Final Study Plan

Klamath Hydroelectric Project Interim Measure 11
Study Activities for 2020

April 8, 2020

Introduction

The Klamath Hydroelectric Settlement Agreement (KHSA; as amended on April 6, 2016) includes Interim Measure 11 (Interim Water Quality Improvements), which is intended to address water quality improvement in the Klamath River during the interim period leading up to potential dam removal. Regarding Interim Measure (IM) 11, the KHSA states "The emphasis of this measure shall be nutrient reduction projects in the watershed to provide water quality improvements in the mainstem Klamath River, while also addressing water quality, algal and public health issues in Project reservoirs and dissolved oxygen in J.C. Boyle Reservoir." The measure calls for PacifiCorp to spend up to $250,000 per year[1] for studies or pilot projects in consultation with the Interim Measures Implementation Committee[2] (IMIC). Specifically, 2020 Activities described[3] in this study plan that are related to IM 11 include:

1. Sprague River Valley Floodplain Restoration
2. Evaluation of the Iron Gate Intake Barrier Curtain System for Water Quality Improvement of Powerhouse Releases
3. Increasing Sediment Phosphorus Binding Capacity in the Upper Klamath Lake: Phase 1, Initial Feasibility Study for Phoslock™
4. Tulelake Irrigation District Modernization Study

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[1] Per year until the date that the Dam Removal Entity (DRE) accepts a Surrender Order issued by the Federal Energy Regulatory Committee (FERC) regarding the Klamath Hydroelectric Project. The KHSA indicates that up to 25 percent of the funding in this measure for pre-surrender-order acceptance studies and post-surrender-order acceptance implementation may be directed towards in-reservoir water quality improvement measures, including but not limited to J.C. Boyle reservoir.

[2] The IMIC is comprised of representatives from PacifiCorp and other parties to the KHSA. The purpose of the IMIC is to collaborate with PacifiCorp on ecological and other issues related to the implementation of the Non-Interim Conservation Plan Interim Measures set forth in Appendix D of the KHSA.

[3] Note that the descriptions of the following studies are essentially as submitted by the parties seeking funding. The only changes made have been in formatting and removal of cost information. This results in some inconsistencies in structure, abbreviations, terminology, and other elements between the different studies described in this document.

1: Sprague River Valley Floodplain Restoration

Submitted by: Trout Unlimited

Purpose and Objectives

Phosphorus loading from anthropogenic sources has contributed to the eutrophication of Upper Klamath Lake (UKL). Though historically a productive lake, excess phosphorus has led to large cyanobacterial blooms in UKL that severely degrade water quality during summer months. Bloom dynamics create periods of low dissolved oxygen, high pH, and toxic ammonia concentrations that impact the federally listed Lost River (*Deltistes luxatus*) and shortnose suckers (*Chasmistes brevirostris*).

The Sprague River watershed contributes approximately 30 percent of the external total phosphorus load to UKL. Particulate phosphorus from sediment input and transport has been identified as a major portion of the total phosphorus load from the Sprague River Valley. In addition, the north and south fork reaches of the Sprague River have been shown to contribute the largest proportion of the particulate load. In the 1950s, the U.S. Army Corps of Engineers built levees throughout the Sprague River Valley for flood control and flood protection. This straightening and channelization resulted in floodplain disconnection in many parts of the north fork, south fork, and mainstem Sprague River. River channelization increased flow velocities and accelerated erosion and channel incision causing excess sediment and particulate nutrient input to the Sprague River.

Particulate phosphorus loading from erosion can be ameliorated by restoration actions that create slower water velocities and allow particle settling. In the Sprague River Valley, floodplain reconnection through levee removal and channel re-meandering has been identified as a priority restoration action to reduce total phosphorus loading to UKL. Multiple stakeholders are interested in creating a hydrologic model of the Sprague River Valley that would be able to prioritize areas of floodplain reconnection with the highest water quality benefits to maximize limited restoration funds. Currently the best available digital elevation model (DEM) data for the Sprague River is based on Light Detection and Ranging (LiDAR) data from 2005. It is imperative to evaluate the accuracy of this 15-year-old dataset before investing a large budget into model development. We propose an evaluation of the current DEM to identify areas of significant geomorphic change, updating the DEM in prioritized reaches using low-cost drone imagery and associated technology, and beginning development of a hydrologic model focused on floodplain reconnection.

Results from this effort will review and enhance the baseline dataset needed for development of a hydrologic model of the Sprague River Valley. Ultimately this work will lead to floodplain restoration and the reduction of total phosphorus loading to UKL below Oregon Department of Environmental Quality target compliance concentrations. This proposal addresses Interim Measure 11, which is intended to improve water quality in the Klamath River during this interim period before dam removal.

Schedule and Deliverables

The following is a proposed schedule of deliverables for this project:

- Project kick-off meeting – Spring 2020
- DEM evaluation and geomorphic analysis – through September 2020
- Additional DEM data collection – October through November 2020
- Technical memorandum with summary of DEM analysis and data collection – April 2021
- Detailed project scope and budget to develop hydrologic model – April 2021

2: Evaluation of the Iron Gate Intake Barrier Curtain System for Water Quality Improvement of Powerhouse Releases

Submitted by: PacifiCorp

Purpose and Objectives

The purpose of this activity is to continue to evaluate the effectiveness of the intake barrier system in Iron Gate reservoir to improve water quality in Iron Gate Powerhouse releases to the Klamath River. During 2015-2019, annual studies have been conducted to continue evaluation of the operation of the curtain upstream of the intake as a means of reducing algae entrainment into the intake (Watercourse 2016; PacifiCorp 2017). A comprehensive analysis of the data collected between 2015 and 2018 is nearing completion. Work in 2020 will build on previous years of data collection and continue to inform management and operation of the system.

The concept behind the curtain is to control the depth at which water is withdrawn from the reservoir into the intake, and thereby potentially enhance water quality downstream of Iron Gate dam by reducing the potential entrainment of biomass from blooms of cyanobacteria (blue-green algae) and potential associated algal toxins (i.e., microcystin). These studies have provided valuable insights into the performance of the curtain system under varying conditions. This work has collectively indicated that the curtain functions as it was designed and selectively limits the entrainment of surface water in Iron Gate reservoir. The curtain has been deployed to different depths for different periods of time over the last 5 years and the after-deployment sampling was not always conducted at all deployment depths. This has resulted in small sample sizes at different curtain depths. Rather than

Task and Work Elements

The tasks and work elements associated with this activity in 2020 will include the following:

- The curtain will again be deployed in the summer-fall of 2020 to be operational during the period when blooms of cyanobacteria are most prevalent in Iron Gate reservoir (approximately mid-July through October). Curtain deployment depth and timing will be informed by the curtain effectiveness tool currently being developed.
- Field data collection at the curtain in 2020 will focus on collecting information to support the evaluation of curtain effectiveness and improve the understanding of curtain function. This will include detailed vertical profiles immediately before and after curtain deployment; profiles will be repeated a few days after curtain deployment. PacifiCorp will again deploy data sondes and thermograph arrays upstream and downstream of the curtain to continuously monitor conditions throughout the summer. If the data analysis task discussed above indicates the need for specific data collection efforts in addition to those discussed here, specific study plans will be developed for those investigations.

Schedule and Deliverables

The curtain will be deployed in the summer-fall of 2020. Field data collection will occur to bracket the curtain deployment period per the monitoring plan. Final data analysis and reporting would occur after data collection is complete and likely be completed in 2021.

3: Increasing sediment phosphorus binding capacity in the Upper Klamath Lake: Phase 1, initial feasibility study for Phoslock™

Submitted by: US Fish and Wildlife Services, Stillwater Sciences

Overview

While Upper Klamath Lake (UKL) was historically eutrophic (EPA 1974, Johnson 1985), large-scale watershed development from the late-1800s through the 1900s has likely contributed to the current hypereutrophic condition in UKL (USGS 1993). This legacy, combined with current nutrient loading from the watershed and lake sediment, facilitates extensive cyanobacteria blooms (ODEQ 2002) that typically result in large diel fluctuations in dissolved oxygen (DO) concentrations and pH, high concentrations of the hepatotoxin microcystin, and toxic levels of un-ionized ammonia during bloom decomposition (ODEQ 2002, Walker et al. 2012). Together, these conditions create a suboptimal environment for native aquatic biota and likely play a role in the decline of Endangered Species Act-listed Shortnose and Lost River suckers (USGS 2000).

Phosphorus (P) is the key driver of water quality issues in the Upper Klamath Basin (ODEQ 2002, Walker et al. 2012). P occurs in relatively high levels in the local geology of the Upper Klamath Basin (ODEQ 2002, Walker et al. 2015), but has been, and continues to be, produced through past and current land use activities in the watershed (Walker et al. 2012, Walker et al. 2015). Specifically, average annual external phosphorus load to UKL is now approximately 40 percent higher than the natural background (ODEQ 2002, Walker et al. 2012). Additionally, the intact riparian areas and lake-fringe wetlands that historically filtered and retained phosphorus have been much diminished, further exacerbating the phosphorus loading issue. These factors, combined with internal loading as a result of current and historical external load (ODEQ 2002), result in summer water column phosphorus concentrations up to six times higher than the natural background (NRC 2004).

Numerous restoration actions have been recommended to reduce external P load to UKL, and thereby improve water quality conditions within the lake itself. Two of these actions, restoration of lake-fringe wetlands and construction of diffuse source treatment wetlands (DSTWs), were specifically identified by the Interim Measures Implementation Committee as priority projects for water quality improvement in the Upper Klamath Basin. Wetlands, including DSTWs, sequester P by:

1. Allowing particulate P to settle out of the water column;
2. Allowing for uptake of inorganic dissolved P (soluble reactive P [SRP]; the form most readily available to plants and algae):
    a. Temporarily, through redox-dependent sorption to metal hydroxide oxides (Mortimer 1942, 1943)
    b. Seasonally, through biomass uptake (Kadlec 1997)
    c. More permanently through accretion of peat soils (i.e., wetland vegetation is not fully decomposed and associated P is therefore sequestered in peat soils [Kadlec 1997, Juston et al. 2013])

However, there is some concern that restored wetlands, particularly when used previously for agricultural production and grazing, can be a source of SRP initially following re-inundation and these wetlands may not function as P sinks for years to decades following restoration (Aldous et al. 2005, Graham et al. 2005). Similarly, DSTWs may have limited capacity to sequester SRP until a robust emergent vegetation component has been established. Finally, in areas with higher SRP (relative to particulate phosphorus) loads, such as the Wood River Valley, focus on increasing the capacity to sequester SRP is warranted.

Given these possible limitations in the ability of restored wetlands and DSTWs to sequester P (particularly SRP) permanently and effectively in the near term, there is interest in exploring other options to increase the P sequestration capacity of restored wetlands and DSTWs. One option is the application of chemical compounds (typically called coagulants) to bind SRP and permanently sequester this P in wetland sediments.

The most commonly used coagulant for P control in surface waters is alum (aluminum sulfate), which if applied in an unbuffered form may result in low pH and potential toxicity-related concerns associated with free aluminum. Phoslock™ (bentonite clay amended with lanthanum [La]) is a different and increasingly common coagulant for control of P in aquatic systems. Phoslock™ generally did not result in changes in pH in recent jar tests of Upper Klamath Basin waters (CH2M Hill 2015) and to date it appears to have low toxicity potential, particularly at lower application doses (Herrmann et al. 2016, Lürling and Tolman 2010, Afsar and Groves 2009). Similarly, there is some indication that PAX-18 (polyaluminum hydroxychloride) and buffered alum (2:1 aluminum sulfate and sodium aluminate) may be effective in sequestering P in Upper Klamath Basin waters, with some effects on pH and soluble aluminum concentrations (CH2M Hill 2015).

While much work has focused on application of coagulants to water surfaces, to date we are aware of no studies that examine the feasibility and/or effectiveness of applying coagulants directly to soil surfaces prior to inundation of newly restored wetlands and/or just-constructed DSTWs to enhance P sequestration capacity. There are numerous associated questions related to such an approach. First, it is critical to determine if a pre-inundation sediment application method effectively increases the SRP binding capacity of wetland sediments and reduces SRP flux from these sediments. Second, determining the appropriate application rate, the durability of treatment (e.g., do coagulants continue binding SRP for months to years or are binding sites saturated within days?), potential changes in water chemistry (e.g., changes in pH, increases in concentrations of potentially toxic compounds) resulting from application, general availability of coagulants, and cost.

Given the number of outstanding questions and the likely need for a pilot study if concerns around effectiveness and toxicity are addressed, we propose to start with an initial (i.e., Phase 1) laboratory-scale feasibility study of Phoslock™ that focuses on the question of whether direct application of Phoslock™ to wetland sediments will reduce SRP flux from these sediments, given a constant overlying water concentration of SRP. Additional study of whether sediment binding capacity for SRP is affected by overlying water concentration of SRP, pH, or water temperature would be conducted separately or as a later experimental phase. The potential for scale-up of the Phoslock™ dosing approach and/or to fill other data gaps would be dependent on the outcome of any laboratory-scale feasibility studies.

Accordingly, the Phase 1 proposed study will test the following hypotheses:

- *Direct application of Phoslock™ to the wetland sediment surface prior to inundation will increase sediment binding capacity for SRP relative to non-amended sediments and will reduce the amount of SRP that fluxes out of the sediments as a response to inundation.*

- *Application of Phoslock™ to the wetland sediment surface prior to inundation will not result in a release of potentially toxic levels[4] of lanthanum (La) as a response to inundation.*

An increase in sediment SRP binding capacity would increase the capacity of DSTWs and restored wetlands to sequester P in the short term until emergent vegetation is established and accretion of peat soils begins (which can take several years [Aldous et al. 2005, Graham et al. 2005]). Additionally, since this potential novel application method would target a particular component of P cycling (i.e., SRP that would otherwise flux out of the sediments), rather than P throughout the wetland water column, it is possible that lower coagulant doses may be effective as compared with a treatment approach targeting the entire water column. Lower application rates should minimize unintended “side effects” to surface water chemistry and would be less expensive than higher application rates.

Finally, the specific purpose of the Interim Measure 11 of the Klamath Hydroelectric Settlement Agreement is to address water quality improvements in the Klamath River during the interim period leading to dam removal. If determined to be effective in the proposed feasibility study and a future pilot study, chemical coagulants could be used to reduce external P loads to UKL. Extensive monitoring and research conducted in the Klamath Basin indicate that UKL is a major source of dissolved and particulate P to downstream reaches of the Klamath River. As such, the proposed study fits within the stated purpose and scope of Interim Measure 11.

Tasks

Task 1 Methods Development and Technical Memorandum

In close coordination with USFWS, Stillwater Sciences will prepare a technical memorandum (TM) describing the proposed methods for testing the aforementioned hypotheses. Variables currently proposed versus variables to be determined are noted below under Task 2. Prior to construction of the lab-scale artificial batch-reactor DSTWs and implementation of coagulant testing (Task 2), Stillwater Sciences will submit a Draft Methods TM to the Interim Measures Implementation Committee (IMIC) for review. Stillwater will address one set of compiled review comments on the Draft Methods TM and associated revisions will be incorporated into the Final Methods TM.

Task 2 Coagulant Testing

Stillwater Sciences will construct 8 to 12 lab-scale artificial batch-reactor DSTWs, each lined with homogenized wetland sediments collected from the Wood River Valley, to test Phoslock™ effectiveness. One set (n=2 to 3) of reactors will act as a control, while the remaining batch reactors will be treated with three different amendment levels of Phoslock™ (Table 1). Duplicate or triplicate batch reactors will be run for each amendment level and the control reactor for quality assurance/quality control (QA/QC) purposes, with the final number of replicates to be determined under Task 1 (Table 1) based on final analytical laboratory pricing. The specific Phoslock™ amendment levels will be determined during development of the Task 1 methods. Stillwater Sciences will sample sediment TP within each DSTW batch reactor prior to inundation, and will sample soluble La, SRP, and total suspended solids (TSS) in the overlying water column of each DSTW at specified time intervals post-inundation until equilibrium concentrations are reached. Although not included as variables in the testing matrix presented in Table

[4] Potentially toxic levels will be determined through consideration of available literature reference points including the following: 28-day lethal concentration 50 (LC50) for La to rainbow trout eggs is 20 µg/L (Birge et al. 1978); 96-hour LC50 for La to rainbow trout adults is 127 µg/L or greater (Stauber 2000); proposed water quality criterion of 4 µg/L (Herrmann et al. 2016); proposed maximum sediment concentration of 36.9 mg/kg (Herrmann et al. 2016). There are currently no regulatory thresholds for La.

1, *in situ* water temperature, dissolved oxygen (DO), pH, and turbidity also will be monitored during the experiment to record basic experimental conditions. The exact frequency and timing of the time interval samples relative to treatment application are to be determined; however, we anticipate sampling approximately every 3 hours for the first 12hours of the experiment, every 6 hours for the next 12 hours of the experiment, and every 12 hours for 5 days thereafter.

Table 1. Experimental Matrix for Phase 1 Task 2 Coagulant Testing Batch Reactors.

Sediment Amendment	Sediment Amendment Level[1,2,3]
Phoslock™	High
	Medium
	Low
None (Control)	–

[1] Sediment amendment levels corresponding to High, Medium, and Low are to be determined under Task 1.

[2] Fixed overlying water SRP concentration for the experiment is to be determined under Task 1. The source of inundation water is to be determined under Task 1 and ideally would be native water collected from the downstream portion of the Wood River Valley Sevenmile Canal.

[3] Duplicates or triplicates will be run for each sediment amendment level, as determined under Task 1.

Task 3 Data Analysis and Reporting

Stillwater Sciences will conduct QA/QC on the *in situ* (water temperature, pH, DO, turbidity) and grab (sediment TP, sediment La, water SRP, water La, water TSS) samples collected under Task 2, and will populate the project database. Data analysis will involve development of overlying water concentration time series for each batch reactor, including determination of equilibrium concentrations and adsorption isotherms with consideration of Langmuir (assumes a completely homogeneous surface) and Freundlich isotherm models (assumes a highly homogeneous surface). Stillwater Sciences will submit a Draft Report to the IMIC for review. The report will describe the study results and will provide recommendations for future work. Stillwater will address one set of compiled review comments on the Draft Report and associated revisions will be incorporated into the Final Report.

Task 4 Project Management

Stillwater Sciences in coordination with USFWS will conduct staffing, budget tracking, and monthly invoicing for the project.

Deliverables

The deliverables associated with this proposal are listed below:

- *Draft Methods TM*
- *Final Methods TM*
- *Draft Report*
- *Final Report*

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4: Tulelake Irrigation District Modernization Study

Submitted by: Farmers Conservation Alliance

Background

The Farmers Conservation Alliance (FCA) has developed the Irrigation Modernization Program to help irrigation districts and the farmers they serve revolutionize their infrastructure. This program reduces the cost and time required for project planning and implementation, addresses key regulatory and institutional barriers, leverages funding, and demonstrates how modern agricultural water management can mitigate the impacts of long-term drought and other serious environmental and agricultural challenges.

For this project, FCA will assess opportunities to modernize agricultural infrastructure within Tulelake Irrigation District (Tulelake ID), which would benefit agriculture, water quality in the Klamath River, and the environment. Tulelake ID delivers water to approximately 64,000 acres in the Klamath Basin through over 240 miles of canals; however, much of this infrastructure is aging and inefficient. Modernizing this infrastructure could improve water conveyance efficiency, reduce tailwater discharges, allow for managed groundwater recharge, reduce energy use, generate small-scale hydropower, expand the use of solar power, and reduce operations and maintenance costs.

Over the past 4 years, FCA has identified a wide range of data, assessments, and strategies that can contribute to the irrigation modernization process within each district. FCA works with the irrigation district and its partners to understand how to scale investments in these elements to most efficiently develop a modernization strategy. Each irrigation district operates within a unique context and has a unique vision, goals, and objectives. Initial work with a district interested in participating in the Irrigation Modernization Program ensures that the district clearly articulates their goals and objectives for irrigation modernization and the associated outcomes can produce benefits for both agriculture and the environment.

There are four different work elements in the overall project:

- Work Element 1 – Preliminary Assessment and Initial Findings
- *Work Element 2 – Stakeholder Engagement*
- *Work Element 3 – District Assessment*
- *Work Element 4 – Modernization Strategy Development*

Only funding for Work Element 1 was funded in 2020.

Scope

Work Element 1: Preliminary Assessment and Initial Findings

The first Work Element includes a set of distinct tasks that will collect detailed information about the goals and objectives of Tulelake ID, creates district-level briefing documents, coordinated review of infrastructure conditions and operations patterns within the district, and collect and conduct a comprehensive review of data and reports pertaining to Tulelake ID's operations. All of that information will feed into an Initial Findings Report that summarizes findings from the previously described activities.

The Initial Findings Report informs the assessments to be completed through the irrigation modernization process. Depending on the district's needs, these assessments may focus on an entire district or a subset of the district. A detailed outline of the Findings Report will be developed and shared with Tulelake ID before the report is prepared. Once the Initial Findings Report is complete, FCA will develop a draft scope, budget, and timeline for the activities necessary to achieve the modernization objectives developed during preparation of the Initial Findings Report. This work is scaled based on the initial findings to ensure that FCA can efficiently develop a successful modernization strategy for Tulelake ID.

This Work Element also identifies any projects for accelerated implementation prior to completion of a modernization strategy. These projects typically include actions that meet identified goals and objectives, have strong district and partner support, and complement potential future modernization efforts. These projects can demonstrate early success, strengthening relationships and building momentum for irrigation modernization.

Deliverables

The deliverables associated with this proposal are listed below:

- Draft and Final District Brief
- Draft and Final Initial Findings Report
- Draft scope of work, budget, and schedule for targeted modernization projects