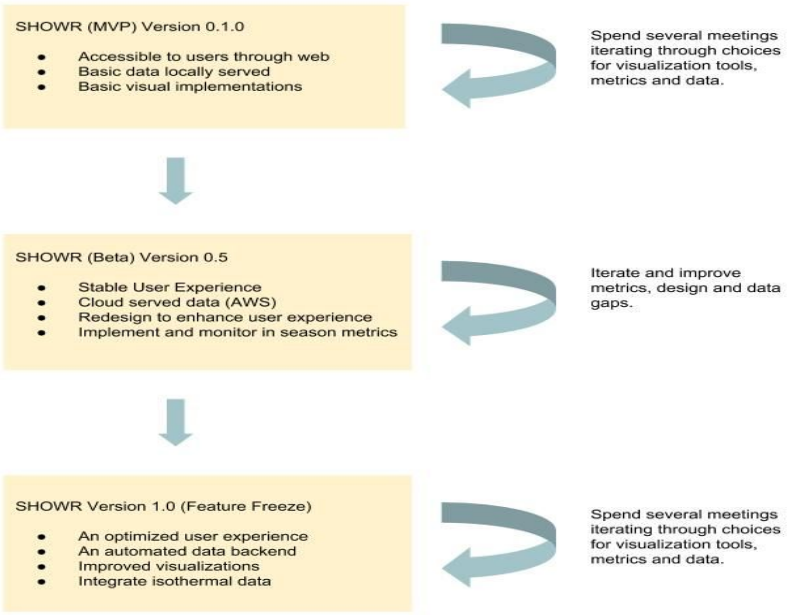


Figure 1: Flow chart illustrating the development process for SHOWR with milestones for each significant iteration in the development of the application.

SHOWR Organization

Home

One of the most significant additions to SHOWR, the Home Page (Figure 2), occurred during the SHOWR 1.0 phase of development. The Home Page improves the overall aesthetic of SHOWR and provides high level summary information about Shasta operations for Winter Run Chinook Salmon management in the current and previous years. This page is intended to draw users into the application with an immersive front page, and to give new and returning users historical context about Winter Run Chinook Salmon and Shasta Reservoir operations. The Home Page gives new users quick access to key information driving Shasta operations decisions for Winter Run Chinook Salmon with web links to foundational documents and related resources. Returning users can review the Shasta Operations Overview metrics on this page to get a quick understanding of how current conditions compare to previous water years, and from this inform their exploration of the data presented in the other parts of SHOWR.

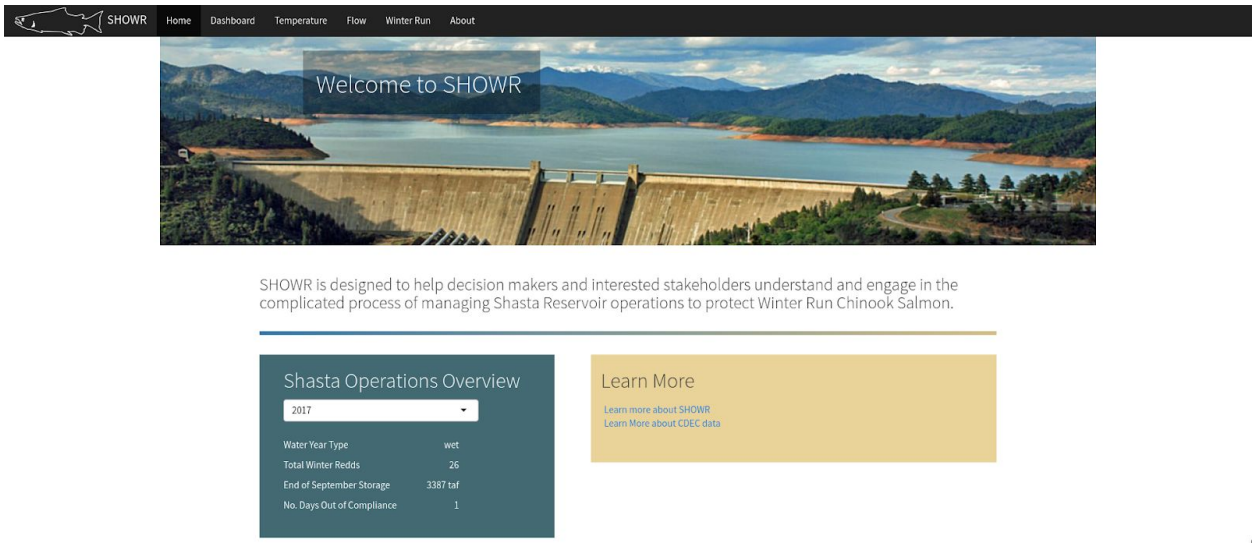


Figure 2: SHOWR 1.0 Home Page.

Dashboard

The SHOWR dashboard (Figure 3) summarizes reservoir operation, water temperature, streamflow, and Winter Run Chinook Salmon fishery data. The presentation of the data on the dashboard was designed collaboratively and iteratively with the Technical Committee to provide “at a glance” understanding of the primary controlling factor on Shasta Reservoir operations in real time and for historical conditions. It is expected that

most users of SHOWR will interact with the web application almost exclusively through the dashboard. The dashboard summarizes all of the key information required by most users to gain a basic understanding of current operations and Winter Run Chinook Salmon conditions. The subpages (described in the following sections) were designed to support more detailed exploration that only highly engaged stakeholders are expected to conduct.

When a user first navigates to the dashboard, the *Date Selector* is set to the current day so that the Dashboard defaults to current conditions. A user is free to select any date as far back as 2010, and upon doing so the Dashboard (as well as the rest of the web application) will update all data to the selected time period. The Dashboard presents data from CDEC (storage, flows, and Sacramento River temperatures), CDFW (aerial redd surveys) and Reclamation (Shasta cold water storage). The *Shasta Operations*, *River Temperature*, *Flow*, and *Chinook Activity* panels on the left side of the application summarize conditions associated with each of the potential controlling factors on Shasta operations related to Winter Run Chinook Salmon. The *Storage* and *Chinook* plots on the right side of the application present interactive visualizations of Shasta storage, flood conservation curve, and cold water, or total redd counts by monitoring reach in the Sacramento River, depending on the time of year selected. The purpose of the minimalist design of the Dashboard is to present the key data quickly without subjecting the user to extraneous information not essential to understanding current or past operations for Winter Run Chinook Salmon management.

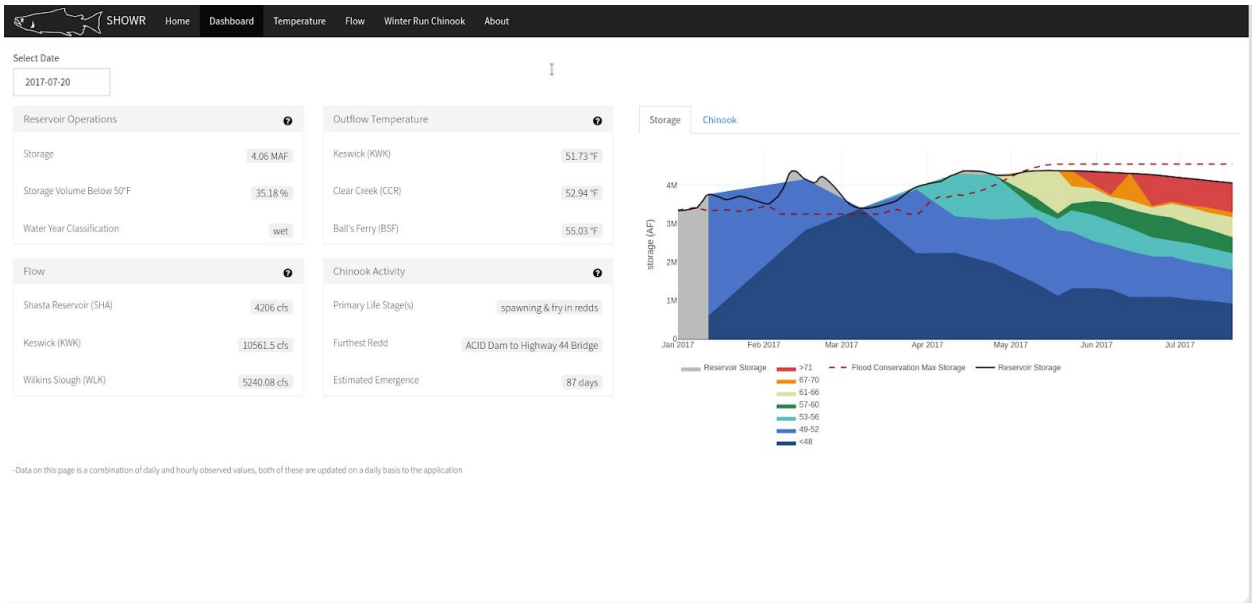


Figure 3: SHOWR 1.0 Dashboard.

Temperature Page

The Temperature page (Figure 4) in SHOWR facilitates exploration of the most important data used to monitor compliance with the Winter Run RPA - Sacramento River water temperature data. The left panel provides contextual information on the role of temperature in Shasta operations for Winter Run Chinook Salmon. The right panel includes real time temperature data for the Keswick, Sacramento, Clear Creek, and Balls Ferry gages from CDEC and the RPA temperature targets. Temperature is presented to users as a set of time series in a plot, and users can add or remove temperature monitoring locations from the plot to customize their data exploration. The Temperature page also includes a number of statistical metrics for Sacramento River water temperatures (e.g. mean, 7 day average daily maximum, and daily maximum) that are used in flow management decision making. The Temperature page also provides tools for data download so that users can extend their data exploration beyond the functionality provided in SHOWR. The next iteration of SHOWR will allow users to programmatically download data by supplying an accompanying url to the data. This will allow stakeholders and users to easily build their own custom data exploration tools that will be consistent with the source data in SHOWR.

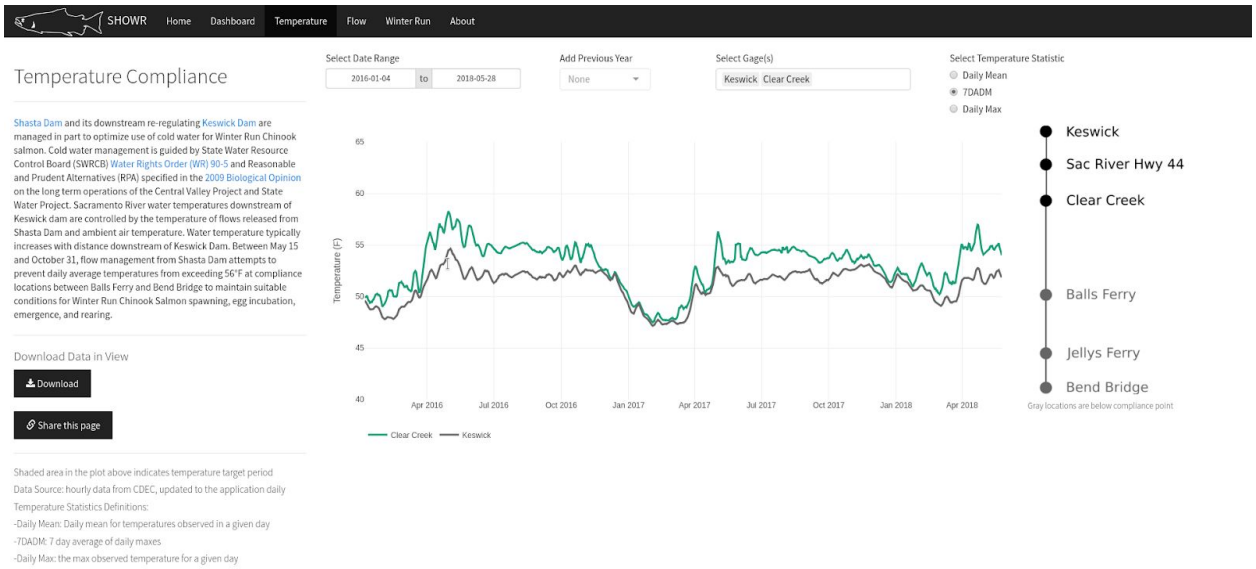


Figure 4: Temperature page in SHOWR 1.0.

Flow Page

The Flow page (Figure 5) provides a data exploration environment for users to better understand how flow conditions are related to temperature compliance and operations at Shasta. The left panel again provides contextual information on flow as it relates to

Winter Run Chinook Salmon management and Shasta operations. Flow data presented in the right panel overlaps somewhat with reservoir operations data and includes Shasta inflow and outflow, Keswick outflow, and Wilkins Slough and Sacramento River at Bend Bridge flow (all from CDEC). This page also provides “sparklines” for the three major tributaries to Shasta Reservoir (Upper Sacramento River, McCloud River, and Pit River) to show inflow trends and relative volume contributions from the three watersheds. Flow data from any other CDEC or U.S. Geological Survey (USGS) gage site can be added to SHOWR with minimal effort at any time because of the back end architecture (see SHOWR: An Ecosystem of Open Water Data section below) supporting the application.

The Flow page has also been integrated with the SRSC’s web portal so that users can incorporate total diversions upstream of Wilkins Slough into their data exploration. SHOWR provides access to historical diversions going back to 2010 as well as near-real time diversions made available as water districts enter their diversions into the SRSC portal. Finally, the Flow page allows users to view Shasta gate change data on the flow time series. Reclamation currently circulates gate change information via email and has expressed interest in possibly automating this notification process through SHOWR. Similar to the Temperature page, the Flow page allows users to choose what data to download, and the next version of SHOWR will add a static url for for flow data to allow for programmatic data downloads.

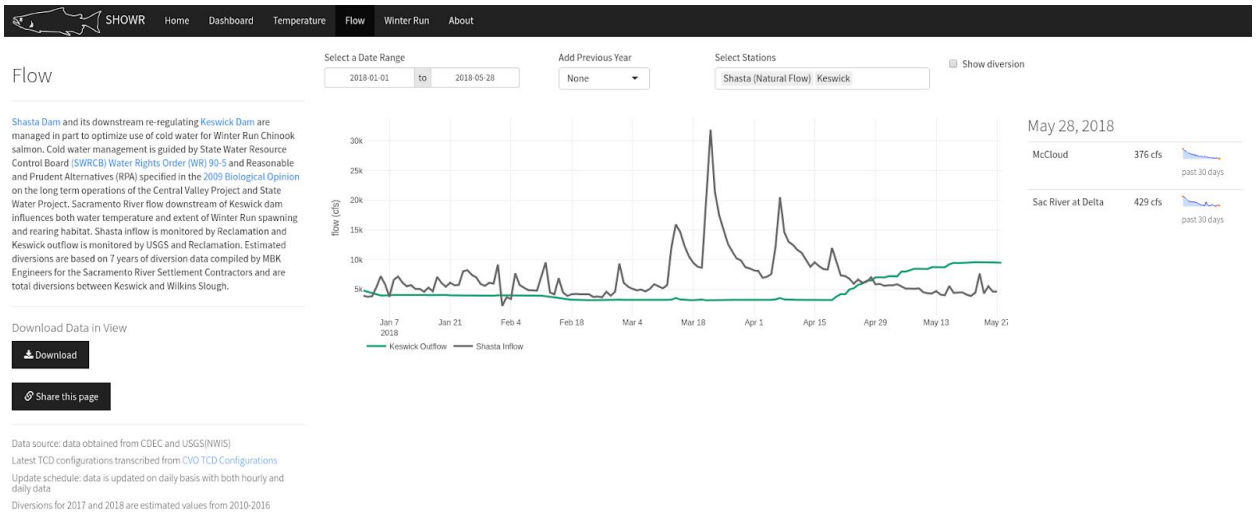


Figure 5: Flow page in SHOWR 1.0.

Winter Run Page

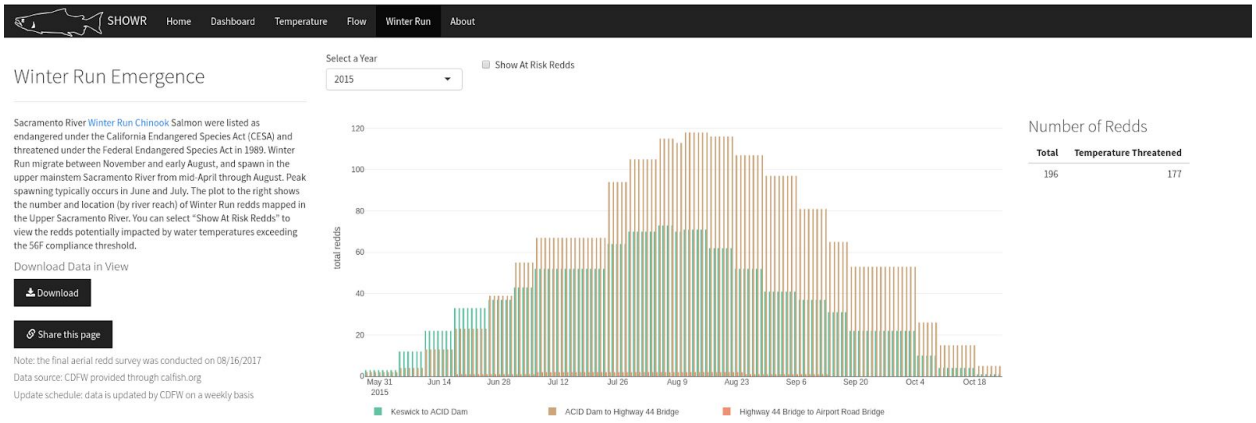
The Winter Run page (Figure 6) provides detail on the Winter Run Chinook salmon aerial redd survey data from CDFW. Here again, the left panel provides contextual

information on Winter Run status and protections under the RPAs. While the SHOWR Dashboard focuses on the most concerning redd by providing its location and the predicted duration of the period prior to emergence (during which maintaining suitable temperatures is critical), the Winter Run page allows users to explore redds system-wide and through years dating back to 2010.

The plot shows all “active” redds at a given point in time. Active redds are determined using accumulated temperature units (ATU’s), which accumulate daily temperatures using the mean as a running sum. As long as the calculated ATU for a redd is below a threshold, the redd is considered active. This page also allows users to view only redds at risk from temperatures exceeding the the RPA thresholds. As on the Flow and Temperature pages, users can download data from this page, and the next iteration of SHOWR will add a static url for users to pull this data programmatically from SHOWR.

Figure 6: Winter Run page in SHOWR 1.0.

SHOWR: An Ecosystem of Open Water Data



SHOWR is a user-designed interface where stakeholders in Shasta operations for Winter Run can quickly connect to, explore, and visualize the key data that drives decision making. SHOWR is the most visibly obvious product of this effort. But in the process of creating SHOWR, something even more valuable that is not visibly obvious was created - ***an ecosystem of open water data***. This ecosystem of open water data standardizes the way data passes from raw sources to users, allowing users to easily build custom applications like SHOWR that yield insights into decision-making or other data-driven processes. In this section, the key technological components of the ecosystem of open water data supporting SHOWR are discussed along with

observations on how these components could be extended or translated to other water management decision making processes.

Back End Architecture

Typically, the back end of a web application or service is the set of logic, implemented through a programming language, that allows data to be processed to and from the user. In SHOWR, users are not required to log in or provide data in order for the application to function. Therefore, the SHOWR back end only needs to provide data to users. The SHOWR backend was carefully designed to handle data sources that entirely lack or have poorly implemented web services. One example of this is CDEC. Most of the flow and temperature data available in SHOWR is from CDEC. However, using CDEC as a direct source to the application would result in excessive downtime and instability, and would severely degrade the SHOWR user experience.

The backend solution implemented for SHOWR is a database and supporting logic that sits in between SHOWR and the original data sources. The design of this backend is straightforward (Figure 7), and includes a set of scripts that process data between source databases and AWS S3, and a second set of scripts that process data between S3 and PostgreSQL. These scripts process, conduct basic QA/QC, and perform a variety of other “wrangling” tasks on the data. Each of these tasks are run frequently (from every minute to every day, depending on the type of data being processed).

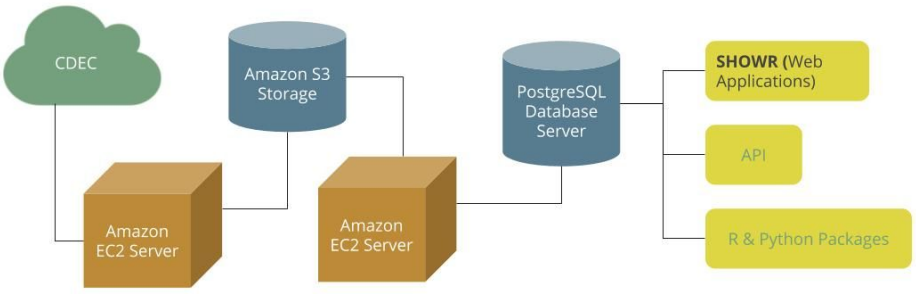


Figure 7: A pipeline for each of the data sources used by SHOWR exists, each is a little different but the overall design is the same. These pipelines were implemented in both R and Python, using the strength of each to add stability to the end product.

Another key reason that the SHOWR back end uses a database is that it is able to impose strict data constraints that allow for data integration and portability to other applications. This allows new applications to be developed on the SHOWR backend very efficiently because the data always has the same specific format. Relationships between data in the SHOWR back end are also more easily expressed in a database.

The structure of the data in the database captures many attributes including collection methods, units, and geographic location. The design of the database exposes these relationships using a set of database specific features that allow applications to explore relationships within and between datasets. Full source code for the database (called SHODB) can be found at https://github.com/FlowWest/shodb.

Open Source Software Developed for SHOWR

The SHOWR back end includes new software required to process data used in the web application. As with the other components of SHOWR, and consistent with the overarching intent of this open data demonstration project, the software developed to support SHOWR is open source. The most important piece of software in the SHOWR back end facilitates and streamlines interactions between CDEC and the R programming language. This software, called CDECRetrieve, is used throughout SHOWR and allows the development team to quickly add new stations to hourly or daily queries and to fix bugs and implement new features in a timely manner. CDECRetrieve was developed by FlowWest to allow any user of R to interact with and download data from CDEC in a consistent and reliable way. CDECRetrieve can be viewed and downloaded at https://github.com/FlowWest/CDECRetrieve.

As of the drafting of this report, CDECRetrieve had been downloaded over 1000 times, an extremely high number for such a specialized piece of software. With regular maintenance and feature updates, this number is expected to grow as it becomes adopted by the large population of CDEC users. Such high usage of a key SHOWR component demonstrates the potential of projects like this to advance the adoption of open data principles in the water resources management sector and provides a highly valuable new resource that the open water data community can use and customize to build more open source water resources management applications.

Lessons Learned

Many lessons were learned over the course of this project. Highlighted below are three of the most important lessons for future efforts aimed at improving decision-making through the implementation of more open data with improved visualization and analysis tools.

Data Acquisition

One of the most challenging technical problems the SHOWR development team had to address was how to consolidate a diverse set of data and make it work together. This challenge is not unique to SHOWR, but the solution implemented in SHOWR had to

contend with unreliable web databases and human-managed data sources. The SHOWR solution includes a set of small data pipelines for each of the data sources. Each of these pipelines shared the same general architecture, but some, like the CDEC pipeline, required development of new software. All of the pipelines led to a database where data integration and integrity could be managed efficiently.

This project demonstrated that a combination of data pipelines and new open source software could make data acquisition and use effective and efficient in a web application like SHOWR. However, this project encountered a related problem of not being able to acquire some of the data relevant to the decision making process from the data managers. The benefits of including all relevant data in SHOWR for all stakeholders in the decision making process were continually communicated to managers of the data sources. In some cases, this ended up working once the data manager understood how the benefits of providing the data outweighed the risks. In other cases, data managers remained concerned about problems that could occur with openly shared data and continued to resist sharing. These interactions demonstrated that achieving fully open water data can take a long time and requires significant trust building to overcome fears about shared data being used inappropriately.

Web Application Design

Another extremely challenging technical problem in the development of SHOWR was the creation of a functional and user friendly front end. A well-designed front end is essential to fully leverage the benefits of a reliable data source like the one provided by the SHOWR back end. Well-designed front ends allow users to explore and analyze data from disparate sources to inform understanding of current and past conditions and drive better decision making. The front end design problem for SHOWR was extremely challenging, and every bit as important as the data acquisition problem. The primary objective of addressing this problem was to take the diverse datasets essential to Shasta operations for Winter Run Chinook Salmon management and present them in a way that minimizes the barriers between users and key information that can be extracted from the data.

This was done by designing a web application that focuses on the workflows of SHOWR users. This design approach made use of an existing front end web development framework, called Bootstrap, to create a well balanced interface ideal for both computer and mobile screens. Several iterations of the web application were developed by engaging with stakeholders for feedback on usability, appearance, functionality, data, metrics, and visualizations. Ultimately, SHOWR settled on a minimalist design with engaging elements that bring open data to users of any internet connected device.

User Adoption of Web Application

A less technical but still challenging problem was maximizing adoption of the SHOWR web application by decision makers and stakeholders in the Shasta operations for Winter Run Chinook Salmon management decision-making process. Reclamation, the primary decision maker, already had data management and dissemination approaches (primarily an in-house database with custom analytics and emailed PDFs) they had been using for many years to support and communicate their decision making. Stakeholder organizations had grown accustomed to receiving and interpreting data as provided by Reclamation. Therefore, to convert a stakeholder into a regular SHOWR user, the user experience of SHOWR had to be an improvement over the Reclamation data products and had to include all relevant data and information available through other, less open, channels.

The approach taken in SHOWR is to emulate elements of existing reports and related materials disseminated to stakeholders in the Shasta operations decision-making process. This allowed users to see the benefits of an interactive environment compared to the static reports they had grown accustomed to interpreting. To address user adoption issues related to trust, SHOWR was open sourced, and all aspects of the web application (e.g. original data sources, metric calculations, etc.) were documented thoroughly (see http://showr-user-guide.s3-website-us-west-2.amazonaws.com/). Ultimately, Reclamation determined that they would not be able to adopt SHOWR as their primary platform for dissemination of decision-making data. However, many of the stakeholders (e.g. SRSC, CDFW, SWRCB, NMFS, and NGOs) appear to have adopted SHOWR as part of their approach to keeping abreast of Shasta operations decision making data. These users have provided very useful feedback through two surveys conducted during this project to inform refinement of SHOWR and are expected to continue using SHOWR.

While Reclamation's decision not to adopt SHOWR was somewhat disappointing, this project has shown that open data architecture and user-friendly front end design can improve user adoption of open data tools in water resources management processes. It is also likely that as SHOWR is maintained through the next Winter Run monitoring cycle it's value to groups like the Sacramento River Temperature Task Group (SRTTG) will increase (especially in a drier year where decision-making is more constrained and contentious) and adoption will subsequently increase among decision-making stakeholders.

SacPAS Integration

SacPAS and SHOWR were developed in parallel, using much of the same data, but aimed at different users. SacPAS exposes a very high level of detail for users interested in interacting with and manipulating data and relationships that inform the decision-making process. This level of functionality is certainly powerful, but to users looking for a higher level understanding of key data and information in the decision-making process, it can be quite daunting. The SHOWR and SacPAS development teams met several times over the course of this project to outline an integration plan. Integration was intended to bring the power of modeling from SacPAS into the more user-friendly SHOWR web application where the data would be presented with priority given to the more general user experience. The integration outlined required a significant technological effort at the outset to implement an automated system that would allow for the SHOWR development team work with SacPAS data. This would be followed by implementation of SacPAS emergence model results visualization in SHOWR and design of a user interface to the SacPAS emergence model. SacPAS integration is an ongoing effort that will continue after publication of this report. Integrations steps completed to date and planned for the next iteration of SHOWR are described below.

Completed Integration Tasks

The initial integration task was to connect and automate the process of sending data from SacPAS to SHOWR. The approach to this included setting up a server in the SacPAS system that would allow SHOWR to scrape results from SacPAS model runs every day. The heavy lifting in this task was done by the SacPAS server, and only a small amount of data from SacPAS was passed to SHOWR. The scheduling was coordinated with SacPAS so that all of the logic could be run by a cronjob (i.e. a program scheduler in the Unix operating system).

The second integration task was to implement a prototype user interface. R Shiny was used for this task and allowed the team to build a prototype quickly. The initial prototypes explored interfaces to parameters and experimented with varying levels of SacPAS complexity to expose to SHOWR users. Being able to protype and deploy these applications within hours allowed the next integration step of porting essential data from SacPAS to SHOWR.

Integration Next Steps

The completed integration tasks described above were carried out during the off season months when no data on Winter Run Chinook Salmon was collected. Therefore, the next integration steps had to wait until new Winter Run Chinook Salmon redds were observed, which started around the time this report was finalized in May 2018. Over the remainder of this monitoring season and in the next monitoring season, a number of SacPAS datasets, including model outputs and inputs, will be brought into SHOWR. Integrating this SacPAS model data with the SHOWR open data ecosystem will allow it to be viewed and used seamlessly with the rest of the SHOWR data. This will showcase the synergies and additional value realized by integrating the detail-oriented SacPAS with the more general use open data-driven SHOWR web application.

Agency Participation

The SRSC coordinate closely with Reclamation on the operation and release patterns from Shasta Dam to meet temperature targets in the Sacramento River for salmon (primarily winter-run), diversion needs of the SRSC group, and flows into the Delta to meet the goal of operating the system efficiently. The SRSC also coordinate with several other state and federal agencies on river operations, habitat needs, data management, education, and accountability. The success of this project has been contingent on active cooperation and participation of key state and federal agencies that acquire and manage data related to Sacramento River operations. In addition to Reclamation, these agencies have included the California Department of Fish and Wildlife, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, the California Department of Water Resources, and the State Water Resources Control Board.

Since the project kickoff meeting on October 28, 2016, monthly Technical Committee meetings have been held with the state and federal agencies, facilitated and documented by Kearns and West. Throughout the project, the agencies provided access to the necessary data and significantly contributed to the development of SHOWR by providing input during and in between the monthly Technical Committee meetings. Importantly, access to all the data sets initially identified as being essential to Shasta Reservoir operations decision-making for Winter Run Chinook Salmon management has been granted to the SHOWR development team.

A day long workshop was held on August 29, 2017 to present the latest version of SHOWR and to solicit additional input from agencies and stakeholders. The workshop was well-attended by water district staff, NGOs, and other stakeholders impacted by Shasta operations, in addition to the Technical Committee, project team, and participants in another water data demonstration project, the Groundwater Recharge and Assessment Tool (GRAT). A wealth of valuable feedback was collected during and after this workshop. The most impactful feedback was on the need for more contextual information in SHOWR, which has been added to the current version of the web application.

Next Steps

While this report concludes the Data-Driven Decision Platform for Sacramento River Real-Time Water and Fishery Coordination open data demonstration project, the SHOWR application will continue to be maintained and improved. This section briefly describes expected next steps related to SHOWR associated with three different entities.

SRSC

The SRSC will maintain SHOWR between June 1, 2018 and May 31, 2019. In addition to basic maintenance, SHOWR will continue to be improved with remaining project budgets. Expected improvements include additional design enhancements, completion of new Home page metrics, completion of SacPAS integration, completion of Shasta gate change functionality, and final revisions to context statements on all pages. New functionality related to the Fall Run Chinook Salmon transition period in the fall will also be explored during this period.

RISE

The SHOWR development team had detailed conversations with the Reclamation Information Sharing Environment (RISE) team on March 13, 2018. The vision of the RISE program is to share Reclamation's data in consistent, open, and machine readable formats via a centralized, sustainable public data portal (see https://water.usbr.gov/docs/RISE.pdf for more details). On the March 13 conference call the RISE team discussed their intent to work with Reclamation staff, other federal agencies, and other partners (including the SHOWR Technical Committee and development team) to develop applications, visualizations, and tools to showcase and

use data in the portal. The RISE team was optimistic that they would be able to consider hosting SHOWR by mid-2019 after the SRSC hosting period.

AB-1755 (DWR)

Assembly Bill 1755 (The Open and Transparent Water Data Act, or AB-1755) requires the Department of Water Resources, in consultation with the California Water Quality Monitoring Council, the State Water Resources Control Board, and the California Department of Fish and Wildlife, to create, operate, and maintain a statewide integrated water data platform; and to develop protocols for data sharing, documentation, quality control, public access, and promotion of open-source platforms and decision support tools related to water data (see https://www.water.ca.gov/Programs/All-Programs/AB-1755 for details). SHOWR was submitted to the University of California and DWR as an AB-1755 “use case” in early 2018. Use cases are being used as test beds to help the implementers of AB-1755 refine their understanding of the data, functionality, and decision support capabilities needed by water data users in California. The SHOWR development team met with the AB-1755 team at DWR on May 25, 2018 to discuss next steps for use cases and learned that SHOWR, especially the CDECRetrieve software implemented as part of SHOWR’s back end, is still of interest as a use case test bed and will be discussed further at an AB-1755 implementation meeting in the summer of 2018.

Project Budget Status

The total budget for the project is $565,000, of which $500,000 are grant funds administered by the Windward Fund. The remaining $65,000 will be provided by the SRSCs. To date, approximately $420,000 of the $500,000 grant award has been expended through April 2018. SHOWR development and support will continue past the submittal date (May 31, 2018) of this final report, and remaining project funds will be allocated to these efforts. In addition, the $29,000 budget originally allocated to Socrata has been reallocated to FlowWest as the API support anticipated from Socrata was not required to achieve the project objectives. FlowWest will use these additional funds to implement a variety of improvements to the SHOWR application, including design refinements, new home page reporting metrics, Winter Run page integration with SacPAS, Flow page gate change functionality, and contextual information on all pages. A summary of expenditures to date is provided in Appendix 1.

Project Evaluation Status

Stanford University was awarded a grant to evaluate the two pilot data platforms being developed from grants from the Windward Fund, including this Sacramento River project. The purpose of Stanford's evaluation is to test whether better access to scientific data for water management results in more timely, efficient, transparent, and informed decision-making. The evaluation is being conducted in two phases.

Phase 1 of the evaluation process, summarized here, focused on establishing the baseline decision making process for the Sacramento River project, i.e., how temperature management decisions have been made prior to the development of the application now called SHOWR. Once established, the baseline decision making process will serve as the basis against which changes resulting from development and implementation of the data integration platforms are evaluated.

The phase 1 project goal was met through the development of two baseline decision reports, one of which was for the Sacramento River pilot project discussed above. This report is based on a total of 25 60-minute interviews, interview analysis, meeting observations, and document analysis. The baseline report was submitted to Windward in November 2017.

Completed evaluation project tasks: During phase 1 of the evaluation project, the Stanford team:

1. Conducted and analyzed 37 60-minute baseline interviews with agency representatives, stakeholders, platform developers, and others, 25 of which were for the Sacramento River pilot project
2. Attended approximately 20 technical committee meetings, in addition to a host of check-in, planning, and coordination meetings.
3. Compiled and analyzed numerous documents related to the SRP and GRAT decision making process.
4. Synthesized materials outlined in bullet points 1-4 into two baseline decision making reports for the SRP and GRAT.
5. Collated research articles for a literature review report.
6. Conducted several interviews with potential case studies.
7. Coordinated research with Anthony Saracino via weekly check-in meetings.
8. Helped with the interim and final reports submitted by Anthony Saracino for his portion of the project, when requested.

Next steps: To meet the overarching project goal, the Stanford team will continue their evaluation research over the next year. The next steps for the project include: conducting and analyzing one round of implementation interviews for each pilot project; developing a literature review report that includes case studies; evaluating changes to the decision making process and additional benefits resulting from implementation of the data platforms for each pilot project; and summarizing our research findings into a final report.

Publications and Media:
Two baseline reports were developed during phase 1 of this project. Both reports have been distributed to the project proponents and funders. However, because the reports are largely intended for research purposes they have not been released publicly.

Preliminary results from this research were presented at the American Water Resources Association Fall Meeting in November 2017, at the Association of Pacific Coast Geographers Annual Meeting in October 2017, and at the National Groundwater Association conference on Groundwater Issues and Science Affecting Policy and Management in the Southwest in Albuquerque, NM in February 2018.

Appendix 1. Project Budget Expenditure Summary

Windward Fund Grant Budget Tracking Sheet

	Actual Costs to Date			Budget			Remaining	Percent
Vendor	Invoice #	Period	Amount	Total Budget	Grant Budget	SRSC/NCWA Budget	Grant Budget $$	Complete
FlowWest				**$ 415,055**	**$ 415,055**	**$ -**		
	311	10/6/2016 - 10/31/2016	$ 20,620.00					
	352	11/1/2016 - 11/30/2016	$ 21,110.00					
	356	12/1/2016 - 12/31/2016	$ 27,350.00					
	391	1/1/2017 - 1/31/2017	$ 37,826.25					
	407	2/1/2017 - 2/28/2017	$ 28,562.50					
	422	3/1/2017 - 3/31/2017	$ 34,416.92					
	447	4/1/2017 - 4/30/2017	$ 19,631.25					
	487	5/1/2017 - 7/31/2017	$ 61,062.50					
	487	8/1/2017 - 9/30/2017	$ 34,362.50					
	502	10/1/2017 - 10/31/2017	$ 10,008.55					
	529	11/01/2017 - 11/30/2017	$ 8,575.00					
	546	12/01/2017 - 12/31/2017	$ 6,926.45					
	559	01/01/2018 - 01/31/2018	$ 14,284.84					
	573	02/01/2018 - 02/28/2018	$ 17,081.18					
	594	03/01/2018 - 03/31/2018	$ 11,195.17					
	626	04/01/2018 - 04/30/2018	$ 17,628.57					
Total FlowWest			**$ 370,641.68**				**$ 44,413.32**	**89%**
Kearns & West				**$ 55,945**	**$ 55,945**	**$ -**		
	13871	10/1/2016 - 10/31/2016	$ 2,128.75					
	13920	11/1/2016 - 11/30/2016	$ 2,323.75					
	14000	12/1/2016 - 12/31/2016	$ 4,460.20					
	14108	01/01/2017 - 01/31/2017	$ 2,551.25					
	14189	2/1/2017 - 2/28/2017	$ 2,502.50					
	14284	3/1/2017 - 3/31/2017	$ 7,540.00					
	14323	4/1/2017 - 4/30/2017	$ 3,412.50					
	14412	5/1/2017 - 5/31/2017	$ 3,900.36					
	14495	6/1/2017 - 6/30/2017	$ 610.84					
	14575	7/1/2017 - 7/31/2017	$ 3,047.44					
	14635	8/1/2017 - 8/31/2017	$ 5,191.00					
	14693	9/1/2017 - 9/30/2017	$ 2,859.58					
	14783	10/1/2017 - 10/31/2017	$ 1,517.19					
	14873	11/1/2017 - 11/30/2017	$ 211.25					
	14948	12/01/2017 - 12/31/2017	$ 2,105.25					
	15109	01/01/2018 - 01/31/2018	$ 910.00					
	15119	02/01/2018 - 02/28/2018	$ 1,702.75					
	15167	03/01/2018 - 03/28/2017	$ 1,023.75					
	15271	04/01/2018 - 04/30/2018	$ 1,920.15					
Total Kearns & West			**$ 49,918.51**				**$ 6,026.49**	**89%**
Socrata				**$ 29,000**	**$ 29,000**	**$ -**	**$ 29,000.00**	**0%**
MBK Engineers				**$ 50,000**	**$ -**	**$ 50,000**		
	16-11-4850	11/1/2016 - 11/30/2016	$ 1,044.00					
	17-01-4850.0	12/01/2016 - 1/31/2017	$ 2,790.00					
	17-02-4850.2	2/1/2017 - 2/28/2017	$ 2,047.35					
	17-03-4850.2	3/1/2017 - 3/31/2017	$ 1,565.50					
	17-04-4850.2	4/1/2017 - 4/30/2017	$ 7,016.25					
	17-05-4850.2	5/1/2017 - 5/31/2017	$ 9,624.75					
	17-06-4850.2	6/1/2017 - 6/30/2017	$ 10,566.00					
	17-07-4850.2	7/1/2017 - 7/30/2017	$ 1,422.50					
	17-08-4850.2	8/1/2017 - 8/31/2017	$ 2,368.30					
	17-10-4850.2	10/01/2017 - 10/31/2017	$ 117.50					
	17-12-4850.2	12/01/2017 - 12/31/2017	$ 426.00					
	18-01-4850.2	01/01/2018 - 01/31/2018	$ 3,437.25					
	18-02-4850.2	02/01/2018 - 02/28/2018	$ 517.50					
	18-04-1850.2	03/01/2018 - 04/30/2018	$ 573.25					
Total MBK Engineers			**$ 43,518.15**					**87%**
Natural Resource Scientists				**$ 15,000**	**$ -**	**$ 15,000**		**0%**
Total Grant				**$ 565,000**	**$ 500,000**	**$ 65,000**	**$ 79,439.81**	**82%**

Appendix 2: Report Certification

All activities by the Sacramento River Settlement Contractors conducted using the Grant funding were and are consistent with Internal Revenue Code Sections 501(c)(3) and 509(a)(1), (2) or (3). If any lobbying was conducted by the Sacramento River Settlement Contractors with the Grant funding (whether or not discussed in this report), the Sacramento River Settlement Contractors complied with the limits of Internal Revenue Code Sections 501(c)(3) and/or 501(h) and 4911 applicable to the Foundation. The Sacramento River Settlement Contractors warrants that it is in full compliance with its Grant Agreement with the Windward Fund, dated September 13, 2016, and that, if the Grant was subject to any restrictions, all such restrictions were observed.