Stakeholder Engagement to Demonstrate Integrated Water Resources Science and Services

Russian River Basin Partner Report

January 2016

Contract # EAJ33C-09-CQ-0034

EXECUTIVE SUMMARY

The Integrated Water Resources Science and Services (IWRSS) is a new business model for interagency collaboration among the U.S. Geological Survey, the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration, and the Federal Emergency Management Agency. These federal agencies have complementary missions in water science, observation, management, prediction, and response. IWRSS agencies are working together to design, develop, and implement a national water modeling and information services framework to infuse new hydrologic science into current water resource management, develop hydrologic techniques and information to support operational water resource decisions, and provide advanced hydrologic services to meet stakeholder needs. The overarching objective of IWRSS is to serve as a reliable and authoritative means of adaptive water-related planning, preparedness, and response.

It is critical that IWRSS services meet the needs of water resource managers, planners, and decision-makers. The purpose of this project was to engage local, state, and federal officials in the Russian River basin to:

- Validate priority needs and existing gaps for managing water resources.
- Identify IWRSS pilot projects that could address the gaps.
- Develop a methodology to quantify economic benefits of the pilot projects and, if possible, estimate the economic benefits of one pilot project.

For this project, the Sonoma County Water Agency (SCWA) served as the lead convening partner agency. A preliminary meeting, held in December 2013, focused on sharing initial research on water resource issues and gaps in the Russian River. Participants discussed key issues and gaps; shared current water resource initiatives; and provided input on the stakeholder forum. Participants provided reports and other information to supplement initial research on priority issues and needs. They also recommended that because of stakeholder "burnout," it would be most productive to convene partner agencies and collaborators. Based on this information, the IWRSS team worked with the SCWA to develop a participant list (see Appendix A) and drafted an issues paper (see Appendix B), which identified data management, monitoring, forecasting, and hydrologic modeling as the priority needs.

In April 2014, IWRSS agencies reconvened a larger group of partner agencies and collaborating organizations to validate the priority issues. Participants divided into breakout groups reflecting priority needs. The breakout groups then identified key gaps and proposed pilot projects to demonstrate how IWRSS science and services could fill the gaps, building upon existing efforts. The following pilot projects were proposed:

- Forecasting: Improve forecasting through forecast informed reservoir operations (FIRO) to modernize Lake Mendocino management and achieve increased reliability and resiliency.
- Hydrologic modeling #1: Create an inventory of hydrologic models in the Russian River basin and organize a symposium to identify gaps in modeling based on the inventory.
- Hydrologic modeling #2: Inform placement of new stream and precipitation gages to enhance monitoring capability and improve modeling inputs.
- Data management: Create a central repository for active data streams for common data access.

The meeting concluded with a discussion of next steps, including general timelines and agency leads for each project. A summary of this meeting is contained in the body of this report. The group agreed to meet every six months to track progress, share results, and collaborate on other water resources management activities to maximize information exchange and efficiencies between organizations. At the end of one year, partners made significant progress on all four pilot projects. An information sheet titled "Russian River Integrated Water Resources Locally Led Pilot Projects" provides a progress report on the pilot projects (see Appendix C).

Follow-up partners meeting on the forecasting pilot project held at Scripps Institution of Oceanography, La Jolla, CA, *photo courtesy of Arleen O'Donnell, ERG.*

Following development of the pilot projects, ERG economists developed a methodology for assessing their economic benefits to demonstrate the IWRSS's value. Because FIRO draws on the results of the other pilot projects and represents a concrete project that will enable identification and quantification of benefits, the benefits methodology focuses on quantifying FIRO benefits (see Appendix D). It provides examples of data that were readily available and identifies the data gaps for quantifying seven identified benefits. This proposed methodology could be applied to other areas across the country to quantify benefits of IWRSS.

LIST OF ACRONYMS

CA DWR	California Department of Water Resources
CDEC	California Water Data Exchange Center
CNRFC	California-Nevada River Forecast Center
CWMS	Corps Water Management System
DHM	Diffusion hydrodynamic model
FIRO	Forecast Informed Reservoir Operations
HEC	Hydrologic Engineering Center
HEFS	Hydrologic Ensemble Forecast System
HMT	Hydro-Meteorological Testbed
IWRSS	Integrated Water Resource Science and Services
NGO	Nongovernmental organization
NIDIS	National Integrated Drought Information System
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service (NOAA)
OAR	Office of Oceanic and Atmospheric Research (NOAA)
RCD	Resource Conservation District
RRFC	Mendocino County Russian River Flood Control and Water Conservation Improvement District
SCWA	Sonoma County Water Agency
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WFOs	Weather Forecast Offices (NOAA, NWS)

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APPENDICES

1.0 INTRODUCTION

The Integrated Water Resources Science and Services (IWRSS) is supported by a consortium of federal agencies with complementary missions in water science, observation, management, and prediction: the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers (USACE), and the National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service (NWS). The objective of IWRSS is to design, develop, and implement a national water modelling and information services framework to infuse new hydrologic science into current water resource management, develop hydrologic techniques and decision support applications for operational use, and provide advanced hydrologic services to address growing stakeholder needs.

Toward this end, IWRSS applies a multidisciplinary approach to address complex water resource problems collaboratively. Planned IWRSS services include:

- Conducting high spatial and temporal resolution "summit to sea" analyses and forecasts for a full spectrum of water budget parameters.
- Conducting short- to long-term river forecasts that quantify uncertainty.
- Creating static flood inundation map libraries and real-time flood forecast inundation mapping to show the aerial extent and depth of flooding.
- Linking river forecasts and associated flood inundation maps to potential socioeconomic impacts.
- Integrating the access to geospatial water resource information from multiple federal agencies through a single portal.

The purpose of this project was to engage partners in the Russian River basin to:

- Validate water resource priorities and existing gaps to address them.
- Identify IWRSS capabilities that could fill the gaps and address priority needs.
- Develop pilot projects to demonstrate IWRSS capabilities.
- Estimate the economic benefit of addressing these gaps by developing an economic assessment methodology and applying it to one of the pilot projects.

The Sonoma County Water Agency (SWCA) in Santa Rosa, California, served as the local convening entity and helped plan the forum by suggesting participants, directing the IWRSS team to reports and other resources, and providing meeting support. In April 2014, the IWRSS agencies met with local, regional, state, and academic partners in the Russian River basin to validate water resource priorities, identify gaps that must be filled to meet priority needs, and inform decision-making on critical issues facing the watershed. The group developed four pilot projects, each with its own lead and implementation plan. The SCWA and IWRSS convened two subsequent partner meetings over an 18-month period to share progress and explore other collaboration opportunities.

Implementation of all four pilot projects is a remarkable outcome of this effort, demonstrating the convening power of IWRSS. By bringing all the partners together to innovate, collaborate, and share information, the initiative has already made much progress toward better managing water resources in the Russian River basin. To help communicate this progress, a one-page information sheet was developed for distribution by all partners. This effort was so successful that the group has unanimously agreed to continue meeting on a regular basis to build on the momentum created by this initiative.

1.1 IWRSS Partner Engagement Forum

1.1.1 Purpose of the Meeting

On April 2, 2014, NOAA NWS and the SCWA coordinated with IWRSS federal partner agencies to convene a one-day meeting in Santa Rosa, California, involving 41 representatives from national, regional, state, and local organizations. IWRSS federal partner agencies include the USGS, USACE, and NOAA NWS. During the meeting, participants engaged in full-group discussions and breakout group sessions to achieve the following objectives:

- Verify key gaps that IWRSS might fill to inform water resource decision-making.
- Identify pilot projects that could demonstrate IWRSS capability and build on existing efforts.
- Identify functional components of pilot projects, assign lead roles, establish timeframes, and approximate costs.
- Discuss benefits and map out next steps.

The following is a summary of meeting discussions and recommendations.

1.2 Priority Water Resources Issues in the Russian River Basin

The Russian River basin faces many water resource management challenges related to flow levels, as evidenced by the current drought conditions and statewide drought emergency declaration for California. Calendar year 2013 was the driest year on record in Sonoma County. Although storms in the late winter and early spring slightly mitigated the emergency conditions, rainfall during 2013 through March 2014 was only one-third of the long-term average. As of September 15, 2014, Lake Mendocino water levels were at 27.6 percent of capacity.

In December 2013, a kickoff meeting was held between the IWRSS team and local groups, including the SCWA and Mendocino County Russian River Flood Control and Water Conservation Improvement District (RRFC). This meeting served as a forum to discuss previous stakeholder engagement initiatives and current/planned activities in the Russian River basin. Based on input received during this meeting and a subsequent review and summary of recommended reference materials (see Appendix B), the team developed the following list of priority water resource issues in the Russian River watershed (see Appendix B).

- *Providing flows to protect, maintain, and restore fisheries and aquatic habitat, especially for endangered species such as Coho salmon, as well as human uses.* Providing these flows is a primary focus of integrated water management efforts in the basin. The Russian River Biological Opinion, published in 2008 by the NOAA National Marine Fisheries Service (NMFS), mandates creating pools, backwaters, and side channels and maintaining flow velocities conducive for young fish. Additionally, the Russian River serves multiple human needs, including domestic and agricultural uses, as well as recreational uses (see third bullet below).

Juvenile Coho Salmon *(Courtesy SCWA)*

  Related to this priority area, NOAA's Habitat Blueprint initiative currently provides funding to several projects in the Russian River basin for protecting and restoring habitat for salmonid stocks; improving frost, rainfall, and river forecasts through improved data collection and modeling; and increasing community and ecosystem resiliency to flooding and drought through improved planning and water management strategies. In addition, the SCWA has a plan in place to restore endangered fisheries (Russian River Instream Flow and Restoration Plan).

- *Predicting, managing, and responding to hydrologic extremes (floods and droughts).* Significant flooding occurs in the Russian River basin approximately every four years. Atmospheric rivers are a major source of the heavy precipitation that causes this flooding. These extreme precipitation events can contribute mudslides, which can cause significant damage to buildings and infrastructure. In addition, drought conditions require well-informed management responses for successfully navigating multiple competing uses.

  Related to this priority area, NOAA's Hydro-Meteorological Testbed (HMT) conducts research on precipitation and weather conditions and accelerates the infusion of new science and technology into daily forecasting. The HMT maintains a coastal atmospheric river observatory in the southern part of the Russian River basin. NOAA's National Integrated Drought Information System (NIDIS) is working to implement an integrated drought monitoring and forecasting system at federal, state, and local levels. The Russian River basin was selected as a pilot project as part of NIDIS to explore design and implementation of early warning systems.

- *Managing water for competing uses closely linked to reservoir storage, releases for fisheries, and groundwater withdrawals for crop frost protection.* The challenge of managing water resources during extreme weather periods is compounded by growing demands of an increasing population in the Russian River basin, paired with a lack of surface storage and finite local groundwater supplies. Grapes are an increasingly dominant agricultural crop in the basin and vineyard tourism has grown in popularity, incentivizing conversion of land into vineyards, which require water withdrawals for irrigation and frost protection.

Sonoma County Vineyard *(Courtesy SCWA)*

Currently, the NWS California-Nevada River Forecast Center (CNRFC) provides reservoir inflow information and river flow forecasts. The California Department of Water Resources, Division of Flood Management, and USGS California Water Science Center also provide river flow information. The California Water Data Exchange Center (CDEC) disseminates various water-related information and data.

- *Predicting and managing the effect of climate change on both air and water temperature and on the intensity and frequency of extreme events.* According to the U.S. Global Change Research Program, extreme events, such as flooding and droughts, are predicted to increase in severity and intensity in California. Climatic fluctuations may further stress salmonid populations in the Russian River.
- *Ensuring water quality through prevention, management, and remediation of point and nonpoint source pollution.* Under Section 303(d) of the Clean Water Act, the Russian River mainstem and many of its major tributaries are impaired. Nonpoint sources of pollution in the Russian River Basin include agriculture, construction-related runoff from buildings and roads, stormwater runoff from impervious surfaces, and septic systems.

1.3 Russian River Basin Gaps and Needs

The IWRSS team also identified information needs and gaps that contribute to water resource challenges in the region, which participants reviewed before the forum. In plenary session, the group discussed and further explained these needs and gaps as follows:

1. **Improved forecasting for water management** (including forecast-based operations), to address gaps related to river flows, reservoir releases, water use, groundwater dynamics, atmospheric rivers, seasonal variations, and extreme temperatures.
2. **Improved hydrologic modeling** to address gaps related to surface-groundwater interactions; understanding of the gain and loss of reaches on tributaries; water quality parameters, including sediment, temperature, and dissolved oxygen; flood inundation mapping; and characterization of managed and natural flows.
3. **Improved data management** to address gaps in cross-agency coordination, data interoperability, measurements and models, accessibility, and dissemination of data to stakeholders.

4. **Improved monitoring and data collection** to address gaps in water quantity information, including precipitation, spatial distribution, and interaction of surface water and groundwater, soil moisture, and unregulated or illegal diversions; water quality information, including water temperature and fisheries/habitat; and real-time, finer scale atmospheric data.

Improved monitoring and data collection was the fourth need identified by the IWRSS team as a crosscutting topic. During the opening plenary session, participants agreed to integrate this need into the three breakout group discussions.

2.0 PARTNERS MEETING

2.1 Opening Plenary Session

Mary Mullusky (Acting Chief, NWS Hydrologic Services Division) laid the groundwork for the day by providing an overview of IWRSS objectives and ongoing activities. Natalie Cosentino-Manning (NOAA Fisheries Restoration Center) presented on the NOAA Habitat Blueprint and the selection of the Russian River basin as the first "Habitat Focus Area" for this initiative. Participants asked questions after each presentation related to project coordination across the agencies involved in the IWRSS and Habitat Blueprint, future expansion of agency participation, and agency budget coordination.

In preparation for the first breakout group session, the four Russian River basin needs (outlined above) were presented to participants, who briefly discussed each gap and added their input.

Russian River *(courtesy SCWA)*

2.2 Morning and Afternoon Breakout Sessions

The following is a summary of the breakout group discussions. Participants divided into issue-based groups reflecting the three priority gaps and needs. During the morning breakout session, each group worked on identifying one or two pilot projects to demonstrate how IWRSS could help address their need/gap. The groups were asked to describe at least one project (or part of a longer-term project) that could be completed in the near term (within one to two years). Participants brainstormed pilot projects that would inform event-driven, high-impact or important decisions or questions that "keep you up at night." For the afternoon breakout session, each group further developed their pilot project ideas by identifying the major functional components of each pilot project, assigning lead agency roles, and noting potential economic benefits. Worksheets helped structure the breakout discussions. Participants (by breakout group) are listed below (the full participant list can be found in Appendix A).

Forecasting	Hydrologic Modeling	Data Management
Marchia Bond	Rich Niswonger	Jerad Bales
Lynn Johnson	Tracy Nishikawa	Don Seymour
Jay Jasperse	Dawn Taffler	Craig Lichty
Rob Hartman	Bill Charley	Mark Strudley
Bill Jacoby	Reginald Kennedy	Rob Cifelli
Jack Hogan	Michael Schaffner	Natalie Cosentino-Manning
Zachary Hamill	Brittany Heck	Alan Haynes
Marty Ralph	Alan Flint	Stu Townsley
Michael Anderson	Mary Mullusky	Art Hinojosa
Ann DuBay	Mike Dillabough	Donna Page
Sean White	Chris Delaney	
Dick Butler	Josh Fuller	
Patrick Rutten	Grant Davis	
Lorraine Flint		
Micah Effron		
David Manning		

2.3 Results from the Forecasting Breakout Group

Lake Mendocino: Aerial view and plane view *(courtesy SCWA)*

2.4 Pilot Project Identification

Proposed pilot project

- Modernize the Lake Mendocino water management strategy to achieve increased reliability and resiliency. This project would improve water management methods and strategies and would include the following elements:
    - **Element 1:** Quantify forecast attributes that would improve decision-making, identify forecasts needed, and determine what level of certainty is appropriate.
    - **Element 2:** Total water forecasting.
    - **Element 3:** Water quality forecasting.
    - **Element 4:** Institutional change (updated policies; risk management).

What decision(s) would this pilot project inform?

- Optimizing reservoir operations.

What foundation would it build upon?

Existing Effort/Foundation	Organization(s)
Increased instrumentation (hydromet, soil probes)	SCWA/HMT
Enhanced flood response and emergency preparedness (EFREP) (a state program to improve forecast and warning capabilities)	California Department of Water Resources (CA DWR)/ NOAA/Scripps
Hydrologic ensemble forecast system (HEFS), integration into Corps Water Management System (CWMS) (could be used to test forecast scenarios/hindcasting)	NOAA NWS, USACE
Basin characterization model, diffusion hydrodynamic model (DHM), SCWA models, Hydrologic Engineering Center (HEC) models	USGS, NOAA, SCWA, USACE HEC
Long-term feasibility study for modification of dam at Lake Mendocino (long-term), short-term study	USACE
Cal Water 2: Climate change impact study—future of atmospheric rivers and aerosols and impact on clouds and precipitation	Scripps Center for Western Weather and Water Extremes, and others
Habitat Blueprint	NOAA, SCWA
NIDIS atmospheric rivers and drought project	USGS, Scripps

Define success. This project would be successful if:

- A prospectus development workshop is held to develop scope and create a roadmap for the project.
- An interagency collaborative process is established to identify projects that would improve reservoir operations.
- Ways to reduce forecast uncertainty are identified and quantified.
- Forecast uncertainty is reduced.
- Storage in Lake Mendocino is more effectively managed for multiple purposes.
- Science is used to demonstrate improved water management.
- This process is documented so other organizations can benefit (lessons learned).

- Barriers (i.e., institutional) to forecast-based operations are documented (lessons learned).

What can be done shorter term (with little/no additional resources)? What can be done longer term (with additional resources)?

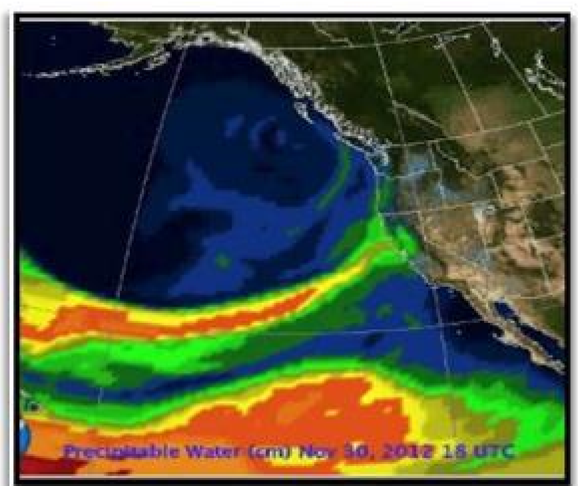
- Short term (within six months):
    - Hold a two-day prospectus development workshop at Scripps to outline a multi-year effort to improve reservoir operations (within three months).
    - Create a roadmap with longer term goals (within six months).

- Medium term (within two years):
    - Define forecast baseline (streamflow, atmospheric river, seasonal forecast; e.g., El Niño).
    - Set up monitoring locations (early in process).
    - Identify requirements for FIRO. Quantify predictability of atmospheric rivers, precipitation and streamflow, and pathways for their improvement (both wet events and dry periods).
    - Define conditions that create worst-case scenarios (too much and too little) and develop conceptual FIRO scenarios for flood and drought. Challenge: how to handle truly extreme/rare events with few examples to draw from.
    - Develop conceptual reservoir alternative; test it with historic extreme flood and droughts. Challenge: how to handle extreme events with dearth of examples.
    - Quantify potential economic benefits of FIRO drought and flood scenarios (not just for flood control).

- Longer term (> two years):
    - Improve forecast skill gaps identified in the FIRO requirements analysis.
    - Conduct retrospective "what-if" analyses using FIRO scenarios.
    - Design a real-time demonstration of FIRO for two winters (no actual changes in releases).
    - Carry out real-time demonstration project.
    - Evaluate results (positive and negative).

2.5 Pilot Project Functional Component Analysis

Pilot project #1: Modernize water management strategy for Lake Mendocino to achieve increased reliability and resiliency.



Water vapor image showing atmospheric river
(courtesy Scripps Institution of Oceanography)

Subcomponent descriptions

- Identify requirements to enable FIRO:
    - Improve forecasting of atmospheric river events, rain event intensity, and duration.
    - Establish forecast timescale requirements (may be different for different uses). For example, seasonal

flood control during the spring needs a forecast of a different timescale as compared to forecast needs for frost and water supply concerns. Short-term evacuation timing considerations also need to be taken into account.
  - Consider forecast needs upstream (capture for fisheries) and downstream of the reservoir to account for releases.
  - Improve understanding of the runoff ratio and quantification of "losses" to soil moisture.
  - Determine what forecasts are needed and help determine what level of certainty is appropriate (best possible forecast scenario).

- Define forecast baseline:
  - Define the capability of current forecasts for streamflow, atmospheric rivers, and seasonal events such as El Niño.

- Conduct total upstream water balance forecasting (this is a tool for validation) for reservoir re-operations.
  - Include monitoring and modeling.

- Improve water quality forecasting:
  - Reduce turbidity of discharge by better timing releases after precipitation events.
  - Require water of sufficient quality/quantity for fisheries (e.g., temperature).
  - Balance between release and retention to minimize turbidity (e.g., socioeconomic impacts; recreational fisheries impacts).

IWRSS roles

- NOAA (CNRFC, Office of Oceanic and Atmospheric Research [OAR]/HMT, and NMFS):
  - Provide information on current capabilities (e.g., hindcasting).
  - Habitat Blueprint to conduct ecological, flood avoidance, and commodity water-value quantification.
  - Determine uncertainty in streamflow, atmospheric river occurrence.
  - NOAA NWS (Rob Hartman) to review list of developed forecast baselines.

- USACE:
  - If possible, identify risk thresholds.

- USGS:
  - Determine uncertainty in streamflow observations.

Other agency roles

- The RRFC and other groups:
  - Act as representatives for locally affected stakeholders.

Pilot project leadership:

Scripps Center for Western Weather and Water Extremes: Marty Ralph (co-lead)

USGS/Scripps: Mike Dettinger (co-lead)
NOAA NMFS: Pat Rutten
USACE: Mike Dillabough
SCWA: Jay Jasperse
CA DWR: Mike Anderson

Timeline

- April/May 2014: Planning group gathers to plan workshop and establish monthly call schedule.
- July 2014: Workshop to create roadmap and list of possible forecast baselines.
- October 2014: Report out in form of written prospectus for FIRO demonstration.
- Winter 2015: Regroup to discuss lessons learned and future work/transferable projects; quantify benefits.
- See longer-term actions and timeline above.

2.6 Results from the Hydrologic Modeling Breakout Group

2.6.1 Pilot Project Identification

Proposed pilot project

- Brainstorming: Pilot projects for runoff modeling, small basin modeling, low-flow modeling, and groundwater modeling. Soil moisture, stream temperatures, precipitation, and streamflow monitoring were identified as data necessary to support modeling. A need for a unified model platform led to the identification of the first pilot project.
- Pilot project #1: Model inventory and local symposium. The model inventory would identify when a model could be used and what decisions could be made using the model. Once the inventory is complete, a local forum would be a follow-up activity to present the findings of the project to watershed stakeholders.
- Pilot project #2: Consultation for NOAA NMFS gage siting (enhanced monitoring to inform gaps in modeling).

What decision(s) would this pilot project inform?

- Pilot project #1:
    - Forecast drought/floods.
    - Manage irrigation.
    - Manage fisheries (flow expectations).
    - Improve decision-making credibility by using accepted/vetted models.
    - Identify monitoring needs and support gage placement (see project #2).

- Project #2:
    - Model and provide baseline data.

What foundation would it build upon?

Project #1

Existing Effort/Foundation	Organization(s)
HydroTech Meeting/Workshop	NOAA OAR
Russian River Watershed Independent Science Review Panel	SCWA
Tributary gaging project (see "Project #2")	NOAA Restoration Center
Recently awarded SCWA consultant work	Kennedy/Jenks Consultants

Project #2:

Existing Effort/Foundation	Organization(s)
Existing gages in the basin	USGS, Resource Conservation Districts (RCDs), University of California Cooperative Extension Service

Define Success: This project would be successful if:

- Project #1:
    - A Web page inventory for users is developed.
    - Outstanding science gaps are identified.
    - Scenario planning is addressed.
    - Models are implemented appropriately.
    - The inventory supported identification of monitoring needs and placement of gages in Project #2.

- Project #2:
    - A geo-database of federal and local monitoring efforts was created.

What can be done shorter term (with little/no additional resources)? What can be done longer term (with additional resources)?

- Project #1:
    - Short term (within seven months):
        - Convene a symposium.

  - Longer term:
    - Create an online inventory, Web page.
    - Develop more pilot projects to address key priorities.
- Project #2:
  - Site NOAA gages by spring 2015.

2.7 Pilot Project Functional Component Analysis

Pilot Project #1: Model Inventory and Local Symposium

Subcomponent descriptions:

- Hydrologic modeling inventory: The inventory will focus on existing models (both codes and programs) and contain information on the model's purpose, accuracy, spatial and temporal resolution, known strengths and weaknesses, access location, and application examples. The group will review surface-water and groundwater interaction models to support basin water supply planning, as well as hydrologic models that could be used to support project #1, the FIRO project. A working group will be formed to agree on criteria to evaluate each model and will then evaluate the strengths and weaknesses of each based on the criteria.
- Modeling symposium: After the working group has reviewed the inventory, a symposium will be convened with working group participants and model users in the watershed. It is anticipated that the symposium will cover three general topics:
  - Inventory of model platforms:
    - Potential modeling platforms (Hydrology and & Hydraulics, watershed, integrated surface and groundwater, etc.) completed by IWRSS federal agencies.
    - Geospatial database tool of existing Russian River watershed models (the SCWA will develop the prototype).
  - Evaluation of integrated surface water and groundwater model for the Alexander Valley. The SCWA and consultant Kennedy/Jenks will present analysis results and recommendations for the Alexander Valley integrated model. Input received during the symposium will be incorporated into the final report of the model scoping study conducted as part of a grant from the California Water Foundation.
    - Hydrologic Working Group will present on potential high-flow modeling platforms, which could be used to support future implementation of FIRO for Lake Mendocino.

IWRSS agency roles: NOAA, USACE, and the USGS will identify subject matter experts within their agencies and create a working group to develop criteria and evaluate each model.

Other agency roles:

- The SCWA will coordinate the working group.
- Kennedy/Jenks (SCWA contractor) will work on an inventory of surface water and groundwater models that can serve as framework for organizing the IWRSS inventory.

Pilot project leadership

SCWA: Chris Delaney (lead)
NOAA OAR: Lynn Johnson
USACE: Bill Charley
USGS: Tracy Nishikawa

Timeline:

- April/May 2014: SCWA and IWRSS agency leads schedule some scoping discussions and determine a more detailed project schedule.
- June 2014: Each agency compiles its model inventory. NOAA Blueprint projects would be greatly enhanced by credible, vetted models, but this would require the modeling symposium to be held within the next six months (October 2014).
- August/September 2014: Determine evaluation criteria and complete inventory.
- October 2014: Hold modeling symposium.
- Winter 2015: Regroup to discuss lessons learned and future work/transferable projects, and; quantify benefits.

Pilot Project #2: NOAA Stream Gage and Weather Station Placement

Subcomponent descriptions:

- Geospatial database: Create an inventory of existing monitoring gages across all agencies.
- Coordinated instrumentation placement: Funding could be available for 12 gages and 20 weather stations. Subject matter experts from IWRSS agencies could convene to identify priorities for gages and tributaries for installation. Place one or two gages as pilot project test-bed in particularly sensitive basins (depending on landowner cooperation).

IWRSS agency roles: NOAA, USACE, and the USGS will identify monitoring gages, with the USGS taking the lead. This coordinated instrumentation activity will leverage some of the early information that comes out of the data management pilot project.

Other agency roles: Landowners, RCDs, Mendocino Farm Bureau, the SCWA, Mendocino Flood, other non-regulatory agencies and groups.

Pilot Project Leadership:

USGS: Debra Curry and Lorraine Flint
NOAA NWS: Mark Strudley, Weather Forecast Office (WFO) Monterey
USACE: Holly Costa, Regulatory Division San Francisco District, USACE

Timeline:

- Spring 2015: Install gages.

2.8 Results from the Data Management Breakout Group

Pilot Project Identification

Proposed pilot project

- Pilot project #1: Central repository for data sharing/exchange. Develop a platform for the storage and use of raw data, processed data, and quality assured/quality controlled data to improve coordination and water resource management in the basin. This effort will first require defining processes to allow for common data access (fully integrated, discoverable). Secondly, the pilot project will need to define the specific-use data needs. The target audience would be management agencies and the public.

What decision(s) would this pilot project inform?

- Fully integrated and accessible data would support data-informed management decisions, which would help the agricultural sector make informed decisions on when/how much water to pump. Currently, operations are poorly coordinated due to a lack of information.

What foundation would it build upon?

Existing Effort/Foundation	Organization(s)
CDEC	CA DWR
Environmental Response Management Application	NOAA
Hobbes Project	University of California, Davis

Define Success: This project would be successful if:

- All agencies commit to providing a consistent and reliable data stream to the CDEC, which is a robust and well-maintained central repository for relevant agencies to upload their respective water-related data for the Russian River basin.

What can be done shorter term (with little/no additional resources)?

- Participating agencies migrate data streams to a single location.
- IWRSS partner group conducts testing.

What can be done longer term (with additional resources)?

- Receive feedback from testers; incorporate additional data from other organizations (e.g., nongovernmental organizations [NGOs]).

2.9 Pilot Project Functional Component Analysis

Pilot Project: Central Data Repository

Subcomponent descriptions

- Initial inventory: The CDEC will provide a list of all Russian River data that they currently receive. Each agency will also provide types of data they could make available for the repository in native format and provide schema. A team will organize a webinar to roll out the project and gather suggestions.
- Needs assessment: Evaluate what users need (e.g., precipitation estimates, reservoir outflows, water quality, soil moisture, reservoir release data). Additionally, a second tier of data collection from NGOs could be included.
- Server deployment: Deploy all collected data.

IWRSS agency roles

- NOAA, USACE, and the USGS will gather data for submittal as well as identify other data sources to create comprehensive data inventory.

Other agency roles

- The SCWA will coordinate the working group.
- The CDEC will inventory data currently in the CDEC from federal agencies and provide staff to work with the IWRSS team.
- After data are gathered from federal and state agencies, NGOs will inventory and incorporate data into the repository.

Pilot project leadership

SCWA: Don Seymour (lead)
CDEC: Arthur Hinojosa or designate
NOAA NMFS: Natalie Cosentino-Manning or designate
NOAA NWS: Mark Strudley and Alan Haynes
OAR: Allen White or designate
USACE: Christy Jones
USGS: TBD

Timeline

- Summer 2014: Team holds calls to refine schedule and plan kickoff webinar.
- October 2014: Participating agencies complete migration of data streams to a single location, which will go live for testing by the IWRSS partner group.
- Later: Wider rollout for testing beyond IWRSS partner group.
- Winter 2015: Regroup to discuss lessons learned and future work/transferable projects; quantify benefits.

2.10 Next Steps

- The IWRSS Executive Committee will coordinate and track each group's progress through semi-annual meetings. The Executive Committee will be composed of IWRSS agency representatives, as well as pilot project coordinators and SCWA representatives:
  - Rob Hartman, NOAA NWS (co-lead)
  - Pat Rutten, NOAA NMFS (co-lead)
  - Stu Townsley, USACE
  - Debra Curry, USGS
  - Jay Jasperse, SCWA
  - Data Group Coordinator: Don Seymour, SCWA
  - Modeling Group 1 Coordinator: Chris Delaney, SCWA
  - Modeling Group 2 Coordinator: USGS (Lorraine Flint)
  - Forecast Group Coordinator: Marty Ralph, Scripps, and Mike Dettinger, USGS/Scripps
- The next Russian River Basin IWRSS meeting will be scheduled for December 2014. The Executive Committee, pilot project group leadership, and participants in the April 2 partner meeting will reconvene to discuss lessons learned and future work and project transferability; they will also quantify the benefits of the pilot projects.

APPENDICES

APPENDIX A

Integrated Water Resources Science and Services (IWRSS):
A Forum to Discuss this New Federal Initiative

Russian River Basin

April 2, 2014

Attendee List

Kate Abshire
National Weather Service-
Office of Hydrologic Development
Silver Spring, MD
301-713-0640 x162
kate.abshire@noaa.gov

Sam Allin
ERG
Chantilly, VA
703-408-0620
sam.allin@erg.com

Michael Anderson
State Climatologist California
California DWR
Sacramento, CA
916-574-2830
Michael.L.Anderson@water.ca.gov

Jerad Bales
Acting Assoc. Dir. Water
U.S. Geological Survey
Reston, VA
703-648-5044
jdbales@usgs.gov

Marchia Bond
Senior Water Manager
U.S. Army Corps of Engineers
Sacramento, CA
916-557-7127
marchia.v.bond@usace.army.mil

Dick Butler
North Coast Branch Chief
NOAA, NMFS
Santa Rosa, CA
707-575-6058
dick.butler@noaa.gov

William Charley
USACE - Hydrologic Engineering Ctr
Davis, CA
530-756-1104
William.Charley@usace.army.mil

Rob Cifelli Research Meteorologist
NOAA
Boulder, CO
303-497-7369
rob.cifelli@noaa.gov

Natalie Cosentino-Manning
NOAA Fisheries Restoration Center
Santa Rosa, CA
707-206-1642
natalie.c-manning@noaa.gov

Grant Davis
General Manager
Sonoma County Water Agency
Santa Rosa, CA
707-547-1911
grant.davis@scwa.ca.gov

Chris Delaney
Engineer
Sonoma County Water Agency
Santa Rosa, CA
707-547-1946
chris.delaney@scwa.ca.gov

Mike Dillabough
Chief Operatons and Readiness Div.
U.S. Army Corps of Engineers
San Francisco, CA
415-503-6770
michael.a.dillabough@usace.army.mil

Ann DuBay
Community & Government Affairs
Sonoma County Water Agency
Santa Rosa, CA
707-524-8378
Ann.dubay@scwa.ca.gov

Micah Effron
Social Science Analyst
NOAA/I.M. Systems Group
Washington, DC
862-485-4117
micah.effron@noaa.gov

Alan Flint
USGS
6000 S St
Sacramento, CA 95810
aflint@usgs.gov

Lorraine Flint
Research hydrologist
U.S. Geological Survey
Sacramento, CA
916-278-3223
lflint@usgs.gov

Joshua Fuller
Fishery Biologist
NOAA
Santa Rosa, CA
707-575-6096
Joshua.Fuller@noaa.gov

Zachary Hamill
Emergency Coordinator
Sonoma County Fire and Emergency Services
Santa Rosa, CA
707-565-1152
zhamill@sonoma-county.org

Robert Hartman
Acting Director, Office of Hydrologic Development
National Weather Service
Silver Spring, MD
301-713-0640 x143
robert.hartman@noaa.gov

Alan Haynes
Service Coordination Hydrologist
NOAA/NWS/ California Nevada River Forecast Center
Sacramento, CA
916-979-3056
Alan.Haynes@noaa.gov

Brittany Heck
Executive Director
Gold Ridge Resource Cons. District
Sebastopol, CA
707-823-5244
Brittany@goldridgercd.org

Arthur Hinojosa
Chief, Hydrology & Flood Operations
California DWR
Sacramento, CA
916-574-2613
hinojosa@water.ca.gov

Jack Hogan
U.S. Army Corps of Engineers
San Francisco, CA
415-503-6910
john.w.hogan@usace.army.mil

Bill Jacoby
Consultant to
California Water Foundation
San Diego, CA
619-200-3731
billjjacoby@aol.com

Jay Jasperse
Chief Engineer
Sonoma County Water Agency
Santa Rosa, CA
707-547-1959
jay@scwa.ca.gov

Lynn Johnson
NOAA ESRL Water Cycle Branch
Boulder, CO
303-775-5544
Lynn.E.Johnson@noaa.gov

Reginald Kennedy
Hydrologist
National Weather Service
Eureka, CA
707-443-6484 x228
reginald.kennedy@noaa.gov

Craig Lichty
Water/Infrastructure Market Dir.
Kennedy/Jenks Consultants
Santa Rosa, CA
707-526-1064 x1302
clichty@kennedyjenks.com

David Manning
Environmental Resources Coordinator
Sonoma County Water Agency
Santa Rosa, CA
707-547-1988
dmanning@scwa.ca.gov

Martina McPherson
ERG
Boston, MA
781-674-7205
martina.mcpherson@erg.com

Mary Mullusky
Acting Chief, Hydroogic Services Division
National Weather Service
Silver Spring, MD
301-713-0006 x169
Mary.Mullusky@noaa.gov

Tracy Nishikawa
Research Hydrologist
U.S. Geological Survey
San Diego, CA
619-225-6148
tnish@usgs.gov

Rich Niswonger
U.S. Geological Survey
Carson City, NV
775-887-7727
rniswon@usgs.gov

Arleen ODonnell
ERG
Lexington, MA
781-674-7220
arleen.odonnell@erg.com

Donna Page
National Weather Service- Office of Hydrologic Development
Silver Spring, MD
301-713-0640 x119
donna.page@noaa.gov

Marty Ralph
Director, Ctr for Western Weather & Water Extremes
University of California, San Diego/Scripps Institution of Oceanography
La Jolla, CA
858-822-1809
Mralph@ucsd.edu

Patrick Rutten
SW Regional Supervisor
NOAA Restoration Center
Santa Rosa, CA
707-575-6059
patrick.rutten@noaa.gov

Samuel Sandoval
Professor
University of California, Davis
Davis, CA
530-750-9722
samsandoval@ucdavis.edu

Michael Schaffner
Hydrology Program Manager
National Weather Service - Western Region
Salt Lake City, UT
mike.schaffner@noaa.gov
801-524-5137

Don Seymour
Principal Engineer
Sonoma County Water Agency
Santa Rosa, CA
707-547-1925
dseymour@scwa.ca.gov

Mark Strudley
Service Hydrologist
NOAA NWS
Monterey, CA
831-656-1710 x228
mark.strudley@noaa.gov

Dawn Taffler
Project Manager
415-243-2484
Kennedy/Jenks Consultants
San Francisco, CA
Dawn.Taffler@Kennedyjenks.com

Stu Townsley
Flood Risk Program Manager
U.S. Army Corps of Engineers
San Francisco, CA
415-513-3698
edwin.s.townsley@usace.army.mil

Sean White
General Manaer
Russian River Flood Control
Ukiah, CA
707-462-5278
rrfc@pacific.net

APPENDIX B

Russian River Basin – Water Resources Issues and Gaps

An Issues Paper Prepared for the IWRSS Forum

April 2, 2014

The Russian River basin faces many water resource challenges. It has also been the site of various plans and projects to take steps toward solving these challenges, including early conceptual planning for IWRSS activities. A stakeholder engagement kickoff meeting with IWRSS federal partners and local groups, including the SCWA and Mendocino County RRFC, was held in December 2013 and served as a forum to discuss previous stakeholder engagement and planned activities. Additionally, the participants highlighted overarching issues and gaps that confront their agencies and stakeholders. To provide a background on past work, current planning, and future projects, kickoff-meeting participants offered reference materials from previous or ongoing activities. The December meeting and review of existing efforts helped ensure that future IWRSS activities in the Russian River basin would not be redundant and that stakeholders would not be burdened by participation in duplicative projects or excessive outreach. This document summarizes some of the priority issues identified by previous work in the Russian River basin, as well as prevailing information gaps that should be addressed in order to ensure the success of IWRSS moving forward.

Since the December meeting, a drought emergency has been called statewide in California and in Sonoma County, with calendar year 2013 being the driest year on record locally. While storms in February and March have somewhat mitigated the extreme conditions, 2013–2014 has still seen less than one-third of average rainfall, and Lake Mendocino levels are at 44 percent. This latest weather pattern highlights the need to address the region's most pressing water issues.

Stakeholders at the kickoff meeting identified a several key issues that underlie water resource challenges in the basin:

- An overarching concern for providing flows to protect, maintain, and restore fisheries and aquatic habitat,[1] especially for endangered species[2] such as Coho salmon.[3]
- The prediction, management, and response to hydrologic extremes (floods and droughts) to manage water availability and use, especially in terms of quantity and reliability.
- The effect of climate change on the intensity and frequency of extreme events, along with temperature, and the resulting effect on water management planning.[4]

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[1] Improve Precipitation and River Flow Forecasting to Maximize Water Capture for Fisheries, 2013. http://www.habitat.noaa.gov/pdf/shared/NOAA_RR_HBFA_PrecipFcastFBO_final.pdf

[2] Russian River kickoff meeting discussion, December 17, 2013.

[3] Russian River CCC Coho Salmon Recovery Plan, 2012. http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/north_central_california_coast/central_california_coast_coho/russian.pdf

[4] Russian River kickoff meeting discussion, December 17, 2013.

- Management of water for competing uses (e.g., agriculture, ecological flows, and other uses) was also identified as a key issue in additional documents, closely linked to reservoir storage and releases for fisheries[5] and withdrawals from groundwater for agricultural frost protection.[6,7]
- Water quality, especially prevention, management, and remediation of point and nonpoint source pollution.[8]

Documents provided by partners outlined key issues in detail. A concept paper[9] was developed for early IWRSS activities based on major issues facing the Russian River basin, including:

- Extreme wintertime precipitation due to atmospheric rivers, which can cause coastal flooding and mudslide events.
- Competing uses for domestic and agricultural water supply.
- Maintenance of stream flows for endangered fisheries habitat based on the Russian River Biological Opinion.
- Demands for water-based recreation.
- Hydrologic extremes, from floods to droughts.
- Balancing water allocations for multiple uses.
- Ongoing groundwater storage depletion.
- Concerns about climate change and the long-term impacts on the weather and water budget in the basin.

In interviews conducted by the Mendocino County RCD,[10] a majority of stakeholders identified “the presence of un-regulated and often illegal stream diversions from tributaries and the mainstem” as “the biggest problem affecting natural hydrologic and ecologic function of the Russian River.” Other issues included:

- Effect of instream flow management in tributaries and the suppression of natural processes.
- Human-induced habitat loss, including agriculture, urban expansion, road systems, and gravel mining; impacts to river hydrology and geomorphology due to reduced riparian habitat, urban development, dams, pumps, diversions, wells, and changes to flow regime; hydrologic

[5] Case Study—California: Russian River Watershed, 2013. http://cpo.noaa.gov/LinkClick.aspx?fileticket=XsEgCpNf978%3D&tabid=517&mid=1439

[6] Improving Frost Forecasts for the Russian River Basin, 2013. http://www.habitat.noaa.gov/pdf/shared/NOAA_RR_HFA_Frost_Forecast_system_final.pdf

[7] NOAA's Habitat Blueprint—Habitat Focus Area: California's Russian River, 2013. http://www.habitat.noaa.gov/habitatblueprint/pdf/hb_russian_river_fact_sheet.pdf

[8] Russian River kickoff meeting discussion, December 17, 2013.

[9] Concept Paper: Russian River, California Pilot Study for Integrated Water Resources Science and Services, 2010. https://drive.google.com/a/noaa.gov/file/d/0BwNnplUN8Mo7ekJwckZsNEVFcnc/edit?usp=sharing

[10] Russian River Integrated Coastal Watershed Management Plan, 2012. http://mcrcd.org/wp-content/uploads/RussianRiverIRWMP_final1.pdf

disconnection from the floodplain; physical limits to meander; and gravel harvest with limited gravel renourishment.

- Lack of surface storage.
- Increasing human population.
- Water quality, specifically high turbidity.
- Salmonid passage.
- Frost protection.
- Groundwater management.
- Forest fuel management.
- Watershed education.

Important data gaps and needs must be filled before IWRSS can move forward and provide new or additional products and services that would create regulatory certainty and clarity for stakeholders in the watershed. The stakeholder engagement kickoff meeting and previous stakeholder engagement activities identified the following gaps:

Need for monitoring and data collection

Why? When fully integrated with modeling and forecasting, monitoring and data collection can address a diverse array of water quantity and water quality concerns (scaled climate change modeling,[11] fisheries-habitat relationships, runoff predictions, etc.).

This could address some of the following gaps:

- Water quantity information, including precipitation data,[12,13] surface water and groundwater distributions, soil moisture monitoring,[14] and quantification of unregulated or illegal diversions.[15,16]
- Water quality information, including temperature data and fisheries/habitat data.
- Real-time and finer scale atmospheric monitoring data.[17]

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[11] Biological Opinion for Water Supply, Flood Control Operations, and Channel Maintenance, 2008. http://www.scwa.ca.gov/files/docs/projects/rrifr/Signed-RussianRiverFinalBO9-24-08.pdf

[12] An Overview of the NOAA Habitat Blueprint and a Description of the Russian River Habitat Focus Area, 2013. http://www.habitat.noaa.gov/pdf/shared/NOAA_RR_HBFA_Overview_final.pdf

[13] Russian River Tributaries Water Budget High Resolution Characterization of Historical, Current and Future Conditions, 2013. http://www.habitat.noaa.gov/pdf/shared/NOAA_RR_HBFA_WaterBudget_final.pdf

[14] Russian River kickoff meeting discussion, December 17, 2013.

[15] Russian River Integrated Coastal Watershed Management Plan, 2012. http://mcrcd.org/wp-content/uploads/RussianRiverIRWMP_final1.pdf

[16] Russian River Integrated Coastal Watershed Management Plan, 2012. http://mcrcd.org/wp-content/uploads/RussianRiverIRWMP_final1.pdf

Need for improved forecasting and water management

Why? Improved forecasting of extreme weather events and river levels can improve flooding and drought predictions, which will allow for more effective management decisions regarding supply, flood control, and storage.

This could address some of the following gaps:

- Forecasting river flows, taking into account reservoir releases and water use.
- Enhanced atmospheric river forecasting (help anticipate extreme flooding and adjust releases accordingly).
- Forecast-based operations.[18]

Need for improved hydrologic modeling

Why? Improved hydrologic modeling will increase understanding of flow regimes (for salmon and human use), storage capacity, and—paired with improved meteorological forecasting—potential future hydrologic conditions.

This could address some of the following gaps:

- Surface water and groundwater interactions.[19]
- Understanding of the gain and loss of reaches on tributaries under various levels of impairment and future conditions.[20]
- Sediment transport impacts on flooding and biota.

Need for improved data management

Why? Improved data management can mean better coordination (and less redundant dataset collection or production), as well as data standardization (improves interoperability of models). A better sense of existing data and models means easier prioritization of future data collection efforts and model building.

This could address some of the following gaps:

- The need for more coordination between agencies.
- Improved data interoperability to inform water availability for competing needs.

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[17] Improving Frost Forecasts for the Russian River Basin, 2013. http://www.habitat.noaa.gov/pdf/shared/NOAA_RR_HFA_Frost_Forecast_system_final.pdf

[18] Improve Precipitation and River Flow Forecasting to Maximize Water Capture for Fisheries, 2013. http://www.habitat.noaa.gov/pdf/shared/NOAA_RR_HBFA_PrecipFcastFBO_final.pdf

[19] Case Study—California: Russian River Watershed, 2013. http://cpo.noaa.gov/LinkClick.aspx?fileticket=XsEgCpNf978%3D&tabid=517&mid=1439

[20] Russian River Tributaries Water Budget High Resolution Characterization of Historical, Current and Future Conditions, 2013. http://www.habitat.noaa.gov/pdf/shared/NOAA_RR_HBFA_WaterBudget_final.pdf

APPENDIX C

Russian River Integrated Water Resources

LOCALLY LED PILOT PROJECTS

Integrated Water Resources Science and Services (IWRSS) is a new model for interagency collaboration between the U.S. Geological Survey (USGS), U.S. Army Corps of Engineers (USACE), National Oceanic and Atmospheric Administration (NOAA), and Federal Emergency Management Agency (FEMA). These agencies are working together to develop and implement advanced hydrologic services to address flooding, drought, and other national water-related challenges. IWRSS served a pivotal role in launching the locally led Russian River pilot projects. More than 40 representatives from all levels of government are working collaboratively to address priority issues in the watershed. IWRSS helped strengthen and focus collaboration, which is already yielding benefits beyond those associated with the pilot projects. The four pilot projects are summarized below.

Russian River watershed.

ENHANCED MONITORING

Monitoring data on soil moisture, precipitation, and streamflow reduces uncertainties in modeling and increases confidence in forecasting. This pilot project improves watershed monitoring by identifying locations that are optimal for precipitation gages and represent the complete range of soil responses to precipitation. The USGS and California Water Science Center are identifying monitoring locations, and NOAA's Hydrometeorological Testbed group and the Sonoma County Water Agency (SCWA) are collaborating to install and collect the real-time data. To date, the East and West Forks of the Russian River have been analyzed for monitoring locations. The data will be used to refine and validate watershed models to inform potential applications of forecast informed reservoir operations (FIRO) for Lake Mendocino. Additional stations will be sited in the Lake Sonoma watershed following a one-year analysis of Lake Mendocino data.

NOAA observing station managed by the Sonoma County Water Agency.
Photo by Caitlyn Kennedy

DATA MANAGEMENT AND SHARING

A significant amount of real-time and near real-time hydrologic data are available on the Internet. Unfortunately, there is no single location to view, access, and analyze these data. Consequently, it is burdensome for water managers and stakeholders to view current watershed conditions and use existing data to conduct analyses. This project, led by the SCWA in collaboration with the California Department of Fish and Wildlife and California Water Foundation, will result in a Web-based geographic information management system

Juvenile Coho Salmon depend on reliable stream flows for survival.

that provides a comprehensive overview of real-time hydrologic and meteorological data in the watershed. A scoping study has been completed, and collaborators are using the scoping study to consider options for platform development. This project will result in improved quality and accessibility of hydrometeorological data, reduced time and resources spent sifting through disparate data sets, and improved decision-making.

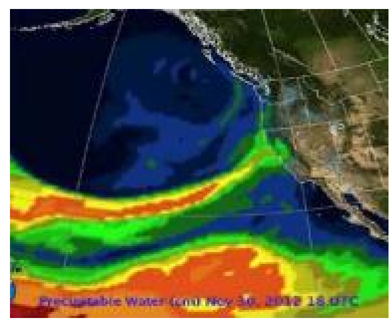
COMPREHENSIVE GEO-DATABASE OF HYDRO-MODELS

Many models have been developed in the Russian River watershed to sup- port studies of local water resources. This project will develop a comprehensive geo-database of models to inform new modeling endeavors. To date, a geo-database consists of hydrologic and hydraulic models that have been developed by or in cooperation with the SCWA within the past 10 years. The geo-database contains summary information about the model and the study that the model supports. This will provide researchers with enough information to determine whether an existing model could be used to support their study. The pilot project's benefits include reducing time spent researching existing models, avoiding duplicate efforts, and providing a tool to track modeling efforts. The geo-database will be expanded to include models completed by local stakeholders and will be publicly available and easy to use.

Lake Mendocino water level, July 2014.

FORECAST INFORMED RESERVOIR OPERATIONS

Lake Mendocino provides flood protection, water supply for municipal and agricultural uses, and flow to support three endangered salmonids. Water levels in Lake Mendocino are governed by a "rule curve," which specifies how much of the reservoir's storage capacity must be used to capture floodwaters throughout the year. Unfortunately, the rule curve does not recognize advances in science and technology. This inflexibility in operations has resulted in the release of valuable water that could have been used for human and environmental needs during dry periods. Several dry years have recently resulted in water supply shortages. Future water demand and climate change will exacerbate this situation. To address this issue, a partnership comprised of USACE, NOAA, the USGS, the SCWA, Scripps Institution of Oceanography Center for Western Weather and Water Extremes, the California Department of Water Resources, and the Bureau of Reclamation is exploring the use of scientific and technological advances to employ FIRO to improve Lake Mendocino water supply reliability without impairing flood protection. The partnership completed a work plan and has begun a preliminary viability assessment. If some FIRO strategies are found to be viable, the project team will develop tools to operationalize these strategies. The project also includes longer term research projects (e.g., improving forecasting of atmospheric river events) to provide for continual improvements in reservoir management.



Atmospheric river approaching the Russian River.

For more information, contact Rob Hartman (Robert.Hartman@noaa.gov)

APPENDIX D

AN APPROACH TO ASSESS THE ECONOMIC BENEFITS OF IWRSS IN THE RUSSIAN RIVER WATERSHED: PILOT PROJECTS TO IMPROVE MONITORING, MODELING, DATA MANAGEMENT AND FORECAST INFORMED RESERVOIR OPERATIONS FOR LAKE MENDOCINO

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List of Acronyms

AF	Acre-feet
CV	Contingent valuation
FIRO	Forecast Informed Reservoir Operations
IWRSS	Integrated Water Resources Science and Service
SCWA	Sonoma County Water Agency
TUCP	Temporary urgency change petition
USACE	U.S. Army Corps of Engineers
WTA	Willingness-to-accept
WTP	Willingness-to-pay

Introduction

The purpose of this project is to develop an approach to estimate the benefits of Integrated Water Resources Science and Services (IWRSS) pilot projects in the Russian River watershed, which could serve as a transferable model for quantifying the benefits of IWRSS at project locations across the county. The pilot projects include developing a data clearinghouse for easier access/exchange of hydrologic data; developing an inventory of models with applicability/limitations information; improving monitoring data, particularly improved soil moisture information; and developing forecast informed reservoir operations (FIRO for Lake Mendocino. We focus on quantifying benefits of FIRO because 1) these benefits draw on the results of the other pilot projects, and 2) FIRO represents a concrete project that will enable identification and quantification of benefits.

A fundamental underpinning of FIRO is improved forecasting of precipitation (and non-precipitation) events through enhanced prediction of atmospheric rivers, which are primarily responsible for precipitation (or the lack thereof) in this region. FIRO entails improving data inputs and modeling outputs for better (more accurate and more lead time) precipitation predictions, which will allow reservoir managers to optimize reservoir operations. Improved predictive capacity can support requests to allow deviations from the U.S. Army Corps of Engineers' (USACE's) "rule curve," which governs seasonal elevations of the flood control pool in the reservoir. Better precipitation predictions could support holding more water in the flood pool when the risk of flooding is low, as well as releasing more water (and at more controlled flows) when high rainfall is predicted, compared to strictly adhering to the rule curve. There are three main ways that FIRO may impact reservoir operations:

1. If lack of precipitation is predicted following a rainfall event, then USACE could retain more water in the reservoir than the rule curve would otherwise allow for use during times of drought (for the purposes of this analysis, we assume a hypothetical storage target of an additional 10,000 acre-feet [AF]). *This is the primary focus of this project.*
2. If heavy precipitation events are predicted, then more water could be released from the reservoir to prevent flooding and retain adequate flood storage capacity in the reservoir in anticipation of the precipitation events.
3. Longer term forecasting can enable the timing and volume of releases to be better controlled to avoid sudden high-volume releases that can harm fisheries.

A wide range of benefits could result from FIRO. Each of these generally stems from one or more of the three actions listed above. Methodologically, each benefit must be treated somewhat differently based on the scenario, data available, and benefit to be measured. In this document, we outline how one could monetize seven benefits: six associated with FIRO and one associated with the other three pilot projects. We identify some relevant data sources and note where there are data gaps.

- **Benefit #1: improved data sharing and better collaboration.** This program will reduce the costs of obtaining information, which frees up resources for other uses.
- **Benefit #2: water supply for agriculture**. Utilizing and improving predictions will allow storage of more water in the reservoir for use by agriculture when water is scarce, increasing production.
- **Benefit #3: water supply for non-agricultural, commercial use.** Utilizing and improving predictions will allow storage of more water in the reservoir for use by businesses when water is

scarce, increasing production for those businesses dependent on sustainable, year-round water supplies.

- **Benefit #4: water supply for residential use**. Utilizing and improving predictions will allow more water to be stored in the reservoir for use by households when water is scarce, increasing the wellbeing of residents.
- **Benefit #5: riverine habitats and fish populations**. Utilizing and improving forecasts may allow for more water to be released from the reservoir during low flow periods, and for flows to be better controlled (timing, velocity) during high flows, which will improve flow conditions, water quality, and habitat and improve fish populations.
- **Benefit #6: recreation**. More water flow during low flow periods will enhance recreational use (e.g., boating, fishing) on the Russian River.
- **Benefit #7: flooding**. Utilizing and improving forecasting of high rainfall events will provide greater lead time for flood preparation and more controlled releases from the reservoir in advance of flooding, which will result in lower damages due to flooding.

There are other benefits that are not be addressed in this report. For example, FIRO benefits to transportation, commercial fisheries, and hydropower are not considered. Another benefit that is not discussed is the value of a collaborative community. Relationships created and maintained through IWRSS are extremely valuable, especially when the region is faced with critical, short-fused challenges. Relationships forged through IWRSS create continuous opportunities for collaboration inside and outside of the Russian River basin. Administrative savings to the Sonoma County Water Agency (SCWA) are also not discussed in this report. When flows fall below certain regulated levels, the SCWA must file temporary urgency change petitions (TUCPs). FIRO may reduce the need to file said petitions and thus save on the costs associated with this requirement.

Quantifying Change in Water Releases

In general, the primary benefits of FIRO stem from improvement and utilization of precipitation and river forecasting in reservoir operations, which would allow deviations from the rule curve. Allowing more water storage in the reservoir during rainfall events enables release of this water during periods of low flow. In order to quantify benefits, an important first step is to determine the change in the amount of water released during periods of low flow (and high water demand). In addition to the quantity of water released during low flow periods, one would also need to assume a total number of dry periods that could benefit and the timeframe over which these occur (because benefits occurring in the future should be discounted).

One criterion to consider is the number of years over which to assess benefits and costs. The timeframe should be long enough for all costs and benefits to accrue. For example, for construction projects, this may be the life of the infrastructure. Since no new infrastructure is created in this project, one would need to consider other methods to determine longevity. We believe a 20- or 50-year time horizon may be appropriate. However, if new technology renders FIRO obsolete, the appropriate time horizon may be shorter.

Another criterion is how often FIRO will result in additional storage and releases. **For the purposes of this exploratory document we assume that 10,000 AF of additional storage (and thus low flow releases) will occur every year, recognizing that during some years there will be less or more opportunities for this to happen** (Johnson, Cifelli, & White, 2015).

Note that the release of 10,000 AF of water can provide multiple benefits to multiple users: even small changes in streamflow may have numerous additive downstream effects. For example, an AF of streamflow increase might be used for recreation, agriculture, power production, and municipal water supply while at the same time helping to assimilate wastes and enhance fish habitat. "The aggregate value of a change in streamflow is equal to the sum of its values in the different instream and offstream uses to which the water is put during its journey to the sea" (Brown, 2004).

Finally, the beneficiaries must be defined. These pilot projects impact the Russian River watershed. Therefore, benefits will accrue mostly to residents, businesses, and governments in Sonoma County and Mendocino County.

Benefit #1: Improved Data Sharing and Better Collaboration

"[D]ata sharing has important long- and short-term benefits for the researcher, the research sponsor, the data repository, the scientific community, and the public." (USGS, 2015)

Improved data sharing and better collaboration reduce the cost of obtaining information, which frees up resources for other uses. These benefits are associated with two of the pilot studies and goals of IWRSS: 1) developing a data clearinghouse for easier access/exchange of hydrologic data, and 2) developing an inventory of models with applicability/limitations information.

Significant resources are spent finding data and researching modeling techniques. Having these data in a central location will reduce resource costs and prevent unnecessary duplication of modeling efforts. Redundant data collection will be avoided and agencies will be able to make more informed decisions that benefit all sectors if they are aware of and can leverage existing data sets. This will save time and expense. There is value in co-developing and using improved models of all kinds. Resources are wasted when agencies develop and model the same processes independently. Resources are also wasted when agencies (local, state, federal) have to spend time understanding and developing confidence in a variety of models that are all doing essentially the same thing. Combined efforts reduce model development resources and time, create a common operating picture, and result in better and more effective models that lead to improved decisions. These improved models then allow for better resource management, which translates into economic benefits.

In addition to reducing costs spent conducting research and developing models, these programs may reduce errors and shorten permit waiting time. If an incorrect model is used, then the results may contain errors—this can result in additional labor costs to reassess the results or, worse, can increase capital costs if infrastructure needs to be altered. Using incorrect models can also increase the time it takes to acquire a permit. Therefore, developing an inventory of models can reduce time and cost.

Methodology: Foregone Cost

Having data in a central location reduces costs.

There are clearly benefits to improved data sharing and better collaboration. However, it is not straightforward to quantify these benefits. If benefits are quantified, we believe the most appropriate method is to calculate foregone costs. This would include reduction in all resource costs, including labor and capital costs. However, alternatively, one could measure benefits by the return on investment for similar previous projects. This methodology is also discussed.

Figure 1 shows the process by which these benefits accrue.

Figure 1: Improved Data Sharing and Better Collaboration Flow Diagram

To measure this benefit using the foregone costs methodology, one would need to know how many resources are saved by developing this clearinghouse and inventory of models. The main resource saved is time, so we focus on the number of labor hours saved. There are two main pieces of information needed to compute this benefit: 1) the number of labor hours saved and 2) the average cost of labor per hour for these workers.

Alternatively, one could measure benefits by the return on investment for similar previous projects. One would want to estimate the social rate of return rather than the return to a single company. For example, Nadiri (1993) found the social rate of return of private research and development expenditures can be twice the private rate of return.

One other benefit of improved data sharing and better collaboration is there may be a reduction in time spent accessing data and efficiently analyzing data. For example, the time it takes to issue and obtain a permit can be reduced because data accessibility allows the analysis to be conducted more efficiently. To calculate such savings, one would need to baseline existing time spent on data (on average, for a specific type of permit) and the reduction in time spent on data (on average, for a specific type of permit) using the data clearinghouse. Time savings can be calculated for both applicants and regulators. In addition, the data clearinghouse may reduce the length of time to obtain a permit (between the time the permit is applied for and the time of issuance). Time savings to permittees can result from reduced project financing costs, yielding additional benefits. To estimate these benefits, one would need to know the reduction in time for permit approval/application, the hourly cost of staff reviewer/permittee time, and the cost of awaiting the permit.

Table 1 shows the types of data needed and potential sources.

Table 1: Data to Quantify Improved Data Sharing and Collaboration Benefits

Data Needed	Potential Source	Example
Reduction in Labor Costs		
Average wage per affected workers	Occupational Employment Statistics (2014)	Environmental engineers earn an average raw wage of $41.51 (without benefits)
Number of labor hours saved	Employee surveys	Employee surveys may be conducted to estimate hours saved

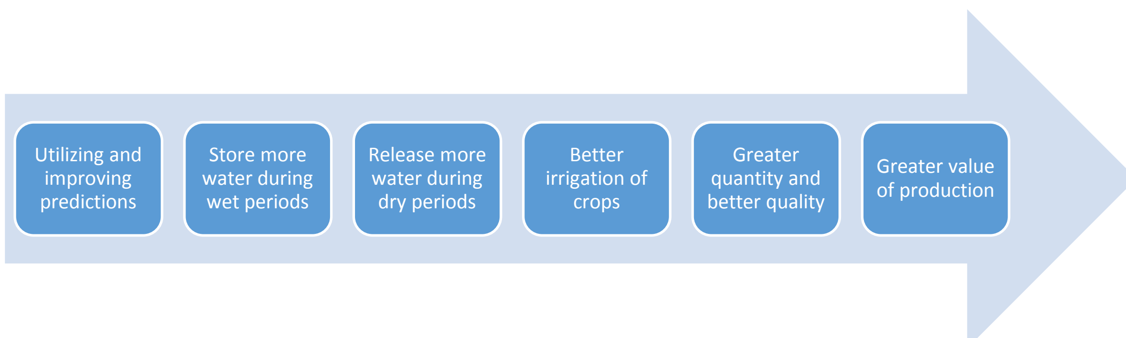
Data Needed	Potential Source	Example
Social Return on Investment		
Return on investment of data sharing	Charles Beagrie Ltd. (2013)	The British Atmospheric Data Center (BADC) shares data, which results in a societal return on investment between 4 and 12, depending on the method

Benefit #2: Water Supply for Agriculture

"Nearly 60 thousand acres of agricultural land is irrigated with water from the Russian River and its tributaries." (Sonoma County Water Agency, 2009)

Utilizing and improving forecasting can allow more water to be stored for use during dry periods, allowing better irrigation of crops and avoidance of crop losses due to drought. This may increase the value of agricultural output by both fallowing less land and generating greater yields on cultivated land. In combination with improved data management and monitoring, this can also lead to more efficient choices by farmers for frost and heat prevention. The majority of this discussion focuses on measuring benefits of improved agricultural output. The process by which benefits accrue can be shown with a flow diagram; see Figure 2.

Figure 2: Agricultural Flow Diagram



To measure this benefit, one would need to know:

- The change in the amount of water released during dry seasons.
- The change in the amount that is available for irrigation.
- How this change in irrigation impacts crop value (or alternatively, what the crop losses would be without this change in irrigation) based on quality and quantity of the crop.

Changes in crop quantity can be measured by changes in yield and acres cultivated while changes in quality are generally measured as changes in price. However, total change in agricultural productivity can be measured as the change in total output price (quantity multiplied by price). Since there are tradeoffs between quality and quantity, it may be easier to measure only the aggregate change in total product attributable to the project.

Although the total quantity of water released from the reservoir may increase, decrease, or stay the same, based on FIRO, more water would be released when in higher demand. Therefore, this analysis may need to consider the marginal productivity of water at different times. In the wet season, when farmers already have enough water, additional flow has little benefit. Conversely, in the dry season, when farmers are short on water, additional flow has large benefits. For example, let's say FIRO anticipates a drought and consequently more water is stored in the reservoir. That water would then be available for release during the drought when the marginal productivity of water is higher.

Methodology: Productivity Method

Utilizing and improving forecasts lead to greater water supply for irrigation and thus greater production value.

Benefits to agriculture are generally measured with either the productivity method (e.g., how much does agricultural production increase) or with avoided costs (e.g., value of the marginal cost of water). The avoided cost method does not capture all benefits, just costs evaded; therefore, we believe the productivity method may be more appropriate.

For demonstration purposes, we attempted to apply the productivity method to agriculture in the Upper Russian River. We identified several data gaps that are necessary to conduct the analysis. Here we lay out the framework for estimating benefits to agriculture and show where data gaps limited our ability to monetize benefits.

We began by modelling current annual supply and demand for agricultural water use in the Upper Russian River and predicting these values forward. Information on demand for agricultural water supply and predicted growth in demand is available from the SCWA (2015). Data on supply was not identified, but if one assumes the market is currently in equilibrium, then supply can be modeled (if in equilibrium, then supply equals demand). Combining current and predicted supply and demand would allow us to estimate unmet demand (i.e., the amount by which demand exceeds supply). Lastly, supply and demand are both impacted by the weather, so predicted weather patterns are necessary. Data on past weather conditions are available, which may provide rough approximations of future weather patterns. However, meteorological modeling would improve the validity.

Next, one would need to determine whether FIRO can supply this unmet demand. The SCWA modeled the hypothetical reservoir operations for the past 100 years with a modified rule curve that resulted in a 20 percent increase in flood space (meant to approximate the effects of FIRO). From this analysis, they tabulated the percentile distribution of the minimum annual storage in Lake Mendocino under the current rule curve and the modified rule curve. These data could be used to ascertain how much more water FIRO might provide. We would then need to identify how much of this additional water would be allocated to agriculture.

The above steps would identify whether additional water would benefit agriculture and whether FIRO could provide this additional water. Next, we would need to estimate the benefit to the agriculture industry if the above conditions are true. Benefits could be estimated as the reduction in damages caused by water shortages that could be offset by FIRO. To determine benefits, we need to know: 1) the current market value, without water shortages, of crops that use water from the Upper Russian River and 2) the percent loss due to limited water supply.

Total agricultural output in Mendocino and Sonoma Counties is available through the counties' crop reports (Sonoma County Office of the Agricultural Commissioner, 2015; Mendocino County Department of Agriculture, 2015). However, only a share of agriculture in these two counties uses water supplied by the Russian River and Lake Mendocino. Therefore, we should only consider the share of agriculture that may be affected. This is unknown, but could be estimated by overlaying maps of agricultural land with areas that are likely to use water from the river or from the aquifer that recharges the river. Additionally, we do not have an estimated loss due to water shortages for all agriculture in the Upper Russian River. However, the wine grape industry in Mendocino County estimated a 19 percent loss due to the drought (Mendocino County Department of Agriculture, 2014). This could be used as a rough approximation, but ideally a model that determines the relationship between water and productivity would be preferred. Finally, the value of the product varies by crop. Even within the wine industry, different vintages can yield quite different revenues; to estimate benefits via the productivity method, one would need to know the value of the crops affected.

Table 2 outlines the data necessary to conduct the analysis described.

Table 2: Data to Quantify Benefits of Water Supply to Agriculture

Data Needed	Source	Example
Agricultural water demand	SCWA	48,365 AF in 2015
Growth in agricultural water demand	SCWA	53,036 AF in 2045 with low growth
Agricultural water supply	Unknown	Could assume the market is in equilibrium
Growth in agricultural water supply	Unknown	Could assume no growth in supply
Future weather patterns	Unknown	Could assume past weather patterns + nonstationarity will continue
Change in the amount of water released	NOAA/SCWA/USACE	Goal is to store an additional 10,000 AF in the flood pool annually
Water supplied by FIRO	SCWA	The SCWA modeled reservoir operations for the past 100 years with a modified rule curve that resulted in a 20 percent increase in flood space
Share of water available for agricultural irrigation	Unknown	Could estimate based on past amount of water allocated for agricultural use, if available
Amount of crops relying on Russian River/Lake Mendocino water in Sonoma County	Unknown	Could be estimated by mapping crop land in areas that draw from the Upper Russian River
Market value, without water shortages, of crops that use water from the Upper Russian River	Unknown	Could use share of total agricultural value provided by Mendocino and Sonoma County Crop Reports
Loss due to water shortages that could be offset by FIRO	Unknown	Could use the 19 percent in the grape industry in Mendocino County as approximation

Other considerations

Better forecasting and improved monitoring can lead to more efficient choices by farmers for frost and heat prevention, which can help reduce water usage by preventing unnecessary protection. The amount of water used for frost and heat prevention is substantial; roughly one-fifth of water demanded for irrigated agriculture is for heat suppression and frost protection (4,891 of 25,669 AF) (Lewis, et al., 2008). This benefit can be valued two ways: 1) the price/value of water and 2) improved crop yields based on avoided damage. In addition to reducing the quantity of water used in frost and heat prevention, better predictions and monitoring can help farmers better protect their crops from frost and heat. This benefit may be less likely depending on the extent to which farmers' practices change (for example, they may tend to "over protect" crops from frost and heat impacts). Interviewing representative farmers is recommended to estimate expected practices and resulting benefits. Valuation would require an estimate of the damage to crops from frost and heat that might be prevented.

Part of the increase in agricultural production is due to more land being farmed. When more land is cultivated, additional labor is required. Therefore, one could tabulate the impact of the project on employment. However, when aggregating benefits, one cannot include increased earnings as a benefit because this would result in double-counting. The production value is equivalent to the income/payments to all factors of production. It can be represented as either total production or total income. We choose to report benefits as total production.

Another thing to consider is that benefits are not necessarily constrained to one year. For example, in wineries, bud development is determined the previous year (Williams, 2000).

Some studies, such as Howitt et al. (2014), include multiplier effects. Increased revenue for farmers has both a direct and indirect impact on the economy. The direct impact is the additional revenue (discussed above). The indirect impact is derived by the multiplier effect: when farmers spend this additional income, it generates additional production and income for other workers and the process continues to repeat.

Benefit #3: Water Supply for Non-Agricultural, Commercial Uses

"The hardest hit industries are those that are water-intensive, such as wineries, restaurants, construction. Job losses are concentrated in these industries. Grocery stores, banking and financial jobs, employment and other professional services are affected based on the entire economy contracting further." (Sonoma County Water Agency, 2009)

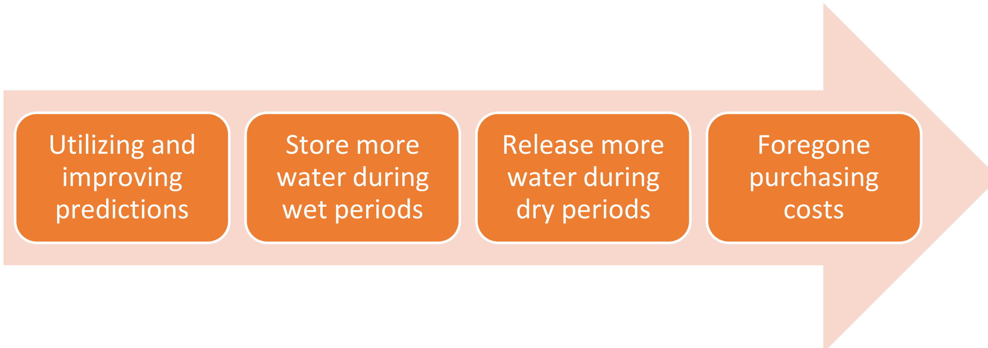
FIRO will allow USACE to store more water in the reservoir for use by businesses when water is scarce. This is similar to the process by which the agriculture industry benefits, as discussed above. We separate agriculture and other businesses because agriculture is more likely to get a portion of its water through its own supplies, whereas other businesses are more likely to purchase their water from a municipality.

As with agriculture, benefits accrue because a greater supply of water may increase production. This can be due to both more production taking place (external margin) and greater productivity for production that would take place regardless (internal margin). One way to measure benefits is the change in production. However, this may be hard to measure for many businesses because there are many factors affecting production that are hard to disentangle. An alternative, and potentially more straightforward approach, is to use foregone cost methodology to measure benefits. One would compare total expenditures on water with FIRO to expenditures on water with the current paradigm . The difference in expenditures is the net benefit. Figure 4 shows the process by which benefits accrue to non-agricultural businesses.

Methodology: Foregone Cost

Utilizing and improving forecasts lead to greater water supply and thus less expenditure on water.

Figure 3: Water Supply to Businesses Flow Diagram



To measure this benefit, one would need to know:

- Cost of water to businesses during dry season under current paradigm.
- Cost of water to businesses during dry season with FIRO.
- Quantity of water purchases by businesses during dry season under current paradigm.
- Quantity of water purchases by businesses during dry season with FIRO.

Table 3 shows the types of data needed and potential sources.

Table 3: Data to Quantify Benefits of Water Supply for Non-Agricultural Commercial Use

Data Needed	Potential Source	Example
Cost of water to businesses during dry season under current paradigm	SCWA, Mendocino County	Water rates during historical low flow periods
Cost of water to businesses during dry season with FIRO	N/A	Would need to model market
Quantity of water purchases by businesses during dry season under current paradigm	SCWA, Mendocino County	Water quantities during historical low flow periods
Quantity of water purchases by businesses during dry season with FIRO	N/A	Would need to model market

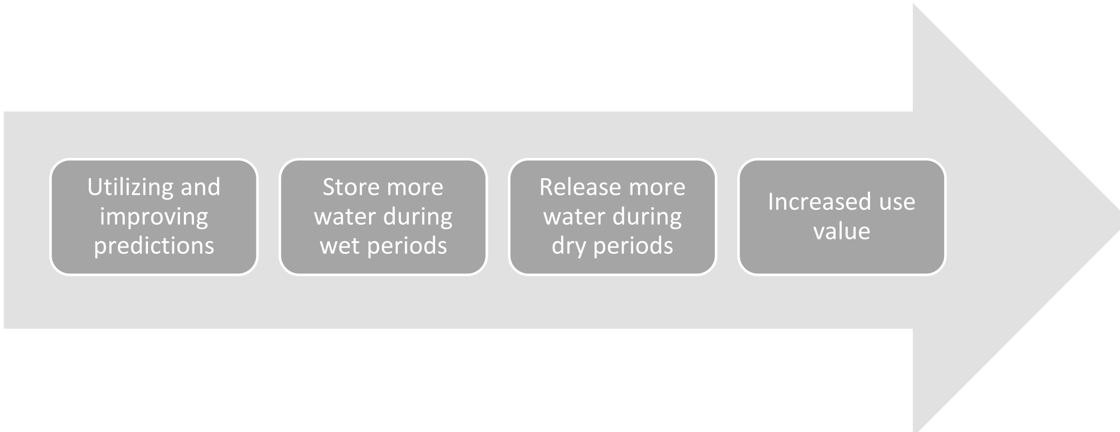
Benefit #4: Water Supply for Residential Use

"Lake Mendocino and Lake Sonoma water plays a significant role in providing drinking water to about 750,000 residents in portions of Mendocino, Sonoma and Marin counties." (Sonoma County Water Agency, 2009)

For the purposes of this analysis, residential water restrictions are presumed detrimental to households because (although attitudes are changing) conserving water is considered an inconvenience and may reduce utility (e.g., utility may be lower if someone who values green lawns cannot maintain one). One way to measure the change in utility is by multiplying the change in quantity of water consumed by the price of water.

Figure 4 shows the process by which benefits accrue for drinking water supply.

Figure 4: Drinking Water Flow Diagram



To value this benefit using use-value methodology, estimates of the following are needed:

- The value of water to households.
- The change in the quantity of water purchases by households because of FIRO.

The true value of water to households is unknown. However, a reasonably good and easily available proxy is the price paid by households for water (Table 4). A potential concern with using price to measure value is it tends to results in an underestimate. There are alternative methods one could use to estimate value. For example, one could directly ask households the value they place on marginal water supply. This could be conducted with a contingent valuation (CV) study that estimates the respondents' willingness-to-pay (WTP) or willingness-to-accept (WTA).

Table 4: Data to Quantify Benefits of Water Supply for Residential Use

Data Needed	Potential Source	Example
Price of water	Public Policy Institute of California (2011)	The average price of treated water delivered to households was roughly $960 per AF (in 2008 $)
	Sonoma County Water Agency (2015)	Average cost per household $0.80 per day or $.002 per gallon ($652 per AF) [a]
	The Mendocino County Russian River Flood Control and Water Conservation Improvement District (2015)	$47 per AF
Value of water	CUWA (1994)	CV surveys show California household WTP is $12 to $17 more per month to avoid water shortages
Change in the amount of water released	NOAA/SCWA/USACE	Goal is to store an additional 10,000 AF in the flood pool annually
Change in quantity of water used by households due to project	Public Policy Institute of CA (2011)	Roughly 80% of water in the state is used in agriculture. Assume half of remainder is for households.

[a] Determined by multiplying $.002 by 326,000. 326,000 is a rough estimate of the number of gallons in an AF based on 1 AF/year = approximately 893 gallons (3.38 m³) per day.

Based on the above numbers, a hypothetical example of a rough estimate of the value of an additional 10,000 AF of water during a drought is $6.5 million ($652 per AF multiplied by 10,000 AF). This assumes the cost to households of foregoing this water during non-drought times is zero, since FIRO does not generate more water, just changes when it is released. It also assumes households value water at the amount they pay for water.

There are several secondary benefits to municipalities that one may want to consider. First, less rapid releases of water from the reservoirs in anticipation of large storms leads to less erosion and better water quality. This could potentially be measured as avoided costs of treating the water. Second, better supply of water in the Russian River may lead to less reliance on groundwater pumping, which has associated costs (e.g., energy).

Benefit #5: Habitats and Fish Populations

"Coho and Chinook salmon and steelhead trout, species listed on the endangered species list, depend on water to be released from reservoirs for spawning, rearing, and out migration." (Sonoma County Water Agency, 2009)

A major benefit of FIRO (and the associated improvements of the other pilot projects in monitoring, modeling and data management/accessibility) is it may allow USACE to release more water from the reservoir during dry periods, improving streamflow conditions. Additionally, it may allow better controlled releases when precipitation is forecast, which will improve habitats by reducing turbidity. There are three endangered or threatened fish species in the Russian River that would benefit: the Coho salmon, the Chinook salmon, and the Steelhead trout (however, the largest impact would probably be for Chinook since they spawn in the mainstem of the Russian River).

In general, healthy habitats provide a benefit to society: "studies have shown that regardless of direct interaction with salmon populations, many Californians hold a positive willingness to pay to ensure the long-term survival of salmon" (ECONorthwest, 2012). This section focuses on the benefit of improved habitats from a societal standpoint. It does not include ecosystem services derived from use of the habitat, such as recreation (which is considered in the following section).

In particular, this section focuses on one benefit of improved habitats that can be quantified: the benefit of improved fish populations. To measure this benefit, one would need to know 1) the increase in fish populations due to FIRO and 2) the value society places on each fish. The value of fish can be monetized using non-use evaluation methods, such as CV, and will be discussed in more detail below. Estimating the impact of FIRO on fish populations is somewhat more complicated. Fish populations are impacted by water levels, flows, turbidity, temperature, and dissolved oxygen content, all of which may be influenced by FIRO. There is not a clear relationship between these variables and fish populations. Additionally, there are no clear predictions on how FIRO will impact these variables. Each of these variables and their impact on fish populations is discussed briefly.

Methodology:
Benefit Transfer Analysis and Contingent Valuation

Benefit transfer analysis applies benefits derived from previous studies. These previous studies may use contingent valuation to determine non-use values.

Water levels and flows: Utilizing and improving forecasts may allow USACE to release more water from the reservoir during dry periods and less water during wet periods, improving water levels and flows.[21] Studies have found that fish survival rates are dependent on both the amount of water and the rate at which the water is flowing, especially during the spring and fall salmon runs. Low water levels may result in fish being caught in pools (British Columbia Heritage, 2015). High velocity flows can also be detrimental.[22,23]

Turbidity: FIRO may prevent releases of large quantities of water immediately before an expected storm. This will benefit fish populations through improved water quality. Lower velocity flows lead to less erosion and thus less sediment deposition and water turbidity, thereby improving conditions for fish.[24]

Temperature: Water temperature is an important factor in the physiological transition of juvenile salmonids. Rising water temperature is an environmental cue that triggers the smoltification process. If water temperature is too low, then smolts may remain in freshwater for another year (Zedonis & Newcomb, 1997). Conversely, high water temperature during migration can cause stunted growth.[25] The quantity and timing of reservoir water releases can impact water temperature and thus fish populations. Letting the reservoir get too low raises water temperatures, and when the water is released, it is too warm for anadromous fish. Large releases of water from the reservoir can also result in temperature drops in the river because reservoir temperatures can be colder than river temperatures. Therefore, to prevent the water from being too cold, releases should be made gradually (which is also beneficial due to decreased turbidity discussed above).

Dissolved oxygen: Water flows and temperature also have an indirect effect on fish populations by influencing dissolved oxygen levels. Low dissolved oxygen levels influence growth, food conversion ratios, disease, and more (Mallya, 2007). If water flow levels are too low or temperatures too high, dissolved oxygen levels are low.

Figure 5 and Figure 6 show the process by which benefits accrue from improved habitat.

[21] The SCWA has filed five TUCPs to allow flow levels to drop below required minimums. This occurred because low water levels in the reservoir required lower flow levels to fulfill water contracts and maintain adequate storage levels. This occurred in 2007, 2009, May 2013, December 2013, and 2014. FIRO could reduce the incidence of this happening, which may help fish populations. However, the impact on fish populations is uncertain. Some literature suggests current levels may be too high for young fish, in which case dropping below the minimum threshold may be beneficial (Sonoma County Water Agency, 2015).

[22] Increased flows reduce travel time for smolts; Achord et al. (1996) suggested releasing more water after mid-May may be beneficial to outmigrating Chinook smolts (Zedonis & Newcomb, 1997).

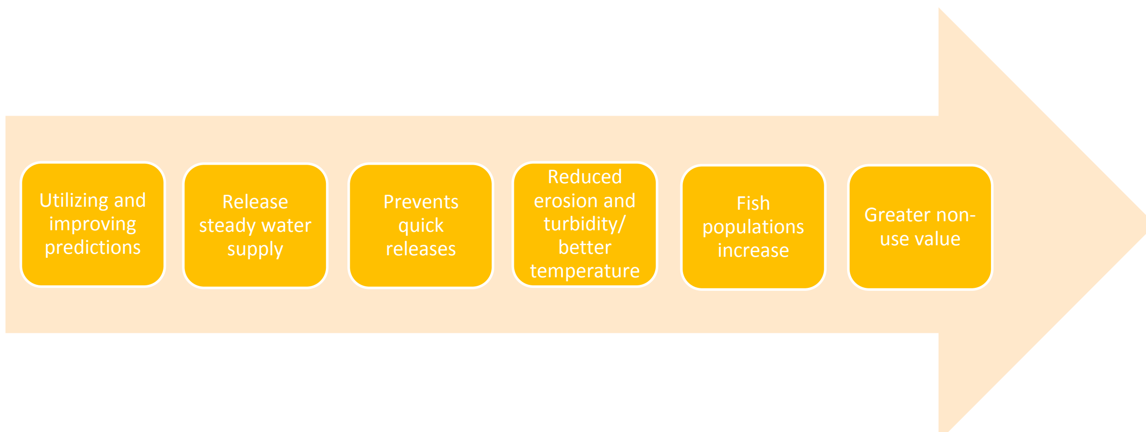
[23] Current flow levels are too high for young Coho salmon and steelhead during the summer months, so additional releases during these months may have a negative impact on fish populations (Sonoma County Water Agency, 2015).

[24] For more information on the relationship between turbidity and fish populations, see Alabaster and Lloyd (1982).

[25] Additionally, high water temperature is associated with less dissolved oxygen, which can hurt fish populations.

Figure 5: Improved Fish Populations Flow Diagram – Benefits from Greater Flow during Migration

Figure 6: Improved Fish Populations Flow Diagram – Benefits from Steady Flow



We present two methods to quantify the value of changes in fish populations. The first step is the same in both: estimate the change in fish populations. As discussed above, this can be influenced by a variety of factors. Here we discuss how to value the change in fish population once the change has been identified. The first approach uses non-use values of fish. The second approach considers the market value of these fish if they were to be delisted as endangered/threatened.

Approach #1: non-use value. One could use non-use values from CV studies. CV studies ask survey respondents how they value a commodity. A CV study could be conducted for this analysis, but conducting these surveys can be costly and time-consuming. An alternative option is to use benefit transfer analysis. In benefit transfer analysis, applicable findings from other studies (likely CV) are analyzed and applied to the current study.

Approach #2: market value. This approach considers the benefits to commercial fisheries if the threatened/endangered fish populations were to be delisted. This would theoretically allow a market value for these fish.[26] To estimate these benefits, one would need to know how much additional water

[26] Even if the populations of fish were to increase in the Russian River this may not impact ocean fishing since populations may still be limited in other rivers. For example, quotas for the "Fall-run" Chinook are presently based on Klamath River escapement.

is necessary to restore these populations to the levels where a commercial market would develop. We would also need to know the value of said market.

Table 5: Data to Quantify Benefits of Improved Fish Populations

Data Needed	Potential Source	Example
Data necessary for all approaches		
Current fish populations in Russian River	California Department of Fish & Wildlife (2014)	107 Coho salmon in 2012/2013 6,713 Chinook salmon in 2012/2013 334 steelhead in 2012/2013
Change in fish populations	Modeled, expert panel, or benefit transfer Obedzinski & Nossaman (2012)	FIRO will increase fish populations by X Correlation between flow with over-summer survival of juvenile Coho found to be weak to moderate
Data necessary for approach #1: Non-use value		
Non-use value of improved fish populations	Olsen, Richards, and Scott (1991)	Value per fish= $500
	Loomis (1996)	Value per fish= $4,200
	Bell, Huppert, and Johnson (2003) [a]	Value per fish= $9,300
Data necessary for approach #2: Market value		
Market value of fish populations	WildSalmonSeafood.com NASDAQ	$10–$21 per pound for wild Pacific salmon $40.89 per kilogram–$18.59 per lb. (97-week average on commodity market for Atlantic salmon)
Required population to delist as endangered/threatened	The Nature Conservancy (2013)	10,100 for Coho [b] 9,900 for Chinook [c] 25,800 for steelhead [c]
Additional water necessary to restore these populations	Modeled, expert panel, or benefit transfer	An additional X AF are required

[a] Other potential sources include NOAA's Office of National Marine Sanctuaries and USACE.

[b] "Spawning adult fish recovery target represent the biological conditions National Marine Fisheries Service [NMFS] would use to delist the species and remove them from the Federal List of Endangered and Threatened Wildlife and Plants (50 CFR 223.102)" (NMFS 2012a).

[c] "Chinook salmon and steelhead in the Russian River are federally listed as threatened; however, NMFS recovery targets are not yet defined. Spawning adult fish abundance numbers listed here are characteristic of the populations having high probability of long-term (>100 years) persistence."

Benefit #6: Recreation

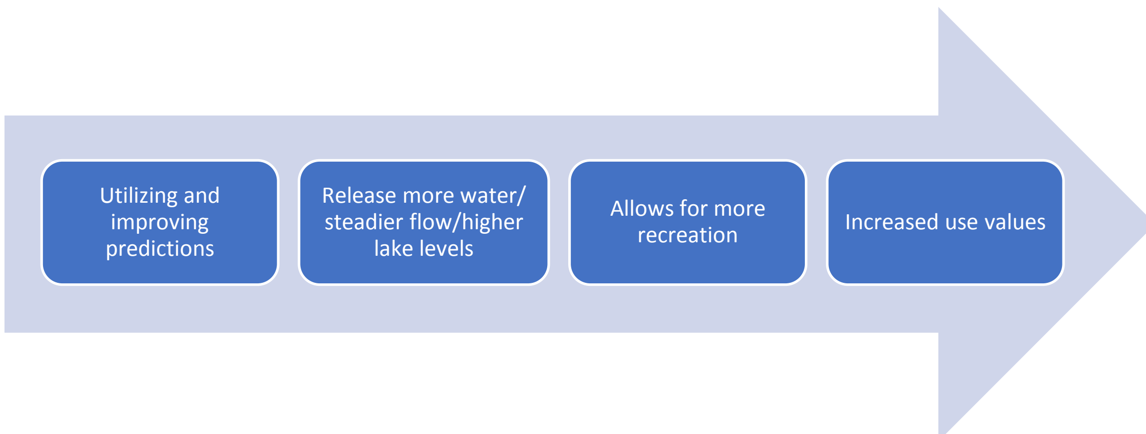
"[Recreation] and tourism depend on water released from the reservoirs." (Sonoma County Water Agency, 2009)

FIRO can lead to a steadier stream of water flowing through the Russian River, which increases opportunities for recreation. Additionally, the higher water levels in Lake Mendocino, due to the adjusted rule curve, may result in more recreational use. For example, researchers have found that reduction in flows from Potter Valley have decreased recreation in Lake Mendocino. This recreation is valued at roughly $2.5 million. FIRO may be able to help recover some of this lost revenue (Dillabough, 2015). Figure 7 shows the process by which recreation benefits may accrue.

Methodology: Benefit Transfer Analysis, Travel Cost, and Contingent Valuation

Benefit transfer analysis will be used to apply benefits derived from previous studies. These previous studies will utilize travel cost and contingent valuation methods to measure daily use values.

Figure 7: Increased Recreation Flow Diagram



One could value additional recreational activity with the following data:

1. The current types of recreation and usage amounts.
2. The change in recreation usage by activity type attributable to FIRO.
3. Daily use values by activity type.

Data on recreational use in the Russian River basin may be directly measured from government sources; however, in our initial research, we were unable to find such estimates. Therefore, one may need to compile data from recreational vendors. Estimating the change in recreation usage attributable to FIRO is likely to be the most difficult aspect. This may require modeling, compiling an expert panel, or conducting benefit transfer if similar initiatives were enacted elsewhere.

The third step is estimating daily use values. Ideally, one would conduct an original survey to identify users' valuations through either a travel cost or CV methodology. A more feasible approach is to use benefit transfer to determine daily use values. Benefit transfer analysis applies existing studies' results to derive benefits. Benefit transfer analyses are successful when the characteristics of the location studied are similar to the location where they are being applied. Because many studies have been conducted on use values, we believe one could identify appropriate values for the Russian River. Dr. John Loomis from Colorado State University has compiled a large database of recreational use values which would be a useful resource. Another valuable resource is the Environmental Valuation Reference Inventory (2015).

Table 6: Data to Quantify Recreational Activity Benefits

Data Needed	Potential Source	Example
What recreational activities are done in Russian river and lake Mendocino	Sonoma County Chamber of Commerce	Boating, kayaking/canoeing, stand-up paddle boarding, fishing, wildlife watching, swimming
Additional days of recreation	Modeled, expert panel, or benefit transfer	FIRO will result in X additional days of river recreation
Daily participation rates, per activity	Russian River Chamber of Commerce	On average, there are X boaters on the Russian River per day
Daily use values, per activity	Loomis (2005)	One study included found that the value of fishing day in California is $26.89
Revenues for recreation	Business data	Revenues for boat rentals in the Russian River is $X annually

Recreational fishing differs somewhat from other recreational activities because it yields a good which can then be consumed, resulting in two benefits: recreation and consumption. If use values only reflect recreational value, then one may also want to account for the monetary value of the fish caught and not released.

An indirect benefit to consider is job creation from increased recreation. This is somewhat harder to quantify since it is not clear whether these jobs come at the expense of other jobs. For example, if people did not partake in water recreation, then they may have sat at home and watched TV, in which case water recreation probably increases total jobs. However, if they took cooking classes instead of partaking in water activities, then the increase in water recreation may not increase total jobs.

Another potential benefit is increased safety of participants due to better weather forecasts. For example, “storm forecasts alert boaters, fishermen and swimmers of potential threats so that they do not get caught in life threatening conditions.” (Johnson, Cifelli, & White, 2015). To quantify this benefit, one would need to know several pieces of information that are difficult to obtain, including the additional number of advisories that would be put into effect and the impact of each on property and lives.

Benefit #7: Flooding

According by the National Flood Warning Council increased preparation time results in approximately a 10% reduction in annual damages. (Johnson, Cifelli, & White, 2015)

FIRO may result in benefits from reduced flood damages. Use of and improvement in precipitation forecasts can prevent flooding by 1) releasing more water from the reservoir prior to a large storm, causing Lake Mendocino releases to be less likely to cause flooding during an event, and 2) allowing greater lead time to prepare for storms and flooding (e.g., to place sandbags, evacuate people). Other secondary benefits may include improved water quality due to less frequent sewage overflow events, as well as less wear and tear on stormwater infrastructure, thereby extending the longevity

Methodology: Avoided Cost

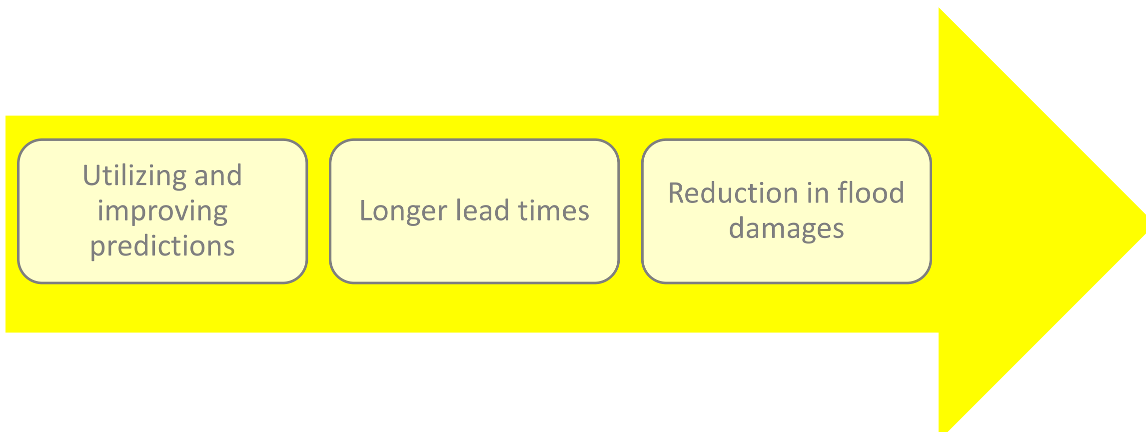
Utilizing and improving forecasts leads to better preparations and consequently reduced damages.

of the system. Conversely, FIRO may result in water levels rising above the suggested flood pool in anticipation of a drought. If this is followed by a large, unpredicted storm, then the area downstream of Lake Mendocino may be more likely to flood.

Benefits of reduced flooding include:

- Reduction of loss of life.
- Reduction of loss of property.
- Improved water quality.
- Less operation and maintenance costs of stormwater infrastructure.

Figure 8: Reduced Flooding Damages Flow Diagram



Better information will allow decision-makers to prepare for flooding (e.g., place sandbags, evacuate people). If flooding occurs, then these actions yield benefits; however, if flooding does not occur, they incur costs without any benefits. Therefore, you want to maximize the probability you prepare when flooding would have otherwise occurred and minimize precautions when flooding would not have occurred.

To estimate benefits, one would need to know:

- The expected cost of flooding during the life of the project.
- The reduction in flooding costs due to increased lead time.

When evaluating benefits, one may want to separate damages associated with loss of life, structural damage, and property damage. For example, Hazus modeling can be used to evaluate structural damages associated with flooding. Literature on the value of a statistical life could be used to evaluate benefits associated with fewer deaths.

Table 7: Data to Quantify Reduction in Flooding Costs

Data Needed	Potential Source	Example
How lead time impacts damages	National Hydrologic Warning Council (2002)	Increased lead time results in approximately a 10% reduction in annual damages
	Day (1970)	The Day curve shows the relationship between lead time and damages
	Carsell, Pingel, & Ford (2004)	Model to determine the relationship between lead time and damages
Flood level data	USACE	USACE may be able to provide data on the relationship between reservoir levels and flood depth levels
Flood damages	Case Study: California: Russian River Watershed (NOAA, 2013)	2006 New Year's Day flood resulted in $104 million in damages to Sonoma County businesses and residences
	Sonoma County Fire and Emergency Services Department (2011)	Flood costs in Sonoma County from 1995 to 2006
	Los Angeles Times (1987)	Flood of 1986 cost roughly $40 million (in 1986 dollars)
	Ralph, Neiman, Wick, & Gutman (2006)	List of all floods along Russian River between 1997 and 2006
	CaDWR (1965)	1964 flood caused damages of $15.2 million in Mendocino County and $6.4 in Sonoma County
	FEMA's Hazus program (2015)	Hazus is a modeling method to estimate structural damages

As a simple hypothetical example, let's say the New Year's Day flood is a 100-year storm and the life of the project is 20 years; the probability of this storm occurring within the 20-year period is 20 percent. If increased lead time reduces damages by 10 percent, then expected benefits would be roughly $2.08 million ($104 x 20 percent x 10 percent). Note that this is just one example of costs from a major storm. There may also be benefits for smaller storms.

Bibliography

Achord, S. G., Matthews, M., Johnson, O. W., & Marsh, D. M. (1996). Use of passive integrated transponder (PI1) tags to monitor migration timing of Snake River chinook salmon smolts. *North American Journal Fisheries Management, 16*, 302-313.

Alabaster, J. S., & Lloyd, R. S. (1982). *Water Quality Criteria for Freshwater Fish.* Butterworths.

Bell, K. P., Huppert, D., & Johnson, R. L. (2003). Willingness to Pay for Local Coho Salmon Enhancement in Coastal Communities. *Marine Resource Economics, 18*(1), 15.

Bren School of Environmental Science & Management, UCSB. (2015). *Water Transfer Level Dataset.* Retrieved 2015 from Bren School of Environmental Science & Management: http://www.bren.ucsb.edu/news/water_transfers.htm

British Columbia Heritage. (2015). *Water*. Retrieved 6 24, 2015, from British Columbia Heritage: http://bcheritage.ca/pacificfisheries/habitat/water.html

Brown, T. C. (2004). The Marginal Economic Value of Streamflow from National Forests: Evidence from Western Water Markets. *Advancing the Fundamental Sciences: Proceedings of the Forest Service National Earth Sciences Conference*, (pp. 458-466). San Diego, CA.

California Department of Water Resources. (1965). *FLOOD! December 1964-January 1965.* California Department of Water Resources.

California Urban Water Agencies. (1994). *The Value of Water Supply Reliability: Results of a Contingent Valuation Survey of Residential Customers.* Oakland, CA: California Urban Water Agencies.

Charles Beagrie Ltd and The Centre for Strategic Economic Studies (CSES), Victoria University. (2013). *The Value and Impact of Data Sharing and Curation: A synthesis of three recent studies of UK research data centres.* Swindon, England: The Economic and Social Research Council (ESRC).

Christian-Smith, J., Levy, M., & Gleick, P. H. (2011). *Impacts of the California Drought from 2007 to 2009.* Oakland, CA: Pacific Institute.

Dillabough, M. (2015). (A. O'Donnell, & T. Forsell, Interviewers)

ECONorthwest. (2012). *Handbook for Estimating Economic Benefits of Environmental Projects.* Eugene, OR: ECONorthwest.

Environmental Valuation Reference Inventory (EVRI). (2015). *Environmental Valuation Reference Inventory (EVRI)*. Retrieved 6 24, 2015, from https://www.evri.ca/Global/Splash.aspx

FEMA. (2015). *Hazus*. Retrieved from FEMA: https://www.fema.gov/hazus/

Graham, R. (2012). *Klamath River Basin Restoration Nonuse Value Survey.* Sacramento, CA: U.S. Bureau of Reclamation.

Howitt, R. E., Medellín-Azuara, J., MacEwan, D., & Lund, J. R. (2014). *Preliminary 2014 Drought Economic Impact Estimates in Central Valley Agriculture.* California Department of Food and Agriculture.

Johnson, L. E., Cifelli, R., & White, A. B. (2015). *Benefits of an Advanced Quantitative Precipitation Information System: San Francisco Bay Area Case Study.* Boulder, CO: NOAA.

Lewis, D. J., McGourty, G., Harper, J., Elkins, R., Christian-Smith, J., Nosera, J., . . . Prichard, T. (2008). *Meeting irrigated agriculture water eds in the Mendocino County portion of the Russian River.*

University of California Cooperative Extension Mendocino County, University of California Davis Department of Land Air and Water Resources, and University of California Kearny Agricultural Center.

Loomis, J. (2005). *Updated Outdoor Recreation Use Values on National Forests and Other Public Lands.* U.S. Department of Agriculture.

Loomis, J. B. (1996). Measuring the Economic Benefits of Removing Dams and Restoring the Elwha River: Results of a Contingent Valuation Survey. *Water Resources Research, 32*(2), 441–447.

Los Angeles Times. (1987). *Russian River Area Picks Up After the Devastation of 1986 Floodwaters.* Retrieved 2015 from Los Angeles Times: http://articles.latimes.com/print/1987-02-22/news/mn-5100_1_worst-flood

Mallya, Y. J. (2007). *The Effects of Dissolved Oxygen on Fish Growth in Aquaculture.* Reykjavik, Iceland: The United Nations University.

Mendocino County Department of Agriculture. (2014). *Mendocino County Department of Agriculture Drought Survey.* Ukiah, CA: Mendocino County Department of Agriculture.

Mendocino County Department of Agriculture. (2015). *Mendocino County 2014 Crop Report.* Ukiah, CA: Mendocino County Department of Agriculture.

Nadiri, M. l. (1993). Innovations and Technological Spillovers. *NBER Working Paper Series 4423*.

National Hydrologic Warning Council. (2002). *Use and Benefits of the National Weather Service River and Flood Forecasts.* National Hydrologic Warning Council.

NOAA. (2013). *Case Study: California: Russian River Watershed.* Retrieved 2015 from http://cpo.noaa.gov/sites/cpo/Projects/SARP/CaseStudies/2013/Russian%20River%20Basin%20CA_Case%20Study%20Factsheet_Extreme%20Weather%20Events_2013-2-6v1.pdf

Obedzinski, M., & Nossaman, S. (2012). *Summer survival of hatchery released young-of-year coho in relation to flow and other environmental variables in Russian River tributaries.* Santa Rosa, CA: University of California Cooperative Extension and California Sea Grant.

Olsen, D., Scott, R. D., & Richards, J. (1991). An Existence Value Study for Doubling the Size of the Columbia River Basin Salmon and Steelhead Runs. *Rivers, 2*(1), 44-56.

Public Policy Instititute of California. (2011). California Water Today. In C. D. (CaDWR), *Managing California's Water: From Conflict to Reconciliation* (pp. 71-134). San Francisco, CA: Public Policy Instititute of California. Retrieved 2015 from http://www.ppic.org/content/pubs/report/R_211EHChapter2R.pdf

Ralph, F. M., Neiman, P. J., Wick, G. A., & Gutman, S. I. (2006). Flooding on California's Russian River: Role of Atmospheric Rivers. *Geophysical Research Letters, 33*.

Schulte, P. (2010). Using Recycled Water on Agriculture: Sea Mist Farms and Sonoma County. In P. Institute, *Pacific Institute Farm Water Success Stories: Recycled Water and Agriculture.* Pacific Institute. From http://agwaterstewards.org/images/uploads/docs/recycled_water_and_agriculture3.pdf

Sonoma County Fire and Emergency Services Department. (2011). Flood Hazard and Risk Assessment. In S. C. Department, *Sonoma County Hazard Mitigation Plan* (pp. 85-130).

Sonoma County Office of the Agricultural Commissioner. (2015). *2014 Sonoma County Crop Report.* Santa Rosa, CA: Sonoma County Agricultural Commissioner.

Sonoma County Water Agency. (2009). *Water Storage Projection: Reservoir Will Run Dry.* Retrieved 2015 from Sonoma County Water Agency: http://www.scwa.ca.gov/lower.php?url=press-releases&article=water-storage-projection-reservoir-will-run-dry-2009-02-02

Sonoma County Water Agency. (2015). *Lake Mendocino Water Supply Reliability Evaluation Report.* Santa Rosa, CA: Sonoma County Water Agency.

Sonoma County Water Agency. (2015). *Water Rates*. Retrieved 2 12, 2015, from Sonoma County Water Agency: http://www.scwa.ca.gov/water-rates/

The Herzog Group, Inc.; CH2MHILL. (2006). *Guidelines for the Appraisal of Water Rights in California.* Modesto, CA: U.S. Fish and Wildlife Service.

The Mendocino County Russian River Flood Control and Water Conservation Improvement District. (2015). *Water Supply.* Retrieved 2015 from The Mendocino County Russian River Flood Control and Water Conservation Improvement District: http://rrfc.net/Water%20Supply

The Nature Conservancy. (2013). *Russian River Salmon Snapshot for 2012/13.* The Nature Conservancy. Retrieved 2015 from http://www.casalmon.org/uploads/watersheds/1413228883-321098a5e8bc4ba57/SalmonSnapshot_russian_river_2012-13.pdf

The Nature Conservancy. (2014). *California Salmon Snapshotes: By The Numbers.* Retrieved 2015 from The Nature Conservancy: http://www.casalmon.org/by-the-numbers

U.S. Bureau of Reclamation, Mid-Pacific Region (USBR-MP). (2011). *Summary of Water Supply Allocations, Historical.* Retrieved 2015 from http://www.usbr.gov/mp/cvo/vungvari/water_allocations_historical.pdf

U.S. Department of Labor, Bureau of Labor Statistics. (2010). *National Compensation Survey.* Washington, D.C.: U.S. Department of Labor, Bureau of Labor Statistics.

U.S. Department of Labor, Bureau of Labor Statistics. (2014). *Occupational Employment Statistics.* Washington, D.C.: U.S. Department of Labor, Bureau of Labor Statistics.

USGS. (2015). *USGS Data Management*. Retrieved from USGS: http://www.usgs.gov/datamanagement/share/guidance.php

Wichelns, D. (2010). *Agricultural Water Pricing: United States.* OECD.

Williams, L. E. (2000). Bud Development and Fruitfulness of Grapevines. In L. P. Christensen, *Raisin Production Manual* (pp. 24-29). Oakland, CA: University of California, Agriculture and Natural Resources Communication Services.

Zedonis, P. A., & Newcomb, T. J. (1997). *An Evaluation of Flow and Water Temperatures during the Spring for Protection of Salmon and Steelhead Smolts in the Trinity River, California.* Arcata, CA: U.S. Fish and Wildlife Service, Coastal California Fish and Wildlife Office.