# Demonstration Wetland Facility Preliminary Research and Implementation Plan Klamath River, Oregon

Prepared for

**PacifiCorp**

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# Acronyms and Abbreviations

| | |
|---|---|
| ac | acre |
| ac-ft | acre-feet |
| BAT | best available technology |
| BMP | best management practice |
| BOD | biological oxygen demand |
| C* | wetland equilibrium background concentration (mg/L) |
| cfs | cubic feet per second |
| cm | centimeters |
| $CO_2$ | carbon dioxide |
| COD | chemical oxygen demand |
| CY | cubic yards |
| DIP | dissolved inorganic phosphorus |
| DO | dissolved oxygen |
| DON | dissolved organic nitrogen |
| DOP | dissolved organic phosphorus |
| DP | dissolved phosphorus |
| DRP | dissolved reactive phosphorus |
| DWF | Demonstrated Wetland Facility |
| EPA | U.S. Environmental Protection Agency |
| ESA | Endangered Species Act |
| ET | evapotranspiration |
| $FeCl_3$ | ferric chloride |
| ft | feet |
| $ft^3$ | cubic feet |
| FWS | free water surface |
| g | grams |
| GIS | Geographical Information System |
| gpd | gallons per day |
| gpm | gallons per minute |
| ha | hectares |
| HDPE | high-density polyethylene |
| HLR | hydraulic loading rate |
| HRT | hydraulic residence time / hydraulic retention time |

| | |
|---|---|
| HWTT | Hybrid Wetland Treatment Technology |
| IMIC | Interim Measures Implementation Committee |
| KHSA | Klamath Hydroelectric Settlement Agreement |
| k | first-order, area-based rate constant (m/yr) |
| kg | kilograms |
| L | liter |
| lbs/day | pounds per day |
| lbs/yr | pounds per year |
| LOW | Lake Okeechobee Watershed |
| mg | milligrams |
| mg/kg | milligram per kilogram |
| mg/L | milligram per liter (equivalent to parts per million, or ppm) |
| mgd | million gallons per day |
| mi | mile |
| mL | milliliter |
| mt | Metric Tons |
| N | nitrogen |
| $N0_2$-N | nitrite-nitrogen |
| $N0_3$-N | nitrate-nitrogen |
| $N_20$ | nitrous oxide |
| $NH_3$ | ammonia |
| $NH_3$-N | ammonia-nitrogen |
| $NH_4^+$ | ammonium |
| $NH_4$-N | ammonium-nitrogen |
| NMFS | National Marine Fisheries Service |
| $NO_2$ | nitrite |
| $NO_3$ | nitrate |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resources Conservation Service |
| NuRF | Nutrient Reduction Facility (located in Lake County, Florida) |
| Org-N | organic nitrogen |
| ortho-P | ortho-phosphorus |
| P | phosphorus |
| $P0_4$-P | phosphate phosphorus |
| pH | potential of hydrogen ( measurement of acidity of a water sample) |

| | |
|---|---|
| $PO_4$ | orthophosphate |
| PP | particulate organic phosphorus |
| ppb | parts per billion |
| ppt | parts per thousand |
| psi | pounds per square inch |
| SAV | submerged aquatic vegetation |
| SCADA | Supervisory Control and Data Acquisition |
| SF | surface flow |
| SFWMD | South Florida Water Management District |
| SRP | soluble reactive phosphorus |
| SSF | subsurface flow |
| STA | Stormwater Treatment Area |
| TDS | total dissolved solids |
| TIN | total inorganic nitrogen (ammonia + nitrite + nitrate) |
| TKN | total Kjeldahl nitrogen |
| TMDL | total maximum daily load |
| TN | total nitrogen |
| TP | total phosphorus |
| TSS | total suspended solids |
| USACE | United States Army Corps of Engineers |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |
| VSS | volatile suspended solids |
| µg/g | microgram per gram |
| µg/L | microgram per liter (equivalent to parts per billion, or ppb) |

SECTION 1

# Introduction

## 1.1 Background

This report presents a Preliminary Research and Implementation Plan (Research Plan) for the implementation of a Demonstration Wetland Facility (DWF) on the Klamath River as part of a series of activities undertaken by PacifiCorp through Interim Measure 11 of the Klamath Hydroelectric Settlement Agreement (KHSA). Interim Measure 11 is intended to improve water quality in the Klamath River during the interim period leading up to dam removal under the KHSA. The emphasis of Interim Measure 11 is nutrient reduction projects to provide benefits to the main stem of the Klamath River that will benefit environmental resources following potential dam removal, while also addressing water quality, algal and public health issues in reservoirs of the Klamath Hydroelectric Project and dissolved oxygen in J.C. Boyle reservoir. PacifiCorp worked with representatives of the KHSA Interim Measures Implementation Committee (IMIC) to develop study plans for six studies and pilot projects to be implemented prior to the Secretarial Determination with funding provided by PacifiCorp.

This section provides brief backgrounds on the KHSA, the details of Activity 2, an overview of the Research Plan, and a short description of the TAC's composition and role.

### 1.1.1 Hydroelectric Settlement Agreement

On February 18, 2010, the United States, the states of California and Oregon, PacifiCorp, Native American tribes, and a number of other stakeholder groups signed the KHSA. The KHSA lays out the process for additional studies, environmental review, and a determination by the Secretary of the Interior regarding whether removal of four dams owned by PacifiCorp on the Klamath River will advance restoration of the salmonid fisheries of the Klamath Basin and is in the public interest (which includes local communities and tribes).

The KHSA includes provisions for the interim operation of the dams and mitigation activities prior to potential removal of the hydroelectric facilities. One such provision—titled Interim Measure 11: Interim Water Quality Improvements—emphasizes water quality improvement projects in the Klamath Basin during the interim period.

Regarding Interim Measure 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 provide support for studies or pilot projects in consultation with the IMIC. These studies or pilot projects need to address the following four categories of studies specified for Interim Measure 11:

- Development of a Water Quality Accounting Framework
- Constructed Treatment Wetlands Pilot Evaluation
- Assessment of In-Reservoir Water Quality Control Techniques
- Improvement of J.C. Boyle Reservoir Dissolved Oxygen

PacifiCorp initiated several activities in 2013-2014 related to Interim Measure 11, including:

1. Continued Development of the Water Quality Accounting Framework
2. Planning and Design for a Demonstration Wetlands Facility Adjacent to the Klamath River
3. Preliminary Design of an Organic Matter Removal System at Link River/Keno Reservoir
4. Continued Evaluation of Selective Withdrawal/Intake Barrier Systems for Water Quality Control at Iron Gate Reservoir

5. Pilot Study of Algal Conditions Management within a Selected Reservoir Cove
6. Research on *Microcystis* Genotypes in the Klamath River System
7. Pilot Study of Nutrient Reduction Methods in Klamath Basin Waterbodies

### 1.1.2 Activity 2: Demonstration Wetlands Facility

The purpose of Activity 2 of Interim Measure 11 is to continue research and development for anticipated development of wetland systems for water quality improvement in the upper Klamath River basin. Constructed and diffuse source wetland treatment systems have been identified as potentially viable means of improving water quality conditions in the upper Klamath River, as documented recently in the summary of the nutrient reduction workshop held in 2012 (Stillwater 2012) and previous reports (e.g. CH2M HILL, 2012).

As described below, PacifiCorp proposes to develop a research plan for a DWF adjacent to the upper Klamath River. The DWF would provide an important opportunity for interested stakeholders and researchers to investigate site-specific requirements, effectiveness, feasibility, and costs of wetlands technologies in the Upper Klamath basin. This information would be valuable for future planning, design, and ultimate implementation of wetland technologies to improve water quality in the Upper Klamath basin.

To further the development of the DWF research plan, PacifiCorp initiated a series of conference call meetings beginning in September 2013 to coordinate with stakeholders to develop this Research Plan and to lay out the planning, design, and implementation of the DWF, including locating potential sites for the DWF. The DWF itself would be constructed, operated, and maintained by stakeholder “partners” that have an interest in pursuing the unique and important wetland research and demonstration opportunities that the DWF would provide to inform basin-wide planning for water quality improvement strategies. The DWF could consist of a newly identified site or could be integrated and developed within an existing wetland site that has already been identified.

Potential candidate sites were discussed with the TAC and focused on available properties adjacent to the Upper Klamath Lake and Agency Lake with water rights and water delivery infrastructure. A candidate location has been identified through a process described in Section 4. The DWF Research and Implementation Plan is intended to describe research objectives, preferred features of the DWF, anticipated studies, the expected participants and their associated funding or in-kind commitments, and the process and schedule for further planning and design.

For the candidate site, a conceptual level design and cost has been prepared which can be used as a basis for securing permits and for describing the project so that the DWF concept can be communicated to other stakeholders or project participants. The project can be considered as a potential candidate for shared funding from other interested agencies or funding sources in addition to PacifiCorp.

## 1.2 Conceptual Description and Location of the Facility

PacifiCorp originally envisioned a DWF that would consist of a constructed wetland demonstration area, flow control structures, and other ancillary facilities (e.g., fencing, access) or a diffuse source wetland system on the fringe of an existing agricultural land parcel. Through discussion with stakeholder representatives in the conference calls, it became apparent that diffuse source wetland systems are being planned and implemented in the Upper Klamath region, and that a research facility designed to address the key questions facing treatment wetland implementation in this region could benefit multiple agencies and researchers.

As described in this Research Plan, the DWF would include four acres of wetlands configured as a bank of "cells" maintained at shallow and deep depths intended to bracket the inundation range typical of restored and natural wetlands in the region. The constructed wetland demonstration cells would allow evaluations, tests, or experiments to be conducted to accomplish the following:

- Assess specific types of wetland components (e.g., soils and vegetation types) and their relative performances
- Evaluate wetland performance regarding nutrient uptake and removal processes under climatic influences and real-world conditions specific to the Upper Klamath basin
- Verify important assumptions used to design and construct potential full-scale wetland treatment systems or diffuse source wetland systems elsewhere in the basin

## 1.3 Purpose

The need for and interest in a DWF originated during the nutrient reduction workshop convened in September 2012 to identify restoration research needs and approaches pertinent to the Klamath River (Stillwater 2012). This workshop focused on methods of nutrient control using cost-effective large-scale measures such as treatment wetlands.

Research needs identified by TAC members during conference call meetings include the following:

- Ranges of feasible nutrient removal performance, including conditions with interactions with groundwater influence
- Consumptive use of water in treatment wetlands, which may thereby limit application, given water rights constraints
- Vegetative community effects on treatment performance and soil rebuilding

Existing research underway in the Klamath River basin has built a detailed understanding and background on the hydrology, water quality, and ecology of wetland restoration in this region. The DWF concept and this Research Plan have been prepared with the objective of providing a versatile platform that can be used by researchers for detailed investigation, while addressing fundamental questions of treatment performance in this region. The objective of this Research Plan is to clarify demonstration objectives, project approaches, and to describe a final DWF configuration. Future modifications to this Research Plan are envisioned through the completion of this activity as input is sought and incorporated from the TAC.

## 1.4 Research Plan Organization

This draft research plan is organized into a series of sections designed to provide a technical basis and a conceptual description for the DWF. **Section 2** provides an overview of the use of treatment wetlands for nutrient reduction globally, and an overview of recent nutrient reduction studies in the Klamath River, with specific attention to similar large scale planning projects. **Section 3** summarizes key research issues identified through discussions with TAC members and review of pertinent literature. **Section 4** provides an overview of the proposed facility configuration and components and a preliminary review of potential sites that warrant consideration for implementation. **Section 5** describes the core elements of a conceptual research plan. **Section 6** provides an overview of sample data collection methodologies.

**Appendix A** provides general guidance on the elements of a research monitoring plan. **Appendix B** provides a preliminary Quality Assurance Plan. **Appendix C** provides the minutes and exhibits developed from each of the TAC conference calls.

## 1.5 TAC Composition and Role

The purpose of the TAC is to provide input on the demonstration wetland facility concepts and to act as a coordination link to the IMIC and stakeholders. TAC members participated in monthly teleconference calls that began in October 2013 and ended in October 2014. The dates of the meetings are shown in Table 1-1.

TABLE 1-1
**TAC Meeting Topics and Dates**

| TAC Meeting # | Topic | Date |
|---|---|---|
| 1 | Initiate discussion on DWF concept | October 1, 2013 |
| 2 | Establish Research Plan format | October 24, 2013 |
| 3 | Initiate discussion regarding identification of prospective partners and roles | November 18, 2013 |
| 4 | Initiate discussion regarding identification of prospective site(s) | December 17, 2013 |
| 5 | Review key topics and analysis approach | January 21, 2014 |
| 6 | Finalize topics, sites and partners | February 18, 2014 |
| 7 | Discussion regarding conceptual site locations and configurations | March 18, 2014 |
| 8 | Receive and discuss comments on Draft Plan | April 20, 2014 |
| 9 | Receive and discuss comments on Draft Plan | June 17, 2014 |
| 10 | Receive and discuss comments on Draft Plan, and on-site meeting | July 01-02, 2014 |
| 11 | Receive and discuss comments on Draft Plan, and on-site meeting | July 22, 2014 |
| 12 | Final discussion of Final Plan (submitted September 16), partners and funding. | October 22, 2014 |

The TAC is composed of various interested stakeholders. TAC members and their affiliations are listed in Table 1-2.

TABLE 1-2
**TAC Participants**

| TAC Participant Name | Affiliation |
|---|---|
| Andy Hamilton | Bureau of Land Management |
| Bob Gearhart | Humboldt State University |
| Brittany Hughes | CH2M HILL |
| Chauncey Anderson | US Geological Survey |
| Chelsea Aquino | Bureau of Land Management |
| Chris Stine | Oregon DEQ |
| Clayton Creager | California Regional Water Quality Control Board |
| Crystal Bowman | Karuk Tribe |
| Dan Blake | US Fish and Wildlife Service |
| Eli Asarian | Riverbend Sciences |
| Heather Hendrixson | The Nature Conservancy |
| Jacob Kann | Aquatic Ecosystem Sciences, LLC |

TABLE 1-2
**TAC Participants**

| TAC Participant Name | Affiliation |
|---|---|
| Jane Vorpagel | California Department of Fish and Game |
| Jared Bottcher | Klamath Basin Rangeland Trust |
| Jed Redwine | SF Environments |
| Jessica Asbill-Case | U.S. Bureau of Reclamation |
| Jim Bays | CH2M HILL |
| John Hamilton | US Fish and Wildlife Service |
| Kathleen Sloan | Yurok Tribe |
| Ken Carlson | CH2M HILL |
| Kris Fischer | Klamath Tribe |
| Kurt Carpenter | US Geological Survey |
| Kyle Gorman | Oregon Water Resources Department |
| Linda Prendergast | PacifiCorp |
| Maia Singer | Stillwater Sciences |
| Mary Grainey | Oregon Water Resources Department |
| Micah Gibson | Yurok Tribe |
| Michael Hughes | Oregon Institute of Technology |
| Mike Deas | Watercourse Engineering, Inc. |
| Nell Kolden | Klamath Basin Rangeland Trust |
| Rick Carlson | U.S. Bureau of Reclamation |
| Ron Larson | US Fish and Wildlife Service |
| Ted Wise | Oregon Department of Fish and Wildlife |
| Tim Hemstreet | PacifiCorp |

The TAC has provided critically useful technical input, shared essential information about projects in the Upper Klamath Basin through discussion on several conference calls, and provided assistance in identifying pertinent project reports that are referenced throughout this research plan. Comments provided by TAC members to the draft version of plan were incorporated into the final version, and discussions on the content of the final version are included in the minutes of the 12th conference call meeting (see Appendix C). This discussion included preliminary estimates of operating and monitoring costs for the project, subject to a set of assumptions that may be expected to vary depending upon the operating organization and researcher interests.

SECTION 2

# Relevant Research and Technical Review

## 2.1 Treatment Wetlands Phosphorus Removal Processes

Phosphorus (P) typically enters wetlands with suspended solids or as dissolved P. Dissolved P is processed by wetland soil microorganisms, plants, and geochemical mechanisms (Walbridge and Struthers, 1993 and Kadlec and Wallace, 2009). Wetland systems can remove P through the following processes:

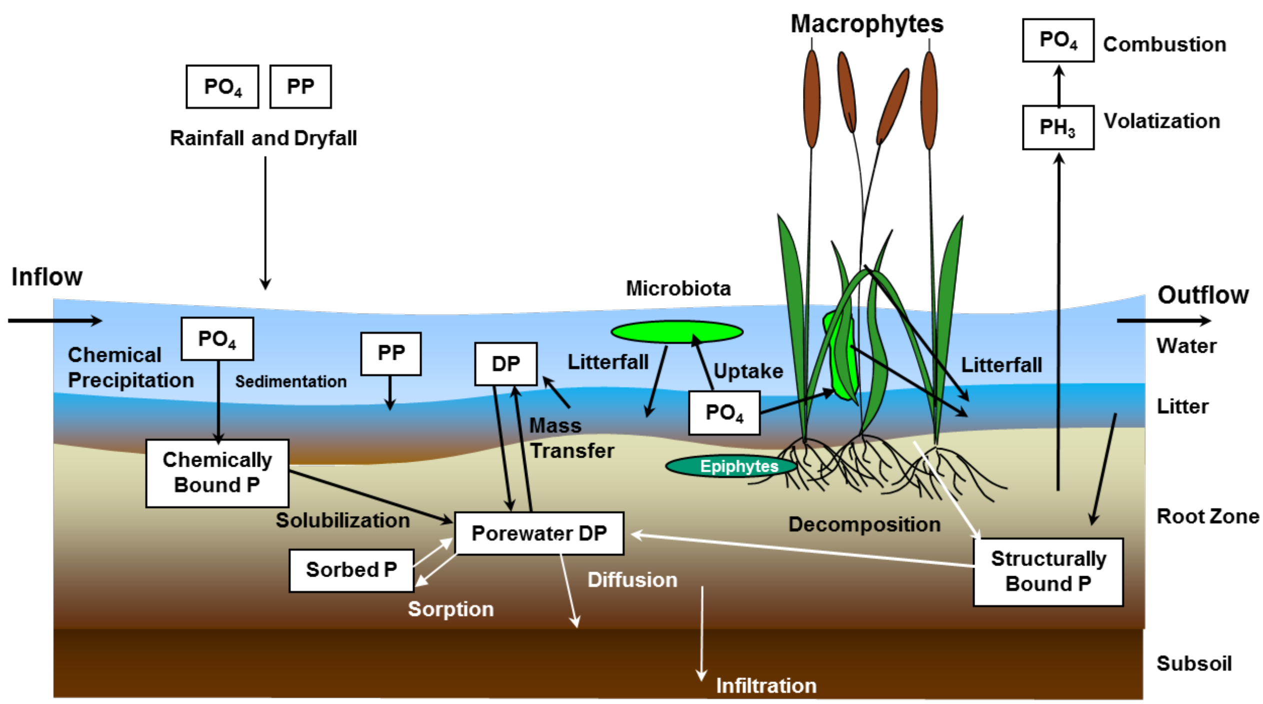
- Assimilation (i.e., direct uptake into tissues)
- Adsorption (i.e., attachment to mineral surfaces)
- Accumulation (i.e., buildup and storage)

Accumulation of P occurs in various abiotic and biotic components, including organic and inorganic soil and sediment particles, aboveground and below ground plant tissues, detritus, periphyton, microorganisms, and other organic matter (Johnston, 1991; Walbridge and Struthers, 1993; and Reddy et al., 2011).

Figure 2-1 shows the key pathways for P in wetland systems.

FIGURE 2-1

**Major Pathways for Phosphorus (P) in Wetland Systems**




Source: Kadlec and Knight, 1996. $PO_4$=orthophosphate, PP = particulate organic P; DP = dissolved phosphorus; $PH_3$ = phosphine inorganic P; DIP = dissolved inorganic P; DOP = dissolved organic P.

Significant quantities of P associated with suspended solids are deposited in wetlands as long term sinks (Walbridge and Struthers, 1993). Soils and sediments serve as long term sinks for P and store most of the P in the ecosystem. The main long term sink for P in a treatment wetland system is burial in wetland sediments (Kadlec and Wallace, 2009).

Storage of P in vegetation and other biotic communities (including microbial) of wetlands tend to be comparatively small and short term relative to wetland-wide storage (EPA, 2000a; EPA, 2000b; and Kadlec and Wallace, 2009). Microbial removal of P from wetland soil or water is rapid and highly efficient. Uptake occurs during the growth phase of these organisms. Release into surface water occurs during subsequent senescence and death, as organic matter decomposes. Release and uptake of P can have a strong seasonal pattern. For example, Beutel et al. (2014) found minimum removal by constructed treatment wetlands in the summer when high temperatures likely enhanced P release from decaying plant biomass.

The potential for long term storage of P through adsorption to wetland soil is greater than the maximum rates of P accumulation possible in plant biomass (Johnston, 1991; Walbridge and Struthers, 1993; and Kadlec and Wallace, 2009). The ability of wetland soils to retain P, in particular, can vary depending on the net equilibrium P concentration—defined as the P concentration where the amount of P sorption is equal to the amount of P desorption, resulting in a net P adsorption of zero. If the net equilibrium P concentration is greater than the P concentration in solution, the sediment (soil) will release P (House and Denison, 2002 and Zhou et al., 2005). Adsorption can also be a temporary sink if sorption sites are saturated within a few years of operation (Kadlec and Wallace, 2009), which commonly occurs if the wetland has low amounts of aluminum and iron or calcium (Richardson, 1985). The presence of aluminum is a significant predictor of dissolved P sorption and removal from water in most wetland systems (Walbridge and Struthers, 1993). Wetlands along rivers have a high capacity for P adsorption because, as clay is deposited in the floodplain, sorbed and crystalline-bound iron and aluminum in the clay will accumulate in successive layers (Gambrell, 1994). Thus, in addition to the removal of P through sediment deposition, floodplains tend to be important sites for P adsorption from the water column (Walbridge and Struthers, 1993).

Phosphorus is stored in both organic and inorganic forms in wetlands soils and sediments (Kadlec and Wallace, 2009 and Reddy et al., 2011). A large proportion of P in wetland soils occur in organic form as peats, suggesting the importance of organic P sequestration in the long term stabilization of P in wetlands. Eutrophic lakes and nutrient enriched wetlands typically exhibit high rates of recently accreted organic material, consisting of partially decomposed detritus matter originating from microbes, periphyton, macrophytes, and particulate inorganic material (Reddy et al., 2011). In productive wetland systems, this accreted organic matter ultimately forms peat over time that has different physical and biological characteristics than the underlying soil. Recently accreted organic material (also referred to as “floc”) can act as a sink or source of nutrients to the overlying water column and serves as an indicator of the nutrient retention characteristics of a wetland (Reddy et al., 2011). The efficiency of any wetland to store P on a long term basis is determined by the peat or sediment accretion rate times the net increase of P stored by these processes each year. To retain as much P as possible, the P input rates should be limited to the long term storage capacity, which is controlled by peat and sediment accretion. In typical North American freshwater wetlands, accretion rates average from one to two mm/year (Craft and Richardson, 1993). Locally, accretion rates of 3.8 cm/yr have been measured in emergent vegetation in the Wood River Wetlands (BLM, 2013). When wetland soils reach a state of P saturation, P may be released from the system (Richardson, 1985).

A portion of wetland P accumulates in soil as inorganic P compounds, categorized into one of two groups: those containing calcium or those containing iron and aluminum (Walbridge and Struthers, 1993 and Kadlec and Wallace, 2009). In more alkaline wetlands, P precipitates with calcium as calcium phosphate (Novotny and Olem, 1994). While this process may be limited in the relatively moderate alkaline water of the Klamath River basin, presence of oxygen, carbonate, and oxides of iron and aluminum variably influences P release.

## 2.2 Design Factors Affecting Wetland Treatment Performance

In constructed treatment wetlands, effective interception and removal of P from influent (inflow) water requires careful wetland system design and management to foster and sustain conditions that maximize long term storage of P, similar to conditions promoting the P removal process found in natural wetland ecosystems. At the most general level, removal rates of nutrients and particulates via any of the identified mechanisms (known as treatment efficiency) require that the average residence time of water in the wetland—referred to as “hydraulic residence time” or “hydraulic retention time” (HRT)—is of sufficient duration (on the order of several days) for these mechanisms to occur. In addition to HRT, other important factors that determine the treatment efficiency of wetlands are the influent concentrations and mass loading of the constituents of interest. Treatment efficiencies decline to zero as influent concentrations and mass loading of the constituents of interest approach biogeochemical background constituent concentrations for a given wetland—concentrations that would occur as a result of hydrologic, climatologic, internal storage (e.g. sediments, plants, including that present in materials used to construct or restore a wetland system), and parent geochemical conditions. Most variability in constructed treatment wetland efficiencies for P removal can be traced to differences in these controlling factors (Table 2-1).

TABLE 2-1
**Phosphorus Removal Data in Wetlands Receiving Flow from River Diversions and Other Large Systems**

| Location | Median Influent TP (mg/L) | TP Removal Efficiency (percent) | Reference |
|---|---|---|---|
| Caernarvon Diversion, Mississippi River, Louisiana | 0.15 | 62 | Day et al., 2009 |
| Fourleague Bay, Atchafalaya River, Louisiana | 0.13 | 20 | Perez et al., 2011 |
| Richland Chambers Wetlands, Trinity River, Texas | 0.97 | 45 | Kadlec et al., 2011 |
| Everglades Construction Project, Florida | 0.145 | 72 | SFWMD, 2010 |

CH2M HILL-constructed treatment wetland system process models use documented treatment efficiencies from 282 treatment wetland projects to estimate the values for the first-order, area-based removal rate constants (k) (Kadlec and Wallace, 2009; CH2M HILL, 2012; Sections 3 and 7 of this document). The model parameter C* that represents irreducible background concentrations (i.e., a biogeochemical background for a specific region, produced by cumulative interactions of soil, vegetation, water column chemistry), water temperatures, and hydraulic loading rates are based on review of pertinent local data from existing seasonal datasets for the two specific Klamath River locations where the system might be installed. This model provides the basis for predictions of annual removal rates, taking into account seasonal patterns, and sets basic design criteria for HRT, wetted area, and water depth.

Within this framework, the focus of the constructed treatment wetland design is to promote the most efficient sequestration mechanisms operation in this application, which in the Klamath region is storage in both organic and inorganic forms in wetlands soils and sediments. P-accumulating soil accretion rates are dependent on organic matter accumulation rates, which are controlled by organic matter production rates (likely to be high in this eutrophic environment especially in the summer months for selected plant types), temperature, water saturation, and maintenance of anaerobic sediments to retard decomposition, as well as sediment and chemical particulate accumulation rates, controlled by particle size and flow velocities.

Highly productive and dense wetland vegetation provides both shading of the water surface (to minimize solar heating) and organic material. Algae and microorganisms provide additional organic material. Selected areas of open water also provide heat loss and evaporative cooling, which help to dissipate energy and reduce wetland internal water and effluent temperatures. Lower temperatures decrease the rate of organic litter decomposition and increase rates of accumulation, in addition to discharge water quality benefits. On average, with two days of detention time through a densely vegetated wetland, effluent temperatures can be reduced to approximately average daily air temperatures during the summer months. Highly productive native plant types that can maximize these objectives (as well as other benefits) to be evaluated for use in Klamath constructed wetland systems include emergent plant genera cattail (*Typha latifolia*), bulrush (*Schoenoplectus acutus*), and bur-reed (*Sparganium spp.*) and floating-leaved aquatic plants such as wocus (*Nuphar polysepalum*). Preference is recommended for local plant types and sites that already contain wetland vegetation as sources to establish quickly new wetland plant communities (Mahugh et al., 2008).

Water saturation of deposited organic materials can be established through constructed wetland hydraulic loading management that maintains a minimum water depth of 1 foot throughout the water year, with average water depths that promote growth of the most productive native plant material and anaerobic conditions. The constructed wetland design will prevent extreme fluctuations of water depth and sudden high flow rates, with associated oxygenation of soils and creation of aerobic conditions.

Accumulation of particulates, whether delivered as suspended solids in inflows or created through chemical or biochemical processes (e.g. flocs or resuspension), can best be managed within the constructed system through control of internal flow rates, location and sizing of control structures, internal grading, and plant establishment. Because of the multiple values to be gained through close flow management, longer hydraulic retention times within these planned systems may be preferable within a given preferred range of hydraulic retention times.

Inorganic accretion of P may be enhanced through chemical interaction and adsorption with calcium, iron, and aluminum-rich particulate material, and subsequent settling into sediment layers. Specific physical and chemical conditions promote both interactions and accumulation into sediment. In general, increasing soil pH (from acidic to more neutral) can lead to increased mineralization of P due to increased soil microbial activity (Follett et al., 1981). Phosphorus can react with increased calcium in solution, increased calcium sorbed on soil surfaces, or directly onto particles of calcium carbonate, if lime is available in soil media or as a chemical added to the water column. Resultant amorphous calcium-phosphorus solids gradually transition to the more stable and much less soluble forms, for example, hydroxyapatite (Snoeyink and Jenkins, 1980). Thus, higher pH with available calcium will bind P that can settle into sediments. There is relatively little impact of changes in oxidation-reduction (redox) potential on calcium-phosphorus forms (Ann et al., 2000b). Shilton et al. (2005) did find in batch wetland reactor experiments with calcium augmentation that, as temperature increased, rates of P removal also increased, suggesting that an alkaline or circumneutral highly productive constructed wetlands system with calcium present may maximize P sequestration seasonally and diurnally during the higher temperature summer months.

Interaction with iron may involve addition of iron amendments or suspended iron-rich clay particles. Iron precipitated and bound P is strongly affected by changes in redox potential (Ann et al., 2000b); in particular, iron hydroxides have been shown to be very sensitive to changes in redox potential (Sherwood and Qualls, 2001). Under anaerobic conditions, phosphate adsorbed to iron oxyhydroxide complexes or precipitated ferric phosphate complexes may redissolve as $Fe+^{3}$ to $Fe+^{2}$ reduction occurs. However, the potential release of P under reducing conditions depends not only on redox conditions, but also on the solubility of the various iron oxyhydroxide-phosphate complexes formed. Lack of easily mineralized organic matter could impede the development of reduced conditions and subsequent Fe reduction, thus design of a constructed wetland in waters containing dissolved iron or iron-rich clay particles must maximize recalcitrant organic material production in order to maximize P binding through inorganic as well as organic processes. Higher temperatures also increase the rate of the iron-associated P-removal pathway, indicating that in the Klamath Basin region it could be expected to be maximized primarily during the summer months.

Interaction with aluminum may involve addition of aluminum amendments or suspended aluminum-rich clay particles. If alum is added, the metal phosphate $Al_{0.8}H_2PO_4(OH)_{1.4}$ is formed (Sedlak, 1991). When only moderate P removal is required, and relatively small alum dosages used, the metal phosphate is the predominant complex formed. However, when lower soluble P concentrations are required, larger alum dosages are required, and the formation of aluminum hydroxide precipitate [$Al(OH)_3$] becomes an important reaction. The aluminum hydroxide precipitate constitutes a gelatinous floc. As the floc settles, the associated bound P is removed from the water. The floc also tends to collect suspended particles in the water and carry them down to the bottom. On the bottom, the floc forms a layer that also can act as a P barrier by combining with P as it is released from the sediments. Alum addition also results in $Al^{3+}$ ions in solution, which can combine with dissolved phosphate to form an $AlPO_4$ precipitate. The formation of aluminum hydroxide precipitate with large doses of alum can result in a significant production of additional solids or sludge, which consumes alkalinity and decreases pH (Bottcher et al., 2009). Alum additions to treatment wetlands can increase P removal; however, safe and effective operation of a constructed treatment wetland must address management of the flocculant aluminum hydroxide precipitate that is produced, including monitoring the potential for aluminum toxicity in acidic or low alkalinity conditions and avoiding or minimizing conditions that support the methylation of mercury. The Klamath River alkalinity is relatively low, and generally in a seasonal average of 80-90 mg/L (as CaCO3) (Yurok Trib, 2009).

Additional factors to address in constructed wetland treatment system design are seasonal conditions and extremes. The Upper Klamath basin has seasonally distinct and varied climatological conditions, characterized by hot, dry summers and wet winters with moderate to low temperatures and frequent freezing periods. Wetland biological processes slow in response to colder temperatures. Wetland plants are dormant and production of new plant biomass stops below freezing temperatures. Ice cover can further affect constructed wetlands by altering wetland hydraulics and restricting solar insolation and atmospheric reaeration. However, the insulating layer provided by ice cover slows the rate and degree of cooling in the water column and does not appear to affect physical processes such as settling, filtration, and flocculation. Total phosphorus (TP) removal is not significantly affected by the cold temperatures that exist in treatment wetlands covered by ice and snow (Kadlec and Reddy, 2001).

Beyond P removal, constructed wetland treatment system goals of beneficial water use and support of high quality wildlife habitat are affected more by seasonal conditions than attainment of the P removal water quality goal. Thus, generation and deposition of organic material serves to store water that is less susceptible to evaporative forces, and provide more insulation from high temperatures and winds that drive high evaporation losses during the April through October period (Mayer et al., 2006). Such wetlands can provide substantial net addition of flow to the Klamath River flows during the early (and perhaps late) summer months.

Dense monotypic stands of vegetation in broad areas, however, neither optimize wildlife habitat nor support wildlife diversity to the extent that a mosaic of open water, wetland, and upland communities and landscapes do. Thus, the siting and layout of constructed treatment wetlands may ultimately focus on using more degraded sites with higher P soil accumulations and greater subsidence. On such sites, landforms (through soil accretion) and the desired mosaic over time can develop while discharging improved water quality and more consistent volumes to existing higher quality habitat areas.

## 2.3 Similar Wetland Treatment Projects

Constructed wetland treatment system design for the Klamath Basin builds upon “lessons learned” from successfully implemented systems with similar objectives; that is, they accomplish P removal, water management and flow augmentation, and wildlife habitat goals with inflow water from a riverine system. Demonstration systems address the factors contributing to variability observed in these systems, as well as design and operation questions specific to the Klamath Basin setting.

For comparison purposes, the aquatic P and N TMDL goals for the Klamath system are summarized in Table 2-2. Note that these numbers apply at various points in lakes or river reaches and are generated through modeling as a part of the TMDL-setting process. These numbers are presented to provide a range of outcomes by which to evaluate the applicability of case study results to attaining Klamath Basin objectives.

TABLE 2-2
**TMDL Concentration Targets, Klamath River Basin**

| | Annual Mean | Spring (March-May) Mean | Tributary Inflows Annual Mean |
|---|---|---|---|
| **Upper Klamath and Agency Lake** | | | |
| Total Phosphorus (µ/L) | 110 | 30 | 66 |
| **Klamath River** | | | |
| Total Phosphorus (mg/L) | 0.014-0.027 [a] | | |
| Total Nitrogen (mg/L) | 0.25-0.52 [a] | | |
| **Lost River** | | | |
| Total Ammonia (as $NH_4$; mg/L) | 0.025-0.55 [b] | | |

Notes:

[a] Summer average (June 1 – September 30), range across river miles
[b] Annual average, range across river miles

### 2.3.1 Other Regions in the U.S. and World

Table 2-3 summarizes key design and operations features of wetland treatment systems contributing to the body of knowledge and informing demonstration constructed wetland treatment system design.

TABLE 2-3
**Comparable US and Global River-fed Wetland Treatment Systems**

| Wetland Name and Location | Flow | Size | Cost | Treatment Efficiency | Treatment Mechanism and Drivers | Notes |
|---|---|---|---|---|---|---|
| Prado Wetlands, Santa Ana River, CA[1] | ≤ 200 cfs | 465 acres | $5 million | Removes 20 tons of $NO_3$ per month; $NO_3$ concentrations decrease from 10 mg/L to less than 1 mg/L (summer). | Denitrification driven by quality/quantity of organics produced by vegetation, longer HRT, warmer temperatures, and maturity of system. | System remodel 1997: increased HRT by creating parallel flow trains, subdividing larger ponds, increasing flow delivery flexibility. |
| Imperial and Brawley Wetlands, New River to Salton Sea, CA[2] | | 43 acres (I), 9 acres (B) | $2 million; O&M $140,000 per year | >90 percent removal TSS and pathogens; 38 percent TP (I) and 49 percent TP (B) removal; 49 percent TN (I) and 72 percent TN (B) removal. | TP and TN removal driven by longer HRT, infiltration of 25 percent of influent water. | High temperatures and low precipitation climate, infiltrating systems receiving eutrophic inflows. |
| Stormwater Wetlands, Tahoe City, CA[3] | | 1.5 acres | $6 million | ≥ 49 percent removal dissolved P, NO3, SRP, and TSS; event median TP concentrations reduced from 279 μg/L to 94 μg/L. | Winter/spring treatment occurs but at lower rates. | Receives stormwater runoff from commercial, residential and highways; FWS wetland. |
| Wetlands Demonstration Project, Des Plaines River, IL[4] | | 550 acres | | Average 92, 84, and 85 percent removal for TSS, $NO_3$-N, and TP, respectively; growing season removal TSS 76-99 percent, $NO_3$-N 39-99 percent, and TP 52-99 percent. | Sediment long term removal of TP, pulsed loading increases $NO_3$-N removal efficiency, year-round treatment occurs. | Cell sizes 5-8.5 ac; HLR 1.3 to 5.7 cm/day; modeling concludes that TP was retained in sediments at a rate of 1.08 to 2.47 g/m$^2$/yr. |
| Richland-Chambers Treatment Wetlands, Trinity River, TX[5] | 12-15 mgd | 443 acres initial phases, 1,500 acres at build-out | $16 million initial phase | In pilots, >65 percent TP, >80 percent TN, 95 percent TSS removed; in initial phase, 45, 77, and 96 percent removal of TP, $NO_3$-N, and TSS, respect (inflow concentrations 0.97, 3.17, and 212 mg/L, respectively). | HRT of 7-10.5 days in pilot cells; bulk of TSS plus substantial fraction of TP removal in initial sedimentation basins; diverse wetland plant community disperses flow; need deep and shallow water zones; must be able to manage water depths. | After treatment, water is stored for reuse by Dallas/ Ft. Worth region; 2.25-acre total pilot cell wetland area taking 0.1 mgd flow. |
| Caernarvon Freshwater Diversion Project, Mississippi River, LA[6] | 1-3 billion m$^3$/yr | 16,000 acres | $26.1 million | 62, 44, and 57 percent removal of TP, TN, and DIN, respect (inflow concentrations 0.15, 1.9, and 1.46 to 2.14 mg/L, respectively) during inundated period. | Pulsed flows favor denitrification while TP is consistently removed only during inundated periods. | Pulsed flow delivery system. |
| Everglades Construction Project, FL[7] | 1.7 million L/yr (2010) | >65,000 acres | $1.2 billion | Over 16-year period discharge P load reduced by 74 percent and concentrations from annual flow-weighted mean TP 145 to 40 μg/L; 76 percent TP load reduction and median TP concentrations lowered from influent 147 μg/L to effluent 33 μg/L; 100-acre SAV cell yields geometric flow-weighted mean TP concentrations of 8- 10 μg/L. | Submersed aquatic vegetation (SAV) and native calcareous periphyton exhibit greater removal rates for P compared to emergent aquatic vegetative systems. | Stormwater treatment wetlands constructed to treat agricultural runoff; average hydraulic loading rate of 2.83 cm/d and TP loading rate of 1.52 g/m$^2$/yr (2010). |

TABLE 2-3

**Comparable US and Global River-fed Wetland Treatment Systems**

| Wetland Name and Location | Flow | Size | Cost | Treatment Efficiency | Treatment Mechanism and Drivers | Notes |
|---|---|---|---|---|---|---|
| Sacramento Delta, Sacramento and San Joaquin Rivers, CA[8] | Mean inflow rate 900±200L/min (Res time 6 and 13 d) | Two 3-ha pilot wetland sites | | From 1997-2005, linear increase in surface level obtained to 22.6 cm or 3.1 cm/yr in shallow wetland and to 27.4 cm or 3.8 cm/yr in deep wetland but with lots of spatial variability similar to vegetation variability; high small scale variability in sediment accretion, without statistical different results between sites (1.8 and 2.0 cm/yr). | Since suspended solids inflow accounted for 0.47 cm/yr accumulated material, plant biomass from emergent vegetation was primarily responsible for elevation increases; sediment redistribution occurred throughout the wetland, with belowground material largest contributor; long residence times related to highest sediment accumulation rates. | Objective is to manage freshwater hydrology to re-establish wetlands and accrete new peat to raise land-surface elevations in the Delta; pilot study; water depths to 55 and 25 cm, with pH mean of 7.5 s.u. and DO >50 percent at wetland entrance. |
| Kis-Balaton Water Protection System, Zala River, Hungary[9] | | Res 1: 18 $km^2$, Res 2: 16 $km^2$ | | Approx. 80,000 t TSS, 300 t TP, 250 t PO4-P, 850 t TN, and 2450 t $NO_3$-N were retained 1986 -1997 in Res 1; as of 1999, 50 percent TSS, >33 percent TP, >67 percent $PO_4$-P, 10 percent TN, >50 percent $NO_3$-N retained annually both Res. | Heavy P loads were received and removed in Res 1 up until 1991, when the upstream WWTP added P treatment and loads to Res 1 greatly decreased; with the mean carbonate content of sediments approximately 20 percent and P sorption the dominant retention process of this algal dominated system, P began to be released from the sediments. | Consists of two reservoirs, through which entire Zala River flows; Res 1 is open water with algae dominant, Res 2 was reed beds but die off has occurred as in many European reed bed wetlands. |

References:

[1] OCWD, 2008 and Ibekwe et al., 2006

[2] Tetra Tech and WMS, 2007

[3] Heyvaert et al., 2006 and Strecker et al., 2005

[4] WRI, 1992; Hey et al., 1994a and 1994b; Wang and Mitsch, 2000; Alvord and Kadlec, 1996

[5] Kadlec et al., 2011

[6] Day et al., 2009; Lane et al., 2004; and Patrick and Khalid, 1974

[7] SFWMD, 2010; DeBusk et al., 2001; Dierberg et al., 2002; and Pietro et al., 2010

[8] Miller et al., 2008

[9] Istvanovics and Somlyody, 1998; Clement et al., 1998; Istvanovics and Somlyody, 1999; Tatrai et al., 2000; and Zlinszky, 2013

### 2.3.2 Klamath River Basin

Research and monitoring have been conducted to characterize the hydrology, water and soil chemistry, and vegetation communities in Klamath River basin wetlands, which informs and focuses controlled experiments for which the DWFs are designed to support. Especially critical to DWF designs are design criteria and features that ensure clarification, through data collection and statistical analysis, of the factors that maximize successful P sequestration by wetlands within the region. A brief overview of pertinent Klamath Basin wetlands research is summarized in Table 2-4, highlighting key results that inform DWF siting and design.

In general, the following observations regarding site-specific factors that might affect wetland P removal are found in Klamath Basin wetlands research:

1. With water depth managed to ensure constant surface water and optimal emergent plant growth during the growing season, P is being removed and soil is accumulating in the system annually.
2. Timing of controlled inflows to restoration wetlands and controlled outflows to lakes can be used to maximize long term sequestration in wetlands and minimize loading to Klamath Lake during sensitive periods or when such discharge will increase lake sediment mobile P. For example, Stevens and Tullos (2011) reported that early timing of inundation and longer duration led to less P release for directly connected wetland than for indirectly or mechanically connected wetlands.
3. Macrophyte, submerged aquatic vegetation, attached algae (periphyton), and phytoplankton interactions (both alive and as detritus material) interact with SRP pool to dominate phosphorus cycling. Rates, timing, and interaction of processes and conditions to maximize long term storage of P in these systems are yet undetermined.
4. Groundwater delivers significant nutrient and some mineral loadings to the Klamath Basin wetlands and likely Klamath Lake, regulating water budget and chemistry conditions. Diurnal phytoplankton productivity during summer months and macrophyte plant material organic availability in late summer/early fall are also factors driving chemical cycling rates and processes between living plant material, water, and soil substrate compartments.
5. Larger proportions of open water in treatment and restoration wetlands will increase water loss to evaporation.
6. High DOC and POC concentrations (up to 100 mg/L), and variability in same, may need to be taken into account for effects on light availability on vegetation productivity, in estimating sediment and soil accumulation, as well as potential matrix effects on water chemistry analyses.
7. Trace metals iron and aluminum are present in Klamath Basin soils and may participate in biogeochemical cycling when soils and sediments undergo changing hydrologic conditions.

These factors point to many unique features of the Klamath River basin wetlands that can influence the planning and application of treatment wetlands. Demonstration constructed treatment wetlands can test how to use these factors to maximize long term nutrient sequestration within wetland systems.

TABLE 2-4
**Klamath Basin Wetlands Research**

| Research Site | Hydrology/Water Budget/Water Depth | Chemistry | Vegetation/Wildlife | Comments |
|---|---|---|---|---|
| Wood River Wetlands[1] | Managed to maintain average water depths within a range of -13 (S. cell) to +40 cm during growing season; Sources groundwater 59 percent, precipitation 21 percent, irrigation/leakage 20 percent; outflows: ET 69 percent, pumping 31 percent. | Approx. annual loss/sequestration within wetlands of 28-41 metric tons N, 17-22 metric tons P; discharged water concentrations of P decreased nearly an order of magnitude, soluble N concentrations have decreased to near detection limits, and TN:TP ratio has increased 3 fold over the period. | Wocus, bur reed, and bulrush potentially maintained at target water depths; within current vegetation communities, 2.4 cm annual soil depth gain was measured while benchmark annual elevation gains of 3.8 cm were measured. | 2008-2012 period monitored. |
| Williamson River Delta Wetlands[2] | Deeper water areas appear to have lower TP concentrations in water. | Mid-August through early October TP concentrations up to 4 times lower in 2012 compared to 2008 in open water and deep water (permanently flooded) wetlands and 3 times lower in lakes; during June–August of the same period, shallow water (emergent and transitional) wetlands in Tulana showed a decrease in TP by up to 2.4 times. June-July in 2009 vs. 2012 in Goose Bay emergent and transitional wetlands TP concentrations were up to 2.8 times lower; TP had been released from agricultural lands after initial flooding prior to 2008. Restoration monitoring over 5 years showed decreasing frequency of periods when sucker DO and temperature tolerances (intolerant to DO<4 mg/L and temperature greater than 28ºC) were violated, with increasing time since restoration, especially in Tulana and Goose Bay emergent sites, which have the densest wetland vegetation that provide shading from solar radiation. | Vegetated areas appear to decrease water temperatures, which in turn allow higher absolute water DO concentrations. | 2008-2012 period monitored. |
| Wood River, Williamson River Delta, Agency Lake Ranch, and South Marsh Wetlands[3] | Three hydrologic management strategies represented direct connection to lakes, no direct connection to lakes and seasonal mechanical in pumping/passive dewatering, or no direct connection to lakes and mechanical pumping (in and out). Directly connected wetlands may release less phosphorus than indirectly or mechanically connected wetlands, possibly due to early timing of flooding during lower temperature periods and longer duration of inundation during lower temperature periods. | Greater release rates of total phosphorus occurred in summer temperature treatments for all study wetlands (average 31.81 to 240.61 $mg/m^2/d$), while release rates of soluble reactive phosphorus (average -15.9 to 62.19 $mg/m^2/d$) varied with temperature and soil characteristics. Wetlands with mineral soils and direct hydrologic connectivity to the lakes released the lowest concentrations of total phosphorus, while soluble reactive phosphorus release varied across management strategies and soil types. | | Beyond temperature effects, organic composition and pH of soil type drives P release upon inundation. |
| Wood River, Williamson River Delta, Agency Lake Ranch, and South Marsh Wetlands[4] | Management strategies modeled to identify effect on discharges to Klamath Lake during algae growth-stimulating months: Early Outflow, Macrophyte Harvest, and Dry Wetland management approaches provide summer sequestration of P in plant material, with the latter storing the greatest P mass; No Outflow management approach stores P in sediments. | Wetland resuspension of P at high rates throughout year; macrophyte uptake and sedimentation key factors for sequestration of P such that monitored wetlands are net sink of P over time; however, rate of P recycled from lake sediments exceeds wetland P sequestration. | Vegetation is lumped into two categories: macrophyte and algal. | Mass balance model of biological P dynamics concludes that, over the course of one year, while wetlands are effective at decreasing or eliminating P discharge to Klamath Lake, minimizing external loading is not likely to diminish algal blooms in the lakes because annual P amount released from the sediments far exceeds sequestration capabilities of current wetlands. This does not prove, however, that over a longer time period, P will not be released from sediments and support algal growth, with a net decrease in sediment and available P storage. |
| Wood River Wetlands[5] | Surface water levels reached maximum levels in early spring, and minimum levels August through November. Shallow groundwater levels followed the same trends and showed a strong upward gradient. Water budgets developed indicated proportions of sources: precipitation 43 percent, regional groundwater discharge 40 percent, irrigation water 12 percent, groundwater seepage through dikes and artesian wells 5 percent. Outflows from open water evaporation (64 percent) and vegetated area evapotranspiration (36 percent) contributed to a net deficit of approximately 19 percent. Soil moisture could be a significant portion of the water budget. | Dominant forms of surface water nutrients are SRP and DIN + $NH_4$ which are in high concentrations as is DOC; in artesian well water and the deepest (26-28 m) piezometer samples, concentrations are even higher. Surface water nutrient concentrations increase in spring and summer due to decomposing peat, decomposing aquatic vegetation, groundwater upwelling, and evapotranspiration. SRP concentrations decrease during fall and winter, due to dilution plus potentially adsorption or deposition with iron, and manganese compounds. | Plant community of grazing resistant edge and upland plants trending to obligate wetland plants including emergent species *Typha latifolia*, *Sparganium eurycarpum,* and *Eleocharis macrostachya,* and submerged macrophyte species *Ceratophyllum demersum*, *Elodea canadensis*, and *Potomagetan crispus.* | In situ mesocosm studies indicated high oxygen demand, positive flux of $NH_4$ and SRP from bed sediments, and confirmed active denitrification, although low and probably limited by low nitrate availability. |
| Upper Klamath National Wildlife Refuge[6] | Mean wetland ET varied from 6-7 mm/day midsummer to <1mm/day midwinter, with pure bulrush and mixed bulrush-cattail-wocus wetland means ± 2.5 percent. Hydroperiod has minor influence on ET. Estimate of 3-year annual ET is 0.938 m/yr, less than alfalfa rates (0.997m/yr) and more than pasture rates (0.820 m/yr). Overall, open water evaporation was 20 percent greater than wetland ET. | | | |

TABLE 2-4
**Klamath Basin Wetlands Research**

| Research Site | Hydrology/Water Budget/Water Depth | Chemistry | Vegetation/Wildlife | Comments |
|---|---|---|---|---|
| Keno Reservoir, Klamath River Reach 233-235[7] | Keno Reservoir is operated to meet water needs within the reservoir and releases from Keno Dam to meet downstream flow requirements, which result in a highly variable flow regime within the reservoir. | Treatment wetland needs to be able to remove dissolved organic carbon (DOC) and particulate carbon (POC) which are measures of seasonal organic matter concentrations in Keno Reservoir (6-11 and 2.5-9.0 mg/L respectively); trace amounts of mercury (Hg) found in surface water, so likely found in sediments and other system compartments, so formation and availability of methyl mercury is a concern in treatment and restoration wetlands. | Potential for making treatment wetland a "fish-friendly" design, especially for Lost River and Shortnose suckers (*Deltistes luxatus* and *Chasmistes brevirostris*). | OWRD may require water rights for a treatment wetland if it requires continuous flow through conditions because this is not an exempt use. A hydrologically connected wetland placed in or adjacent to the channel without active flow regulation would be exempted. |
| Upper Klamath and Agency Lakes [8] | Wetlands were hydrologically reconnected to these lakes through engineered levee breaches in 2007. | Benthic flux measurements of SRP, ammonium, dissolved iron, and manganese remained elevated over the 4-year period, while DOC benthic fluxes dissipated in the reconnected wetlands. Dissolved copper flux was negligible, as was the flux of cobalt, nickel, lead, and zinc; and dissolved zinc flux was negligible to slightly negative. | Aquatic benthic invertebrates recolonized over the period of time, becoming like assemblages found in established wetlands between 2007 and 2011. | Establishment of long term biochemical cycling in any wetland system will require longer than 4-year periods. |
| Arcata Marsh, CA[9] | | Carbon and nitrogen were concentrated in peat compartment (both species) at 37 and 42 percent respectively; phosphorus was concentrated in the live root and live aboveground compartments, at 32 and 23 percent, respectively. Settled solids compartment, including algal solids, were a significant compartment for carbon, nitrogen, and phosphorus (20 percent, 37 percent, and 24 percent respectively). | *Typha latifolia* and *Scirpus acutus* studied for biomass productivity, decomposition, and potential for nutrient storage. For aboveground primary productivity, *Typha* averaged 23,696 kg/ha and *Scirpus* averaged 11, 073 kg/ha; below ground primary productivity was 6,703 and 30,191 kg/ha respectively; both were more productive in mixed- species communities. *Typha* decomposition rate was higher with about 0.4 percent remaining after 487 days; *Scirpus* had just less than 0.8 percent remaining after the same period, less than literature rates. | Concludes that *Scirpus acutus* is a more appropriate plant to use in constructed wetlands for wastewater treatment because it stores more biomass and nutrients in below ground tissues and releases less accumulated constituents as decomposition byproducts. |

References:
[1] BLM, 2013
[2] The Nature Conservancy, 2013; Wong and Hendrixon, 2011
[3] Stevens and Tullos, 2011
[4] Mulford, 2011
[5] Carpenter et al., 2009
[6] Stannard et al., 2013
[7] Deas et al., 2012
[8] Kuwabara et al., 2012
[9] Burke, 2011

SECTION 3

# Klamath River Wetland Research and Design Issues

The use of wetlands for improving water quality is a common application worldwide, as outlined in Section 2, and the specific use of wetlands for improving river and lake water quality is an established approach. The functional design of treatment wetlands for nutrient reduction has been made more consistent through the publication of numerous technical publications, key texts such as Kadlec and Wallace (2009) and similar design handbooks. Similarly, the approach to functional wetland restoration in the Klamath River basin has gained in understanding over the past decade through the implementation of full-scale projects such as the Wood River Wetlands and the Williamson River Delta. Through review of technical publications, and through discussions with the TAC members, critical factors that influence and constrain full-scale treatment wetland performance have been identified, including the variable importance of groundwater as a source of nutrients, consumptive losses of water by evapotranspiration and groundwater infiltration, and rates and processes of wetland soil development.

Because future focal areas of research at the DWF cannot be exactly known at this time, this section proposes preliminary hypotheses for testing in the DWF. The set of hypotheses are focused on the importance of the key factors identified above, with the following emphases:

- An approach to develop regionally-specific treatment wetland sizing criteria
- A method of evaluating the effect of groundwater interactions and their influence on the nutrient balance experimentally; controlled approaches to estimating the rate and process of wetland soil development as a restoration tool
- The experimental determination of plant community type on these factors
- The community composition and wildlife habitat utilization of regionally important wetland vegetation types used in a treatment wetland context

The TAC members were surveyed to confirm the topics and their relative priorities of research interests for the demonstration wetland facility. This section summarizes the results of the survey, provides an overview of the general experimental design of the DWF, and the set of research topics the system is designed to assess.

## 3.1 Technical Advisory Committee Research Priorities

The TAC is comprised of public and private stakeholders with a broad range of organizational missions and research interests. The demonstration wetland facility is envisioned as a versatile research platform that would yield information useful to all interested in water quality restoration and enhancement in the Upper Klamath River. To capture and characterize this range of interests, the TAC was provided a list of potential attributes and objectives of the DWF and requested to rate them as high, medium, or low. These features ranged from key topics such as demonstrating nutrient removal and retention, key hypotheses such as groundwater interaction effects on nutrient retention, to key features such as the suitability of the information for scaling from individual farms to large restoration areas. A total of 12 responses were received, providing a useful cross-section of the TAC's interests and responses. The list of topics and their prioritization by each TAC member respondent is summarized in Figure 3-1.

FIGURE 3-1

**Candidate Research Priorities for the Demonstration Wetland Facility and Technical Advisory Committee Member Priority**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Key Topics Priority | - | - | - | - | - | - | - | - | - | - | - | - |
| Nutrient Removal & Retention | H | H | H | H | H | H | H | H | H | H | H | H |
| Hydrology & Water Balance | H | M | L | H | M | H | H | L | M | H | H | H |
| Soils & Accretion (Soil Rebuilding) | M | H | L | H | L | M | M | H | M | M | L | L |
| Biodiversity & Habitat | L | M | L | L | H | M | H | L | L | H | M | M |
| Hypotheses to be Evaluated | - | - | - | - | - | - | - | - | - | - | - | - |
| Site Factors Affect Background Nutrient Concentrations | H | H | M | H | L | H | H | H | M | H | M | H |
| Vegetation Type and Loading Rate Affect Nutrient Removal and Retention | H | H | M | H | M | H | H | M | H | H | M | H |
| Vegetative Cover and Loading Rate Affect Water Loss | H | H | L | H | M | H | H | L | M | H | M | H |
| Groundwater Upwelling and Losses Affect Nutrient Removal and Retention | H | H | H | H | M | H | H | L | M | H | L | H |
| Vegetation Type and Loading Rate Affects Soil Accretion Rate | M | H | L | H | L | M | M | L | M | M | L | L |
| Wetland Type and Conditions Affect Biodiversity and Habitat Use | L | M | L | L | H | M | H | L | L | H | L | M |
| DWF Features & Operations | - | - | - | - | - | - | - | - | - | - | - | - |
| Assess passively-restored systems | H | H | H | H | L | H | H | H | M | M | M | L |
| Assess more designed/engineered systems | H | L | H | H | H | H | M | H | H | H | H | H |
| Assess pre-treatment techniques to enhance nutrient removal & retention | M | H | L | H | M | H | H | H | L | H | H | M |
| Assess diffuse source treatment wetlands | H | H | H | H | L | H | H | H | H | M | M | M |
| Determine O&M requirements and costs | H | H | M | L | H | H | M | M | H | H | H | H |
| Ability to be Scaled Up | H | M | H | M | H | H | H | H | H | H | M | H |
| Assess facility siting on private land | H | H | L | M | H | M | M | L | H | H | M | M |
| Assess facility siting on public land | H | H | L | H | L | M | M | M | H | H | M | M |
| Assess on-farm suitability | H | H | M | H | H | M | H | L | M | M | H | M |
| Incorporate public education opportunity | L | H | M | M | M | H | M | M | L | H | M | H |
| Incorporate Scientific Research opportunities | H | M | H | H | L | H | M | H | H | H | M | H |

To provide a basis for prioritization, a score of 1, 2, and 3 were assigned to each L, M, and H response, respectively, and the scores were summed for each topic and normalized to a scale of 1-100, where 100 is highest priority. Ranking of topics is provided in Table 3-1.

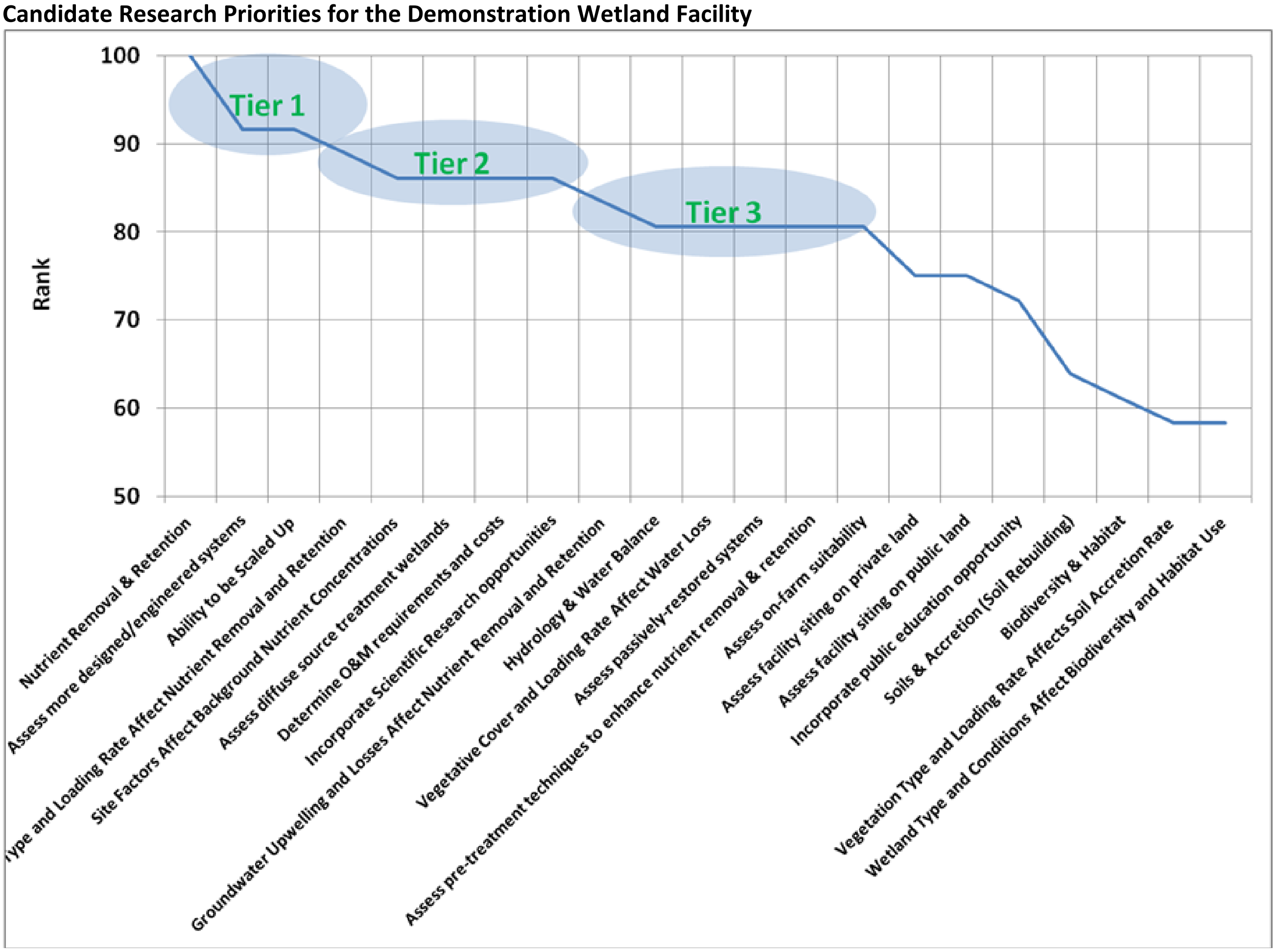
TABLE 3-2

**Candidate Research Priorities for the Demonstration Wetland Facility Ranked in Descending Priority**

| Key Topics Priority | Ranks |
|---|---|
| Nutrient Removal & Retention | 100 |
| Assess more designed/engineered systems | 92 |
| Ability to be Scaled Up | 92 |
| Vegetation Type and Loading Rate Affect Nutrient Removal and Retention | 89 |
| Site Factors Affect Background Nutrient Concentrations | 86 |
| Assess diffuse source treatment wetlands | 86 |
| Determine O&M requirements and costs | 86 |
| Incorporate Scientific Research opportunities | 86 |
| Groundwater Upwelling and Losses Affect Nutrient Removal and Retention | 83 |
| Hydrology & Water Balance | 81 |
| Vegetative Cover and Loading Rate Affect Water Loss | 81 |
| Assess passively-restored systems | 81 |
| Assess pre-treatment techniques to enhance nutrient removal & retention | 81 |
| Assess on-farm suitability | 81 |
| Assess facility siting on private land | 75 |
| Assess facility siting on public land | 75 |
| Incorporate public education opportunity | 72 |
| Soils & Accretion (Soil Rebuilding) | 64 |
| Biodiversity & Habitat | 61 |
| Vegetation Type and Loading Rate Affects Soil Accretion Rate | 58 |
| Wetland Type and Conditions Affect Biodiversity and Habitat Use | 58 |

Topics, hypotheses, and features grouped into several priority rankings and established several apparent “tiers” of priorities (Figure 3-2). Tier 1 ranged in rank from 92-100, and included the key topic of nutrient removal and retention (all respondents placed this uniformly as the highest priority); the operational ability to assess designed and engineered systems; and the scale-up ability of findings. Tier 2 ranged from 86-89, and included key hypotheses of vegetation type and loading rate effect on nutrient removal and retention; effect of site factors on irreducible background nutrient concentrations; the features useful in assessing diffuse source treatment wetlands; O&M requirements and costs; and incorporating scientific research opportunities. Tier 3 ranged in rank from 81-86, and included key hypotheses related to groundwater upwelling and loss effects on nutrient removal and retention; vegetative cover and loading effects on water loss, a key focus on hydrology and the water balance; features that support the assessment of passively restored systems; pre-treatment techniques to enhance nutrient removal and retention; and on-farm suitability. The remaining topic priorities ranked less than 80, and included operational features to assess facility siting on private and public lands; incorporate public education opportunities; study of soil accretion and rebuilding and vegetation effects; and biodiversity and habitat.

FIGURE 3-2
**Candidate Research Priorities for the Demonstration Wetland Facility**




As a consequence of the findings of this preliminary survey of TAC interests and priorities, the demonstration facility features, and this Research Plan, have been adjusted to better respond to these expectations. Subsequent descriptions in this section, and the greater detail on research hypotheses in Sections 3 and the features of the demonstration wetland facility in Section 4 describe how these prioritized topic groups have been incorporated into the Research Plan.

## 3.2 Experimental Design of the Demonstration Wetland Facility

The experimental design of DWF is conceptualized as having the following factors and operational ranges:

- Vegetation types: 2 (shallow emergent, e.g., cattail, bulrush and deep and floating-leaved (e.g., SAV, wocus); with a total 5 cells for each type, including cells and subcells)
- Hydraulic loading rates: 3 (target ranges of 10 cm/d, 3 cm/d, and 1 cm/d for maximum, average and minimum flows). This term is analogous to an irrigation rate, or the volume of water applied per unit area of land. For surface flow wetlands, the average value of treatment wetlands has tended to be on the order of 3 cm/d (Kadlec and Knight, 1996). An HLR of 10 cm/d would be a relatively highly loaded wetland.
- Water depths: 2 (deep and shallow, which varies by community, and corresponding to the target range of water depths described in Section 4).
- Groundwater interaction modes: 4 (none [lined cells], ambient [unlined cells], groundwater input and groundwater infiltration [4 lined subcells with subsurface distribution and drainage piping])

Establishment of the wetland cells would be expected to commence concurrently, and sufficient time and water depth control would be allotted for the cells to grow uniform and dense stands of vegetation. Given the extreme seasonality of the Klamath River basin, two full growing seasons should be allowed for the wetland cells to develop before experimental testing. During this establishment period, trends in nutrient concentration, soil accretion, vegetation community growth, water balance effects, and wildlife occurrence would be tracked, providing useful baselines in a developing wetland.

Once established, the system would allow side-by-side comparison of system response under experimental conditions. Each test condition could be operated for an annual cycle in order to capture seasonal variation. Conceptual examples of these the paired experimental trials tests and their potential contribution to wetland planning are described below. For each, average removal rates, outflow concentrations or other variables in each test cell could be compared statistically and with other cells.

- Effect of hydraulic loading: The three large cells and/or two subcells for each community type would be operated at the same depth, but receive different hydraulic load rates (HLR). For example, Cell A would receive an average HLR and Cell B an HLR 2-3x greater. This comparison would characterize the range of flows associated with maximum mass removal for a given range of inlet concentrations. As a key scaling factor, a focus on hydraulic loading supports the highest ranked Tier 1 topic priority of ability to scale the results to different settings, from large restorations to small farms.
- Effect of water depth: Because wetland plant community composition is directly influenced by depth and duration of inundation, comparative testing of wetlands of different depths will identify similarities and differences of performance by type, a high-ranking Tier 2 TAC priority. The three cells within each community type would receive the same hydraulic loading rate but would be operated at two different depths. For example, both cells would receive an identical HLR but Cell A would be operated at one depth; Cell B depths would be varied seasonally or operated at a greater depth, within range of the normal hydroperiod tolerance of the community. With different HRTs, the objective would be to characterize a minimum HRT associated with a maximum nutrient reduction for a plant community type. Findings from this comparison would support the objective of minimizing consumptive water in future wetland sizing.
- Effect of inlet concentration: Pairs of cells could receive identical HLRs for one year but be operated under a different water source for the second year. This comparison would enable model parameter calibration under a range of nutrient loadings encompassing higher canal inflow concentrations or lower river inflow concentrations. This focus supports the investigation of Tier 1 priority of nutrient reduction, given the importance of inflow concentration on wetland area requirements and performance expectations. Of equal importance is the interest in establishing an understanding of the effect of prior, or cumulative, nutrient loading on performance. Changing loadings annually may lead to release of the internal load from detrital decay and obscure subsequent P uptake. Late fall and spring warm periods tend to release loads as senescent plants decompose. It is recommended that loadings to all cells begin

with the lowest load and sequentially proceed to the highest load to minimize this effects. Comparisons of performance between cells amongst years may identify system response to high or variable loadings.

- Effect of groundwater interaction: The demonstration of the effect of groundwater on wetland performance was included in the Tier 3 priorities but is considered a key factor influencing wetland hydrology and nutrient balances in the region, given the local geology and seasonal artesian flow measurements in prior studies. Four lined subcells have been included in the facility to allow direct control of groundwater as a source or as a loss term. A provision has been made to allow inflow water to the subcells to be spiked experimentally with P and N at rates that can simulate the potential for artesian flow of high nutrient groundwater. Two unlined cells have been included to allow direct comparisons with lined cells to establish differences in performance attributable to groundwater interactions. Nested piezometer wells in the unlined cells and in a reference cell adjacent to the demonstration wetland facility in the Wood River Wetland would allow daily and monthly ground water inflow or loss to be estimated directly.

Other comparisons are likely, and importantly, extend beyond our current ability to foresee. The DWF is envisioned as a versatile research platform that would facilitate detailed analysis of factors most important to characterizing the nutrient removal performance of treatment wetlands and their ecological attributes. Because the system is envisioned to be operable for many years of operation, there will be opportunities for testing wetland treatment performance under a range of conditions.

## 3.3 Nutrient Removal and Retention

### 3.3.1 General Approach to Wetland Performance Evaluation

The underlying approach to sizing of treatment wetlands centers on the application of models that describe the disappearance of phosphorus, nitrogen and most parameters in wetlands as a first-order treatment process. Calibrated rate constants (k) can be applied using known quantities of fluid flow and concentration, to estimate the area required for treatment to a specific objective.

The sizing approach is based upon a wetland area basis but may also be expressed in terms of the HRT of a system. Area-based removal rates can be estimated using the following relationship defined in Kadlec and Knight (1996):

$$J = k\,(C - C^*) \qquad (1)$$

Where

J = area-based removal rate, in $g/m^2*yr$
k = first-order rate constant, in m/yr
C = target concentration reduction, in $g/m^3$
C* = irreducible background, in $g/m^3$.

The product of the rate constant k and the target concentration reduction is a removal rate related to the area of the system. The irreducible background concentration (C*) is included to account for the internal cycling of an element or compound in a treatment system. This parameter tends to have an influence on sizing important only when inflow concentrations approach C*.

This basis is widely adopted in the treatment wetland literature, and current sizing approaches may be adapted readily to treatment wetland planning in the Klamath River basin. Specifically, the P-k-C* model described in Kadlec and Wallace (2009) is commonly applied, defined as follows:

$$A = \frac{QP}{k} * \left(\frac{(C_o - C^*)}{(C_i - C^*)}\right)^{-\left(\frac{1}{P}\right)} \qquad (2)$$

Where:

$A$ = wetland area (square meters [$m^2$])
$Q$ = flow (cubic meters per year [$m^3$/yr])
$C_i$ = influent concentration (mg/L)
$C_o$ = effluent concentration (mg/L)
$C^*$ = irreducible background concentration (mg/L)
$k$ = first-order rate constant (m/yr), calibrated to specific pollutants.
$P$ = weathering factor that takes into account the estimated number of hydraulic tanks-in-series and the number of component compounds for a particular parameter (dimensionless)

In this model, the value of $k$ is temperature-dependent and is adjusted using the Arrhenius equation as follows:

$$k = k_{20}\theta^{(T - 20)} \tag{3}$$

Where:

$\theta$ = temperature coefficient
$T$ = temperature (degree Celsius [°C]).

Model factors (i.e., k, C*, $\theta$) are typically determined by calibration from data sets spanning a range of mass and hydraulic loads, vegetation and soil types, and seasonal temperatures. The value for P can be assumed using recommendations of Kadlec and Wallace (2009); alternatively, if data are available, P can be approximated from tracer studies using conservative elements (e.g., lithium chloride, sodium bromide), as described in Kadlec and Wallace, 2009; App.2). To accomplish the calibration, data sets from a wetland system must build upon a water balance, with all important inputs (i.e., inlet flow, precipitation) and outputs (i.e., outlet flows, evapotranspiration) quantified or estimated. A monthly water balance is usually found to be sufficient; more frequent intervals significantly affect the data collection effort and analytical cost. (More detail on the water balance is provided below).

One important feature of the model in common application, as shown above, is its relative simplicity and ease of use. However, the removal rate is unidirectional (i.e., the constituent is always exiting the system), and seasonal storage of nutrients in sediments, and time-varying net gain or loss from sediments or other sources is not factored explicitly into the expression. Two approaches have been implemented to address this aspect. The first approach is to develop a calibration of the model on a time-step consistent with the seasonality of the factors affecting the system. Normally, this is captured adequately by a monthly calibration. As described in Kadlec and Wallace (2009), for example, ammonia and phosphorus removal rates show significant month-to-month variation in temperate regions on a timing consistent with expectations of high removal during periods of peak vegetation growth (e.g., early spring to mid-summer) and low removal or losses during senescence in autumn or winter. A second approach is to add in a specific storage component of the model that yields varying release rates calibrated to observed rates of uptake by growth and release under varying influences, such as alternating aerobic and anaerobic conditions associated with drydown and reflooding, respectively.

From the perspective of the planning and design of the DWF, it is important that the wetland system support the development of a water balance within a reasonable range of accuracy, and to facilitate sampling at frequencies pertinent to the research objectives. As described in Section 4, the potential to obtain good closure on the water balance is factored into the configuration and construction of the DWF.

### 3.3.2 Influence of Background Concentrations on Treatment Performance

To implement constructed wetlands in the Klamath River basin as a method of lake and river restoration, there is a need to quantify the performance potential of a wetland system within the geographical constraints. As shown in the above modeling framework, wetland performance is a function of flow rates, inlet concentrations, and available area: all are factors that likely differ between proposed sites. However, nutrient background concentrations may also vary with local geochemical characteristics, the prior history of disturbance, groundwater influence, and other factors, potentially limiting performance expectations.

Treatment performance targets should be set with the regional background concentration in mind. If background concentrations are relatively low, wetlands could be sized in the future to achieve those values, or nearly so. Alternatively, if background concentrations are high, a wetland could be designed as a mass-reduction system, where C* exerts less of an influence on outflowing water quality. Performance models require an accurate characterization of background P to establish realistic projections.

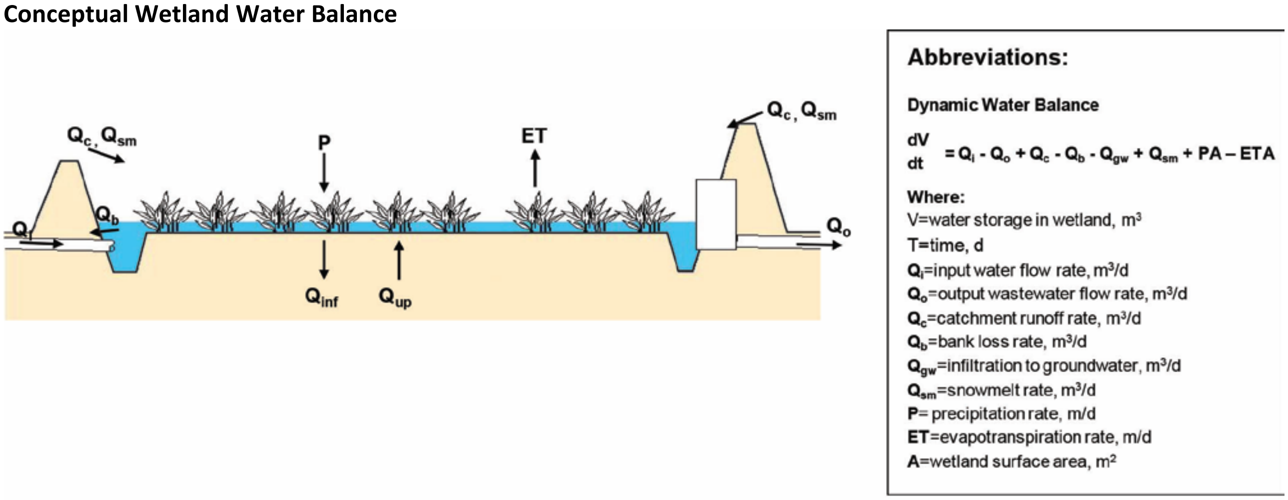
### 3.3.3 Hypothesis: Site Factors Affect Background Nutrient Concentrations

Soil and vegetation type, nutrient loading history, and/or hydroperiod history would be evaluated in the DWF Test Cells under conditions of controlled flow and nutrient loading. As described in Section 4, the proposed conceptual configuration of the DWF includes two distinct vegetation communities, each of which can be tested at different mass and hydraulic loading rates and depth. Conceptually, a null hypothesis would be that there is no difference in nutrient flux rate under different test conditions. The effect of different wetland communities and inlet concentrations on nutrient removals could be compared. Tests for significant differences could be made between model parameters in each of the test conditions. Nutrient removal performance would be measured for all systems.

## 3.4 Water Balance Effects on Treatment Performance and Sizing

The water balance of a treatment wetland consists of inputs that include the inflow, direct precipitation, snowmelt and berm runoff; outputs, including the outflow, evapotranspiration and berm losses, and the net change in storage (Figure 3-1). In settings where a liner is not used, groundwater may be a source through upwelling or intercepted water table, or a loss through seepage through the bottom of the wetland. In treatment wetlands, by intent, the water bring treated typically comprises the major inflow and outflow.

**Figure 3-3**
**Conceptual Wetland Water Balance**




Modified from Kadlec and Wallace (2009).

In arid regions, or areas with extreme seasonality of precipitation and temperatures, such as the Upper Klamath, evapotranspiration can lead to a significant loss of water through direct evaporation from the water surface or via transpiration by plants. Water loss, which is necessary for plant growth and unavoidable in open waters, varies annually in response to natural variation in weather and climate, and changes with time as the wetland matures from more open vegetation cover to a denser canopy. In addition, ground water may be a significant term in the system water balance, through either infiltration or through regional upwelling.

Given the need for large restoration projects in the Klamath River basin, these terms may exert an important influence on the feasibility of a treatment wetland project. From a treatment perspective, the loss of water to evapotranspiration or net gain or less from groundwater can affect the system sizing, in that a wetland sized to achieve a specific load reduction may be too large to sustain hydrated conditions or to return treated waters to the river. These hydrologic gains and losses were likely a natural feature of the historic Klamath River wetland coverage, but may now be exacerbated by human alteration, and they vary in importance from historic regional conditions. Because the allocation of water to wetlands is constrained by existing water rights, there is a need to understand better the relationship between wetland size, treatment performance, and water loss.

### 3.4.1 Hypothesis: Water Loss Affected by Vegetative Cover and Loading Rate

The experimental design of the DWF is intended to allow closure of the wetland water balance with reasonable accuracy; thus, allowing consumptive water losses to be established and compared between communities. As described in Section 4, the wetland cell flows in and out would be metered, which accounts for the major terms of the water balance. Cells would be lined in all but two cells so berm and groundwater losses or gains would be prevented. Unlined cells would reflect ambient groundwater infiltration or surcharge. In four lined subcells, subsurface input or infiltration from the wetland could be adjusted to match ambient hydrologic conditions. Precipitation could be measured directly on site with precipitation gauges and compared to regional values. Berm runoff could be estimated from precipitation and berm areas. Water levels would be measured continuously. Evapotranspiration could be estimated as a residual term in the water balance and validated through periodic comparisons of day- and night-water level recession rates. Typical methods employed to measure these variables are described in Kadlec and Knight (1996) and Kadlec and Wallace (2009). Simpler methods of measuring evapotranspiration (e.g., pan evaporation, relative humidity, wind speed or others) may be monitored concurrently to develop simpler methods of proxy estimation for future use.

Through comparison across the wetland cells, differences in estimates of evaporative loss could be evaluated for statistical significance. The wetland plant species cover and composition could be a variable in the comparison, with the objective of determining the rate of water loss over time as the wetland becomes established or if the vegetative community changes in cover and composition over time.

As water loading rates are adjusted between operational phases, the relative contribution of the evaporative loss to the total water balance could be compared, with the objective of establishing an expectation of a minimum rate of water loss during full-scale operations.

Conceptually, a null hypothesis would be that there is no difference in evaporative losses across the different vegetation communities and under different hydraulic loading rates. Concurrent measurements of nutrient removal performance would allow effects of snowmelt and high spring flows, or evaporative loss during dry seasons to be estimated on nutrient concentrations.

### 3.4.2 Hypothesis: Groundwater Upwelling and Losses Affect Nutrient Removal and Retention

Groundwater upwelling has been hypothesized as a source of nutrients to the Klamath River marshes, based upon hydrologic gradients and available groundwater quality data, as documented by regional researchers (Carpenter et al, 2009). This could have an important effect on wetland treatment performance, in that upwelling nutrients may be intercepted by the wetland vegetation root-soil zone and assimilated, or only partly so, and then enter into the wetland water column. This essentially could function as a type of short-circuit within the wetland and could be measured as an elevated background concentration. The design implication for future wetland projects in the region could be that treatment wetland performance estimated from calibrated data sets may be overstated unless groundwater upwelling is specifically taken into consideration.

Similarly, seasonal or annual groundwater infiltration would affect wetland treatment performance and reduce the amount of treated water returned to the river. Knowing the potential importance of both of these water balance components on treatment performance would contribute to an improved understanding of sizing and performance in future constructed treatment wetlands. As described in Section 4, consideration has been given in the DWF plan for installation of a subsurface piping network to be installed at the bottom of the wetland soil substrate in four subcells that either could receive a pumped inflow of water to simulate an upwelling effect, or could be opened to simulate a range of infiltration losses. Measurement of a water and nutrient mass balance under this configuration could provide a controlled process for estimating potential differences in treatment performance. Experimentally, one of the pairs of wetland subcells could be operated as a flow-through system with no groundwater interactions, while the other matching subcell could include upwelling or infiltration. The performance could be compared statistically between the two subcells and between vegetation types. Conceptually, water spiked with known mass of nutrients could be introduced at low flow rates into the subsurface distribution network. The flow rates for the subsurface augmentation would be expected to be matched to regional estimates of upwelling rates, and infiltration loss rates would similarly be matched to regional rates, if known. For planning purposes at this early stage of the Research Plan development, these rates are estimated to be as much as 40 percent of the wetland inflow rate (Carpenter et al., 2009).

## 3.5 Vegetation Effect on Nutrient Removal and Retention

Based on studies of submersed aquatic vegetation (SAV), floating-leaved communities and emergent aquatic vegetation in other studies, differences in performance may reasonably be expected (e.g., Dierburg et al., 2002; Kadlec and Wallace 2009; Chimney et al, 2014). For example, the Everglades Stormwater Treatment Areas include initial cells vegetated with emergent aquatic plants (i.e., cattails) followed by cells of SAV for a sequence of phosphorus reduction. Recent studies have pointed to the potential for floating-leaved vegetation (e.g., water lily) communities to achieve low target phosphorus concentrations (Chimney et al 2004). Water depth ranges associated with each community type differ, with emergent vegetation typically occupying a depth of 1-2 feet (ft) and SAV and 3-5 ft for floating-leaved vegetation. Deeper systems will have a longer hydraulic residence time, for an equivalent area, allowing more time for treatment processes, but also the potential for excessive or extended algal development, which can affect SAV or vascular plant development. During initial reflooding of wetland restoration areas, subsided areas will have greater depths than historically would have occurred, creating a predominantly open water habitat. As the wetland accretes sediment through deposition of inflowing solids or via biological production, the plant community can be expected to shift toward emergent vegetation cover dominance. The cycling of phosphorus internally to each wetland cell will warrant detailed analysis to capture the relative differences between statistical treatments (e.g., lined vs. unlined, deep vs. shallow). Repeated measurements of biomass, cover and nutrient composition of plants or quadrats through time allows standing crop accumulation and degradation to be measured. Litterbag analyses could be used to establish net nutrient loss of litter and detrital material. More sophisticated analyses such as the use microbial enzyme analysis or other tracers could be applied.

The potential for different levels of treatment to be provided by different vegetation communities, and their successional pattern of development, warrants controlled research in the DWF. Guided by the results of studies at the proposed facility, or by project circumstance, future wetlands could be configured and management to yield a natural gradient of water depths and associated mosaic of vegetation communities, and treatment performance could be predicted. In addition, the effects of wetland vegetation on soil development can be studied, with a view toward optimizing future restoration projects to enhance or accelerate soil rebuilding.

### 3.5.1 Hypothesis: Vegetation Type Affects Nutrient Removal and Retention

The experimental design of the DWF anticipates detailed analysis of nutrient budgets by wetland vegetation type, allowing a comparison of the relative effectiveness at each under identical hydraulic loading rates. As the system matures, HLRs could be varied by replicate cell within each type, thereby allowing a range of performance evaluations. Each shallow cell type would be planted uniformly with locally dominant species of cattail, bulrush, bur-reed and other emergent species, and each deep cell would be planted with SAV and wocus (*Nuphar advena*). However, colonization by other species is anticipated to occur naturally and welcomed as a natural expression of regional successional patterns. With the exception of noxious non-native species such as loosestrife, Eurasian phragmites or other similar nuisance species, this succession should be allowed to take place. Long term tracking of nutrient reduction by the different species could allow evaluation of trends as to whether original performance by the respective vegetation types can be sustained. Conceptually, a null hypothesis would be that there is no difference in nutrient removal and retention between vegetation types under identical HLRs.

### 3.5.2 Hypothesis: Vegetation Type Affects Soil Accretion Rate

Given the differences in life habit and methods of biomass production between emergent aquatic vegetation, SAV, and floating-leaved plants, the relative rate of accretion can be expected to vary. While not ranked as a high priority by the TAC, soil accretion is a natural process that will ultimately compensate for and repair historic soil losses upon reflooding. Emergent aquatic vegetation develop significant and extensive root systems, which provides a foundation for future accretion of aerial biomass with time, while accretion rates by SAV and floating-leaved plants may differ but they are able to establish in the deeper areas that might be expected in areas of subsided soils. With the historical soil loss through oxidation throughout drained former wetlands, a return to natural soil profiles and vegetation communities may be delayed. A controlled comparison of soil accretion rates for each wetland type would allow estimates of soil rebuilding rates in future wetland projects, based upon comparisons of existing wetland soil surface and future water surface elevations. Conceivably, future wetland projects could be designed to enhance or accelerate the rate of soil rebuilding. Conceptually, a null hypothesis would be that there is no difference in soil accretion between vegetation types under identical HLR.

## 3.6 Habitat Quality and Faunal Use of Treatment Wetlands

Existing surface flow treatment wetlands are known to be productive and diverse habitats for wetland wildlife. As a presumed goal of wetland restoration projects, creating a habitat that increases the presence and abundance of wildlife could be considered a benefit of treatment wetlands that complements wetland restoration planning. This response was assigned a relatively low priority (Tier 4) by the TAC, and could be studied opportunistically rather than as a specific research topic. The species occurrence, colonization rate, and habitat quality and utilization of constructed test cells could be recorded and used as a basis for future planning. This level of study could include bird, mammal, fish, amphibian, and invertebrate communities for a comprehensive assessment of the ecological quality and diversity of the constructed treatment test cells. Repeated assessments during later years could identify colonization rates and facets of design and planning that identify what makes wetlands attractive to particular species groups.

### 3.6.1 Hypothesis: Wetland Vegetation Type Affects Faunal Occurrence, Use and Community Composition

Significant differences in species occurrence and density may be expected to become apparent with time, as the DWF Test Cells develop into functional wetland ecosystems. Initially open and with an aquatic aspect immediately after planning and startup, they will change in density and structure with time where the deeper water systems will remain relatively open, while the emergent marsh cells will close in for a virtually complete canopy within two years of initial planting. Similarly, vegetative structure and habitat will affect the diversity and composition of wetland plants, algae and microinvertebrates. Conceptually, a null hypothesis would be that there is no significant difference in habitat use or species occurrence between vegetation types. This could be assessed by periodic wetland mapping, species sampling, and other measures of wetland and animal production. The occurrence or introduction of protected species within the site could be a component of this facet of the demonstration, including possibly controlled introduction of local protected fish species into the deeper cells.

## 3.7 Other Potential Topics

The construction of the DWF would allow a managed research platform to be established that could serve a wide range of research topics complementary to the research needs and interests of the region. For example, the use of chemical coagulants and precipitants has been discussed as a method of enhancing phosphorus treatment in marshes. Conceivably, with sufficient planning and controls, an alum or ferric chloride coagulant could be delivered to the inflow of one of the test cells, and performance compared side by side under identical loading rates with the replicate cell, and the performance and fate of the metal supplement could be assessed through detailed study. This approach has the potential to demonstrate a tool found to be effective in enhancing phosphorus reduction in other locations, but would presumably receive full consideration and be implemented under controlled conditions. Other potential topics that warrant mention include the production and degradation of humic materials (e.g., plant tissue decomposition products) and their relative effects on algal growth (.e., *Aphanizomenon flos-aquae*) and the effects of dissolved organic carbon production on water and sediment nutrient transformation (e.g., denitrification).

## 3.8 Summary

The potential applications of the proposed DWF have been envisioned in this Research Plan to be comprehensive and definitive, and oriented specifically to the needs of researchers and planners working to improve the Klamath River basin water quality. Parallel comparison of the effect of hydraulic loading and water depth in lined and unlined cells will yield estimates of model performance factors fundamental to establishing realistic expectations of treatment in the Upper Klamath Basin environment. The DWF includes a versatile hydrologic design that should allow the importance of groundwater flux to be established. To be sure that the Research Plan is pertinent in concept and implementation, alternative research concepts, and approaches are welcomed for discussion and inclusion in future revisions of this Research Plan.

SECTION 4

# Demonstration Wetland Facility Description

## 4.1 Overview

The design of a DWF for the Klamath Basin builds upon "lessons learned" from successfully implemented systems with similar objectives; that is, they accomplish P removal, water management, and flow augmentation with inflow water from a riverine system. Demonstration systems address the factors contributing to variability observed in these systems, and design and operation questions specific to the Klamath Basin setting. The objective of this section is to discuss the design components of a demonstration wetland facility and a conceptual facility siting effort.

## 4.2 Demonstration Wetland Facility Size and Configuration

The DWF will encompass an area of about 8 acres, consisting of a system of parallel cells of different sizes, with or without the presence of liners. The cells will allow various evaluations, tests, or experiments to be conducted to accomplish the following:

1. Assess the effect of hydrologic and hydraulic design variables (e.g., hydraulic loading, hydraulic residence time) on wetland performance
2. Evaluate wetland performance under hydrogeologic conditions (e.g., groundwater influx and infiltration) and climatic influences (e.g., winter temperature) specific to the Upper Klamath Basin
3. Provide opportunities to describe ecosystem process and wetland ecological response in-depth

The design considerations for constructed wetlands systems are varied and site dependent (EPA, 2000a; EPA, 2000b; ITRC, 2003; and Kadlec and Wallace, 2008). Wetlands are constructed as either surface flow or subsurface flow systems. This DWF focuses on surface flow systems because the intent is to provide treatment of Klamath Basin surface waters near the facility. Surface flow wetlands require more land, but generally are easier to design, construct, and maintain (Lyon et al., 2009). The objective of the DWF is to be able to control as many input and output variables as possible. Detailed design criteria for the DWF test cells are summarized in Table 4-1, including flow in gallons per minute (gpm) followed by a description of the features of the facility. Wall area is included as a potential variable for assessing performance, in that attached algal growth is expected to be greater in deeper cells.

TABLE 4-1
**Summary of Detailed Design Criteria for DWF Test Cells**

| Design Parameter | Shallow Cells | | Deep Cells | |
|---|---|---|---|---|
| | Cell | Sub-Cell | Cell | Sub-Cell |
| **Number of Cells** | 3 | 2 | 3 | 2 |
| **Flow ($m^3$/d) [gpm]** | | | | |
| Average | 47 [8.6] | 21 [3.9] | 47 [8.6] | 21 [3.9] |
| Maximum | 156 [28.6] | 70 [12.8] | 156 [28.6] | 70 [12.6] |
| Minimum | 16 [2.9] | 7 [1.3] | 16 [2.9] | 7 [1.3] |
| Cell Length (m) | 87 | 39 | 87 | 39 |
| Cell Width (m) | 18 | | 18 | |
| Aspect Ratio | 4.8 | 2.2 | 4.8 | 2.2 |
| **Area ($m^2$)** | | | | |
| Surface Area | 1557 | 702 | 1557 | 702 |

TABLE 4-1
**Summary of Detailed Design Criteria for DWF Test Cells**

| Design Parameter | Shallow Cells | | Deep Cells | |
|---|---|---|---|---|
| | Cell | Sub-Cell | Cell | Sub-Cell |
| Wall Area (at Design Depth) | 62 | 33 | 178 | 91 |
| **Operational Water Depth (m)** | | | | |
| Average | 0.3 | | 0.9 | |
| Maximum | 0.9 | | 1.5 | |
| Minimum | 0.2 | | 0.6 | |
| **Operational Water Volume ($m^3$)** | | | | |
| Average | 436 | 193 | 1082 | 465 |
| Maximum | 1540 | 465 | 2167 | 603 |
| Minimum | 209 | 102 | 651 | 347 |
| **Nominal Hydraulic Residence Time (d)** | | | | |
| At average flow and depth | 9.3 | 9.2 | 23.2 | 22.1 |
| At maximum flow and minimum depth | 1.5 | 1.5 | 5.0 | 4.8 |
| At minimum flow and maximum depth | 73.7 | 70.7 | 104 | 97 |
| **Hydraulic Loading Rate (cm/d)** | | | | |
| At average flow and depth | 3 | | 3 | |
| At maximum flow | 10 | | 10 | |
| At minimum flow | 1 | | 1 | |
| **Nominal Linear Velocity (m/d)** | | | | |
| At average flow and depth | 9.3 | 4.3 | 3.7 | 1.8 |
| At maximum flow and minimum depth | 58.5 | 26.2 | 16.9 | 7.6 |
| At minimum flow and maximum depth | 1.2 | 0.6 | 0.9 | 0.5 |
| **Substrate** | Local Soils | | Local Soils | |
| **Freeboard (m)** | | | | |
| At average depth | 0.3 | | 0.3 | |
| **Deep Zones (Inlet/Outlet)** | | | | |
| Number per Cell | 2 | | 2 | |
| Depth Below Floor Elevation (m) | 0.6 | | 0.6 | |
| **Plant Species** | Emergent Vegetation | | Submerged Aquatic Vegetation, Wocus | |

### 4.2.1 Features

The key features of the DWF are the wetland cells, which are designed to include lined and unlined cells; the basic components are described in detail in the following subsections. Figures 4-1, 4-2, and 4-3 provide plan and cross-section views.

#### 4.2.1.1 Cells

The DWF will have six 0.6-acre cells and four 0.3-acre subcells. The cells will vary in depth with three shallow cells and two shallow subcells that can maintain a water level between 1 and 3 ft (0.30 - 0.91 m) and three deep cells and two deep subcells that can maintain a water level between 3 and 5 ft (0.91-1.52 m[meter]).

The cells are separated by berms made of imported material and are graded with side slopes of 4H:1V with 1 ft of freeboard provided for each of the cells.

#### 4.2.1.2 Liner

With the exception of the two outermost cells (one shallow and one deep), the DWF cells and subcells will be lined to prevent both infiltration and groundwater upwelling. This will allow for control of the water balance within the cells. The two main options for liners include an earthen liner (made from clay) or a synthetic liner. In situ soil mixed with bentonite can serve as an earthen liner. There are also commercially available geosynthetic clay liners that include a layer of polyethylene or polypropylene mesh or geotextile. While earthen liners have a very low permeability, they are not impermeable. They also need to be installed on dry soil and in dry weather conditions to prevent immediate swelling of the liner. Synthetic liners come in a variety of materials including polyvinyl chloride, polyethylene, and polypropylene. Some synthetic liners are subject to punctures, cracks, and degradation from ultraviolet light and would be required to be completely covered by soil.

The recommended liner type for the demonstration wetland facility is a synthetic liner, as it will provide an impermeable barrier, preventing any leakage from the test cells.

FIGURE 4-1
**Conceptual Facility Layout: Plan View**

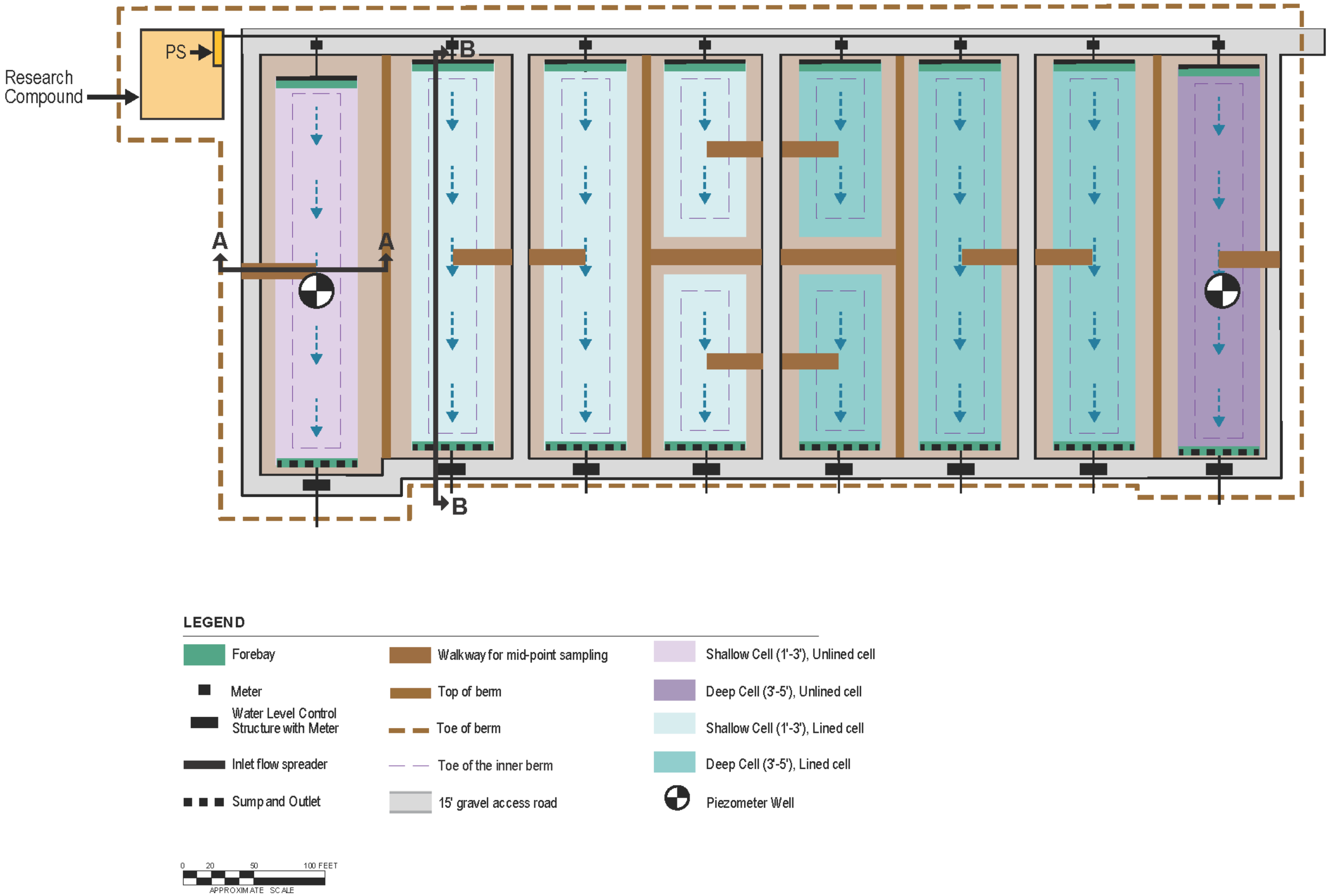


FIGURE 4-2
**Conceptual Facility Layout: Cross-Section A-A**

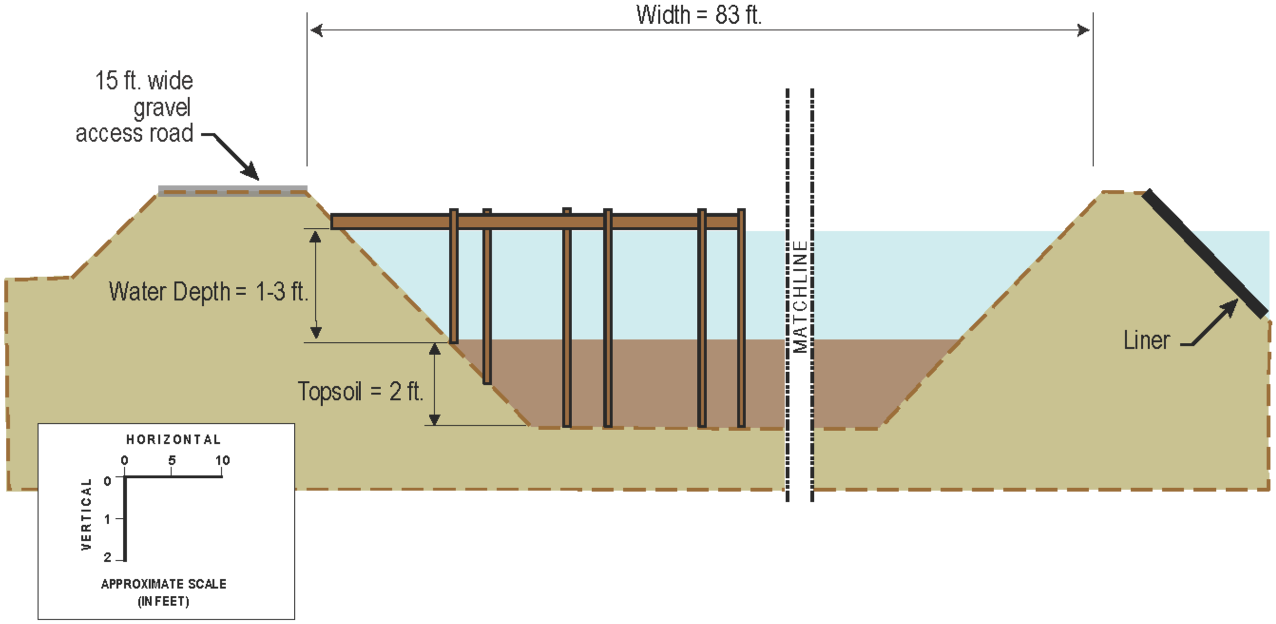
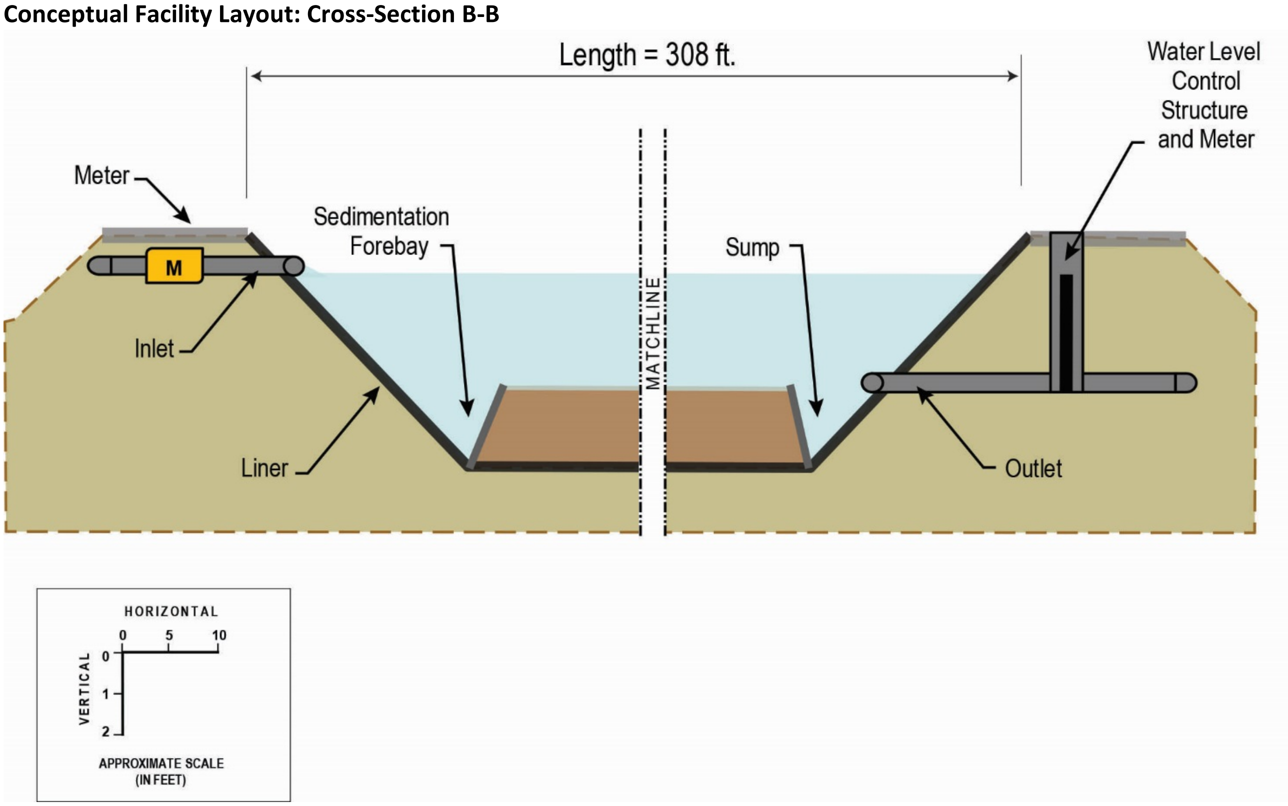



Figure 4-3
**Conceptual Facility Layout: Cross-Section B-B**




### 4.2.1.3 Pump Station

The demonstration wetland facility will have one pump station located on the research compound near the doublewide trailer. Based on the peak flows listed in Table 4-1, three pumps capable of pumping 100 gallons per minute (gpm) each will be needed. The pumps can be located within a structure similar to a TUFF SHED© that would provide protection to the pumps from the weather. The pumps will require a power source that could be overhead, underground, or solar.

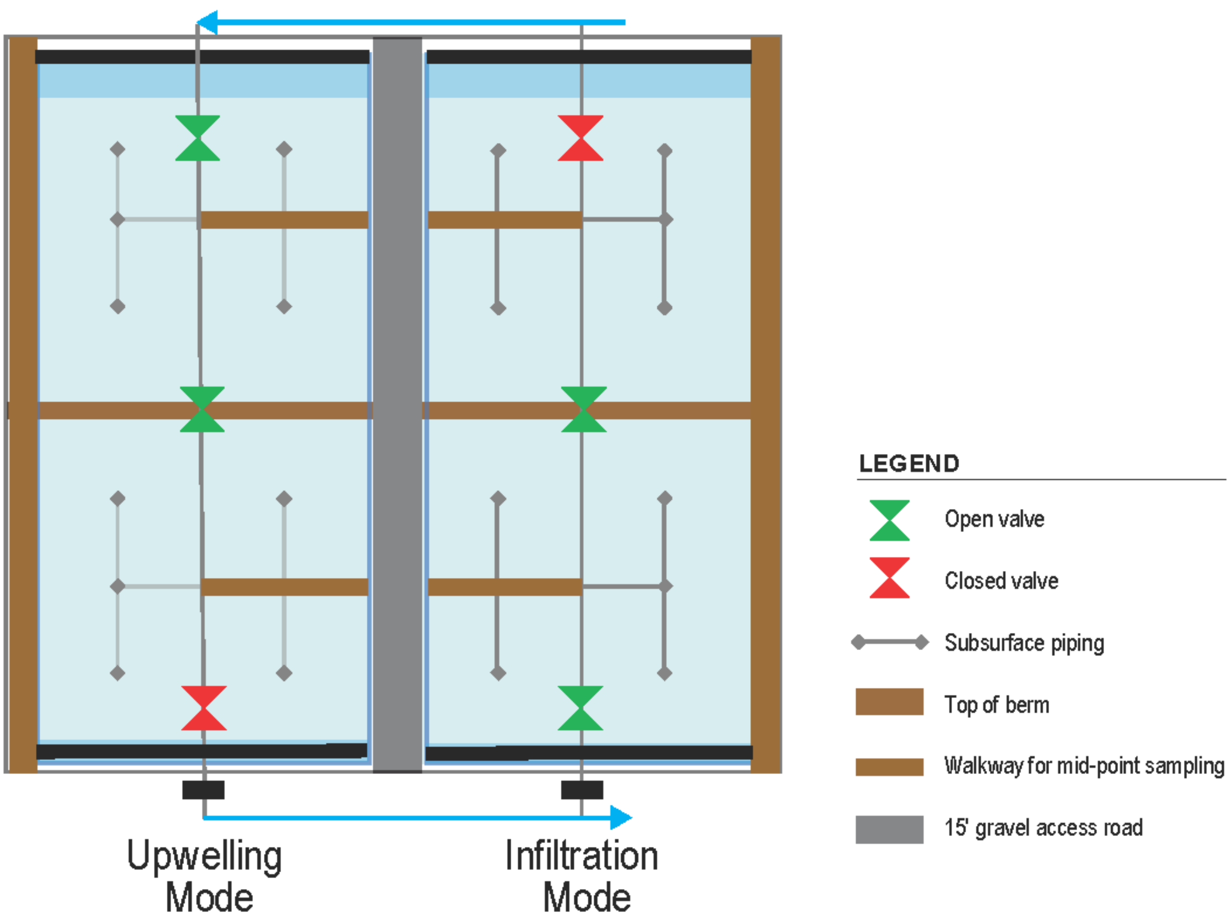
#### 4.2.1.4 Research Compound

The DWF will have a 60-ft by 56-ft research compound. The research compound will be a graveled area that contains a doublewide trailer to house a laboratory for testing, as well as for storage and maintenance gear, a laydown or staging area suitable for construction or as a possible site for small-scale mesocosm construction, a small parking area for a few vehicles, and the wetland supply pump station. The research compound would be surrounded by 15-ft-wide access roads. The compound would be fenced and gated to control access and provide security.

#### 4.2.1.5 Piping

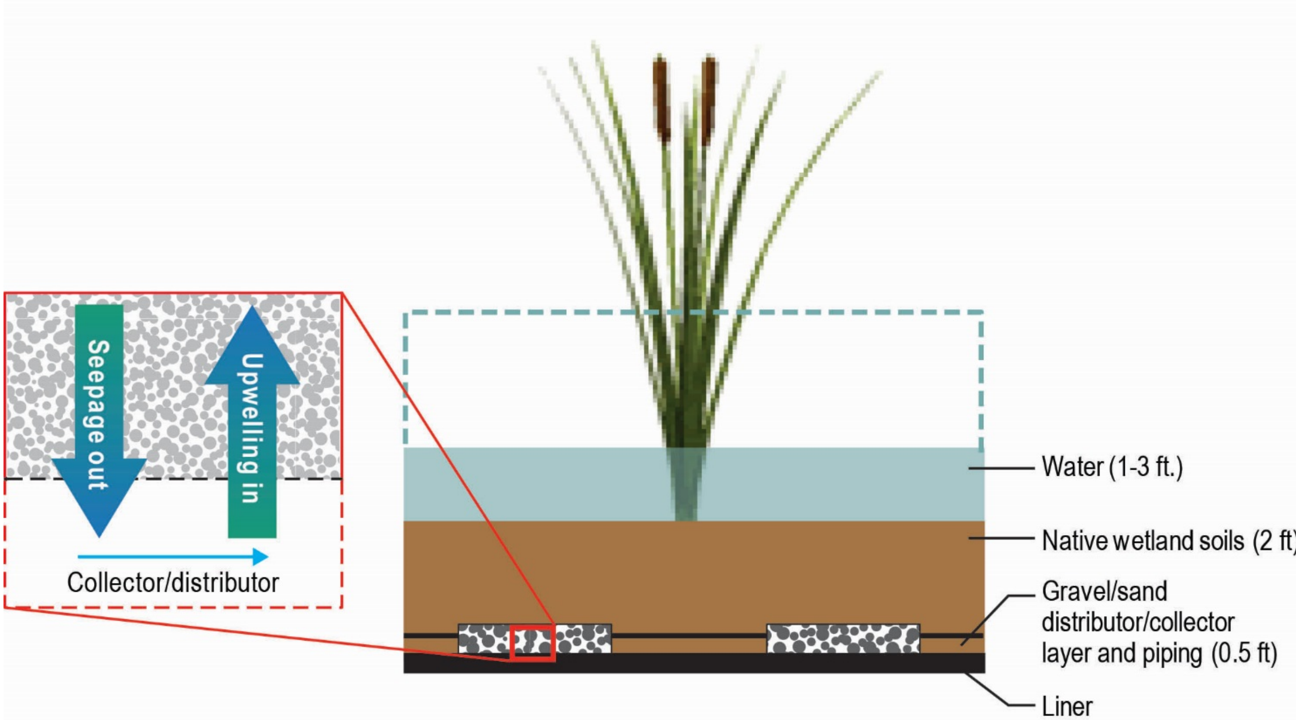
The DWF will require inlet and outlet piping. The inlet piping can be constructed to gather water from multiple water sources (i.e., Seven-mile Canal, spring runoff, and wetland water) that would flow into a pipe manifold near the pump station. Each water source would be isolated from the manifold with a ball valve. Researchers would have the option to select from multiple source waters by opening/closing the ball valves. The inlet manifold would then enter the pump station, where it will be pumped through a second inlet manifold to each of the cells and subcells. The DWF cells would operate in parallel; however, more advanced features of the piping network could be included to allow for operation of the cells and subcells in series. A subsurface piping network used to simulate infiltration or groundwater upwelling would be installed in the subcells. An example of subsurface piping is shown in Figure 4-4.

FIGURE 4-4
**Conceptual Subsurface Infiltration System Piping**



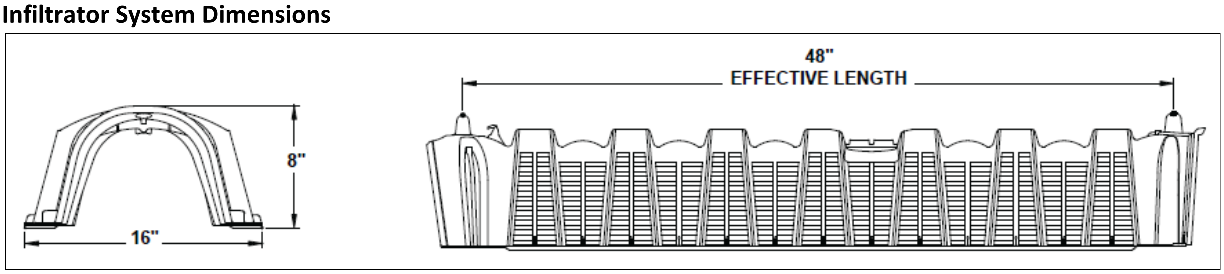

Infiltration or groundwater upwelling can be simulated using valves and perforated piping structures, termed infiltrators. Infiltrators are covered with aggregate and substrate. Operation of valves will allow water to be pumped into the cell to simulate groundwater upwelling or drained through the topsoil and aggregate material before entering the infiltrator and flowing through piping to the discharge. Figure 4-5 shows a cross-section view of the placement of the subsurface piping and infiltrators within a cell.

FIGURE 4-5
**Conceptual Infiltrator System Cross-Section**




An example of the Quick 4® Equalizer® 24 Low Profile infiltrator manufactured by Infiltrators Systems, Inc. (www.infiltratorsystems.com) is shown in Figure 4-6. Each chamber is 4 ft long, and multiple chambers may be connected together to reach a desired length.

FIGURE 4-6
**Infiltrator System Dimensions**




Source: Infiltrator Systems, Inc., 2010

A port would also be provided at the inlet of each of the subcells to allow for the introduction of a groundwater surrogate (spiked with P and/or N) into the subcells through the subsurface piping system to simulate groundwater influx. This port would allow for an experimental test on groundwater influx and concentrations to be completed during normal operations of the facility.

#### 4.2.1.6 Water Source(s)

Research on wetland treatment using the DWF would benefit from having the ability to pull water from different sources for research and testing. If located within the Wood River Wetland, two sources of water are available. The total P influent quality from those sources is listed in Table 4-2.

Table 4-2
**Water Source Water Quality Information**

| Sample Site | Total Phosphorus Influent Quality (µg/L)[1] | | | Design TP Mass Loading ($g/m^2/y$) | | |
|---|---|---|---|---|---|---|
| | Median | Min | Max | Average | Min | Max |
| Sevenmile Canal | 74 | 59 | 130 | 0.81 | 0.65 | 1.42 |
| Wood River | 100 | 90 | 210 | 1.10 | 0.99 | 2.30 |

1. Source: Carpenter et al., 2009

The design total P mass loading shown in Table 4-2 presents a conceptual example of P loading that can be applied to a wetland cell. This same approach can be used for other nutrient loads such as N.

There are also artesian wells located within the Wood River Wetland that have total phosphorus influent quality concentrations that range between 6,340 and 6,760 µg/L. However, most of these artesian wells have been capped. Instead of utilizing this artesian water directly to facilitate the testing of groundwater influx from these artesian wells, the port on the inlet of the subsurface piping network can be utilized to introduce a groundwater surrogate into the subcells at the demonstration wetland facility. TP mass loading for the groundwater surrogate could be tested for a range of nutrient concentrations. This port would allow for experimental control over the importance of the effect of different nutrient concentrations. This experimental test can be conducted without concerns related to uncapping or modifications to be made to the existing wells.

#### 4.2.1.7 Metering

Flow meters need to be included on all piping entering and exiting the cells. This includes meters on the inlet and outlets of the cells, and the inlet and outlet of the subsurface piping in the subcells. Meters will allow for monitoring of flow in and out of the wetland.

#### 4.2.1.8 Inlet Distribution System

In order to distribute inflow into the wetland evenly across the test cells and subcells, an inlet distribution system will be used. Perforated or slotted PVC pipe can be used for flow distribution.

#### 4.2.1.9 Sedimentation Forebay

The DWF test cells will include a depression at the entrance of each cell and subcell where heavier suspended solids will settle out prior to the wetland. The sedimentation forebay will take up approximately 5 percent of the cell area, based on general practice and an intended focus on vegetative processes.

#### 4.2.1.10 Soils and Vegetation

Native or imported soils can be used to meet the objectives of the research being completed. With multiple test cells that can operate at a range of depths, a variety of vegetation can also be researched. Vegetation may include bulrush, cattail, wocus, and submerged aquatic vegetation. Ray et al. (2012) have compiled similar information on nutrient content of Klamath Basin wetland plant species.

#### 4.2.1.11 Sump and Outlet

Each test cell and subcell will have a sump at the marsh outlet graded down to liner as an open area. Based on general practice, an open area of about 2 percent will ensure that flow across the full width of the wetland is discharged evenly thus ensuring maximum wetland usage.

#### 4.2.1.12 Water Level Control Structure

An Agri Drain is an inline water level control structure manufactured by Agri Drain Corporation of Adair, Iowa (http://www.agridrain.com/watercontrolproductsinline.asp). These are simple devices for controlling the water level in a DWF. Water level can be adjusted by adding or removing stop logs in 5- or 7-in heights, using a metal tool designed to hook the stop logs to allow them to be pulled up from the surface.

#### 4.2.1.13 Access Roads and Fencing

Access roads that provide vehicle access to three sides of each of the cells and subcells will be incorporated. The access roads will be constructed of compacted gravel and will be between 12 and 15 ft wide. These access roads will need to connect to the existing road system that runs out to the facility and will run along the top of the berms around the cells.

#### 4.2.1.14 Boardwalk

Boardwalks will be used to access the center of each of the cells for sampling. Boardwalks can be fabricated and installed at the center of each cell transverse to the flow direction. Given the low velocities, impacts to flow patterns are not likely, but vanes can be attached to boardwalk support to minimize drag, if necessary. These boardwalks will have expanded base supports to prevent any damage to liner integrity. A boardwalk will also need to be provided to the reference cell.

#### 4.2.1.15 Other Infrastructure Needs

Power will need to be available at the site in order to operate pump(s) and flow meters. Power can be supplied through existing power sources or through the installation of a solar power system. Other infrastructure needs could include instrumentation and controls for remote operation of the demonstration wetland facility through Supervisory Control and Data Acquisition (SCADA).

#### 4.2.1.16 Piezometer Well Nests

Groups of three piezometer wells, referred to as piezometer nests, will be installed in both the unlined cells and the reference cell. The piezometers will be used to sample water quality at a point or specific depth range in the subsurface and to measure ground-water pressure head. The piezometers will range in depth from shallow (3 to 5 ft) to intermediate (10 to 12 ft) to deep (26 to 28 ft).

#### 4.2.1.17 Reference Cell

A reference cell, which is an undisturbed plot of natural wetland, will be located adjacent to the demonstration wetland facility. The cell is intended to be undisturbed except for the installation of a boardwalk and piezometer well nest. The purpose of the reference cell is to provide an internal reference to local groundwater and surface water interactions as well as a reference for soil nutrient content and vegetative cover. The general approach envisioned in this facility plan is to map the vegetation within this site at the inception of the project and conduct parallel sampling of the vegetation, water quality, soils, and other features of the site concurrent with the demonstration wetland facility sampling.

#### 4.2.1.18 Mesocosms

Demonstration wetland facilities can be adapted to any size site by varying the size and number of test cells and may include numerous smaller mesocosms. Mesocosms offer the opportunity for less expensive operations for studies that can be replicated at a large scale. Mesocosms could be constructed using plastic fruit bins or cattle tanks. However, due to harsh weather conditions in the Klamath Basin, the mesocosms would need to be hardened or protected from the weather. A large gravel area within the research compound next to the trailer and pump station would be well suited for a mesocosm community due to its proximity to water supply and power.

## 4.3 Construction

The site for the DWF will need to be accessible for construction vehicles via existing roads. Construction would begin by removing about 2 ft of native soil for the bottom of the demonstration wetland test cells. The inlet, outlet, and subsurface piping network would then be installed. Imported fill would then be brought in to the site and the berms would be built up around the test cells. The test cell liner and boardwalks would then be installed, with the selected substrate placed on top of the liner and subsurface piping system. The native soils that were removed could be used as the substrate in the test cells. The piezometer nests would then be installed in the unlined and reference cells. Next, the gravel access roads would be installed along the tops of the berms and the research compound would be built. The construction for the research compound would include installation of both the trailer and the pump station. Finally, the instrumentation and selected plant communities could be installed.

The site would then be ready for a start-up phase where the test cells are flooded. A period will be required to allow the test cells to equilibrate. This period could be as long as 1 to 2 years.

## 4.4 Operation

The DWF is built for a longterm study plan. If the site is accessible by road, all-weather monitoring, and flow control management can occur. If the facility is not accessible at all times during the year, control of the system can be automated through the installation and use of a SCADA system. Although not anticipated to be a frequent occurrence, the site may be subject to vandalism. All structures should be designed with lockable caps and controls, and fences and signage should be installed to caution against entering the test cells and compound.

## 4.5 Conceptual Site Locations

Initial discussions regarding conceptual site locations have focused on potential sites near Upper Klamath Lake. This focus is a result of a presentation made to the TAC by Jacob Kann on his recent work researching nutrient balances and response to phosphorus load reductions in Upper Klamath Lake. Upper Klamath Lake serves as a receiving water for several streams including the Williamson, Wood, and Sprague Rivers and as the headwaters for the Klamath River. The goal of the study was to observe all sources contributing nutrients to the lake, all the sources leaving the lake, and the change in phosphorus and nitrogen mass within the lake. External loading of phosphorus to Upper Klamath Lake originates from a variety of sources, as shown in Table 4-3. It is important to note that the small drainage areas (such as the Wood River) are large contributors to phosphorus loading.

Table 4-3
**Sources of External Phosphorus Loading to Upper Klamath Lake**

| Source | Percent of External Phosphorus Load |
|---|---|
| Williamson River | 26 |
| Sprague River | 18 |
| Wood River | 29 |
| Sevenmile Canal | 11 |
| Pumped to Lake | 9 |
| Springs, Ungaged Tributaries, and Groundwater | 7 |

Source: Kann, J. 2013

The study revealed that phosphorus outflow loads and concentrations appear to respond relatively rapidly (1-yr lag time) to changes in external loading. The study concluded that implementing water quality improvements upstream of Upper Klamath Lake would have greater impacts (on both the lake and downstream river) than implementation of improvements downstream of the lake.

In order to maximize the impact that a DWF can have on the lake and downstream river, conceptual site locations within the Wood River Wetland (WRW) were identified, visited by representatives from the TAC in July 2014, and evaluated and ranked for suitability. The WRW provides an ideal location in many ways: the availability of multiple water sources, proximity to significant sources of phosphorus loading to the river, accessibility, and similarity to site conditions elsewhere in the basin. Multiple sites were identified within the WRW that could be appropriate for siting a DWF based on what is required for understanding P removal. However, real constraints may remove these sites from consideration based on their individual attributes. Five potential sites were identified and their respective benefits and constraints were reviewed and discussed with the TAC. The conceptual site locations are shown on Figure 4-7. At this time, there are no confirmed locations for a DWF, although a preferred location for the facility has been identified and has been used as the basis for the conceptual site description and cost estimate. Additional discussion on site prioritization is provided below.

## 4.5.1 Site Attributes

There are particular attributes that make a location desirable for siting a DWF. These attributes include the available of multiple water sources for evaluating wetland performance under different loading conditions; existing water rights, landowner goals for property use, the potential level of interest or utilization by the public on site activity, vehicular accessibility, proximity to a power source, potential impacts to endangered species, relative difficulty of environmental permitting, availability of existing infrastructure, existing vegetation type and density, construction requirements for a fully functional site, operational impacts, potential partnerships for funding and research, and future conditions. These attributes are described in more detail in the following subsections. Table 4-4 presents a matrix of the conceptual site locations and their attributes.

### 4.5.1.1 Water Sources and Existing Water Rights

Sites that have the ability to pull water from different sources for research and testing purposes complement the intent and capacity for a wide range of testing for siting a DWF. Different influent qualities, such as canal, such as from wetland, river or lake sources, provides different ranges of P, N, suspended solids, and particulate organic matter. By experimentally varying water supplies to a fixed facility, the experimental power of the facility can be enhanced.

Water rights and potential water losses (from seepage or evapotranspiration) will be challenging issues for a DWF in the Klamath Basin. It would be advantageous to locate the facility on a site where water rights exist. If a site requires acquisition of a water right or transfer, processing time without opposition can take 6 to 8 months. Given the importance of evapotranspiration and likely seepage losses to groundwater in water rights accounting, the DWF needs to include sufficient control through construction to enable the water balance to experimentally adjusted and measured.

### 4.5.1.2 Landowner Goals for Property Use

The landowner where the DWF is located will need to share common goals with the research facility. For example, by locating a facility in the WRW, the demonstration wetlands would share a common goal with the US Bureau of Land Management for environmental restoration and water quality treatment.

### 4.5.1.3 Public Interest and Utilization

A site that is easily visible and accessible to the public may be both beneficial and controversial. A site accessible to the public would allow for public outreach and teaching of community members regarding the benefits of wetland treatment systems. The TAC has discussed the idea of the DWF serving as an educational area for the public by incorporating additional signage at the site. However, the construction of a DWF in public view in a well-established wetland may be controversial, as the construction of the facility with structures and fencing may be viewed as a disturbance of the site’s natural aspect. There is also increased potential for vandalism of a site when it is more readily accessible to the public.

FIGURE 4-7
**Conceptual Demonstration Wetland Facility Site Locations near Upper Klamath Lake**

TABLE 4-4
**Conceptual Site Location Attributes**

| Site Name | Approximate Existing Site Elevation (feet) | Water Source | | | | | Landowner | Existing Power Source | Public Visibility | Operational Impacts | Post-KBRA Effect | Impacts to Protected Species | | Vegetation Type/Density | Site Accessibility (High/Low) | Site Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Canal | River | Wetland | Lake | Pasture | | | | | | Oregon Spotted Frog | Fish | | | |
| WRW Site 1 | 4,135 | X | | X | X | | BLM | Underground | Moderate | Yes | High | No | Yes | Wetland- High | Good | 9 |
| WRW Site 2 | 4,136-4,137 | | X | X | X | | BLM | Underground | High | None | High | Yes | Yes | Wetland- High | Good | 8 |
| WRW Site 3 | 4,136-4,137 | | X | X | | | BLM | Overhead | Moderate | None | Low | Yes | Yes | Wetland- High | Fair | 8 |
| WRW Site 4 | 4,137-4,140 | X | X | | | X | BLM | None | Moderate | None | Low | Yes | Yes | Upland- Low | Fair | 9 |
| WRW Site 5 | 4,137 | X | | X | | X | BLM | Overhead | Low | None | Low | No | No | Wetland-Low | Fair | 13 |

#### 4.5.1.4 Accessibility

Vehicular accessibility of the site is important from both a construction and research standpoint. It is important that the site can be accessed by heavy equipment to facilitate construction. Numerous truck trips will be needed to bring in the amount of fill required to construct the berms for the test cells and to deliver the other materials required to construct the facility.

#### 4.5.1.5 Proximity to Power

A power source at the site is needed to supply power to the research compound, which includes the trailer, pump station, equipment, and controls systems. A site that already has a power source readily available is desirable. Solar power may also be an option as a power source.

#### 4.5.1.6 Permitting and Endangered Species

Permitting will be a major component of the DWF, which will be driven by the site that is selected for the facility. Dependent upon the site, the permitting process could take a significant amount of time. Potential permits include:

- Removal-Fill Permit or General Authorization from the Oregon Division of State Lands
- A federal 404 permit from the U.S. Army Corps of Engineers
- Water Storage Permit from the Oregon Water Resources Department
- Instream water right transfers or leases require approval from the Oregon Water Resources Department
- Incidental take permit from USFWS and National Marine Fisheries Service (NMFS), if endangered or threatened species are present; this includes the NEPA process, which could require an Environmental Impact Statement
- National Pollutant Discharge Elimination System (NPDES) Permit from Oregon Department of Environmental Quality

Through discussions with the TAC, protected species became an important factor in site selection. If a facility is constructed within the WRW, special consideration will need to be taken to make sure there will be no impacts to the protected species including the Oregon Spotted Frog, Bull Trout, and the Lost River and Shortnose Sucker populations. Sites where the DWF is located outside of critical habitat are the most desirable, although construction impacts for sites located near critical habitat may also require mitigation.

#### 4.5.1.7 Existing Infrastructure

A proposed site should also be evaluated for other existing infrastructure already available. An example of other infrastructure that is potentially useful at a site includes fish screens installed on the intake or existing canals or channels to protect juvenile fish from entrainment and impingement effects.

#### 4.5.1.8 Existing Vegetation Type and Density

Sites where the existing vegetation is well established or dense are viewed as less desirable sites for construction of a DWF; any construction work would affect existing vegetation.

#### 4.5.1.9 Operational Impacts

Part of the site selection process should also consider how the site might affect operations of the landowner. Construction of facilities at sites where there will be no impacts to existing site operations are desired.

#### 4.5.1.10 Future Conditions

This site selection criterion is specific to siting of the DWF within the WRW. A future condition of the WRW that is referred to herein as the "Post-KBRA Effect" is a future setting where dikes have been breached and Agency Lake inundates the wetland areas. Sites closest to the lake may be completely flooded due to their low elevation, so construction of a demonstration wetland at a site near Agency Lake is less desirable than an upland site.

### 4.5.2 Site Prioritization

Five sites at the WRW were selected as potential locations. Following a site visit by TAC members on July 2, 2014, the site attributes discussed above were developed and the sites were then prioritized, or ranked, based on their attributes to determine a preferred location within the WRW. No weighting was used, so all attributes were ranked as equally important. Site scores were based on the following attributes:

- Water Sources: Five potential water sources were identified. An optimal site would be able to take water from all five sites. One point was given for each water source available at a site. The sum total of water sources for each site provided a total point value. For example, a site with one water source would get one point, whereas a site with four potential water sources would receive four points.
- Power: A site was given one point if an existing power source was available at the site. Sites without power did not receive a point.
- Public Visibility: Rankings for this attribute ranged between one and three points. Sites that were further from the public eye were ranked higher than sites that were readily accessible to the public.
- Operational Impacts: Sites where the construction of a demonstration wetland facility would impact landowner operations were not given a point, whereas sites that would not impact landowner operations were given one point.
- Post-KBRA Effect: DWF locations that would be impacted by the Klamath Basin Restoration Agreement (KBRA) restoration plans were not given a point, whereas upland sites located further from Agency Lake were given a point as effects from the Post-KBRA Effect are expected to be less impactful.
- Protected Species: Sites where no impacts were expected to protected species were given one point and sites that were expected to impact protected species did not receive a point.
- Vegetation Type and Density: A site that would impact existing healthy, dense vegetation were not given a point, whereas sites with less dense vegetation were given one point.
- Site Access: Sites that are easily accessible for construction and continued operations were given two points and sites that are less accessible were given one point.

The locations of the five sites are shown on Figure 4-7. Table 4-4 presents the attributes of each site, which were the basis for the site scores. Based on the site prioritization, Site WRW-5 scored highest and is the preferred location; Figure 4-8 shows the conceptual placement and orientation of the DWF at Site 5 in the WRW.

FIGURE 4-8
**Site 5: Conceptual Placement and Orientation**


# 4.6 Cost

A planning-level conceptual cost estimate was developed for the DWF using the CH2M HILL's proprietary Parametric Cost Estimating System (CPES). CPES uses standardized infrastructure models developed from actual projects and builds up estimates using current material, equipment, and labor prices based on project inputs. The built-up estimates include an 8.3 percent adjustment to adjust the price to mid-2016 and a -1.8 percent adjustment to account for location. The adjustments are based on Engineering News-Record cost index data. The midpoint of construction was assumed to be September 2016. The cost estimate is Class 4 as defined by the Association for the Advancement of Cost Estimating International. The actual cost of the improvements is likely to be between +50 percent and -30 percent of the estimate if constructed in 2016. The cost estimate for the DWF should be refined during preliminary engineering design of the facility.

Table 4-5 shows the construction cost estimate that was developed assuming the DWF would be located at Site 5 in the WRW. The estimate does not include non-construction-related costs such as permitting or engineering.

TABLE 4-5
**Demonstration Wetland Facility Cost Estimate**

| Work Description | Quantity | Unit | Unit Price | Total Price |
|---|---|---|---|---|
| **Sitework:** | | | | |
| Clear and Grub | 8.00 | acres | $2,453.04 | $20,000 |
| Topsoil Stripping, Stockpiling, and Re-Applying | 3,802.00 | CY | $7.67 | $29,000 |

TABLE 4-5
**Demonstration Wetland Facility Cost Estimate**

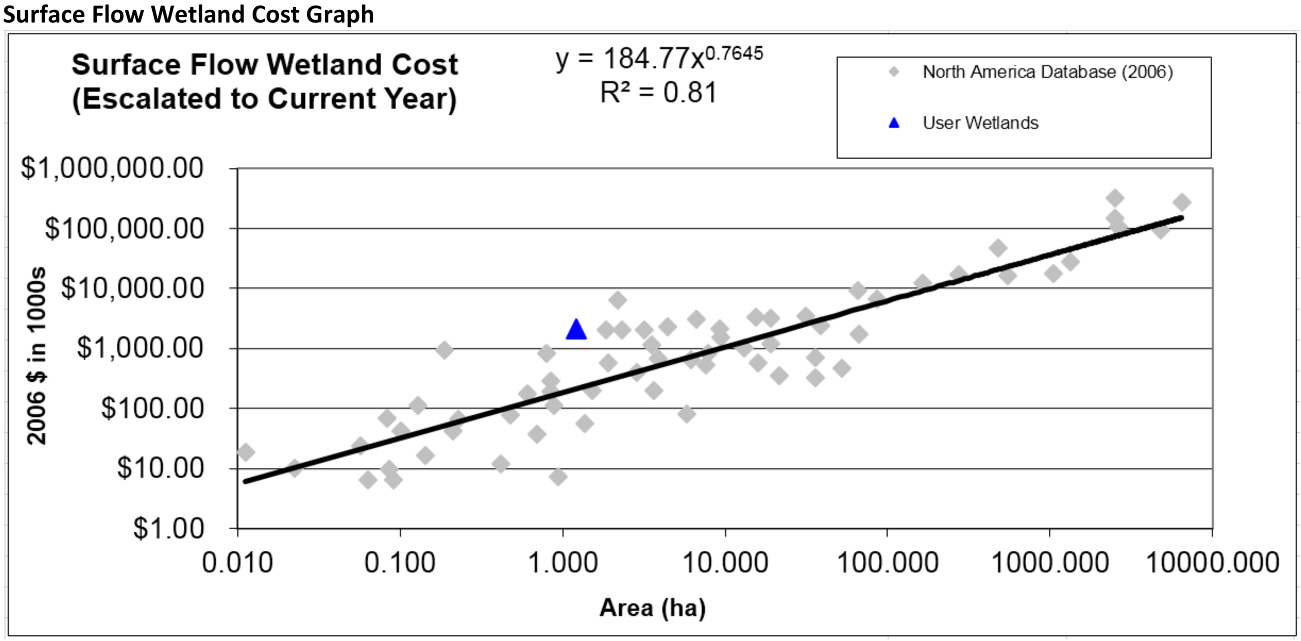
| Work Description | Quantity | Unit | Unit Price | Total Price |
|---|---|---|---|---|
| Excavation | 1,929 | CY | $5.97 | $12,000 |
| Cell Lining | 159,850 | SF | $1.47 | $235,000 |
| Perimeter Public Deterrent Fence | 2,464 | LF | $30.66 | $76,000 |
| Berm | 46,072 | CY | $6.13 | $282,000 |
| Gravel Road on Top of Berms | 666 | CY | $61.33 | $41,000 |
| **Berm Sideslope/Upland Vegetation:** | | | | |
| Hydro seeding | 1.65 | acres | $2,671.36 | $4,000 |
| **Media:** | | | | |
| Gravel 1 (1-1/2-in Stone) | 362.00 | CY | $45.26 | $16,000 |
| **Nuisance Wildlife Control:** | | | | |
| Mosquito Control (bird nesting boxes, bat roosting boxes, chemical) | 1 | LS | $613.26 | $600 |
| **Piping:** | | | | |
| Pipe 1 Inlet (4-in diameter, PVC) | 1,700 | LF | $13.72 | $23,000 |
| Pipe 2 Inlet distribution (4-in diameter, Perforated PVC) | 670 | LF | $9.61 | $6,000 |
| Pipe 3 Outlet (4-in diameter, PVC) | 2,310 | LF | $13.72 | $32,000 |
| Pipe 4 Subsurface Piping (4-in diameter, PVC) | 1,750 | LF | $13.72 | $24,000 |
| **Wetland Vegetation:** | | | | |
| Plantings (1 per sy density) | 24,110 | EA | $6.75 | $163,000 |
| **Water Control Structures:** | | | | |
| Minor Structures | 10 | EA | $3,679.56 | $37,000 |
| Manholes (4-ft diameter) | 14 | EA | $2,783.85 | $39,000 |
| **Instrumentation:** | | | | |
| Flow (parshall flume/magmeter) | 18 | EA | $1,000.00 | $18,000 |
| Level/weir | 10 | EA | $1,000.00 | $10,000 |
| Board walks | 600 | LF | $100.00 | $60,000 |
| Pump Station (includes tuff shed structure and (3) 100 gpm pumps) | 1 | EA | $5,000.00 | $5,000 |
| 4-inch Ball Valve (PVC, non-actuated) | 25 | EA | $250.00 | $6,250 |
| Piezometer Wells | 9 | EA | $2,777.78 | $25,000 |
| Doublewide Trailer (Research Facility) – includes trailer, transport, and foundation/set-up | 1 | EA | $100,000.00 | $100,000 |
| | | | **TOTAL** | **$1,263,850** |
| Allowance for Miscellaneous Items | 5 percent | | $1,263,850.00 | $63,000 |
| | | | **TOTAL** | **$1,327,000** |
| **Site Electrical:** | | | | |
| Yard Electrical | 2 percent | | $1,327,000.00 | $27,000 |
| | | | **TOTAL** | **$1,354,000** |
| **Contractor Mark-ups:** | | | | |
| Overhead | 10 percent | | $1,354,000.00 | $136,000 |
| Profit | 5 percent | | $1,490,000.00 | $75,000 |
| Mobilization/Bonds/Insurance | 5 percent | | $1,565,000.00 | $79,000 |
| Contingency | 30 percent | | $1,644,000.00 | $494,000 |

TABLE 4-5
**Demonstration Wetland Facility Cost Estimate**

| Work Description | Quantity | Unit | Unit Price | Total Price |
|---|---|---|---|---|
| | | | **TOTAL** | **$2,138,000** |
| **Escalation (to Mid-Point of Construction):** | | | | |
| Escalation | 8.3 percent | | $2,138,000.00 | $178,000 |
| | | | **TOTAL** | **$2,316,000** |
| **Location Adjustment Factor:** | | | | |
| Location Adjustment Factor | -1.8 percent | | $2,316,000.00 | $2,275,000 |
| | | | **TOTAL CONSTRUCTION COST** | **$2,275,000** |

Wetland costs are known to have an economy of scale, where larger facilities have a lower unit cost (i.e., cost per unit area or unit flow). The projected cost of the demonstration wetland facility can be compared to costs of other wetlands, such as those summarized in Kadlec and Wallace (2009), with prices adjusted to 2014. Figure 4-9 shows the cost of the demonstration wetland facility (blue triangle) compared to costs for over 100 constructed treatment wetlands ranging in size from <1 acre to more than 10,000 acres. The estimated cost of the demonstration wetland facility is within a cost range that agrees with other similarly sized facilities but toward the higher range of costs. The range in variation around the central tendency of the graph is an important consideration, in that it reflects the practical reality that wetland costs can vary significantly based upon site-specific requirements, such as the need for a liner system, extensive earthwork, challenging construction conditions, and many other factors. For the demonstration wetland facility, the liner system and the multiple cells with inlet and outlet controls, and the presumed volume of embankment needed to construct the site contribute to a higher-than-average cost. A full-scale facility would not be lined, would not require the complexity of grading estimated for this site, may have simpler hydrologic control features, and would be expected to have a lower unit cost.

FIGURE 4-9
**Surface Flow Wetland Cost Graph**




Construction costs for locating the demonstration wetland facility at a different site location within the WRW have been developed relative to the construction cost for locating the facility at Site 5. The main contributor to the cost differential is due to the amount of fill that would be required to build-up berms at each of the sites. Sites that are lower than Site 5 will require more fill for the berms, whereas sites that are higher than site 5 will require less imported fill. The relative cost increase or decrease (expressed as a percentage of the Site 5 cost) for each site is as follows:

- Site 1: +14 percent
- Site 2: +7 percent
- Site 3: +7 percent
- Site 4: -5 percent

The construction costs summarized here are greater than what might be expected on a unit area basis for a full-scale system. That is, the inclusion of the multiple cells and structures, piping, and monitoring appurtenances as well as the lining of the system to manage the groundwater influence add costs that would not be expected for a full-scale system. The extrapolation of these costs to a full-scale system must be performed with care and with consideration to the specifics of the site. As shown on Figure 4-9, the cost for the demonstration wetland facility is shown above the regression line, indicating that the costs are above average. For a full-scale cost, assuming no lining and a minimum number of structures, the unit cost is expected to be more toward the central tendency of the regression line. Importantly, the cost of wetland construction has an economy of scale where larger wetlands show a lower unit cost. As wetlands are constructed within the Upper Klamath Basin, the costs that are encountered will be become valuable reference points for estimating and comparing construction costs for similar, future wetland projects.

SECTION 5

# Experimental Design

The ultimate benefits to be gained from constructing and monitoring pilot scale wetland treatment systems are generated from the degree to which their performance sheds light on the technical issues and hypotheses set forth in Section 3. The experimental design is thus developed around these technical issues and hypotheses to provide data which identify optimal approaches to solving technical design and operations issues and which confirm or refute hypotheses. The experimental design seeks to maximize clarity of the results relative to the investment in replication, number of parameters, and frequency of monitoring and analyses. A successful experimental design aims to produce significant statistical analysis results.

The specific hypothesis tested in the DWF is that vegetation density, groundwater interaction, or water depth and associated plant community (i.e. the null hypothesis) do not affect TP sequestration in a typical Klamath Lake wetland ecosystem. Thus significant differences among cell measured sequestration results can identify where a feature does in fact affect TP removal, and with what degree of certainty.

In order to estimate within year and between year variability, which helps set the risk tolerance for full-scale wetland system and restoration design, it is assumed that the cells would be operated under similar loading rates for a minimum of 2 years to stabilize systems and set baseline conditions. After system stabilization, additional treatments would be applied to cells to test responses over time, the required period for monitoring dependent on the treatment (for example, the timescale over which the treatment factor varies, with sufficient replication of timescales to estimate probably variability). Cells may also be retrofitted to re-establish baseline conditions in between treatments.

As such, the research facilities may be used over an extended time period, using the same blocking (deep vs. shallow water, lined vs. unlined) and examining different hypotheses related to biogeochemical dynamics. The benefits of such facilities are numerous. They allow long term demonstrations, which increase the certainty around results and greater predictability for restoration ecosystem development and resilience. In addition, they provide flexibility to examine numerous factors in phosphorus cycling processes in a controlled but "typical" Klamath Basin setting, including coupled carbon, nitrogen, metals, and sediment processes.

Table 5-1 presents the range of monitoring approaches that may be used in different research projects using the DWF. As shown in Table 5-1, experimental designs considered include paired DWFs. These paired DWFs are sited in the WRW with the same water sources as the existing wetlands. They have existing wetland inflow/outflow monitoring, and include an adjacent reference wetland site to compare and contrast with the DWFs. Paired DWFs with applied treatments allow isolation and analysis of driving factors (drivers) in attaining high and permanent P sequestration rates. Paired DWFs are combined readily with small scale subcells onsite to further identify drivers such as groundwater interaction. Complementing paired DWFs with reference inflow and outflow monitoring of the adjacent natural wetland site provides a validation of DWF baseline conditions as well as identification of conditions that might be unique to DWF design.

Water depth with associated vegetation type and degree of groundwater interaction has been identified as key drivers of P sequestration in Klamath Lake wetland systems. The proposed experimental design thus identifies blocks of replicates that have shallow or deep water conditions with associated vegetation and an installed liner or no liner (dug into native soils). This experimental design framework allows isolation of the effects of these two factors as well as their interaction.

Event and condition-driven monitoring (Table 5-1, Approach 1c) is another monitoring scheme that is not specified for implementation at this time, but could be applied to a paired DWF. Any seasonal set of conditions might favor this more intensive monitoring parameter panel and schedule, and will depend on the interest of a specific researcher. For example, the relationship between seasonal cycling of P and phytoplankton dynamics might be examined during the critical summer months of July and August to identify their relationship with other wetland conditions, sampling throughout diurnal cycles in that period.

Such a sampling scenario is not necessarily treatment or effects driven; similar to Approaches 1a and 1b, differences in parameters in paired systems are refutations of the null hypothesis.

Data collection and analysis approaches that are expected to result from DWF implementation in its earlier phases (first 10 years) are also summarized in Table 5-1. This includes focused comprehensive and focused tiered sampling.

Focused comprehensive sampling selects physical, chemical, and biological parameters that have been implicated as involved in nutrient cycling processes, while tiered sampling drills progressively into causative processes and conditions to provide a framework and dataset for future controlled experimentation. The value of tiered sampling is its efficiency; it allows fewer parameters to be measured in a given sampling session and focuses the monitoring effort on those parameters most likely to indicate effects and the extent of the effects. The risk of tiered sampling is that if the Level 1 parameters are too few and the limited range of parameters is adopted before complex system interactions are understood, the resolution of the monitoring effort to detect driving factors could be lost.

The tiered sampling approach is a sample collection and analysis approach in which a limited number of screening parameters are selected for the first level of sampling, and if the resulting values are outside normal (established or expected) variability, then a second and potentially a third more extensive tier of parameters would be measured to identify drivers that might contribute to this result. Leveled sampling may be distributed across types of metrics. Level 1 sampling includes inflow and outflow water quantity and chemistry (physical parameters and limited nutrient panel), and vegetation community composition and cover. Level 2 sampling contains a more extensive water chemistry panel, groundwater piezometer monitoring, litter production, and sediment accretion. This approach will be implemented in the first 3 years of the study with both Level 1 and 2 parameters sampled to identify variability and to determine when the system is "established." During the initial year, after an applied treatment, both Level 1 and Level 2 parameters are sampled. Then, in subsequent years of a given experiment after applied treatment, only Level 1 parameters are sampled unless statistical changes were noted. Resulting data can provide a basis for developing future hypotheses for testing in the DWFs around vegetation community structure and effects on P sequestration, soil-water interactions, soil accretion, and water storage and balance, as well as concerns regarding mercury and other contaminant potential bioavailability. Having both the facility and a validated dataset accessible to scientific researchers will inspire further research and investigation on the site and further advance scientific-based restoration of Klamath Lake through potentially international collaborations and broad based funding sources.

TABLE 5-1
**Comparison and Contrast of Monitoring Approaches, Associated Data Collection and Analysis Requirements**

| Approach | Strengths | Limitations | How System Status/Treatment Effects are Identified | Evaluation of Causative Factors |
|---|---|---|---|---|
| 1a - Paired DWFs with systems compared/ contrasted (e.g. deep vs. shallow, lined vs. unlined) | Clearly highlights changes over time between initially comparable or intended-to-be-comparable DWFs, especially with tight hydrologic control, with which can elucidate groundwater interactions; lends itself to budget estimates | May be difficult to match "comparable DWFs" even with same design due to individual site factors and "forces of nature" (e.g. beaver intervention); this can be offset by designing to prevent potential interferences, multiple paired DWFs, and multi-year research program | Statistical comparison of datasets by parameter between paired DWFs, including comparing and contrasting relationships among parameters; graphic comparisons of these relationships; change or difference = statistically significant difference in dataset over time or site | Examination of P sequestration outcomes due to different water depths and associated plant species, and to groundwater interaction |
| 1b - Paired DWFs with before/after treatment comparisons (e.g. establishment period vs. treatment period, by depth and liner use) | Clearly highlights treatment-driven changes over time between established comparable DWFs; lends itself to budget estimates<br>Long term trends in sequestration performance can be tracked | Requires multiple DWFs in order to establish statistical significance and confirm responses; DWF systems must be clearly established before applying treatment because baseline systems effectively represent "control" for treatments | Statistical comparison of datasets by parameter between paired DWFs, including comparing and contrasting relationships among parameters and identifying interactions; graphic comparisons of these relationships; change or difference = statistically significant difference found in dataset over time or sites, by depth or liner use | Examination of other causative factors and processes driving P sequestration; comparison of statistical outcomes with establishment years; parallel subcell tests to isolate factors |
| 1c - Paired DWFs with event/condition monitoring: Intensive monitoring occurs during specific events for which DWFs exhibit signature responses (e.g., spring melt and solids load, high ET summer period, fall senescence) | Focuses monitoring on periods when extreme conditions reveal system responses most likely to show effects of treatments and process drivers, and thus ecosystem process differences; may be complemented with SCADA/data sending for broader, continuous picture | Timing of specific conditions may be difficult; access may be especially challenging at these times; annual datasets may be too small to show statistical significance given year-to-year variability. | Statistical comparison of datasets by parameter between paired DWFs and test cells and with reference wetlands (by water depth or liner presence); change or difference = statistically significant difference found in dataset over time or sites. | Examination of meteorological conditions relative to norm; activity and influence of catastrophic and acute factors |

TABLE 5-1
**Comparison and Contrast of Monitoring Approaches, Associated Data Collection and Analysis Requirements**

| Approach | Strengths | Limitations | How System Status/Treatment Effects are Identified | Evaluation of Causative Factors |
|---|---|---|---|---|
| 2 - Reference wetland (existing) and DWFs/subcells compared/contrasted during establishment and treatment phases | Establishes background variability of parameters in existing, non-controlled sites, thus addressing degree to which DWFs are similar to existing, non-controlled sites; provides information about regional wetland functionality in addition to objective of informing design criteria; allows identification of conditions that might be unique to DWF (e.g. boundary conditions or size effects) | Identifying "comparable" based on hydrologic source (proportion groundwater) requires some knowledge of existing wetlands and manipulation of DWFs; factors causing differences may not be readily identified; challenging for one natural wetland site to provide necessary sample size for water depth and associated vegetation community types (subclasses), and should damage/disturbance occur in existing wetlands; groundwater influence needs to be characterized during DWF establishment phase | Statistical comparison of datasets by parameter by test cells and DWF depth type/subclass); change or difference = statistically significant dataset over time or site; could use multi-metric index analysis, which would then be calibrated to apply to regional wetland restoration projects to identify status along trajectory of healthy system establishment | Identification of time to full establishment of DWFs and test cells; tracking of convergence from this baseline during treatment |
| **Data Collection & Analysis** | | | | |
| 1 - Focused Comprehensive – samples collected and results uploaded periodically/continuously over year and analyzed at end of year for information | Ample data to assess variability and gain knowledge of system processes and functions; all data analysis at one time | Early warning of system failures is limited to annually, which could delay subcell research into process and cause and effect dynamics; not possible to add more sampling within same season to clarify observations | N/A | N/A |
| 2 - Focused Tiered – sample collected and results uploaded periodically and continuously over year and reviewed monthly or after each sample session for any site problems and to identify need for tiered sampling, plus at end of year for annual project-to-date conclusions | Early warning of need for correction of DWF system operations problems and additional sampling so fixes and sample collection/on-site examination can be implemented promptly | Tiered sampling may miss conditions that generate numbers suggesting treatment effects or change; multiple data review periods throughout year; complex sample program management decision-making | N/A | N/A |

# Sample Collection and Data Analysis

## 6.1 Identification and Rationale

Parameters were selected for monitoring within each element of the DWF ecosystem. The parameters include "lumped parameter" measurements such as specific conductivity, pH, or reduction potential (Eh), which are the result of and drive of numerous processes and bio-indicators such as the community structure or chemical tissue concentrations of macro- and micro-invertebrates. The parameters are associated with specific technical issues and hypotheses, as discussed in Section 3 and Tables A-1.1 through A-1.9 in Appendix A. Each of the identified parameters informs at least one issue or hypothesis and most relate to more than one. In identifying these parameters for monitoring, ease of measurement, existence of standard methods, likelihood of documenting system establishment or treatment effects, and importance as a contributor to wetland functioning were considered—particularly in achieving restoration objectives for the Klamath Basin. In addition, the extent to which tracking a parameter provides an enhanced overall understanding of these ecosystems was factored into selection of monitored parameters, especially relative to *Anabaena flos-aquae* dynamics. In addition, the selection of monitored parameters might further future research opportunities through having a standard data set.

Tables A-2.1 through A-2.9 (Appendix A) characterize the parameters to meet research plan objectives. Resulting data assist in decision making regarding active monitoring, identifying treatments to be applied to DWFs, determining design criteria for full scale treatment and restored systems, anticipating operations needs for treatment and restoration wetlands, and identifying specific questions for focused research (such as process dynamics and microbial communities). Parameters were evaluated for their demonstrated natural variability (as standard deviation) in wetlands (low to high), which may affect the usefulness of a particular parameter to establish a statistically significant change. If a non-parametric indicator is more appropriate than standard deviation for a given parameter, this is noted. Most parameters identified have low or moderate natural variability. This qualitative variability descriptor will be updated based on the DWF establishment phase monitoring results. Inherent error is then also described. Inherent error, related mostly to instrumentation and procedures, can be overcome through quality assurance and quality control (QA/QC) or site location. However, where high error is of a nature that cannot be mitigated, it may need to be considered in the interpretation of results. Challenges for sampling or measuring, preservation, and analysis (where appropriate) are described (Tables A-2.1 through A-2.9). Inherent error and descriptions of challenges are useful for alerting DWF project and system managers to potential sources of error to manage. Remote sensing opportunities are described, and their advantages and disadvantages characterized, to inform final selection of appropriate monitoring methods where remote sensing is cost effective.

Tables B-1.1 through B-1.9 (Appendix B) provide the details regarding sample collection, to enable DWF monitoring implementation. Levels 1 to 3 are specified. If tiered sampling is enabled after the DWF establishment phase and initial treatment monitoring, the Level 1 parameters in any given ecosystem element or medium are expected to be the priority parameters for monitoring. If additional clarification of the wetland health status were called for, then Level 2 and Level 3 parameters would be measured. A suggested sampling frequency is identified. Monitoring point selection criteria are specified to ensure that data collection will avoid errors and confounding factors. Preferred and alternate sampling and analytical methodologies are identified, with comments to clarify advantages and drawbacks of the methodologies.

QA/QC procedures associated with sampling and analyses are described. Sampling, analytical, and QA/QC protocols are referenced in Tables B-1.1 through B-1.9 in Appendix B.

## 6.2 Specific Parameters of Interest

The contribution of surface water and groundwater parameters to wetland health is significant. The results of DWF and associated reference existing wetland sampling can greatly increase the understanding of wetland watershed hydrology and predictive capability of associated surface water and groundwater models for general application in the Klamath Basin region.

Parameters for vegetation also have broad application. Each healthy wetland vegetation community that establishes in the emergent vegetation and SAV communities will develop particular vegetation compositions. When this composition is characterized for each community type by the appropriate parameters, the knowledge gained will allow recommendations for communities to be established in restored wetlands, in order to optimize both water treatment and wildlife habitat. Plant species density and percent cover ranges can both inform harvest density to maintain healthy communities at donor sites and inform appropriate planting density at the receiving site. For this reason, Table A-1.7 in Appendix A references vegetation lists for specific wetlands types in the parameters for plant composition (BLM, 2006).

The higher trophic levels of wildlife and fish integrate the effects on other trophic levels such as vegetation and macro-invertebrates. Thus, parameters related to these levels are particularly useful as sentinels of ecosystem health, along with the direct value to Native American communities of wildlife and fish. While the DWF is managed to avoid fish movement in and out of the cells, given the proximity to natural wetlands and fish habitat, and movement of fish-eating waterfowl and mammals in the area, it is likely that fish will be introduced into the cells, which offers an opportunity to further examine their viability in the DWF environment.

## 6.3 Data Analysis

As noted previously, application of the appropriate data analysis techniques will be key to determining confirmation or refutation of hypotheses posed in DWF experimentation. Specific data analysis techniques to be applied depend on the experimental approach taken (Section 5) and the degree to which assumptions are met by resulting data sets (i.e., whether parametric or non-parametric analyses are to be applied). Useful references include the following: Dowdy et al., 2004; Helsel and Hirsch, 2002; Mendenhall et al., 2013; and Shaw, 2003.

### 6.3.1 Descriptive and Exploratory Statistical Analysis Methodologies

When determining how to analyze any collection of data from DWFs appropriately, the first consideration is the intrinsic characteristics of the data. The data about which a statement or summary is to be made are called the population. In reality, it may be physically impossible or financially impracticable to collect all data of interest. Instead, a subset of the data called a “sample” is selected and measured to allow conclusions about the sample to be extended to the entire population. Therefore, it is important to recognize that statistics computed from the sample are only inferences or estimates about the characteristics of the population.

Data analyzed for wetland and associated hydrological, water quality, biological, and ecological elements often have the following characteristics:

- A lower bound of zero, that is, no negative values are possible
- Presence of “outliers,” which are defined as observations considerably higher or lower than most of the dataset, such as outliers in box plots defined as greater than 1.5 times more or less than the inter-quartile distance
- Positive skewness, that is, datasets are not symmetric around the mean or median, with extreme values extending out longer in one direction than in the other direction
- Seasonal patterns, that is, values tend to be higher or lower in certain seasons of the year

Descriptive statistics provide simple summaries about the sample and about the observations that have been made. In descriptive statistics, summary statistics are used to summarize a set of observations, in order to communicate the largest amount of information as simply as possible.

Commonly used summary statistics to describe the observations include:

- A measure of location, or central tendency, such as the arithmetic mean
- A measure of statistical dispersion like the standard deviation
- A measure of the shape of the distribution like skewness
- If more than one variable is measured, a measure of statistical dependence, such as a correlation coefficient

Standard descriptive and exploratory statistical analysis methodologies are summarized in the following subsections.

#### 6.3.1.1 Test for Normality

Hypothesis tests that assume that the data have a particular distribution (for example, a normal distribution) are called parametric tests. In comparison, hypothesis tests not requiring the assumption that data follow a particular distribution are called non-parametric tests (or distribution-free tests). As non-parametric methods do not rely on a particular distribution of the monitoring data, their applicability is much wider than the corresponding parametric methods. However, in cases where a parametric test would be appropriate (for example, normality condition is met); non-parametric tests have less power than parametric tests. For example, a larger sample size can be required for a non-parametric test to draw statistical conclusions at same confidence level as that which can be achieved using a corresponding parametric test. In those cases, a parametric test should be generally preferred over a non-parametric test.

The primary reason to test whether data follow a normal distribution is to determine if parametric test procedures may be employed in the data analysis to take advantage of this interpretive advantage. Determination of the sample data distribution is critical for analysis, as the type of distribution is a basic assumption of most tests for central tendency or data set comparisons. The selection between parametric or nonparametric tests should be based on the expected distribution of the wetland monitoring data. If similar data in the past were normally distributed, a parametric procedure would usually be selected. If data were expected to be non-normal, or not enough is known to assume any specific distribution, non-parametric tests would be preferred.

For analysis of the DWF research and implementation plan data, non-parametric analysis has been identified as more appropriate for most of the vegetation and wildlife metrics (Tables A-2.1 through A-2.10 in Appendix A). Sample sizes during the first years of the establishment phase are likely to be relatively small. It may be necessary to proceed with non-parametric statistics during the first few years of data collection until sample sizes for each population grow into the hundreds, or specific categories of wetland monitoring data can be statistically tested to determine if they are normally distributed.

There are numerous tests for normal distribution:

- The graphical normal probability quantile-to-quantile plot (often called the “Q-Q plot”) of the standardized data against the standard normal distribution is a frequently and easily used procedure.
- Another commonly used procedure is the Shapiro-Wilk test, because its power to detect non-normality is as good, or better, than other tests. The Shapiro-Wilk test compares the least squares estimate of the slope of the Q-Q plot with the value of the sample variance, and rejects the null hypothesis if these two quantities differ significantly.
- As one of empirical distribution function tests, the Anderson-Darling test is one of the most powerful statistical tools for detecting most departures from normality. The Anderson-Darling test has been used in wetland assessment.
- Alternatively, computing the t-statistic and comparing it with the three-sigma rule will also give an indication of fit with the normal distribution, and the hazards of applying such analyses.

#### 6.3.1.2 Correlation Analysis

Correlation analysis measures the strength of association between two continuous metrics. For example, one metric is from one specific data category (such as hydrology), while another metric is from a different data category (such as water quality). Of interest is if one variable generally increases as the second increases, it decreases as the second increases, or their patterns of variation are totally unrelated.

Correlation measures observed co-variation. It does not provide evidence for a causal relationship between the two variables. Two metrics may be correlated because both share the same cause. Evidence for causation must come from outside the statistical analysis and from the knowledge of the processes involved.

Whenever a correlation coefficient is calculated, the data are plotted on a scatter plot. No single numerical measure can substitute for the visual insight gained from a plot. Many different patterns can produce the same correlation coefficient, and similar strengths of relationships can produce differing coefficients, depending on the curvature of the relationship. In addition, when dealing with multiple interrelated variables, a covariance matrix table is useful.

Identification of covariates is beneficial to regression analysis, as generally only one metric—the one with the greatest power—is included in a regression analysis.

### 6.3.2 Regression Analysis

Regression analysis is a technique used to analyze data consisting of a dependent variable (or response variable) and one or more independent variables (or explanatory variables). Regression is usually performed to learn about the relationship between the two variables, or estimate values of one variable based on knowledge of another variable, for which more data are available or which can be controlled.

#### 6.3.2.1 Univariate Regression

The simplest form of regression analysis is a univariate regression, or a model with one independent variable. The parameter values are estimated to provide the best fit to the data. The most commonly used method to estimate parameter values is least squares, where parameter values are chosen to minimize the squared difference between the true and fitted values summed over all observations.

#### 6.3.2.2 Multivariate Regression

Multivariate regression analysis is the extension of univariate regression for the case of multiple explanatory variables. The goal of this relationship is to explain as much as possible of the variation observed in the response variable, leaving as little variation as possible to unexplained noise or variables for which inadequate data are available. Assessing factors involved in ecosystem change at the ecosystem level usually involves measuring a large number of abiotic and biotic variables. Assessing each variable individually or with many pair-wise bivariate analyses cannot detect patterns that emerge from the interactions of variables. Multivariate regression can be used summarize overall patterns from a large suite of variables. For example, multivariate regression analysis could be well suited to explore relationships among physical, chemical, biological, and ecological parameters measured in various DWFs.

### 6.3.3 Comparison of Two Independent Groups of Data

One of the objectives of the DWF research and implementation plan is to compare data from an establishing or established DWF against data from such a system subjected to some treatment. Among the parametric statistical procedures, the t-test is perhaps the most widely used method for comparing two independent groups of data. The t-test assumes that both groups of data are normally distributed around their respective means, and that they have the same variance. The two groups are assumed to have identical distributions that differ only in their central location (that is, the mean). Therefore, the t-test is a test for differences in central location only, and assumes that there is an additive difference between the two means, if any difference exists. Prior to applying t-test in comparing two independent groups of data, the assumptions of the t-test, such as normal distribution of two datasets, should be verified.

For the non-parametric procedure, Mann–Whitney test is a well known test for assessing if one of two samples of independent observations tends to have larger values than the other sample.

### 6.3.4 Analysis of Variance Using Parametric or Non-parametric Tests

Analysis of variance (ANOVA) is a collection of statistical models, and their associated procedures, in which the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of if the means of several groups are all equal. The ANOVA technique provides a test of the hypothesis that each sample is drawn from the same underlying probability distribution against the alternative hypothesis that underlying probability distributions are not the same for all samples. For example, ANOVA can be used to evaluate whether there is any statistical difference for phosphorus concentrations at different water depths.

The F-test plays an important role in the analysis of variance. The test is used for comparisons of the components of the total deviation. The hypothesis under the statistical test is that the means of several normally distributed populations, all having the same standard deviation, are equal. Most F-tests arise by considering a decomposition of the variability in a collection of data in terms of sums of squares. The test statistic in an F-test is the ratio of two scaled sums of squares reflecting different sources of variability. These sums of squares are constructed so that the statistic tends to be greater when the null hypothesis is not true.

A corresponding non-parametric procedure for analysis of variance is Kruskal-Wallis test. It is used for testing whether samples originate from the same distribution. When the Kruskal-Wallis test leads to significant results, then at least one of the samples is different from the other samples.

In addition, detecting and measuring cause-effect relationships requires sampling designs that can separate and control for the effects of many factors that influence the wetland. DWF and local reference sites monitoring during establishment serves to characterize the natural variability of establishing constructed and natural wetlands. Natural variability encompasses the variance expressed across a predefined proportion of the natural wetlands sampled.

### 6.3.5 Data Classification Techniques

Techniques from decision science can also be used as initial data exploratory analysis. Decision trees used in data classification comprise two main types: Classification Tree analysis and Random Forest classifier.

The term Classification and Regression Tree (CART) analysis is a term used to refer to both procedures. In the tree structures of CART methodology, leaves represent class labels and branches represent conjunctions of features that lead to those class labels (Loh, 2011). Trees used for classification and trees used for regression have some similarities. However, they also have some differences, such as the procedure used to determine where to split.

Another classification technique is the Random Forest (RF) classifier, which uses a number of decision trees to improve the classification rate. Random Forest, which name is derived from “random decision forests,” is a method that combines the random selection of features to construct a collection of decision trees with controlled variation. The method for injecting randomness into each tree is the component of RF framework, which affords the most freedom to model designers. The RF framework consists of several interchangeable parts that can be mixed and matched to create a large number of particular models, all built around the same central theme (Breiman and Cutler, 2013 and Prasad et al., 2004).

While techniques such as RF can be powerful methods for exploring responses along multiple environmental gradients, another method called the Threshold Indicator Taxa Analysis (TITAN) also fits well within a similar framework. TITAN is an analytical approach geared toward identifying synchronous changes in the distribution of multiple taxa as evidence of an ecological community threshold. TITAN uses indicator species scores to integrate occurrence, abundance, and directionality of taxa responses. TITAN can detect changes in taxa distributions along an environmental gradient over space or time. TITAN and extensions of this method could prove useful for detecting community level thresholds and for addressing a variety of basic and applied ecological questions (Baker and King, 2010 and King and Baker, 2010).

Other classification technique includes the Bayes classifier, which is a probabilistic classification technique based on applying Bayes' theorem with independence assumptions. The use of Bayesian classification technique can provide a robust assessment approach to supporting data analysis.

### 6.3.6 Time Series and Trend Analysis

Time series analysis comprises methods for analyzing time series data to extract meaningful statistics and other characteristics of the data. Time series forecasting is the use of a model to predict future values based on previously observed values. When a series of measurements of a process is treated as a time series, trend analysis can be used to make and justify statements about tendencies in the data, by relating the measurements to the times at which they occurred. In particular, it may be useful to determine if measurements exhibit an increasing or decreasing trend, which is statistically distinguished from random behavior.

Trend is a measure of change through time. This change can refer to change in the average condition of all wetlands in an area or of a particular type (e.g. DWFs in the establishment phase) through time or change in the condition of one specific wetland of interest through time. Trend assessment requires repeated sampling. One of the most sensitive ways to detect trends is to measure repeatedly the same units on a fixed schedule. Because the same locations will be visited regularly, resources can be invested in installing equipment that permits a broad range of variables to be measured at a given spatial point.

One of the most widely used statistical techniques for dealing with seasonality is Mann-Kendall test. The seasonal Mann-Kendall trend test is a test for monotonic trend in a time series with seasonal variation. The variance of the test statistic is obtained by summing the variances of the Kendall score statistic for each month. The normal approximation may then be used to evaluate significance level. The seasonal Kendall test accounts for seasonality by computing the Mann-Kendall test on each season separately, and then combining the results.

### 6.3.7 Graphical Depiction Requirements as Related to Monitoring Results and Comparisons

Graphs provide crucial information for the data analysis that is difficult to obtain in any other way. Patterns and trends in how the system behaves can be developed by observing the data through graphs, such as in the discussions of normal distribution and chemical fingerprinting above. Their results provide initial guidance for the selection of appropriate statistical hypothesis testing procedures.

#### 6.3.7.1 Scatter Plot

The two-dimensional scatter plot is one of the most familiar graphical methods for data analysis. It illustrates the relationship between two variables. Of usual interest is if that relationship appears to be linear or curved, different groups of data lie in separate regions of the scatter plot, and the variability or spread is constant over the range of data.

#### 6.3.7.2 Histogram

A histogram is a graphical representation showing a visual impression of the distribution of data. Histograms are useful for depicting large differences in shape or symmetry, such as if a data set appears symmetric or skewed.

A histogram consists of tabular frequencies, shown as adjacent rectangles, erected over discrete intervals, with an area equal to the frequency of the observations in the interval. The height of a rectangle is also equal to the frequency density of the interval (that is, the frequency divided by the width of the interval). The total area of the histogram is equal to the number of data. A histogram may also be normalized displaying relative frequencies (percent).

#### 6.3.7.3 Box-and-Whisker Plot

A useful and concise graphical display for summarizing the distribution of a data set is the box-and-whisker plot. It is a convenient way of graphically depicting groups of numerical data through their five-number summaries: the smallest observation (sample minimum), lower quartile (Q1 or 25 % percentile), median (Q2 or 50% percentile), upper quartile (Q3 or 75% percentile), and largest observation (sample maximum).

Box-and-whisker plots display differences between populations without making any assumptions of the underlying statistical distribution: they are non-parametric. The spacing between the different parts of the box helps indicate the degree of dispersion (spread), skewness in the data, and outliers.

#### 6.3.7.4 Probability Plot

Probability plots are used to determine how well data fit a theoretical distribution, such as the normal, lognormal, or gamma distributions. This could be attempted by visually comparing histograms of sample data to density curves of the theoretical distributions.

By expressing the theoretical distribution as a straight line, departures from the distribution are more easily perceived. To construct a probability plot, quantiles of sample data are plotted against quantiles of the standardized theoretical distribution. If probability plots do not exhibit a linear pattern, their nonlinearity will indicate why the data do not fit the theoretical distribution. Three typical conditions resulting in deviations from linearity are asymmetry or skewness, outliers, and heavy tails of the distribution.

#### 6.3.7.5 Contour Plot

A contour line (or isopleth) of a function of two variables is a curve along which the function has a constant value. More generally, a contour line for a function of two variables is a curve connecting points where the function has the same particular value. The gradient of the function is always perpendicular to the contour lines. When the lines are close together the magnitude of the gradient is large, the variation is steep. For example, concentrations of atmospheric deposition and contour of groundwater level in the regional wetland system.

Contour lines are curved or straight lines on a map describing the intersection of a real or hypothetical surface with one or more horizontal planes. The configuration of these contours allows map or graph readers to infer relative gradient of a parameter and estimate that parameter at specific places. Contour lines may be traced on a visible three-dimensional model of the surface. The lines may also be plotted on a two-dimensional graph or map.

## 6.4 Research Needs Identification

As the DWF research and implementation plan is implemented and data analysis proceeds, it is expected that information needs will surface that go beyond those generated within a monitoring program. For example, there could be a need to address wetland functionality via specific biotic and abiotic process pathways under carefully controlled conditions (i.e. lab or bench scale testing in controlled environments, in addition to subcell controlled experiments) and to develop predictive models.

As data become available, if they can be uploaded to a publicly accessible research site, scientists in different disciplines can query the database and include the DWF in their research programs to answer a broad range of specific research questions. Published papers and accessibility of data can be expected to attract research investment in the Klamath Basin, furthering reclamation objectives and their scientific rationale.

Such research studies will complement the DWF plan and will strengthen the accuracy of data interpretations. They may also reduce the need for measurement of multiple parameters in a medium or ecosystem element. A few topics have been identified at this stage:

- Opportunities to manage Klamath Lake *A. flos-aquae* populations through manipulation of lake conditions and chemistry as a result of wetland reclamation
- Bioavailability, production, and accumulation of methyl mercury (MeHg) in DWF ecosystems

- Applications of remote-sensing and transmission technologies specific to wetlands monitoring
- Organic soil accumulation rates for a range of native plant species that might colonize or be planted in reclamation or treatment projects, under varying conditions

SECTION 7

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# Appendix A
# Sampling Plan Monitoring Parameters

# Tables A-1.1 through A-1.9
# Parameter Relevance to Research Objectives

TABLE A-1.1
**Surface Water Quantity (Essential)**

| **Parameters** | **Continuous Inflow/ Outflow Gauging** | **Total Suspended Solids Concentrations** | **Soil Moisture** | **Surface Water Elevation** | **Meteorological Data (precipitation, air temperature, relative humidity, wind speed, wind direction, solar radiation, snowpack depth and mass)** |
|---|---|---|---|---|---|
| **Research Objectives** | | | | | |
| *Note: A blank cell indicates that this objective is unlikely to be informed by the monitoring parameter, or the likelihood is very small or unknown.* | | | | | |
| Background P concentration | X | X | X | X | X |
| Wetland hydrologic budget | X | | X | X | X |
| Vegetation effect on P sequestration | X | X | X | X | X |
| Treatment (various) effects on P sequestration | X | X | X | X | X |
| Habitat benefits created | | X | X | X | X |

TABLE A-1.2
**Surface Water Chemistry (Essential)**

| **Parameters** | **Temperature** | **pH** | **DO** | **Turbidity** | **Electrical Conductivity** | **DOC** | **Nutrients (TKN, $NH_4$, $NO_3$, TP, SRP, $SO_4$)** | **Total Alkalinity** |
|---|---|---|---|---|---|---|---|---|
| **Research Objectives** | | | | | | | | |
| *Note: A blank cell indicates that this objective is unlikely to be informed by the monitoring parameter, or the likelihood is very small or unknown.* | | | | | | | | |
| Background P concentration | X | X | X | X | X | | X | X |
| Wetland hydrologic budget | X | | | | X | X | | |
| Vegetation effect on P sequestration | X | X | X | X | X | | X | X |
| Treatment (various) effects on P sequestration | X | X | X | X | X | X | X | X |
| Habitat benefits created | X | X | X | | | X | X | X |

TABLE A-1.2
**Surface Water Chemistry (Essential)**

| Metrics Parameters | Total Dissolved Solids | Total Suspended Solids | Metals (Al, Ca, Fe, Mg, and Hg), both total and field-filtered through a 0.45-µ filter |
|---|---|---|---|
| **Research Objectives** | | | |
| *Note: A blank cell indicates that this objective is unlikely to be informed by the monitoring parameter, or the likelihood is very small or unknown.* | | | |
| Background P concentration | X | X | X |
| Wetland hydrologic budget | X | X | |
| Vegetation effect on P sequestration | X | X | X |
| Treatment (various) effects on P sequestration | X | X | X |
| Habitat benefits created | | X | X |

TABLE A-1.3
**Groundwater Quantity (Essential)**

| Parameters | Groundwater Depth and Elevation | Hydraulic Conductivity and Piezometric Surface of Subsurface Zones Monitored with Piezometers | Ground Surface Elevation | Meteorological Station (See Table A-1.1) | Surface Water Levels and Flow (See Table A-1.1) |
|---|---|---|---|---|---|
| **Research Objectives** | | | | | |
| *Note: A blank cell indicates that this objective is unlikely to be informed by the monitoring parameter, or the likelihood is very small or unknown.* | | | | | |
| Background P concentration | X | X | X | X | X |
| Wetland hydrologic budget | X | X | X | X | X |
| Vegetation effect on P sequestration | X | X | X | X | X |
| Treatment (various) effects on P sequestration | X | X | X | X | X |
| Habitat benefits created | X | | X | X | X |

TABLE A-1.4
**Groundwater Chemistry (Essential)**

| Parameters | Temperature | pH | DO | Oxidation-Reduction Potential | Electrical Conductivity | TKN, $NH_4$, $NO_3$, TP, SRP, $SO_4$ | Total Alkalinity |
|---|---|---|---|---|---|---|---|
| **Research Objectives** | | | | | | | |
| *Note: A blank cell indicates that this objective is unlikely to be informed by the monitoring parameter, or the likelihood is very small or unknown.* | | | | | | | |
| Background P concentration | X | X | X | X | X | X | X |
| Wetland hydrologic budget | X | | | | X | X | X |
| Vegetation effect on P sequestration | X | X | X | X | | X | X |
| Treatment (various) effects on P sequestration | X | X | X | X | X | X | X |
| Habitat benefits created | X | X | X | | X | X | |

TABLE A-1.4

**Groundwater Chemistry (Essential)**

| Parameters | Total Dissolved Solids | Metals (Fe, Al, Hg), both total and field-filtered through a 0.45-µ filter | Total Organic Carbon | Major Ions (Na, K, Ca, Mg, $SO_4$, $HCO_3$, Cl) |
|---|---|---|---|---|
| **Research Objectives** | | | | |
| *Note: A blank cell indicates that this objective is unlikely to be informed by the monitoring parameter, or the likelihood is very small or unknown.* | | | | |
| Background P concentration | X | X | X | X |
| Wetland hydrologic budget | X | | | X |
| Vegetation effect on P sequestration | X | | X | X |
| Treatment (various) effects on P sequestration | X | X | X | X |
| Habitat benefits created | X | X | | |

TABLE A-1.5
**Sediment (Essential)**

| Parameters | Particle Size Distribution (mineral soils) | Total Organic Carbon (peat/organic soils) | Total Organic Carbon/ Organic Matter (in mineral soil) | Total Metals (Al, Ca, Fe, Hg, Mg, K, Na, and S) |
|---|---|---|---|---|
| **Research Objectives** | | | | |
| *Note: A blank cell indicates that this objective is unlikely to be informed by the monitoring parameter, or the likelihood is very small or unknown.* | | | | |
| Background P concentration | X | X | X | X |
| Wetland hydrologic budget | X | | X | |
| Vegetation effect on P sequestration | X | X | X | |
| Treatment (various) effects on P sequestration | X | X | X | X |
| Habitat benefits created | | X | X | X |

TABLE A-1.5

**Sediment (Essential)**

| Parameters | pH (lab, 1:2) | EC (lab, 1:1) | ECe (lab, ECe) | SO4-S (extractable) | P (available) | Al, Ca, FeMg (available) | $NH_4$-N | $NO_3$-N | TKN | Methyl Mercury | SARe (sodium adsorption ratio of soil saturation extract) | CEC (cation exchange capacity) | Total Phosphorus |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Research Objectives** | | | | | | | | | | | | | |
| *Note: A blank cell indicates that this objective is unlikely to be informed by the monitoring parameter, or the likelihood is very small or unknown.* | | | | | | | | | | | | | |
| Background P concentration | X | X | X | X | X | X | | | | | X | X | X |
| Wetland hydrologic budget | | | | | | | | | | | | | |
| Vegetation effect on P sequestration | X | X | X | X | X | | X | X | X | | X | X | X |
| Treatment (various) effects on P sequestration | X | X | X | X | X | X | | | | X | X | X | X |
| Habitat benefits created | X | | | X | X | X | X | X | X | X | | | X |

Notes:

1. Symbols used in the table are as follows: Al (Aluminum), Ca (Calcium) Cl (Chloride), EC (Electrical Conductivity), Fe (Iron), K (Potassium), Mg (Magnesium), Na (Sodium), $NH_4$ (Ammonium), $NO_3$ (Nitrate), P (Phosphorus), S (Sulphur), $SO_4$ (Sulphate), TKN (Total Kjeldahl Nitrogen), and TP (Total Phosphorus).

TABLE A-1.6
**Macro/Microinvertebrates (Potential)**

| Parameters | Multi-Habitat Assessments | Abundance | Diversity (biotic indices) | Comparison to Regional Indices of Ecosystem Health | Fish Food Potential |
|---|---|---|---|---|---|
| **Research Objectives** | | | | | |
| *Note: A blank cell indicates that this objective is unlikely to be informed by the monitoring parameter, or the likelihood is very small or unknown.* | | | | | |
| Background P concentration | | | X | | |
| Wetland hydrologic budget | | | | | |
| Vegetation effect on P sequestration | | | X | | |
| Treatment (various) effects on P sequestration | | | X | | |
| Habitat benefits created | X | X | X | X | X |

TABLE A-1.7
**Vegetation (Essential)**

| Parameters | Plant Composition (all strata; abundance and % cover) | | | Vegetation Health and Vigor (categorical) | Peat Accumulation | Vegetative Tissue Sampling |
|---|---|---|---|---|---|---|
| | Species Composition | Species Diversity (Simpson's Index) | Species Richness | | Carbon Sequestration and Decomposition | |
| **Research Objectives** | | | | | | |
| *Note: A blank cell indicates that this objective is unlikely to be informed by the monitoring parameter, or the likelihood is very small or unknown.* | | | | | | |
| Background P concentration | X | | | | X | |
| Wetland hydrologic budget | X | | | | X | |
| Vegetation effect on P sequestration | X | X | X | X | X | X |
| Treatment (various) effects on P sequestration | | | | | X | |
| Habitat benefits created | X | X | X | X | X | X |

TABLE A-1.7
**Vegetation (Essential)**

| Parameters | Focal Species (abundance) | | | | |
|---|---|---|---|---|---|
| | **Typha latifolia (Cattail)** | **Schoenoplectus acutus (Hard-stem Bulrush)** | **Sparganium eurycarpum (Giant Bur-reed)** | ***Nuphar polysepalum*** **(Yellow water lily; Wocus)** | **Eleocharis macrostachya (Spikerush)** |
| **Research Objectives** | | | | | |
| *Note: A blank cell indicates that this objective is unlikely to be informed by the monitoring parameter, or the likelihood is very small or unknown.* | | | | | |
| Background P concentration | X | X | X | X | X |
| Wetland hydrologic budget | X | X | X | X | X |
| Vegetation effect on P sequestration | X | X | X | X | X |
| Treatment (various) effects on P sequestration | | | | | |
| Habitat benefits created | X | X | X | X | X |

TABLE A-1.8
**Wildlife (Potential)**

| | General Wildlife[a] | | | | | | | Amphibians[b] | | | | Waterfowl[c, e] | | | Breeding Birds[f] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameters** | **Raccoon[c] Presence/ Absence** | **Beaver[c] Presence/ Absence** | **Muskrat[c] Presence/ Absence** | **Jackrabbit[c] Presence/ Absence** | **Cottontail[c] Presence/ Absence** | **Yellow rail[c] Presence/ Absence** | **Spotted Frog[c] Presence/ Absence[d]** | **Diversity Index (Shannon)** | **Abundance Index (Wisconsin Index)** | **Richness** | **Health (Qualitative based on visual observations)** | **Diversity Index (Shannon)** | **Abundance** | **Richness** | **Diversity Index (Shannon)** | **Abundance** | **Richness** |
| **Research Objectives** | | | | | | | | | | | | | | | | | |
| *Note: A blank cell indicates that this objective is unlikely to be informed by the monitoring parameter, or the likelihood is very small or unknown..* | | | | | | | | | | | | | | | | | |
| Background P concentration | | X | | | | | | | | | | | X | | | | |
| Wetland hydrologic budget | | X | X | | | | X | X | X | X | X | | | | | | |
| Vegetation effect on P sequestration | | X | X | | | | | | | | | | | | | | |
| Treatment (various) effects on P sequestration | | | | | | | X | X | X | X | X | | | | | | |
| Habitat benefits created | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

Notes:
[a]Timing-dependent.
[b]In wetlands and associated channels (including inlet/outlet channels).
[c]Presence/absence based on probability that many other factors influence the number in the monitoring area. Some will most likely be moving through and not necessarily residing in the monitoring location; therefore, will record whether they are using the area instead of absolute number.
[d]Included as separate from amphibians in general due to importance.
[e]Analysis will be broken into feeding guilds (piscivore, benthic intertivore, aquatic predator, etc.) from the collected species lists.
[f]Analysis will be broken into feeding guilds (aerial insectivore, raptor, terrestrial insectivore, etc.) from the collected species lists.

TABLE A-1.9

**Fish (Potential)**

| Parameters | Fish Abundance | Fish Diversity (biotic indices) | Sentinel Species, Relative Abundance (to be identified) | External Abnormalities | Size Classes |
|---|---|---|---|---|---|
| **Research Objectives** | | | | | |
| *Note: A blank cell indicates that this driver or stressor is unlikely to result in a change in the metric, or the likelihood is very small or unknown. These relationships will be validated during the ORWMP Validation Phase.* | | | | | |
| Background P concentration | | | | | |
| Wetland hydrologic budget | | | | | |
| Vegetation effect on P sequestration | | | | | |
| Treatment (various) effects on P sequestration | X | X | X | X | X |
| Habitat benefits created | X | X | X | X | X |

# Tables A-2.1 through A-2.9
# Parameter Variability and Remote-Sensing Options

TABLE A-2.1
**Surface Water Quantity (Essential)**

| Parameter | Continuous Inflow/Outflow Gauging[a] | Soil Moisture | Surface Water Elevation | Meteorological Data (precipitation, air temperature, relative humidity, wind speed, wind direction, solar radiation, snowpack depth and mass) |
|---|---|---|---|---|
| **Variability** | | | | |
| Standard Deviation | Medium | Medium | Low | Medium |
| Nonparametric Indicators to be used? | N/A | N/A | N/A | N/A |
| **Inherent Error** | | | | |
| Type | Medium –equipment malfunction, improper maintenance, inaccurate stage-discharge relationship | Medium – chance that sample sites are not consistent or if metered real time that sensors are not calibrated | Low – dependent on stable survey benchmarks | Medium – transformation of data from met station to monitoring network |
| **Challenges** | | | | |
| Sampling | Setting up stations is difficult in remote areas and maintenance is required | Maintaining equipment | Maintaining equipment | Finding appropriate met stations within local variability |
| Preservation | N/A | N/A | N/A | N/A |
| Analysis | Medium – clean data to remove statistical outliers, fill in missing data | Low – compilation of data and comparisons relatively simple | Low – compilation of data and comparisons relatively simple | Data availability |
| **Remote-Sensing Options** | | | | |
| Method | Telephone, cellular phone, radio, or satellite communication to download data | Telephone, cellular phone, radio, or satellite communication to download data | Aerial photogrammetric | Download data from agency/entity maintaining met station |
| Advantages | Can look at real-time or current stage readout, reduces travel | Can look at real-time or current stage readout, reduces travel | Infinite number of data points available | Inexpensive and reduces effort |
| Disadvantages | Expensive, reduces potential maintenance of equipment | Expensive, reduces potential maintenance of equipment | Expensive and weather-dependent | Dependent on protocols and QA/QC of station operating entity |

Notes:

[a] Surface water influent from canals/streams to individual cells will be monitored with totalizer flow meters on each pump. For sources where it is not possible to estimate flow rates with continuous flow gauging, an alternative analysis procedure may be performed by computing the water balance from stable isotopes. The monitoring methodology using stable isotopes is contained as an SOP.

1. N/A – Not applicable.

2. Low, Medium, or High reflect relative variability, error, or extent of challenges. Where "High" is indicated, or clarification is otherwise warranted, additional text augments the qualifier.

TABLE A-2.2
**Surface Water Chemistry (Essential)**

| Parameter | Temperature | pH | DO | Turbidity | Electrical Conductivity | DOC | Nutrients (TKN, $NH_4$, $NO_3$, TP, SRP, $SO_4$) | Total Alkalinity | Total Dissolved Solids | Total Suspended Solids | Metals (Al, Ca, Fe, Mg, and Hg), both total and field-filtered through a 0.45-µ filter |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variability** | | | | | | | | | | | |
| Standard Deviation | Low, within season | Low, within season | Low, within season | Medium | Low, within season | Medium | Medium | Low, within season | Low, within season | Medium | Medium |
| Nonparametric Indicators to be used? | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Inherent Error** | | | | | | | | | | | |
| Type | Low | Low | Low | Medium | Low | Low | Low | Low | Low | Low | Low |
| **Challenges** | | | | | | | | | | | |
| Sampling | Field — physical access may be difficult. Measurement probes (field meters) may have wintertime operational difficulties due to temperatures. | Field — physical access may be difficult. Measurement probes (field meters) may have wintertime operational difficulties due to temperatures. | Field — physical access may be difficult. Measurement probes (field meters) may have wintertime operational difficulties due to temperatures. | Field — physical access may be difficult. Measurement probes (field meters) may have wintertime operational difficulties due to temperatures. | Field — physical access may be difficult. Measurement probes (field meters) may have wintertime operational difficulties due to temperatures. | Grab — physical access may be difficult seasonally. | Grab — physical access may be difficult seasonally. | Grab — physical access may be difficult seasonally. | Grab — physical access may be difficult seasonally. | Grab — physical access may be difficult seasonally. | Grab — physical access may be difficult seasonally. |
| Preservation | N/A | N/A | N/A | N/A | N/A | Filter into clean glass containers, store @ 4°C max 24 hrs | No challenges (Acid except for $SO_4$) | N/A | N/A | N/A | No challenges (Acid) |
| Analysis | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Remote-Sensing Options** | | | | | | | | | | | |
| Method | Satellite | None | N/A | Satellite | N/A | N/A | Satellite | N/A | N/A | N/A | N/A |
| Advantages | Large area coverage | N/A | N/A | Large area coverage | N/A | N/A | Large area coverage | N/A | N/A | N/A | N/A |
| Disadvantages | Satellite coverage unknown in this area; requires increase in pixel density over currently available technology. | N/A | N/A | Satellite coverage unknown in this area so impractical; requires increase in pixel density over currently available technology. | N/A | N/A | Satellite coverage unknown in this area so impractical; requires increase in pixel density over currently available technology. | N/A | N/A | N/A | N/A |

Notes:

1. N/A – Not applicable.
2. Low, Medium, or High reflect relative variability, error, or extent of challenges. Where "High" is indicated, or clarification is otherwise warranted, additional text augments the qualifier.
3. Symbols used in the table are as follows: Al (Aluminum), Ca (Calcium), DO (Dissolved Oxygen), DOC (Dissolved Organic Carbon), Fe (Iron), Hg (Mercury), Mg (Magnesium), $NH_4$ (Ammonium), $NO_3$ (Nitrate), $SO_4$ (Sulphate), and TKN (Total Kjeldahl Nitrogen).

TABLE A-2.3
**Groundwater Quantity (Essential)**

| Parameter | Groundwater Depth and Elevation | Hydraulic Conductivity and Piezometric Surface of Subsurface Zones Monitored with Piezometers | Ground Surface Elevation | Meteorological Station (See Table A-2.1) |
|---|---|---|---|---|
| **Variability** | | | | |
| Standard Deviation | Medium | Medium | Low | Medium |
| Nonparametric Indicators to be used? | N/A | N/A | N/A | N/A |
| **Inherent Error** | | | | |
| Type | Medium – equipment malfunction, improper maintenance, survey error | Low – laboratory measurement error. Sample identification error | Low – survey error | Low – transformation of data from met station to monitoring network |
| **Challenges** | | | | |
| Sampling | Medium – availability of suitable sites and O&M effort and costs, potential equipment problems in extreme low temperatures, vandalism potential for aboveground infrastructure | Medium – physical access by heavy equipment may be a challenge | Medium – line of sight survey methods may be difficult in heavily vegetated areas | Medium – availability of established stations may be limited |
| **Preservation** | | | | |
| Analysis | Medium (statistical) – clean data to remove statistical outliers, fill in missing data | None | None | Data availability |
| **Remote-Sensing Options** | | | | |
| Method | Telephone, cellular phone, radio, or satellite communication to download data | None | Airborne LiDAR or standard photogrammetry for topographic mapping for at least upland and water boundary survey | Download data from agency/entity maintaining met station |
| Advantages | Can look at real-time or current stage readout, reduces travel. Off the shelf purpose-designed equipment that should require only slight modification. | N/A | May offer time and cost savings | Inexpensive and reduces effort |
| Disadvantages | Expensive, reduces potential maintenance of equipment, may be more subject to extreme weather problems and/or vandalism | N/A | Aerial photography-based mapping limited by vegetation. LiDAR may be more capable of penetrating vegetation, but dense vegetation can block even the laser signal. | Depends on protocols and QA/QC of entity responsible for station |

Notes:

1. N/A – Not applicable
2. Low, Medium, or High reflect relative variability, error, or extent of challenges. Where "High" is indicated, or clarification is otherwise warranted, additional text augments the qualifier.

TABLE A-2.4
**Groundwater Chemistry (Essential)**

| Parameter | Temperature | pH | DO | Oxidation-Reduction Potential | Electrical Conductivity | TKN, $NH_4$, $NO_3$, TP, SRP, $SO_4$ | Total Alkalinity | Total Dissolved Solids |
|---|---|---|---|---|---|---|---|---|
| **Variability** | | | | | | | | |
| Standard Deviation[a] | Low | Low | Medium | Medium | Low | Medium | Low | Low |
| Nonparametric Indicators to be used? | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Inherent Error** | | | | | | | | |
| Type | Low | Low | Medium | Medium | Low | Low | Low | Low |
| **Challenges** | | | | | | | | |
| Sampling | Field — physical access may be difficult. Measurement probes (sondes/data loggers) may have wintertime operational difficulties due to temperatures. | Field — physical access may be difficult. Measurement probes (sondes/data loggers) may have wintertime operational difficulties due to temperatures. | Field — physical access may be difficult. Measurement probes (sondes/data loggers) may have wintertime operational difficulties due to temperatures. | Field — physical access may be difficult. Measurement probes (sondes/data loggers) may have wintertime operational difficulties due to temperatures. | Field — physical access may be difficult. Measurement probes (sondes/data loggers) may have wintertime operational difficulties due to temperatures. | Grab — physical access may be difficult seasonally. | Grab — physical access may be difficult seasonally. | Grab — physical access may be difficult seasonally. |
| Preservation | N/A | N/A | N/A | N/A | N/A | Acid | N/A | N/A |
| Analysis | Measurement probes (sondes/data loggers) may have wintertime operational difficulties due to temperatures. | Measurement probes (sondes/data loggers) may have wintertime operational difficulties due to temperatures. | Measurement probes (sondes/data loggers) may have wintertime operational difficulties due to temperatures. | Measurement probes (sondes/data loggers) may have wintertime operational difficulties due to temperatures. | Measurement probes (sondes/data loggers) may have wintertime operational difficulties due to temperatures. | N/A | N/A | N/A |
| **Remote-Sensing Options** | | | | | | | | |
| Method | Possible probe/sonde with data download | Possible probe with data download | Possible probe with data download | Possible probe with data download | Possible probe with data download | N/A | N/A | N/A |
| Advantages | Monitoring and profile across range of conditions | Monitoring and profile across range of conditions | Monitoring and profile across range of conditions | Monitoring and profile across range of conditions | Monitoring and profile across range of conditions | N/A | N/A | N/A |
| Disadvantages | Expense of instrumenting, data download, review, and analysis. Probes will require periodic (monthly or bimonthly) visits for calibration, cleaning, and battery maintenance, which may reduce or eliminate any cost advantage offered by remote-sensing. Moreover, temperature lows may exceed equipment operational range. | Expense of instrumenting, data download, review, and analysis. Probes will require periodic (monthly or bimonthly) visits for calibration, cleaning, and battery maintenance, which may reduce or eliminate any cost advantage offered by remote-sensing. Moreover, temperature lows may exceed equipment operational range. | Expense of instrumenting, data download, review, and analysis. Probes will require periodic (monthly or bimonthly) visits for calibration, cleaning, and battery maintenance, which may reduce or eliminate any cost advantage offered by remote-sensing. Moreover, temperature lows may exceed equipment operational range. | Expense of instrumenting, data download, review, and analysis. Probes will require periodic (monthly or bimonthly) visits for calibration, cleaning, and battery maintenance, which may reduce or eliminate any cost advantage offered by remote-sensing. Moreover, temperature lows may exceed equipment operational range. | Expense of instrumenting, data download, review, and analysis. Probes will require periodic (monthly or bimonthly) visits for calibration, cleaning, and battery maintenance, which may reduce or eliminate any cost advantage offered by remote-sensing. Moreover, temperature lows may exceed equipment operational range. | N/A | N/A | N/A |

TABLE A-2.4
**Groundwater Chemistry (Essential)**

| Parameter | Metals (Fe, Al, Hg), both total and field-filtered through a 0.45-µ filter | Total Organic Carbon | Major ions (Na, K, Ca, Mg, $SO_4$, $HCO_3$, Cl) |
|---|---|---|---|
| **Variability** | | | |
| Standard Deviation[a] | Low | Low | Low |
| Nonparametric Indicators to be used? | N/A | N/A | N/A |
| **Inherent Error** | | | |
| Type | Low | Low | Low |
| **Challenges** | | | |
| Sampling | Grab — physical access may be difficult seasonally. | Grab — physical access may be difficult seasonally. | Grab — physical access may be difficult seasonally. |
| Preservation | Acid | N/A | Acid for cations |
| Analysis | N/A | N/A | N/A |
| **Remote-Sensing Options** | | | |
| Method | N/A | N/A | N/A |
| Advantages | N/A | N/A | N/A |
| Disadvantages | N/A | N/A | N/A |

Notes:

[a] Within season analysis.

1. N/A – Not applicable.
2. Low, Medium, or High reflect relative variability, error, or extent of challenges. Where "High" is indicated, or clarification is otherwise warranted, additional text augments the qualifier.
3. Symbols used in the table are as follows: Al (Aluminum), Ca (Calcium), Cl (Chlorine), DO (Dissolved Oxygen), Fe (Iron), $HCO_3$ (Hydrogen Carbonate), Hg (Mercury), K (Potassium), Mg (Magnesium), Na (Sodium), $NH_4$ (Ammonium), $NO_3$ (Nitrate), $SO_4$ (Sulphate), TKN (Total Kjeldahl Nitrogen), and TP (Total Phosphorus)).

TABLE A-2.5
**Sediment (Essential)**

| Parameter | Particle Size Distribution (mineral soils) | Total Organic Carbon | Total Organic Carbon (peat/organic soils) | Total Organic Carbon/ Organic Matter (in mineral soil) | Total Metals (Al, Ca, Fe, Hg, Mg, K, Na, and S) | pH (lab, 1:2 DI Water) |
|---|---|---|---|---|---|---|
| **Variability** | | | | | | |
| Standard Deviation | High | Medium | Medium | Medium | Medium | Medium |
| Nonparametric Indicators to be used? | Yes | Yes | Yes | Yes | Yes | Yes |
| **Inherent Error** | | | | | | |
| Type | Medium | Medium | Medium | Medium | Medium | Medium |
| **Challenges** | | | | | | |
| Sampling | Low | Low | Low | Low | Medium | Low |
| Preservation | Low | Low | Low | Low | Medium | Low |
| Analysis | Low | Low | Low | Low | Medium | Low |
| **Remote-Sensing Options** | | | | | | |
| Method | N/A | N/A | N/A | N/A | N/A | N/A |
| Advantages | N/A | N/A | N/A | N/A | N/A | N/A |
| Disadvantages | N/A | N/A | N/A | N/A | N/A | N/A |

TABLE A-2.5
**Sediment (Essential)**

| Parameter | EC (lab, 1:1) | ECe (lab, ECe) | $SO_4$-S, extractable | P, available | Al, Ca, Fe, Mg (available) | $NH_4$-N | $NO_3$-N | TKN | Methyl Mercury | SARe (sodium adsorption ratio of soil saturation extract) | CEC (cation exchange capacity) | Total Phosphorus |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variability** | | | | | | | | | | | | |
| Standard Deviation | High | High | Low | Low | Low | High; variable in space and time | High; variable in space and time | Medium | High | Medium | Medium | Medium |
| Nonparametric Indicators to be used? | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Inherent Error** | | | | | | | | | | | | |
| Type | Medium | High; subjective endpoint | Medium | Medium | Medium | Low | Low | Medium | High; low level analysis | Medium | High; numerous potential analytical interferences | Low |
| **Challenges** | | | | | | | | | | | | |
| Sampling | Low | Medium | Low | Low | Low | Low | Low | Medium | Medium | Low | Low | Low |
| Preservation | Low | Medium | Low | Low | Low | Low | Low | Medium | High; low level analysis | Low | Low | Low |
| Analysis | Low | Medium | Low | Low | Low | Low | Low | Medium | High; low level analysis | Medium | High; numerous potential analytical interferences | Low |
| **Remote-Sensing Options** | | | | | | | | | | | | |
| Method | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Advantages | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Disadvantages | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

Notes:

1. N/A – Not applicable.

2. Low, Medium, or High reflect relative variability, error, or extent of challenges. Where "High" is indicated, or clarification is otherwise warranted, additional text augments the qualifier.

3. Symbols used in the table are as follows: Al (Aluminum), Ca (Calcium), EC (Electrical Conductivity), Fe (Iron), K (Potassium), Mg (Magnesium), Na (Sodium), $NH_4$ (Ammonium), $NO_3$ (Nitrate), P (Phosphorus), S (Sulphur), $SO_4$ (Sulphate), and TKN (Total Kjeldahl Nitrogen)

TABLE A-2.6
**Macro/Microinvertebrates (Potential)**

| Parameter | Multi-Habitat Assessments | Abundance | Diversity (biotic indices) | Comparison to Regional Indices of Ecosystem Health | Fish Food Potential |
|---|---|---|---|---|---|
| **Variability** | | | | | |
| Standard Deviation | High; non-standard habitats including weedy areas are difficult to characterize | Medium | High; multi-habitat characterizations will yield high variability | Medium | Low |
| Nonparametric Indicators to be used? | N/A | N/A | Yes | Yes | N/A |
| **Inherent Error** | | | | | |
| Type | Low | N/A | N/A | N/A | N/A |
| **Challenges** | | | | | |
| Sampling | High; some habitats are difficult to sample effectively | High; some habitats are difficult to sample effectively | High; some habitats are difficult to sample effectively | N/A | N/A |
| Preservation | N/A | N/A | N/A | N/A | N/A |
| Analysis | N/A | N/A | N/A | Low | Low |
| **Remote-Sensing Options** | | | | | |
| Method | N/A | N/A | N/A | N/A | N/A |
| Advantages | N/A | N/A | N/A | N/A | N/A |
| Disadvantages | N/A | N/A | N/A | N/A | N/A |

Notes:

1. N/A – not applicable.

2. Low, Medium, or High reflect relative variability, error, or extent of challenges. Where "High" is indicated, or clarification is otherwise warranted, additional text augments the qualifier.

TABLE A-2.7
**Vegetation (Essential)**

| Parameter | Plant Composition (all strata; abundance; % cover) | | | Peat Accumulation | | | | Focal Species (abundance) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Species Composition | Species Diversity (Simpson's Index) | Species Richness | Vegetation Health and Vigor (categorical) | Rare Plant Survey (all strata; abundance; percent cover) | Carbon Sequestration and Decomposition | Vegetative Tissue Sampling | *Typha latifolia* (Cattail) | *Schoenoplectus acutus* (Hard-stem Bulrush) | *Sparganium eurycarpum* (Giant Bur-reed) | *Nuphar polysepalum* (Yellow water lily; Wocus) | *Eleocharis macrostachya (Spikerush)* |
| **Variability** | | | | | | | | | | | | |
| Standard Deviation | Potentially high | Potentially high | Potentially high | Potentially high | Potentially high | Potentially high | Potentially high | Potentially high | Potentially high | Potentially high | Potentially high | Potentially high |
| Nonparametric Indicators to be used? | Yes | No | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| **Inherent Error** | | | | | | | | | | | | |
| Type | 2 - false negative | N/A | N/A | 2 - false negative | N/A | N/A | N/A | 2 - false negative | 2 - false negative | 2 - false negative | 2 - false negative | 2 - false negative |
| **Challenges** | | | | | | | | | | | | |
| Sampling | Extremely time consuming; access to all locations; identification of sedges, grasses, willow species outside flowering period is challenging; identification of dead species is challenging | Extremely time consuming; access to all locations; identification of sedges, grasses, willow species outside flowering period is challenging; identification of dead species is challenging | Extremely time consuming; access to all locations; identification of sedges, grasses, willow species outside flowering period is challenging; identification of dead species is challenging | Extremely time consuming; access to all locations; identification of sedges, grasses, willow species outside flowering period is challenging; identification of dead species is challenging | Extremely time consuming; access to all locations; identification of sedges, grasses species outside flowering period is challenging; identification of dead species is challenging | Access to all locations | Seasonal sampling period is critical for new growth or fruit | Extremely time consuming; access to all locations | Extremely time consuming; access to all locations | Extremely time consuming; access to all locations | Extremely time consuming; access to all locations | Extremely time consuming; access to all locations |
| Preservation | Plant samples dried in a plant press if required; no vegetative tissue sampling planned for this parameter. | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Analysis | N/A | N/A | N/A | N/A | N/A | N/A | Underestimating wet weight of material | N/A | N/A | N/A | N/A | N/A |
| **Remote-Sensing Options** | | | | | | | | | | | | |
| Method | Aerial Photography | Analyzed from species composition data | Analyzed from species composition data | Aerial Photography | Aerial Photography - to determine potential location | N/A | N/A | N/A Aerial Photography - to determine potential location | Aerial Photography - to determine potential location | Aerial Photography - to determine potential location | Aerial Photography - to determine potential location | Aerial Photography - to determine potential location |
| Advantages | Layout of plant composition prior to site visit for mapping and planning purposes | Layout of plant composition prior to site visit for mapping and planning purposes | Layout of plant composition prior to site visit for mapping and planning purposes | Layout of large scale mortality events prior to site visit for mapping and planning purposes | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Disadvantages | Identification of some strata will be very difficult. Inaccurate compositional data | Identification of some strata will be very difficult. Inaccurate compositional data | Identification of some strata will be very difficult. Inaccurate compositional data | Not high enough resolution for species-specific information, and only usable for large scale mortality events | Not high enough resolution for species-specific information | N/A | N/A | Not high enough resolution for species-specific information | Not high enough resolution for species-specific information | Not high enough resolution for species-specific information | Not high enough resolution for species-specific information | Not high enough resolution for species-specific information |

TABLE A-2.8
**Wildlife (Potential)**

| Parameter | General Wildlife | | | | | | | Amphibians | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Raccoon Presence/ Absence | Beaver Presence/Absence | Muskrat Presence/ Absence | Jackrabbit Presence/Absence | Cottontail Presence/Absence | Yellow rail Presence/Absence | Spotted Frog Presence/Absence | Diversity | Abundance | Richness | Health (qualitative) | Health (quantitative) |
| **Variability** | | | | | | | | | | | | |
| Standard Deviation | High due to external factors such as weather and human activity | Medium | Medium | Medium | Medium | High due to external factors such as weather and human activity | High due to external factors such as weather and human activity | High due to external factors such as weather and human activity | Reference regional studies | High due to external factors such as weather and human activity | N/A | |
| Nonparametric Indicators to be used? | Yes | N/A | N/A | Yes | Yes | Yes | Yes | N/A | N/A | N/A | N/A | Yes |
| **Inherent Error** | | | | | | | | | | | | |
| Type | High | Medium | Medium | Medium | Medium | High | High | High | Medium | High | High | Medium |
| **Challenges** | | | | | | | | | | | | |
| Sampling | Will be hit or miss and other variables such as human activity will affect results | Should be widespread; might not say much if everywhere | Should be widespread; might not say much if everywhere | Cyclic populations; will be on margins of wetlands | Cyclic populations; will be on margins of wetlands | Will be hit or miss and other variables such as human activity will affect results; Not a common species | Not a common species | Depends on many things like weather and being able to see or hear. Several sampling events/station | Reference regional studies | Depends on many things like weather and being able to see or hear. Several sampling events/station | Depends on many things like weather and being able to see or hear. Several sampling events/station | Depends on many things like weather and being able to see or hear. Several sampling events/station |
| Preservation | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Analysis | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Remote-Sensing Options**[a] | | | | | | | | | | | | |
| Method | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Advantages | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Disadvantages | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

TABLE A-2.8
**Wildlife (Potential)**

| Parameter | Waterfowl | | | Breeding Birds | | |
|---|---|---|---|---|---|---|
| | Diversity | Abundance | Richness | Diversity | Abundance | Richness |
| **Variability** | | | | | | |
| Standard Deviation | Medium | Reference regional studies | Medium | Medium | Reference regional studies | Medium |
| Nonparametric Indicators to be used? | N/A | N/A | N/A | N/A | N/A | N/A |
| **Inherent Error** | | | | | | |
| Type | Medium | Medium | Medium | Medium | Medium | Medium |
| **Challenges** | | | | | | |
| Sampling | Easier to see than amphibians | Reference regional studies | Easier to see than amphibians | Easier to see than amphibians | Easier to see than amphibians | Easier to see than amphibians |
| Preservation | N/A | N/A | N/A | N/A | N/A | N/A |
| Analysis | N/A | N/A | N/A | N/A | N/A | N/A |
| **Remote-Sensing Options**[a] | | | | | | |
| Method | N/A | N/A | N/A | N/A | N/A | N/A |
| Advantages | N/A | N/A | N/A | N/A | N/A | N/A |
| Disadvantages | N/A | N/A | N/A | N/A | N/A | N/A |

Notes:

[a] There would be no remote-sensing for wildlife due to cover/visibility issues.

1. N/A – Not applicable.

2. Low, Medium, or High reflect relative variability, error, or extent of challenges. Where "High" is indicated, or clarification is otherwise warranted, additional text augments the qualifier.

TABLE A-2.9
**Fish (Potential)**

| | Fish Abundance | Fish Diversity (biotic indices) | Sentinel Species, Relative Abundance (to be identified) | External Abnormalities | Size Classes |
|---|---|---|---|---|---|
| **Variability** | | | | | |
| Standard Deviation | Medium-High | Low | Medium-High | Medium | Medium |
| Nonparametric Indicators to be used? | Yes | Yes | Yes | N/A | N/A |
| **Inherent Error** | | | | | |
| Type | Medium | Low | Medium | Medium; field judgment calls | Medium |
| **Challenges** | | | | | |
| Sampling | High; multiple habitats yield methodological difficulties | High; multiple habitats yield methodological difficulties | High; multiple habitats yield methodological difficulties | Medium | Medium |
| Preservation | N/A | N/A | N/A | N/A | N/A |
| Analysis | Low | Low | Low | Medium | Medium |
| **Remote-Sensing Options** | | | | | |
| Method | N/A | N/A | N/A | N/A | N/A |
| Advantages | N/A | N/A | N/A | N/A | N/A |
| Disadvantages | N/A | N/A | N/A | N/A | N/A |

Notes:

1. N/A – Not applicable.
2. Low, Medium, or High reflect relative variability, error, or extent of challenges. Where "High" is indicated, or clarification is otherwise warranted, additional text augments the qualifier.

# Appendix B
# Quality Assurance Plan

# Tables B-1.1 through B-1.9
# Quality Assurance

TABLE B-1.2
**Surface Water Chemistry (Essential)**

| Parameter | Temperature | pH | DO | Turbidity | Conductivity | DOC | Nutrients | Total Alkalinity | Sulphate | Total Dissolved Solids | Total Suspended Solids | Metals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tier** | **1** | **1** | **1** | **1** | **1** | **2** | **2**[a] | **2** | **1** | **1** | **1** | **2**[b] |
| | | | | | | | | | | | | |
| **Sampling Site Selection Requirements** | | | | | | | | | | | | |
| Must Meet | All monitored open water | All monitored open water | All monitored open water | All monitored open water | All monitored open water | N/A | N/A | N/A | All monitored open water | All monitored open water | Downstream of mine-related disturbance, representative cross-section of stream channel and all open water, with sufficient depth to collect representative TSS sample. | N/A |
| Preferred | N/A | N/A | N/A | N/A | N/A | Selected sites and times | Selected sites and times | Selected sites and times | N/A | N/A | N/A | Selected sites and times |
| Not Acceptable | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Sampling Methodology**[c] | | | | | | | | | | | | |
| Preferred | Horiba (or similar) meter | Horiba (or similar) meter | Horiba (or similar) meter | Continuous[c] | Continuous | Grab | Grab | Grab | Grab | Grab | Grab | Grab |
| Alternate | N/A | N/A | N/A | Horiba (or similar) meter[d] | Horiba (or similar) meter | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Comments | Minimum daily meter calibration | Minimum daily meter calibration | Minimum daily meter calibration | Minimum daily meter calibration | Minimum daily meter calibration | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Annual Frequency | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Analytical Methodology**[c] | | | | | | | | | | | | |
| Preferred | Horiba (or similar) meter | Horiba (or similar) meter | Horiba (or similar) meter | Horiba (or similar) meter | Horiba (or similar) meter | UV/persulfate oxidation | Analytical laboratory | Analytical laboratory | Analytical laboratory | Analytical laboratory | Analytical laboratory | Analytical laboratory |
| Alternate | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Comments | Minimum daily meter calibration | Minimum daily meter calibration | Minimum daily meter calibration | Minimum daily meter calibration | Minimum daily meter calibration | High temperature combustion | N/A | N/A | N/A | N/A | N/A | N/A |
| **QA/QC Protocols** | | | | | | | | | | | | |
| Preferred Procedure | Replication | Replication/ blanks | Replication/ blanks | Replication/ blanks | Replication/ blanks | Replication/ blanks | Replication/ blanks | Replication/ blanks | Replication/ blanks | Replication/ blanks | Replication/ blanks | Replication/ blanks |
| Alternate Procedure | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Comments | Minimum daily meter calibration | Minimum daily meter calibration | Minimum daily meter calibration | Minimum daily meter calibration | Minimum daily meter calibration | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

Notes:

[a] Except for TP, Nitrate-N and Total N, which are Tier 1.

[b] Except for Total Al and Fe, which are Tier 1.

[c] Standard Methods for the Examination of Water and Wastewater (2012).

[d] Whenever in the field at sample point, to corroborate continuous readings.

TABLE B-1.3

**Groundwater Quantity (Essential)**

| Parameter | Groundwater Depth and Elevation | Hydraulic Conductivity and Piezometric Surfaces of Subsurface Zones Monitored with Piezometers | Ground Surface Elevation | Meteorological Station (See Table B1.1) |
|---|---|---|---|---|
| **Tier** | **1** | **2** | **1** | **1** |
| | | | | |
| **Sampling Site Selection Requirements** | | | | |
| Must Meet | Install (winter) at least three paired piezometers (adjacent piezometers screened at different depths to allow vertical hydraulic gradients to be observed and quantified) along a transect across the wetlands. Co-locate with surface water level measurements. Install paired piezometers in at least two upland locations adjacent to the wetlands. | Collect undisturbed to slightly disturbed subsurface formation samples for laboratory determination of vertical and horizontal hydraulic conductivity. | Document the topography of the ground surface, including elevation of the bed of streams or submerged wetlands, to allow comparison with groundwater elevation data. Measure submerged bed elevation of wetlands on an approximate 20-metre grid and the elevation of stream channel beds on a 20-metre interval. Include sub-meter GPS coordinates for each elevation measurement point. | If established meteorological stations within a reasonable distance (about 40 kilometers) establish one capable of monitoring, at a minimum, temperature, and precipitation. |
| Preferred | Depending on the morphology of the wetlands, evaluate appropriateness for more than one transect to allow conditions to be monitored in areas potentially having different hydrologic characteristics. | Three samples, spatially distributed, from the vicinity of each transducer transect. | After baseline survey, the elevation in active stream channels should be checked infrequently (annually or biannually) to document shoaling or areas of scour that may need to be accounted for when evaluating the relationship between ground surface and water level data. | Add capability to monitor wind, solar radiation, relative humidity, and snowpack depth. |
| Not Acceptable | Wetland edge areas that have a combination of wetland complex type are not desirable due to their variability. Locations enabling continuous wetland water table measurements from the sample wetland complex are most desirable. | Disturbed, laboratory re-compacted samples. | N/A | N/A |
| **Sampling Methodology** | | | | |
| Preferred | Installation of piezometers and/or monitoring wells equipped with pressure transducers and electronic data loggers (EDLs) capable of providing continuous hourly or daily measurements. Remote telephone or other access to data retrieval. One transducer should be used for barometric pressure monitoring to allow barometric effects on groundwater level measurements, if any, to be understood and filtered out to facilitate data analysis. | [a] | Standard land surveying and GPS techniques. | Established station with known history preferred. |
| Alternate | Physical site visit to retrieve EDLs and download data in the field, then reset EDLs for ongoing recording of data; manual measurements using a calibrated electronic water level indicator while onsite. | N/A | N/A | Site specific station. |
| Comments | Telemetry system to automatically transmit gauge height data from the field recorder to another location is preferred for cost savings and access to near real-time data. Options include wireless GSM units operating off mobile phone networks, or Iridium satellite data transceiver if no mobile phone coverage is available. Individual piezometers may be linked by either wired connections or short-distance radio (900-megahertz [MHz]) powered by solar panels. Generally cost-effective for remote applications and usually reliable except when vandalism or weather-related disruption occurs. | Sampler can be advanced with either a drilling rig or a backhoe equipped with tube head mount. | N/A | N/A |
| Annual Frequency | For automated data monitoring, data frequency should initially be set as continuous (once per every 2 to 4 hours), with a reduced frequency (for example, daily or bi-weekly) after short-term hydrologic conditions are documented. For manual measurements, data frequency of weekly to monthly would likely be the maximum economically possible. | One time baseline characterization of subsurface conditions. If subsurface is subsequently disturbed by grading, compaction, filling, or excavation, repeat as needed to document current conditions. | Once to establish baseline conditions, and then annually or biannually (in summer) survey check of 20 percent of stream bed elevation measurements and 5 to 10 percent of wetland bed elevation measurements, biased toward areas of highest potential for shoaling or scour. | Continuous. |
| **Analytical Methodology** | | | | |
| Preferred | N/A | N/A | N/A | N/A |
| Alternate | N/A | N/A | N/A | N/A |
| Comments | N/A | N/A | N/A | N/A |
| **QA/QC Protocols** | | | | |

TABLE B-1.3
**Groundwater Quantity (Essential)**

| Parameter | Groundwater Depth and Elevation | Hydraulic Conductivity and Piezometric Surfaces of Subsurface Zones Monitored with Piezometers | Ground Surface Elevation | Meteorological Station (See Table B1.1) |
|---|---|---|---|---|
| **Tier** | **1** | **2** | **1** | **1** |
| | | | | |
| Preferred Procedure | Electronically recorded data inspected for malfunctions and unusual events such as floods and vandalism. Telephone access would allow checking and downloading of data without needing to access the site. | Although data volume is too small to quantitatively evaluate for statistical outliers, data should be reviewed for general comparability. If results are substantially different between different samples, consideration should be given to additional sampling and testing completed to resolve uncertainty about subsurface hydraulic properties. | Standard land survey loop closure tolerance. | N/A |
| Alternate Procedure | Physical site visit to take readings and inspect piezometers and data loggers. | N/A | N/A | N/A |
| Comments | EDLs are reliable and efficient and can record as much as 1 year of data (6 readings per day) without the requirement for downloading and battery replacement. | N/A | N/A | N/A |

Notes:

[a] ASTM International D1587-08(2012)e1 Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes.

The term "piezometer" in this context indicates a relatively small diameter well (~30 to 50 millimeters [mm]), constructed and sealed in a manner that makes it suitable for both long-term water level and water quality monitoring.

N/A – Not Applicable

TABLE B-1.4
**Groundwater Chemistry (Essential)**

| Parameter | Temperature | pH | DO | Oxidation-Reduction Potential | Electrical Conductivity | TKN, $NH_4$, $NO_3$, TP, SRP, $SO_4$ | Total Alkalinity | Total Dissolved Solids | Metals[a] | Total Organic Carbon | Major Ions[b] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tier** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **2 (except as noted)** | **2** | **1** |
| | | | | | | | | | | | |
| **Sampling Site Selection Requirements** | | | | | | | | | | | |
| Must Meet | Depth locations distributed at intervals to reflect probable intra-peat, shallow subsurface, and regional groundwater contributions; piezometer transect across wetland. | Same | Same | Same | Same | Same | Same | Same | Same | Same | Same |
| Preferred | Minimum two depths, three piezometers in wetlands, with two depths at two adjacent upland locations. | Same | Same | Same | Same | Same | Same | Same | Same | Same | Same |
| Not Acceptable | Where clear surface water influence or peat/sediment disturbance. | Same | Same | Same | Same | Same | Same | Same | Same | Same | Same |
| **Sampling Methodology** | | | | | | | | | | | |
| Preferred | Horiba, YSI (or similar) meter | Horiba, YSI (or similar) meter[c] | Horiba, YSI (or similar) meter[c] | Horiba, YSI (or similar) meter[c] | Horiba, YSI (or similar) meter[c] | Grab sample[c] | Grab sample[c] | Grab sample[c] | Grab sample[c] | Grab sample[c] | Grab sample[c] |
| Alternate | Grab sample[c] | Grab sample[c] | Grab sample[c] | Grab sample[c] | Grab sample[c] | N/A | N/A | N/A | N/A | N/A | N/A |
| Comments | Access and cost-prohibitive with field visit – in-well sondes and data loggers are more practical and enable more continuous data; however, even with data loggers, monitoring probes (sondes) will need periodic (monthly or bimonthly) visits for calibration, cleaning, and battery replacement (the last could be eliminated by using solar panels and an external battery). | Water quality sonde | Water quality sonde | Water quality sonde | Water quality sonde | Site visit needed to collect physical water samples. | Site visit needed to collect physical water samples. | Site visit needed to collect physical water samples. Correlation with conductivity acceptable after sufficient samples for calibration. | Site visit needed to collect physical water samples. | Site visit needed to collect physical water samples. | Site visit needed to collect physical water samples. |
| Annual Frequency | 4X | 4X | 4X | 4X | 4X | 4X | 4X | 4X | 4X | 4X | 4X |
| **Analytical Methodology** | | | | | | | | | | | |
| Preferred | Data logger equipped with a water quality sonde | Data logger equipped with a water quality sonde | Data logger equipped with a water quality sonde | Data logger equipped with a water quality sonde | Data logger equipped with a water quality sonde | Lab Analysis[d] | Lab Analysis[e] | Lab Analysis[f] | Lab Analysis[g] | Lab Analysis[j] | Lab Analysis[k] |
| Alternate | Calibrated Horiba WQ meter | Calibrated Horiba WQ meter | Calibrated Horiba WQ meter | Calibrated Horiba WQ meter | Calibrated Horiba WQ meter | N/A | N/A | N/A | N/A | N/A | N/A |
| Comments | Access and cost-prohibitive with field visit – logger more practical and enables much more continuous data. | Same | Same | Same | Same | N/A | N/A | N/A | Note that selenium chemically is not classified as a metal; however, selenium is by convention grouped with metals. | N/A | N/A |

TABLE B-1.4
**Groundwater Chemistry (Essential)**

| Parameter | Temperature | pH | DO | Oxidation-Reduction Potential | Electrical Conductivity | TKN, $NH_4$, $NO_3$, TP, SRP, $SO_4$ | Total Alkalinity | Total Dissolved Solids | Metals[a] | Total Organic Carbon | Major Ions[b] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tier** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **2 (except as noted)** | **2** | **1** |
| | | | | | | | | | | | |
| **QA/QC Protocols** | | | | | | | | | | | |
| Preferred Procedure | Replication/blanks | Same | Same | Same | Same | Same | Same | Same | Same | Same | Same |
| Alternate Procedure | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Comments | Some depths/matrices may require filtered sample before measurement, analysis; regularly calibrated meter (minimum daily). | Same | Same | Same | Same | For metrics not possible with meter, filtered sample before measurement, analysis, and preservation. | Same | Field-filtered through a 0.45-micron (μ) filter. | Field-filtered through a 0.45-μ filter | --- | --- |

Notes:

[a] Metals are Fe, Al, and Hg, total and field-filtered through a 0.45-μ filter.

[b] Major ions are Na, K, Ca, Mg, $SO_4$, $HCO_3$, Cl.

[c] Carpenter, K.D., Snyder, D.T., Duff, J.H., Triska, F.J., Lee, K.K., Avanzino, R.J., and Sobieszczyk, Steven. 2009. Hydrologic and water-quality conditions during restoration of the Wood River Wetland, upper Klamath River basin, Oregon, 2003–05: U.S. Geological Survey Scientific Investigations Report 2009-5004, 66 p.

[d] Standard Methods for the Examination of Water and Wastewater. 2012. Methods 4500-Norg, 4500-NO3, 4500-NH3, 4500-P, 4500-SO4

[e] Standard Methods for the Examination of Water and Wastewater. 2012. Method 2320

[f] Standard Methods for the Examination of Water and Wastewater. 2012. Method 2540C

[g] Standard Methods for the Examination of Water and Wastewater. 2102. Methods 3500-Fe

[h] Standard Methods for the Examination of Water and Wastewater. 2012. Method 6440

[i] Standard Methods for the Examination of Water and Wastewater. 2012. Method 2540D

[j] Standard Methods for the Examination of Water and Wastewater. 2012. Method 5310

[k] Standard Methods for the Examination of Water and Wastewater. 2012. Methods 3111 (Na, K, Ca, Mg), 4500-SO4, 2320, 4500-Cl

TABLE B-1.5
**Sediment (Essential)**

| Parameter | Particle Size Distribution (mineral soils) | Total Organic Carbon (mineral soils) | Total Organic Carbon (peat / organic soils) | Total Organic Carbon/Organic Matter (mineral soils) |
|---|---|---|---|---|
| **Tier** | **1** | **1** | **2** | **2** |
| | | | | |
| **Sampling Site Selection Requirements** | | | | |
| Must Meet | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. |
| Preferred | N/A | N/A | N/A | N/A |
| Not Acceptable | Solid rock, organic soils. | N/A | N/A | N/A |
| **Sampling Methodology** | | | | |
| Preferred | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1. [3] | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1. [3] | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1. [3] | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1. [3] |
| Alternate | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. |
| Comments | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. |
| Annual Frequency | 1X | 1X | 1X | 1X |
| **Analytical Methodology** | | | | |
| Preferred | Method 55.3 and 55.4. [3] | Wet combustion (Walkley-Black), Method 21.3 [3] | Method D (750°C Muffle furnace) [2] | Method C (440°C Muffle furnace) [2] |
| Alternate | Methods 55.2 and 55.4 [3] | Dry combustion, Method 21.2 [5] | N/A | N/A |
| Comments | % silt, sand, clay probably sufficient – do not really need full sieve set data | Test and pretreat (if needed) for inorganic C before analysis | N/A | Test and pretreat if inorganic C present |
| **QA/QC Protocols** | | | | |
| Preferred Procedure | [1] | [3] | [2] | [4] |
| Alternate Procedure | N/A | [5] | N/A | N/A |
| Comments | Should be field duplicates (10%) and lab internal standard | --- | --- | --- |

TABLE B-1.5
**Sediment (Essential)**

| Parameter | Total Metals[a] | pH (lab, 1:2 DI water) | EC (lab, 1:1) | ECe (lab, ECe) | $SO_4$-S (extractable) | P (available) | Al, Ca, Fe, Mg (available) | $NH_4$-N | $NO_3$-N | TKN |
|---|---|---|---|---|---|---|---|---|---|---|
| **Tier** | **1** | **1** | **1** | **2** | **2** | **2** | **2** | **1** | **1** | **1** |
| | | | | | | | | | | |
| **Sampling Site Selection Requirements** | | | | | | | | | | |
| Must Meet | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. |
| Preferred | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Not Acceptable | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Sampling Methodology** | | | | | | | | | | |
| Preferred | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1. [5] | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1. [5] | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1. [5] | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1. [5] | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1. [5] | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1 [5]. | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1 [5]. | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1 [5]. | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1. [5] | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1. [5] |
| Alternate | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. |
| Comments | Site-to-site methodology must be uniform. Non-metallic sampling tools. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. |
| Annual Frequency | 1X | 2X | 2X | 1X | 1X | 1X | 1X | 2X | 2X | 2X |
| **Analytical Methodology** | | | | | | | | | | |
| Preferred | Prepared using Strong Acid Leachable Metals in Soil (SALM) [3]; analysis using [9] | Method 16.2, 1:2 (Soil:water) [3] | Method 15.2.2 (1:1) [3] | Saturated paste, Methods 15.2 and 15.3 [3] | Method S-11.10 [10] | Modified Kelowna [4] | DTPA Extraction [5] | Method 6.2, 2N KCl [3] | Method 6.2, 2N KCl [3] | Nitrogen, Total Kjeldahl [3] |
| Alternate | 3050B/6010B/6020 [6] | 1:1 (Soil:0.01 $CaCl_2$) [3] | N/A | 1:1 (Soil:water) [5] | Saturation Extract, Method 15.2 [3] | Bray 1 <pH7; Olsen > pH 7 [5] | Method 7.1, Mehlich 3 [3] | N/A | N/A | [5] |
| Comments | N/A | N/A | N/A | Tier 2 - only run if EC 1:1 > 0.4 dS/m | N/A | N/A | N/A | Only run if TKN is high, as TKN + $NO_3$-N will give TN | N/A | N/A |
| **QA/QC Protocols** | | | | | | | | | | |
| Preferred Procedure | [3] | [3] | [3] | [3] | [10] | [4] | [5] | [3] | [3] | [3] |
| Alternate Procedure | [6] | [5] | N/A | [5] | [3] | [5] | [3] | N/A | N/A | [5] |
| Comments | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |

TABLE B-1.5
**Sediment (Essential)**

| Parameter | Methyl Mercury | SARe (sodium adsorption ratio of soil saturation extract) | CEC (cation exchange capacity) | Total Phosphorus |
|---|---|---|---|---|
| **Tier** | **1** | **2** | **2** | **1** |
| | | | | |
| **Sampling Site Selection Requirements** | | | | |
| Must Meet | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. | Conducted as part of vegetation transect. |
| Preferred | N/A | N/A | N/A | N/A |
| Not Acceptable | N/A | N/A | N/A | N/A |
| **Sampling Methodology** | | | | |
| Preferred | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 1699. [3] | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1. [5] | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1. [5] | Hand auger, corer (assuming 15 cm sediment, up to 30 cm for soil). Sediment sampling per Method 7.1. [5] |
| Alternate | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. | Grab sample (e.g., trowel) may be acceptable for non-cohesive materials. |
| Comments | Discrete samples – no composite. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. |
| Annual Frequency | 1X | 1X | 1X | 1X |
| **Analytical Methodology** | | | | |
| Preferred | Method 5 A-7 [7] | Method 15.4.4 [3] | Barium Replacement, Method 18.2 [3] | Prepared using Strong Acid Leachable Metals in Soil (SALM) [3]; analysis using [8] |
| Alternate | Method 1630 [6] | N/A | Barium replacement; Effective CEC-summation [5]; Sodium replacement, Method 9081 [6] | [3] |
| Comments | For Method 1630, need to specify extraction for soil/sediment | Based on soil saturation extract | $NH_4^+$ Method may be problematic for soils with carbonates, gypsum, vermiculite, zeolites | N/A |
| **QA/QC Protocols** | | | | |
| Preferred Procedure | Method 5 A-7 [7] | [3] | [3] | |
| Alternate Procedure | Method 1630 [6] | N/A | [5], [6] | [5] or [3] |
| Comments | --- | --- | Check filter paper for $NH_4^+$ contamination | --- |

Notes:

[a] Total metals are Aluminum (Al), Calcium (Ca), Iron (Fe), Magnesium (Mg), Potassium (K), Sodium (Na), and Sulphur (S)).

[1] ASTM International. 2007. ASTM D422-63(2007) Standard Test Method for Particle Size Analysis of Soils.

[2] ASTM International. ASTM D2974-07a Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils.

[3] U.S. Environmental Protection Agency (USEPA). 2007. Method 1699: Pesticides in Water, Soil, Sediment, Biosolids, and Tissue by HRGC/HRMS.

[4] Qian, P., J.J. Schoenaru, and R.E. Karamanos. 1994. Simultaneous extraction of available phosphorus and potassium with a new soil test: a modification of Kelowna extraction. Commun. Soil Sci. and Plant Anal. 25(5-6):627-635.

[5] Soil Science Society of America (SSSA). 1996. *Methods of Soil Analysis, Part 3, Chemical Methods.* SSSA Book Series No. 5.

[6] U.S. Environmental Protection Agency (USEPA). 1986. *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*. SW-846, September 1986, as amended.

[7] U.S. Geological Survey (USGS). 2004. *Methods for the preparation and analysis of solids and suspended solids for methyl mercury*. Chapter 7 of Book 5, Laboratory Analysis Section A, Water Analysis. Reston, VA.

[8] USEPA. 2001. Method 200.7 (as amended). *Trace Elements in Water, Solids, and Biosolids by Inductively Coupled Plasma-Atomic Emission Spectrometry*.

[9]. USEPA. 1994. Method 200.8 (as amended). *Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma – Mass Spectrometry*.

[10] Gavlac, R., D. Horneck, R.O. Miller, and J. Kotuby-Amacher. 2003. *Extractable Soil Sulfate-Sulfur. Calcium Phosphate – Turbidimetric Method*. Soil, Plant and Water Reference Methods for the Western Region. 2nd Edition.

TABLE B-1.6
**Macro/Microinvertebrates (Potential)**

| Parameter | Multi-Habitat Assessments | Abundance | Diversity (biotic indices) | Comparison to Regional Indices of Ecosystem Health | Fish Food Potential |
|---|---|---|---|---|---|
| **Tier** | **1** | **1** | **1** | **1** | **2** |
| | | | | | |
| **Sampling Site Selection Requirements** | | | | | |
| Must Meet | N/A | Basic requirement | Basic requirement | Basic requirement | N/A |
| Preferred | EPA methods for multiple habitats | EPA protocols | EPA protocols | EPA protocols | N/A |
| Not Acceptable | N/A | N/A | N/A | N/A | N/A |
| **Sampling Methodology** | | | | | |
| Preferred | EPA methods for multiple habitats | EPA protocols[a]. Neill-Hess cylinder sampler in erosional channels or Ekman dredge in depositional channel areas or pond/lakes. Ten (10) replicates per area characterized. | EPA protocols[a]. Neill-Hess cylinder sampler in erosional channels or Ekman dredge in depositional channel areas or pond/lakes. Ten (10) replicates per area characterized. | EPA protocols[a]. Neill-Hess cylinder sampler in erosional channels or Ekman dredge in depositional channel areas or pond/lakes. Ten (10) replicates per area characterized. | Literature |
| Alternate | N/A | Kicknet sampling of defined bottom areas for erosional channels or for surface sampling of other habitats (USEPA multi-metric methods). | Kicknet sampling of defined bottom areas for erosional channels or for surface sampling of other habitats (USEPA multi-metric methods). | Kicknet sampling of defined bottom areas for erosional channels or for surface sampling of other habitats (USEPA multi-metric methods). | N/A |
| Comments | N/A | Allows region wide comparability. | Allows region wide comparability. | Allows region wide comparability. | Allows region wide comparability. |
| Annual Frequency | 2X | 2X | 2X | 2X | 2X |
| **Analytical Methodology** | | | | | |
| Preferred | EPA protocols[a]. Organisms identified to lowest practical taxonomic levels using up-to-date taxonomic literature. | EPA protocols[a]. Organisms identified to lowest practical taxonomic levels using up-to-date taxonomic literature. | EPA protocols[a]. Organisms identified to lowest practical taxonomic levels using up-to-date taxonomic literature. | EPA protocols[a]. Organisms identified to lowest practical taxonomic levels using up-to-date taxonomic literature. | Literature |
| Alternate | N/A | N/A | N/A | N/A | N/A |
| Comments | See below for bioassessments. | Allows region wide comparability. | Allows region wide comparability. | Allows region wide comparability. | Allows region wide comparability. |
| **QA/QC Protocols** | | | | | |
| Preferred Procedure | EPA protocols[a]. Ten (10) replicate samples per sub-area characterized. | EPA protocols[a]. Ten (10) replicate samples per sub-area characterized. | EPA protocols[a]. Ten (10) replicate samples per sub-area characterized. | EPA protocols[a]. Ten (10) replicate samples per sub-area characterized. | Literature |
| Alternate Procedure | N/A | N/A | N/A | N/A | N/A |
| Comments | EPA methods | N/A | N/A | N/A | Based on literature for fish diet and professional judgment. |

Notes:

[a] Barbour, M. T., J. Gerritsen, B.D. Snyder, and J. B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

TABLE B-1.7
**Vegetation (Essential)**

| Parameter | Plant Composition (all strata; abundance; percent cover) | | | | | Peat Accumulation | |
|---|---|---|---|---|---|---|---|
| | **Species composition** | **Species diversity (Simpson's Index)** | **Species Richness** | **Vegetation Health and Vigor (categorical)** | **Rare Plants (all strata; abundance and % cover)** | **Carbon Sequestration and Decomposition** | **Vegetative Tissue Sampling** |
| **Tier** | **1** | **1** | **1** | **1** | **1** | **1** | **1** |
| | | | | | | | |
| **Sampling Site Selection Requirements** | | | | | | | |
| Must Meet | Transect and plots. Soil sampling needs to be coordinated with veg sampling. | Transect and plots. Soil sampling needs to be coordinated with veg sampling. | Transect and plots. Soil sampling needs to be coordinated with veg sampling. | Transect and plots. Soil sampling needs to be coordinated with veg sampling. | Site-to-site methodology must be uniform. Standardized search effort at each site (based on size). | Coordinated with transect and plots. | Coordinated with transect and plots – season will be an important factor for berry species. |
| Preferred[a] | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Not Acceptable[a] | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Sampling Methodology** | | | | | | | |
| Preferred | Observation within permanent plots. Photograph the plot from all cardinal directions. | Data used from species composition. | Data used from species composition. | Observation within permanent plots. | Meandering searches to locate habitat. Then parallel transects to maximize coverage area. | Erosion pins. | Hand-held clippers – collect 2 cups plant tissue and store in perforated paper plant tissue sampling bag at 4°C. |
| Alternate | Random plot sampling. | Random plot sampling. | Random plot sampling. | Random plot sampling. | Random plot sampling. | Litter decomposition bags. | None |
| Comments | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. Sampling period must be exactly one year. | Collection season is critical for plant tissue selection – during rapid plant growth period. Consideration must be given especially to leaf and berry collections – likely late summer timing. |
| Annual Frequency | 1X per year | 1X per year | 1X per year | 1X per year | 1X per year | 1X per year | 1X per year |
| **Analytical Methodology** | | | | | | | |
| Preferred | ANOVA/Kruskal-Wallis | Simpson's Index | ANOVA/Kruskal-Wallis | ANOVA/Kruskal-Wallis | ANOVA/Kruskal-Wallis | ANOVA/Kruskal-Wallis | Nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), aluminum (Al), and heavy metals. |
| Alternate | Sorenson's or Bray-Curtis | Shannon's Index | Sorenson's or Bray-Curtis | Sorenson's or Bray-Curtis | Sorenson's or Bray-Curtis | N/A | N/A |
| Comments | N/A | Since sampling will be of a small portion of the area, Simpson's Index will give a better idea of dominant vegetation. | N/A | N/A | N/A | N/A | N/A |
| **QA/QC Protocols** | | | | | | | |
| Preferred Procedure | Duplicate Plots | Duplicate Plots | Duplicate Plots | Duplicate Plots | N/A | Duplicate plots | Duplicate sampling of 10% of total quantity collected. |
| Alternate Procedure | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Comments | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

TABLE B-1.7
**Vegetation (Essential)**

| Parameter | Focal Species (abundance) | | | | |
|---|---|---|---|---|---|
| | **Typha latifolia (Cattail)** | **Schoenoplectus acutus (Hard-stem Bulrush)** | **Sparganium eurycarpum (Giant Bur-reed)** | ***Nuphar polysepalum*** **(Yellow water lily; Wocus)** | **Eleocharis macrostachya (Spikerush)** |
| **Tier** | **1** | **1** | **1** | **1** | **1** |
| | | | | | |
| **Sampling Site Selection Requirements** | | | | | |
| Must Meet | Transect and plots. Soil sampling needs to be coordinated with veg sampling. | Transect and plots. Soil sampling needs to be coordinated with veg sampling. | Transect and plots. Soil sampling needs to be coordinated with veg sampling. | Transect and plots. Soil sampling needs to be coordinated with veg sampling. | Transect and plots. Soil sampling needs to be coordinated with veg sampling. |
| Preferred[a] | N/A | N/A | N/A | N/A | N/A |
| Not Acceptable[a] | N/A | N/A | N/A | N/A | N/A |
| **Sampling Methodology** | | | | | |
| Preferred | Observation within permanent plots. | Observation within permanent plots. | Observation within permanent plots. | Observation within permanent plots. | Observation within permanent plots. |
| Alternate | Random plot sampling. | Random plot sampling. | Random plot sampling. | Random plot sampling. | Random plot sampling. |
| Comments | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. | Site-to-site methodology must be uniform. |
| Annual Frequency | 1X per year | 1X per year | 1X per year | 1X per year | 1X per year |
| **Analytical Methodology** | | | | | |
| Preferred | ANOVA/Kruskal-Wallis | ANOVA/Kruskal-Wallis | ANOVA/Kruskal-Wallis | ANOVA/Kruskal-Wallis | ANOVA/Kruskal-Wallis |
| Alternate | Sorenson's or Bray-Curtis | Sorenson's or Bray-Curtis | Sorenson's or Bray-Curtis | Sorenson's or Bray-Curtis | Sorenson's or Bray-Curtis |
| Comments | N/A | N/A | N/A | N/A | N/A |
| **QA/QC Protocols** | | | | | |
| Preferred Procedure | Duplicate Plots | Duplicate Plots | Duplicate Plots | Duplicate Plots | Duplicate Plots |
| Alternate Procedure | N/A | N/A | N/A | N/A | N/A |
| Comments | N/A | N/A | N/A | N/A | N/A |

Note:
[a] Not applicable for vegetation sampling.

TABLE B-1.8
**Wildlife (Potential)**

| | General Wildlife | | | | | | | Amphibians | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Raccoon Presence/ Absence** | **Beaver Presence/ Absence** | **Muskrat Presence/ Absence** | **Jackrabbit Presence/ Absence** | **Cottontail Presence/ Absence** | **Yellow rail Presence/ Absence** | **Spotted Frog Presence/Absence** | **Diversity** | **Abundance** | **Richness** | **Health (qualitative)** | **Health (quantitative)** |
| **Tier** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **2** |
| | | | | | | | | | | | | |
| **Sampling Site Selection Requirements** | | | | | | | | | | | | |
| Must Meet | Same locations as bird and amphibian surveys. | Same locations as bird and amphibian surveys. | Same locations as bird and amphibian surveys. | Same locations as bird and amphibian surveys. | Same locations as bird and amphibian surveys. | Same locations as bird and amphibian surveys. | Same locations as bird and amphibian surveys. | Stratified over all wetland types. | Stratified over all wetland types. | Stratified over all wetland types. | Stratified over all wetland types. | Stratified over all wetland types. |
| Preferred | N/A | N/A | N/A | N/A | N/A | N/A | N/A | Warm temperatures following rain; little wind or rain dripping from leaves. | Warm temperatures following rain; little wind or rain dripping from leaves. | Warm temperatures following rain; little wind or rain dripping from leaves. | Warm temperatures following rain; little wind or rain dripping from leaves. | Warm temperatures following rain; little wind or rain dripping from leaves. |
| Not Acceptable | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Sampling Methodology[a]** | | | | | | | | | | | | |
| Preferred | Incidental observations of sign or animal. | Incidental observations of sign or animal. | Incidental observations of sign or animal. | Incidental observations of sign or animal. | Incidental observations of sign or animal. | Incidental observations of sign or animal. | Incidental observations of sign or animal. | • Nocturnal calling survey [c]<br>• Visual Encounter Surveys [d]<br>• Egg mass surveys [e] | • Nocturnal calling survey [c]<br>• Visual Encounter Surveys [d]<br>• Egg mass surveys [e] | • Nocturnal calling survey [c]<br>• Visual Encounter Surveys [d]<br>• Egg mass surveys [e] | • Nocturnal calling survey [c]<br>• Visual Encounter Surveys [d]<br>• Egg mass surveys [e] | • Nocturnal calling survey [c]<br>• Visual Encounter Surveys [d]<br>• Egg mass surveys [e] |
| Alternate | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Comments | N/A | N/A | N/A | N/A | N/A | N/A | N/A | Need to visit each location several different times to ensure you are getting a good sample. | Need to visit each location several different times to ensure you are getting a good sample. | Need to visit each location several different times to ensure you are getting a good sample. | Need to visit each location several different times to ensure you are getting a good sample. | Need to visit each location several different times to ensure you are getting a good sample. |
| Annual Frequency | Ancillary to all amphibian and avian surveys | Ancillary to all amphibian and avian surveys | Ancillary to all amphibian and avian surveys | Ancillary to all amphibian and avian surveys | Ancillary to all amphibian and avian surveys | Ancillary to all amphibian and avian surveys | Ancillary to all amphibian and avian surveys | 3/year (Calling and VES); 1/yr (egg mass) every 2 wks during egg depositing period | 3/year (Calling and VES); 1/yr (egg mass) every 2 wks during egg depositing period | 3/year (Calling and VES); 1/yr (egg mass) every 2 wks during egg depositing period | 3/year (Calling and VES); 1/yr (egg mass) every 2 wks during egg depositing period | 3/year (Calling and VES); 1/yr (egg mass) every 2 wks during egg depositing period |
| **Analytical Methodology** | | | | | | | | | | | | |
| Preferred | Non-parametric comparisons. | ANOVA | ANOVA | ANOVA | Non-parametric comparisons | Non-parametric comparisons | Non-parametric comparisons. | Shannon's Diversity index | Wisconsin Index | Count Species | Count Species | Count Species |
| Alternate | N/A | N/A | N/A | N/A | N/A | N/A | N/A | Or similar | N/A | N/A | N/A | N/A |
| Comments | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **QA/QC Protocols** | | | | | | | | | | | | |
| Preferred Procedure | Rigorous back checking of data input | Rigorous back checking of data input | Rigorous back checking of data input | Rigorous back checking of data input | Rigorous back checking of data input | Rigorous back checking of data input | Ensure observers recognize Canadian toad and its egg mass. | Train observers to recognize all amphibians, including egg masses, present in survey area. | Train observers to recognize all amphibians, including egg masses, present in survey area. | Train observers to recognize all amphibians, including egg masses, present in survey area. | Train observers to recognize all amphibians, including egg masses, present in survey area. | Train observers to recognize all amphibians, including egg masses, present in survey area. |
| Alternate Procedure | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Comments | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

TABLE B-1.8
**Wildlife**

| Parameter | Waterfowl[a] | | | Breeding Birds[b] | | |
|---|---|---|---|---|---|---|
| | **Diversity** | **Abundance** | **Richness** | **Diversity** | **Abundance** | **Richness** |
| **Tier** | **1** | **1** | **1** | **1** | **1** | **1** |
| | | | | | | |
| **Sampling Site Selection Requirements** | | | | | | |
| Must Meet | Open water and marsh habitats. | Open water and marsh habitats. | Open water and marsh habitats. | Riparian areas, wetland edge, marsh. | Riparian areas, wetland edge, marsh. | Riparian areas, wetland edge, marsh. |
| Preferred | All wetland types. | All wetland types. | All wetland types. | N/A | N/A | N/A |
| Not Acceptable | N/A | N/A | N/A | N/A | N/A | N/A |
| **Sampling Methodology[a]** | | | | | | |
| Preferred | Point counts, round counts, or aerial surveys from fixed locations or transects around wetlands[f,g]. | Point counts, round counts, or aerial surveys from fixed locations or transects around wetlands. | Point counts, round counts, or aerial surveys from fixed locations or transects around wetlands. | Point counts along transects. | Point counts along transects. | Point counts along transects. |
| Alternate | N/A | N/A | N/A | N/A | N/A | N/A |
| Comments | Will want to cover fall and spring migration times and may want to do brood counts for breeding success. | Will want to cover fall and spring migration times and may want to do brood counts for breeding success. | Will want to cover fall and spring migration times and may want to do brood counts for breeding success. | Need to target breeding season. | Need to target breeding season. | Need to target breeding season. |
| Annual Frequency | 1/yr | 1/yr | 1/yr | 1/yr | 1/yr | 1/yr |
| **Analytical Methodology** | | | | | | |
| Preferred | Shannon's Diversity Index | Count Individuals | Count Species | Shannon's Diversity index | Count Individuals | Count Species |
| Alternate | Or similar | N/A | N/A | Or similar | N/A | N/A |
| Comments | N/A | N/A | N/A | N/A | N/A | N/A |
| **QA/QC Protocols** | | | | | | |
| Preferred Procedure | Train observers to recognize all birds present in survey area, including calls. | Train observers to recognize all birds present in survey area, including calls. | Train observers to recognize all birds present in survey area, including calls. | Train observers to recognize all birds present in survey area, including calls. | Train observers to recognize all birds present in survey area, including calls. | Train observers to recognize all birds present in survey area, including calls. |
| Alternate Procedure | N/A | N/A | N/A | N/A | N/A | N/A |
| Comments | N/A | N/A | N/A | N/A | N/A | N/A |

Notes:

[a] Analysis will be broken into feeding guilds (piscivore, benthic intertivore, aquatic predator, etc.) from the collected species lists.

[b] Analysis will be broken into feeding guilds (aerial insectivore, raptor, terrestrial insectivore, etc.) from the collected species lists.

[c] Droege, S. 2012. *Amphibian Calling Surveys*. http://www.pwrc.usgs.gov/monmanual/techniques/amphibcallingsurveys.htm USGS Patuxent Wildlife Research Center. Laurel, MD.

[d] Campbell, H.W. and S.P. Christman. 1982. *Field techniques for herpetofaunal community analysis*. Pp. 193-200. In: N.J. Scott, Jr. (ed.), Herpetological Communities. U.S. Department of the Interior, Fish and Wildlife Service, Wildlife Research Report 13.

[e] Jung, R.E., Funk, L., and Nanjappa, P. 2012. *Egg Mass Surveys*. http://www.pwrc.usgs.gov/monmanual/techniques/eggmass.htm USGS Patuxent Wildlife Research.

[f] Droege, S. 1990. *The North American Breeding Bird Survey*. Pp. 1-4. In: Sauer, J.R. and S. Droege (Eds.), Survey Designs and Statistical Methods for the Estimation of Avian Population Trends. U.S. Fish and Wildlife Service Biological Report 90, Washington, D.C.

[g] Huff, M.H, Bettinger, K.A., Ferguson, H.L., Brown, M.J., and B. Altman. 2000. *A Habitat-Based Point-Count Protocol for Terrestrial Birds, Emphasizing Washington and Oregon*. U.S. Forest Service Pacific Northwest Research Station, Gen Tech Rep PNW-GTR-501.

TABLE B-1.9
**Fish (Potential)**

| Parameter | Fish Abundance | Fish diversity (biotic indices) | Sentinel Species, Relative Abundance (to be identified) | External Abnormalities | Size Classes |
|---|---|---|---|---|---|
| **Tier** | **1** | **1** | **1** | **2** | **2** |
| | | | | | |
| **Sampling Site Selection Requirements** | | | | | |
| Must Meet | Wadeable or other techniques. | Wadeable or other techniques. | Wadeable or other techniques. | Wadeable or other techniques. | Wadeable or other techniques. |
| Preferred | N/A | N/A | N/A | N/A | N/A |
| Not Acceptable | N/A | N/A | N/A | N/A | N/A |
| **Sampling Methodology** | | | | | |
| Preferred | EPA protocols[a]. Electro-fishing of defined reaches or areas. Blocked channels resampled. | EPA protocols[a]. Electro-fishing of defined reaches or areas. Counts by species. | EPA protocols[a]. Electro-fishing of defined reaches or areas. Noted abundance of any sentinel species, along with size and abnormalities. | EPA protocols[a]. Electro-fishing of defined reaches or areas. Assessment of standard external abnormalities. | EPA protocols[a]. Electro-fishing of defined reaches or areas. Measurement of all fish. |
| Alternate | N/A | N/A | N/A | N/A | N/A |
| Comments | Standard fish assessment. Electro-fishing most likely for marked and blocked reaches of channels. | As above | As above | N/A | As above |
| Annual Frequency | 1X | 1X | 1X | 1X | 1X |
| **Analytical Methodology** | | | | | |
| Preferred | EPA methods will be most comparable for this area. | EPA methods will be most comparable for this area. | EPA methods will be most comparable for this area. | Visual, external | Measured, all fish |
| Alternate | Standard techniques | Standard techniques | Standard techniques | Standard techniques | Standard techniques |
| Comments | N/A | N/A | N/A | Literature review | Shows potential for reproduction. |
| **QA/QC Protocols** | | | | | |
| Preferred Procedure | Multiple samples | Multiple samples | Multiple samples | Multiple samples. Independent assessments of abnormalities by multiple members of field team. | Multiple samples |
| Alternate Procedure | N/A | N/A | N/A | N/A | N/A |
| Comments | True replication not possible. | True replication not possible. | True replication not possible. | True replication not possible. | True replication not possible. |

Notes:

[a] Barbour, M. T., J. Gerritsen, B.D. Snyder, and J. B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

# Appendix C
# Meeting Materials

*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

# Technical Advisory Committee (TAC) Meeting #1

**October 2, 2013**
(Via Teleconference)

## Meeting Notes

Attendees (Check mark indicates attendance):

| | | |
|---|---|---|
| ☐ Andy Hamilton | ☒ Eli Asarian | ☒ Linda Prendergast |
| ☒ Beth Bendickson | ☒ Jake Kann | ☒ Maia Singer |
| ☒ Bob Gearhart | ☐ Jed Redwine | ☒ Mary Grainey |
| ☒ Brittany Hughes | ☒ Jim Bays | ☒ Micah Gibson |
| ☐ Chauncey Anderson | ☐ John Hamilton | ☒ Mike Deas |
| ☒ Chris Stine | ☐ Kathleen Sloan | ☐ Rick Carlson |
| ☒ Clayton Creager | ☒ Ken Carlson | ☒ Tim Hemstreet |
| ☒ Crystal Bowman | ☒ Kyle Gorman | ☐ Jane Vorpagel |

The meeting began with introductions and opening remarks from Tim Hemstreet/PacifiCorp. Tim then introduced Jim Bays/CH2M HILL, who has been asked by PacifiCorp to serve as TAC facilitator. Tim also mentioned that Brittany Hughes/CH2M HILL will be assisting to set-up TAC meetings and document the meeting discussions and action items. The meeting then proceeded to cover various topics, and resulted in discussion points and action items, as summarized below.

### 1. Review of Objectives of Demonstration Wetlands Facility (DWF) Planning and Design Study

The focus of the TAC is on Interim Measure (IM) 11 2013-2014 Water Quality Study Activity 2 (Planning and Design for a Demonstration Wetlands Facility Adjacent to the Klamath River). The objectives of IM 11 Study 2 were reviewed and discussed, including:

- The key outcome of the study during 2014 is to develop a Research and Implementation Plan for a DWF, focusing on developing appropriate technologies that can be successful in the Klamath Basin
    - Treatment wetlands are a proven, accepted technology.
    - Different wetland technologies may warrant demonstration.
    - Treatment performance warrants evaluation of factors specific to the Klamath Basin, e.g., climate; seasonal water quality.
    - Demonstrations can be used to develop or verify assumptions for design and construction of a full-scale wetland system.

- The Research and Implementation Plan will be driven by the goals of stakeholders and will determine future steps.
- Knowledge gained from DWF will be used to inform implementation of wetland technologies that may be used in the Klamath Basin in the future.

2. **Review General Purpose and Attributes of the DWF**

The general purpose and attributes envisioned for the DWF were discussed, including:

- Jim Bays presented a few examples of DWFs that he has been a part of. Projects focused on phosphorus removal. Lessons learned included:
    - Scalability- When scaling from small DWF to full-scale wetlands, treatment results were similar. Each unique scale provided more information and scalability was successful.
    - Wetlands were very successful at phosphorus removal (80-90% reduction)
    - Research plan should include: stipulating the objectives, expected outcomes, sampling program, frequency of sampling, who will participate and roles. Needs to be something that can be adjusted/flexible. Puts all expectations on the table for everyone to see and react to.
- Treatment wetlands are a widely accepted technology. Wetlands could be used to provide habitat (dependent upon location) for critical status species (suckers) as well as water quality treatment.
    - Clayton Creager noted that there are entities that are willing to match funding to increase the size of the demonstration wetland if DWF can provide dual benefit.

3. **TAC Purpose and Activities**

The purpose of the TAC and anticipated TAC activities were discussed, including:

- Purpose of the TAC
    - Provide input on DWF and be the coordination link to the Interim Measures Implementation Committee (IMIC) and stakeholders. Utilize everyone's knowledge and experience to get to the most useful outcome.
    - The TAC is focused on IM 11 Study 2 (Planning and Design for a Demonstration Wetlands Facility Adjacent to the Klamath River), however, because of the expertise associated with the TAC related to nutrient reduction strategies, the TAC will also be consulted regarding Study 7 (Pilot Study of Nutrient Reduction Methods in Klamath Basin Waterbodies).
- TAC Activities

    - Build on what has been done previously (e.g., 2012 Workshop).
    - Identify partnership opportunities, including expertise, matching funds, land and other assets
    - Provide input on good candidate site(s)
        - Help to both build and assess landowner interest
    - Review drafts of the Research and Implementation Plan

**4. First Step: Develop a DWF Research and Implementation Plan**

A general overview of the Research and Implementation Plan for the DWF was discussed:

- Plan purpose and content
    - Determine and describe DWF research objectives
    - Describe preferred features and layout of DWF
    - Determine site location(s)
    - Describe anticipated studies
    - Identify participants and funding or in-kind commitments
    - Determine next steps- schedule for planning and design

**5. DWF Considerations**

The group discussed various aspects of DWF planning and potential features, including:

- Research considerations
    - Jim Bays encouraged TAC members to provide first-cut of recommendations for DWF research activities. These could be provided to Jim via email and brought to the next TAC meeting for further detailed discussion.
- Site location considerations
    - Focusing on Keno Reservoir and Upper Klamath Lake- Upper Klamath Lake is driver for issues downstream.
    - Consider the following items as they relate to the selection of a site: DWF size, soil variations, water quality. Explore various siting options for DWF by evaluating a range of attributes for each site.
    - Consider cost when determining size of DWF. 1-3 acres has been a good starting place.
    - Sites need to be accessible, close to water and power. Need some infrastructure to make it a good, reproducible test site.
        - Might be largely focused on one aspect (i.e. water quality), and then also focus a separate area on a different aspect (i.e. habitat).

- Focus on the qualities that are “special” about each basin and build a plan around those qualities. Sub-basins have unique needs:
  - Water quality differences
  - Habitat differences
- Clayton Creager and Maia Singer described that, in reviewing pre-existing efforts in the basin, there is a lot that has already been done. There are slightly different treatment needs throughout basins. Multiple sites might be in different locations to answer specific questions.
- Eli Asarian noted that water rights and potential water losses (from seepage or evapotranspiration) will be challenging issues for a DWF in Klamath Basin. Kyle Gorman said it would be advantageous to find a site where water rights exist. If site requires water right or transfer, processing time without opposition can take 6-8 months. Evapotranspiration and seepage to groundwater need to be accounted for in water rights. Need to find a way to minimize seepage to groundwater. May test a range of soil types or engineer a soil type to minimize infiltration losses.

- Potential partners and participants
  - Clayton Creager suggested to engage BLM and USBR on TAC- may also request others to participate. Largest potential site (Barnes Ranch, Upper Basin) is now under USFWS ownership. Matt Barry/USFWS is a potential contact for his knowledge on Barnes Ranch (or Matt could appoint someone to participate).
  - Jake Kann mentioned that The Nature Conservancy (TNC) may have a potential site - Sevenmile Canal - for treating phosphorus. The TAC should consider consulting with someone from TNC.
  - Maia Singer noted that Upper Klamath Conservation Action Network (UKCAN) is currently determining their objectives for a basin planning effort- tributaries to Upper Klamath Lake and the lake itself. Might be opportunities to overlap.
  - Educational Platforms. Bob Gearhart suggested seeking involvement of educational institutions and associated graduate students.
    - Graduate students from Oregon Institute of Technology (OIT) in Klamath Falls - Contact Michael Hughes. Brittany knows Civil Engineering Department Head Sean St. Clair.
    - Portland State University (PSU) - John Reuter, Mark Sytsma
    - Bob Gearhart has connections at Humboldt State University
      - Bill Trush
    - Brett Milligan at UC Davis

## 6. Study Schedule: 2013-2014

The anticipated schedule for 2013-2014 was summarized:

- Discuss DWF concept with IMIC: October-November 2013
- Coordination and information development for DWF Planning: December 2013- February 2014
- Develop Draft DWF Research and Implementation Plan: March-June 2014
- Complete Final DWF Research and Implementation Plan: July 2014
- Funding options or agency coordination that might drive or alter the schedule.

## 7. Follow-Up Action Items

Action items from this meeting were summarized as follows:

- Jim and Brittany will draft up initial schedule and topics to be covered. Brittany will send out invites and initial schedule.
    - Next call will likely be scheduled for the week of October 21.
    - Sub-TACs could create key points and text for report once we have the inputs for the report mapped out. Bi-weekly call would be a check-in/report back.
- Jim will develop proposed outline to collect input on DWF Research and Implementation Plan. Will distribute to TAC members for input.
- TAC members are encouraged to provide first-cut of recommendations for DWF research activities, potential candidate sites, and partnership opportunities. This input can be provided to Jim by email (for Jim's compilation) or brought to the next TAC meeting. This input will be discussed on the next TAC meeting call.

Interim Measure 11 Study 2: Planning and Design for a Demonstration Wetlands Facility Adjacent to the Klamath River

# Technical Advisory Committee (TAC) Meeting #1

October 2, 2013
Via Teleconference

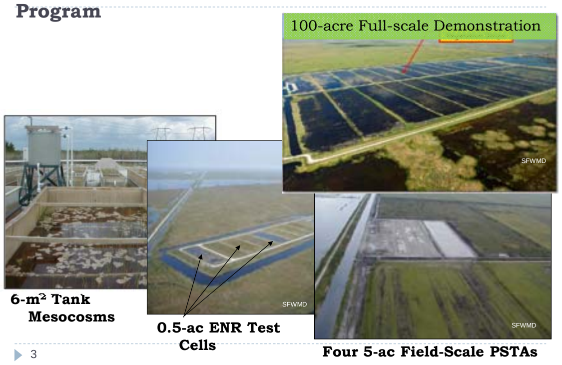
1

## Objectives of Demonstration Wetlands Facility (DWF) Planning and Design Study

- **Purpose of the Study**
  - Plan and design a DWF to investigate wetland technologies to improve water quality in the basin
- **Objectives of the DWF**
  - assess specific wetland types and components
  - evaluate wetland performance under real-world conditions specific to the basin;
  - verify important assumptions to design and construct full-scale wetland systems in the basin
  - help to inform future implementation of wetland technologies in the basin

2

## Example: Periphyton Based Stormwater Treatment Areas (PSTAs) for SFWMD Everglades Restoration Program




3

## Example: Wellington FL Aquatics Pilot Program: Emergent Marsh, SAV, and PSTAS


- Everglades Protection Area: TP discharge standard of 10 ppb
- Sequential wetland cells in series achieved 10-12 ppb at 0.2 $g/m^2/yr$.


## First Step: Develop a DWF Research and Implementation Plan (Summer 2014)



- **Plan Purpose:**
  - describe DWF research objectives
  - describe preferred features and the conceptual layout of the DWF
  - identify potential site locations for the DWF
  - describe anticipated studies
  - identify expected participants and their associated funding or in-kind commitments
  - lay out the process and schedule for further planning and design.

5

## DWF Site Locations Considerations

- **Various options for siting of the DWF**
  - could be a newly identified site
  - could be integrated within an existing available wetland site
  - could consider some PacifiCorp-owned properties
    - e.g., wetland candidate locations previously evaluated on PacifiCorp properties by Lyon et al. (2009)
- **Initially identified site attributes**
  - DWF area of about 1 to 3 acres
  - available properties that ideally have existing water rights and water delivery infrastructure

6

## TAC Purpose and Activities

- **Purpose of the TAC**
  - provide input on DWF planning during 2013-2014
  - coordination link to the IMIC and interested stakeholders
- **TAC Activities**
  - help to integrate recommendations from the Klamath Basin Nutrient Reduction Workshop (held in September 2012)
  - help to identify partnership opportunities for expertise, matching funds, or other in-kind assets for the DWF
  - provide input on potential candidate sites for the DWF on suitable available properties (public or private)
  - help to assess potential landowner interest in the DWF
  - review drafts of the Research and Implementation Plan

7

## Study Schedule: 2013-2014

| General Activity | Anticipated Timeframe |
|---|---|
| Discuss the DWF concept with the IMIC | October – November 2013 |
| Coordination and information development for DWF planning | December 2013 – February 2014 |
| Develop Draft DWF Research and Implementation Plan | March – June 2014 |
| Complete Final DWF Research and Implementation | July 2014 |

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## Follow-Up Action Items

- **Determine schedule of TAC meetings**
  - Assess TAC member preferences (this call)
  - Brittany (CH) to send out schedule & invites
- **Develop proposed outline of the DWF Research and Implementation Plan**
  - Jim (CH) will prepare & distribute to TAC
- **First-cut recommendations for DWF research activities, potential candidate sites, and partnership opportunities**
  - TAC members email input (if any) to Jim (CH)

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*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

# Technical Advisory Committee (TAC) Meeting #2

**October 24, 2013**
(Via Teleconference)

# Meeting Notes

**Attendees (checked box indicates attendance):**

| | | |
|---|---|---|
| ☒ Andy Hamilton | ☐ Eli Asarian | ☒ Kyle Gorman |
| ☐ Beth Bendickson | ☒ Jake Kann | ☒ Linda Prendergast |
| ☒ Bob Gearhart | ☐ Jane Vorpagel | ☒ Maia Singer |
| ☒ Brittany Hughes | ☒ Jed Redwine | ☒ Mary Grainey |
| ☒ Chauncey Anderson | ☒ Jim Bays | ☒ Micah Gibson |
| ☒ Chris Stine | ☒ John Hamilton | ☐ Mike Deas |
| ☐ Clayton Creager | ☐ Kathleen Sloan | ☐ Rick Carlson |
| ☒ Crystal Bowman | ☒ Ken Carlson | ☒ Tim Hemstreet |

## 1. Introductions

Jim Bays/CH2M HILL introduced himself as the TAC facilitator on behalf of PacifiCorp. Jim introduced Tim Hemstreet and Linda Prendergast who are PacifiCorp's representatives on the TAC. The meeting then proceeded to cover various topics, and resulted in discussion points and action items, as summarized below.

## 2. Minutes Review

Jim asked the TAC members for any comments on the minutes from the October 2, 2013 call. Chauncey Anderson asked for a brief synopsis of the first meeting, as some of the TAC members were unable to participate in the last call due to the federal government shut-down. Highlights from the last meeting include:

- The PowerPoint presentation that was sent prior to the last call was reviewed. It contained speaking points and examples of previous projects that Jim has worked on with a mission of identifying treatment wetlands as a proven technology to address water quality, understanding that treatment wetlands warrant demonstrations to build support and understanding of the approach, and that demonstration treatment wetlands (DWF) can be used to determine engineering criteria used to increase the scale of treatment wetlands. DWFs are widely accepted, scalable, and can be used for more than just nutrient removal- can provide habitat for fish and wildlife.
- The intent of the creation of a TAC is to provide/receive input from everyone. It is vital to the success of the research and implementation plan to have good dialog and contributions from all of the TAC participants. The research and implementation plan should build on what has been previously learned. Another goal of the TAC is to identify opportunities for

partnerships and to determine potential candidate sites. TAC participants are expected to actively participate and to review and comment on drafts to help move the implementation plan forward.

- TAC will help determine the important research activities associated with the DWF. A site will need to be selected based on the minimum requirements determined by the TAC. On the last call, Eli pointed out the importance of consumptive uses- finding sites where water rights currently exist, rather than having to obtain or transfer water rights will be key.
- TAC will also be key in helping provide a connection to agencies, universities, and other stakeholders whose participation will be important as we move forward.
- Jed Redwine mentioned he reviewed the Oregon Institute of Technology's EPA Star Fellowship grant for the Klamath Tribe and that one of his goals as a TAC participant is to help OIT revise their EPA star fellowship grant application such that it is up-to-date with all the activities taking place in the Klamath Basin.

**3. Review of Draft Outline of Research Plan**

A draft outline of the research and implementation plan was sent to all the TAC participants to provide a basis for discussion of key issues to be resolved in the plan. The outline is to be used to spark conversation and ideas. It is not definitive, it is a work in progress to add and subtract from. Jim put together the outline based on other research plans that CH2M HILL developed when working on other research projects. The outline is intended to be useful for projects with a large stakeholder contingent. The outline was reviewed by the group resulting in the following discussion points:

- Introduction
    - o The research objectives section is meant to not only outline the research and implementation plan purpose and objectives, but also to provide a history of the development of a DWF research and implementation plan. It will include a consolidated version of the 2012 workshop summary.
    - o Overview- The research plan is intended to provide opportunities for modification during implementation as new information is gained.
- Relevant Research and Technical Review
    - o Literature review summary will be included regarding wetland phosphorus removal processes.
    - o Similar wetland research projects have been completed elsewhere that provide useful precedents (e.g., Texas, Illinois, and Europe). The Plan should also include wetland research examples from the Klamath Basin. 2012 workshop included something similar to this- the goal is to not repeat the same material from the workshop, but to cite that work and expand upon any further research that has been done following the 2012 workshop.

        - Andy Hamilton has been involved with research being completed on a subsided peat wetland adjacent to the Wood River near Agency Lake which is examining the mass balance.
            - No reports have been written on current research, however data collection is on-going.
            - The peat wetland is a unique system with critical uncertainties that may make results of the studies limited. The site wetland receives significant groundwater input that has been complicating interpretation of the research results. Over 3 years of data collection, Andy has noticed differences in nutrient concentrations during wet and dry periods.
        - Jed Redwine mentioned that, in his experience, treatment wetland performance can be influenced by climatic factors and over time. In large-scale mature wetlands that have been heavily loaded for more than 3-4 years, wetland phosphorus removal performance can change.
        - Because of the need to factor in temporal changes to the wetland, the DWF will need at least a 2-3 year run of the wetland system for research/testing. Hydraulic loads could be manipulated in a smaller system to represent dry or wet periods. The system should be designed to allow a dynamic range in inflow rates to bracket the system performance during high and low loading periods.
- Klamath River Wetland Research and Design Issues
    - Understanding the ambient phosphorus concentration is important for modeling, in that it sets a limit on achievable P reduction.
        - Ken Carlson noted that site selection may be based on land suitability that is focused on soil chemistry and soil retention and background characteristics of the soil. Soil characteristics may drive the extent of treatment that could be achieved.
            - Lab and/or in-situ studies of soil will be required.
    - Need to consider techniques for minimizing water loss (infiltration, evaporation) through construction or design techniques.
    - Research needs to be completed to determine what will be the most effective vegetation type. There is conflicting information on the effectiveness of submersed aquatic systems.
        - Jed Redwine mentioned that adding forested wetlands to the list of potential types of wetlands might be useful. A forested wetland is dominated by adult trees (seasonally flooded forest). Cypress trees, broadleaf forests, poplar trees have been used in forested wetlands.
            - A larger biomass can retain more P.

            - Riparian woodlands might the analogous system on the Klamath River.
        - Ideas from the 2012 workshop included diffuse source wetland treatment- floodways, stream, riparian channels contribute water to a dynamically (seasonally) flooded system.
        - Spring-flood capture element should be added to the plan
            - Jake Kann mentioned the Sprague River Valley has potential for spring flood capture.
            - Maia Singer noted that because the subbasins within the Klamath Basin are very different, one demonstration facility may not be able to answer all the questions posed by the research and implementation plan. The TAC should examine multiple locations, identifying ecosystem services that are needed in particular subbasins. Tailor the wetland approach based on the subbasin.
    - Enhanced performance by chemical addition
        - Tim Hemstreet noted that the Measure 11 Activity 7 Study would cover this. The TAC should consider chemical addition as an option for the DWF research and implementation plan and any research could be used to inform the nutrient reduction study.
        - Jed Redwine noted that the Plan could consider the amount of alum as a commonly occurring constituent in the Klamath Basin soils to understand how its occurrence in the Klamath Basin compares to other locations.
    - In order to be able to speak about the multiple benefits of a DWF, providing significant habitat for sensitive species should be considered.
        - Maia Singer noted that Fish and Wildlife Service collaboration/ partnership and buy-in would be important.
            - TAC should consider bringing in some sensitive species experts.
        - California treatment wetland experience with sensitive species of birds has been that birds are interested in a new site, but as the site ages, they are less interested.
        - Bob Gearhart noted that incorporating sensitive species gives the study the appearance of an ecological study that might be hard to monitor and would be more difficult/complex to set-up.
- Other topics:
    - Bob Gearhart noted that infiltrating wetlands that are perched above the lake level may need to be considered.

    - Vertical flow/filtration systems are expensive to build at a large scale.
- John Hamilton asked Jim Bays how big in size the DWF would likely be. Jim Bays noted that he has been thinking the DWF would be a centralized test facility of about 2-3 acres with both test cells and mesocosms. (3) 0.5 ac test cells would allow the DWF to be big enough that operational considerations and ecological variability are real. The mesocosms (tanks) would be used to research specific questions and would allow the study to gain replication and statistical power. The study is envisioned to last a couple of years. The TAC will need to revisit the scale of the DWF.
    - John Hamilton wondered if there is also opportunity to coordinate with the research Andy Hamilton has been involved with, and perhaps even locate the DWF, adjacent to the Wood River.
        - Andy said that the current site operates with a system of headgates, fish screens, and gravity flow to get water into wetland. 2 pumps are used to pump water out of the wetland. Have fairly good control over north and south half of site. Entire site is operated at a water level lower than the Klamath, so the site receives a lot of groundwater input.
        - There are smaller units that may be appropriate for locating the DWF near the Wood River site that are contained by levees with proximity to power and the ability to move water in and out of the site.
- During DWF site selection, consideration needs to be given to both not having enough water and having too much water (groundwater input). Water quality will likely worsen with groundwater input.
- Bob Gearhart noted that the preferred scale of a study is dependent upon the information you're trying to gather.
    - Consider having internal access to retrieve water quality samples using boardwalk/platform
- Jim Bays mentioned that the Plan would contain a monitoring program. Proposed parameters to be collected include phosphorus, physical parameters, rainfall records, insulation and temperature, sediment analysis, plant community type and structure. The Plan would also discuss the approach to modeling, data analysis and statistics.
- Jed Redwine suggested that Laurel Larsen at U.C. Berkeley be contacted regarding some innovative data analyses she is doing to understand the complex interactions between physical and biological processes in flowing-water environments. Her work is using detailed

field and lab experiments to understand the processes and then formulating numerical models to predict changes in driving variables.

  - Jim Bays noted that all TAC members are probably working with specialists in this field and that it will be helpful to bring new information forward as we progress.

- Chauncey Anderson suggested the statistical variability would best be addressed using multiple test wetlands to get a better representation of wetland performance (e.g., phosphorus removal).
- Working in the Klamath Basin is going to present challenges similar to those experienced with the work in the Everglades which is getting people to accept the large scale of implementation that will be required to aid the watershed.
  - It is important to model our approach based on what has been done in other systems with a broad stakeholder base. The research and implementation plan will need to address stakeholders on their terms, understanding stakeholder's base knowledge and building upon that knowledge.
    - Visible projects tend to have a lot of stakeholder acceptance, as projects are tangible to stakeholders.
- Chauncey Anderson mentioned that there have been previous indications about the presence of mercury in the Klamath system. Plan should account for mercury and DWF implementation should be done to ensure no contribution to a mercury problem.
- Performance data gets used in modeling. There is a need to review and make sure that at the end of the day, we'll have a sound basis for model calibration and that all factors needed for modeling are being monitored. Expect differences in seasons to affect removal efficiencies.
  - Data collection will need to happen on a seasonal basis as well as a yearly basis. Quarterly data summaries and annual reports are recommended regarding what may need to be adjusted to keep facility functioning. Periodic workshops to help build acceptance of results and communication about the project are also recommended.

## 4. Follow-Up Action Items

TAC members should email or call Jim Bays with any questions, comments, and concerns regarding draft outline. Comments and suggestions to be submitted to Jim by November 11. Jim will use these comments/suggestions to create a second version of the outline incorporating TAC comments.

Next call will be Monday, November 18th from 1-3 PM PDT.

*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

# Technical Advisory Committee (TAC) Meeting #3

**November 18, 2013**
(Via Teleconference)

# Meeting Notes

**Attendees (checked box indicates attendance):**

| | | |
|---|---|---|
| ☒ Andy Hamilton/BLM | ☒ Jake Kann/AES | ☒ Linda Prendergast/PacifiCorp |
| ☐ Beth Bendickson/PacifiCorp | ☒ Jane Vorpagel/CA DFG | ☐ Maia Singer/Stillwater Sciences |
| ☒ Bob Gearhart/HSU | ☐ Jared Bottcher/KBRT | ☒ Mary Grainey/OWRD |
| ☒ Brittany Hughes/CH2M HILL | ☐ Jed Redwine/SF Environments | ☐ Micah Gibson/Yurok Tribe |
| ☒ Chauncey Anderson/USGS | ☒ Jim Bays/CH2M HILL | ☐ Mike Deas/Watercourse Eng |
| ☒ Chris Stine/ODEQ | ☐ John Hamilton/USFWS | ☒ Nell Kolden/KBRT |
| ☒ Clayton Creager/CA RWQCB | ☒ Kathleen Sloan/Yurok Tribe | ☐ Rick Carlson/USBR |
| ☒ Crystal Bowman/Karuk Tribe | ☒ Ken Carlson/CH2M HILL | ☒ Tim Hemstreet/PacifiCorp |
| ☒ Eli Asarian/Riverbend Sciences | ☐ Kris Fischer/Klamath Tribe | |
| ☒ Heather Hendrixson/TNC | ☐ Kyle Gorman/OWRD | |

## 1. Introductions

Jim Bays introduced himself and reviewed the agenda with the TAC members. Jane Vorpagel asked to be provided with the past meeting materials. Brittany will provide the past meeting materials to her.

## 2. Review Project Purpose

Because of several new attendees on today's call, Jim reviewed the purpose of the TAC. The purpose of the TAC is to be a link to the Interim Measures Implementation Committee (IMIC) to develop a plan of study for a demonstration wetland facility (DWF). The expectation is that the TAC meetings will be a forum for coordination and technical interaction. This year's effort will result in development of a DWF Research and Implementation Plan. The research and implementation plan will be complex and will take a number of meetings to develop the various parts of the plan that are most important to the TAC.

- First meeting of the TAC covered a lot of different topics related to the research and implementation plan in a general sense. Jim highlighted discussion on the plan's purpose, which includes the examination of the effectiveness of wetlands to reduce nutrients in the river. As previously discussed, wetlands are not just treatment systems but are also habitats and ecosystems.

- Tim Hemstreet added that while the draft Research and Implementation Plan outlined was reviewed on the last TAC call, the purpose of the plan still needs more definition. The TAC will help define the purpose of the plan. The

TAC should define what the plan focuses on to maximize the benefit of this process to meet multiple objectives in the Basin.

3. **Discussion on Research and Implementation Plan Focus Areas, Partnership Roles, and Opportunities**

- Jane Vorpagel suggested that the DWF should serve to inform the public that the use of wetlands to improve water quality is possible, thus the DWF should include educational components. The DWF would be useful for showing the public and other interested parties what wetlands treatment looks like and describing how it helps the river.
- Chauncey Anderson suggested that while phosphorus is important, studying nitrogen removal should also be considered. The DWF may be designed/engineered around phosphorus removal, but could also monitor/measure nitrogen removal. Exclusive focus on phosphorus as a removal strategy is something that should be discussed.
- Tim Hemstreet offered that there is currently funding for completing DWF planning efforts, however funding for the design and construction of a DWF is uncertain. Interim Measure 11 has $5.6M dedicated to Upper Klamath Basin nutrient reduction projects. Waiting for post-determination to find out about funding. Research and implementation plan should develop a project that can be completed through any number of funding sources.
- Clayton Creager mentioned that the rehabilitation of Upper Klamath Lake doesn't mean going back to pre-existing conditions. Keep in mind that we'd like to demonstrate that through engineering we can increase removal of phosphorus and nitrogen and preserve agricultural operations. The Nature Conservancy (TNC) and U.S. Fish and Wildlife Service (USFWS) want to protect and enhance the biodiversity of the Lake. Treatment wetlands design at Barnes Ranch and Agency Lake focus on spawning and rearing habitat for the sucker fish and habitat for waterfowl- providing multi-purpose functions/benefits.
- One hypothesis is that by reducing incoming nutrient concentrations that are coming into the Lake, that is has an effect on the internal equilibrium within the Lake. Thus, the water quality in the lake is a key driver of the water quality in the Klamath River system below the lake. However, water quality in reservoirs also contributes to water quality concerns.
- Chauncey Anderson reported that USGS has looked at some potential site areas along the Keno Reservoir. The TAC will need to determine if the plan will focus solely on phosphorus or a broader suite of nutrients. Doing something upstream of Upper Klamath Lake will take a longer length of time to benefit downstream reaches.
- Linda Prendergast offered that there are currently no set locations for the DWF and that the plan and partnerships will help determine the location of the DWF.
- Clayton Creager suggested that land cost will drive DWF location as well. Jake Kann completed an evaluation that suggested there is a 1-year lag time

in reduction of nutrients circulating in the lake. Clayton said the California North Coast Regional Water Quality Control Board didn't want to give credit to projects above the lake, however they have reversed positions on not funding projects above the Lake due to study results showing short lag-time. Lag time may be an important study question for the TAC.

- Jim Bays stated that he has seen implementation of DWFs where conditions of different parts of a river habitat/ecosystem affecting water quality can be simulated by adjusting nitrogen levels (controlled addition of fertilizer). DWF could be a living laboratory/replicated mesocosm study/smaller scale system.
- Ken Carlson suggested that the type of wetland you may select to demonstrate may be different depending on where you are in the landscape.
- Heather Hendrixson stated that there have been a lot of restoration projects in the Upper Klamath Basin including a breached levee "flow through-type" wetland system on the Williamson River Delta. TAC should utilize information on such existing systems. There may be an option to manipulate existing wetlands to provide further information. TNC's priority is to implement diffuse source wetland treatment in Upper Basin.
- Tim Hemstreet reiterated that the goal of the TAC and research and implementation plan is to look at all the reports that have been done and assess the types of wetlands implemented to determine if there are any data gaps in the existing DWF studies.
- Jim mentioned that key findings of existing studies should be engrained into the research and implementation plan. Brittany to provide draft outline of the plan (covered on during TAC Meeting #2) to Heather.
- Heather said TNC completed soil core, nutrient release studies, and vegetation classification studies on Williamson River Delta wetland project. TNC would be willing to share this information from early 2000s. Heather likes the idea of a small pilot wetland treatment facility, but is concerned with scalability. TNC's goal is to restore sucker populations. NEPA and EIS process at Agency Lake and Barnes Ranch may be a challenge to a large wetland system.
- TNC got involved to breach levees interested in seeing reconnection. TNC has concerns about subsidence reversal time scales. Larval fish key in emergent and submerged wetland habitats. Wetlands are an important habitat for young sucker fish. Most of these wetlands have been diked off and separated from the lake for several years. Wetlands along the edge of the Lake would have the most impactful benefit. Some sort of strategic breaching may be important to consider.
- Nell Kolden mentioned that KBRT is looking into implementing a few small scale diffuse source treatment wetlands in the Wood River Valley in the next couple of years working with landowners, the Upper Klamath Conservation Action Network (UKCAN), Department of Fish and Wildlife and the Tribes.

Flow is seasonally distributed to riparian systems such as flow routed from an irrigation ditch to wetland.

- Bob Gearhart mentioned that there are a couple of diffuse source wetlands at K&K ranch, one on the Sprague River, and at “Becky Hines’ place”. The wetlands have all been there long enough to be established, but there’s not been sufficient monitoring. Sites are less than an acre. K&K ranch site is return flow and overbank. Almost pilot-level, but they are site-specific.
- Nell Kolden said KBRT has identified reducing phosphorus as a major item, but don’t want to rush into implementation without proper monitoring and coordination of monitoring. KBRT has been working with Michael Hughes at OIT to get students involved with wetland monitoring as well as using student ideas and providing them real world experience.
- Jane Vorpagel added that diffuse wetlands would be the best way to include a public outreach aspect due to smaller wetland (5-10 acres) size. The wetland facility would need to be located where it would be easy to access.
- Clayton Creager suggested that diffuse wetland treatment systems are an attractive idea because they don’t involve purchase of land and don’t affect existing operations. The California State Coastal Conservancy (CSCC) is interested in providing matching funding whether pilot or full-scale. Clayton has a request in to his agency for $200,000 for next year for a pilot project or full scale project. There are also other entities who are considering matching funds. CSCC needs DWF to demonstrate a habitat objective. The restoration grant is funded by remaining funds from a State Proposition. Clayton will be meeting with CSCC in the next few weeks to get more details about their proposal.
- Public lands around Agency Lake may be public lands that are encumbered. There are competing objectives within USFWS. The EIS is set to begin soon. Have yet to determine primary purpose- suckers, waterfowl, others? Infrastructure maintenance is important due to funding concerns. A lot of consideration to be done before an active project could move forward.
- John Hamilton questioned whether the Agency Lake and Barnes Ranch site may be too complicated for a DWF. John will check into the sites and discuss on the next TAC call.
- Eli Asarian mentioned another potential site is the Miller Island Wildlife Refuge, which is the largest publicly owned land (3000 ac) on Keno Reservoir. Perhaps the Refuge might be interested in partnering on the DWF project. Refuge is managed as a standalone entity and maintained for waterfowl. No info on water rights. Has been looked at as a potential site in previous wetland studies. Is a long way down in the Keno Reach.
- Tim Hemstreet mentioned that the TAC needs to consider how much of the river can be influenced by wetland treatment.
- Chris Stine offered to speak with ODFW about Miller Island Wildlife Refuge.

- Jim Bays mentioned that it may be beneficial to spend some time on the upcoming call and have both Jake and Heather present key findings on PowerPoint Slides about where we stand on current knowledge/information:
    - Jake Kann will present new data showing how quickly the outflow from the lake would respond to inflow loading.
    - Heather will summarize Williamson River Delta work and send along fact sheet about current Williamson River data.
- May be opportunities to study existing systems that are already built and there are upcoming wetlands that are being planned that could be a platform for additional funding/investment to make it a more informative site.
- Clayton Creager mentioned the importance of Bureau of Reclamation (BOR) participation. BOR has sponsored past wetland projects and may be a valuable support and insight. Rick Carlson at BOR is on point. Miranda Campbell/BOR reiterated that BOR is committed to participating in these different DWF forums. Denver and Sacramento representatives are working on global climate change scenario responses and in many ways, the plans they were coming up with included wetland treatment systems.
- It is hard to talk about partnerships and not about sites, they are closely linked. Need to be sure landowners would be a partner and that easements or other mechanisms are in place.

**4. Review Proposed Meeting Schedule**

- Jim Bays described a proposed schedule of future TAC meetings. There is a cumulative series of steps we must take to keep bringing up issues and refining or discarding things as we go. Below is a list of a proposed a series of monthly calls which should allow enough time to make assignments and circle back to group.

| **CC** | **Topic** | **Activity** | **Date** |
|---|---|---|---|
| 1 | Initiate discussion on DWF concept | Planning with TAC | T Oct 1 |
| 2 | Establish Research Plan format | | Th Oct 24 |
| 3 | Initiate discussion regarding identification of prospective partners and roles | | M Nov 18 |
| 4 | Initiate discussion regarding identification of prospective site(s) | | T Dec 17 |
| 5 | Review key topics and analysis approach | | T Jan 21 |
| 6 | Finalize topics, sites and partners | Draft by CH2MHILL | T Feb 18 |
| 7 | Mid-point progress update on Plan | | T Mar 18 |
| 8 | Preview and submit draft Plan | | T Apr 22 |
| 9 | Receive, discuss comments on draft Plan | Review by TAC | T May 20 |
| 10 | Preview and submit final Plan | | T Jun 17 |
| | Submit Final Research Plan | Final by CH2MHILL | F Jul 25 |

| CC | Topic | Activity | Date |
|---|---|---|---|
| | Discuss/Determine next steps for DWF Implementation/Partnerships | | |

**5. TAC for Nutrient Reduction Study (Interim Measure 11, Study 7)**

- As a reminder, Study 7 of Interim Measure 11 is a pilot study of nutrient reduction methods for use in the Klamath Basin. The purpose is to do a proof of concept with a focus on phosphorus (maybe nitrogen too). Study 7 is envisioned as a pilot study to assess the effects of treating volumes of water to reduce nutrient concentrations using coagulants to bind and sequester. Study results from this year's work would affect the applicability of use in coming year(s). Study 7 also calls for TAC review and input.
- As we have talked in previous TAC meetings, it would be good to use this TAC for Study 7 too. Might need to have some separate meetings to tackle Study 7. PacifiCorp plans to send out draft of a suggested initial plan for testing of some agents that could be useful as a way of treating nutrients. The suggested initial plan will be presented on the next TAC call. The TAC's feedback on the plan will be important to ensure agreement about the plan's objectives and approach.
- John Hamilton mentioned there have been some objections to using different agents and concern about public input on the plan. Ken is looking for TAC input. Before technology is implemented, permitting and public input would have to be taken into account. At this point, the study will be a bench scale/lab-type analysis, not implemented at full-scale in the field.

**6. Action Items**

- Brittany to send Jane Vorpagel past meeting materials.
- TAC members are encouraged to jot down potential sites and partners and send to Brittany/Jim.
- Brittany to send out Outlook invite for all upcoming meetings. Calls will be scheduled for 1:30 PM.
- John Hamilton will check into Agency Lake and Barnes Ranch sites to see if they may be a fit for the DWF and discuss on the next TAC call.
- Chris Stine will speak with ODFW about Miller Island Wildlife Refuge.
- Jake Kann will present a summary of new data on next TAC call, focusing on findings of how quickly the outflow from the lake would respond to inflow loading.
- Heather will summarize Williamson River Delta work on next TAC call and send along fact sheet about current Williamson River data.

# Study Schedule: 2013-2014

## Original presented to TAC 10/2

| General Activity | Anticipated Timeframe |
|---|---|
| Discuss the DWF concept with the IMIC | October – November 2013 |
| Coordination and information development for DWF planning | December 2013 – February 2014 |
| Develop Draft DWF Research and Implementation Plan | March – June 2014 |
| Complete Final DWF Research and Implementation | July 2014 |

1

# Study Schedule: 2013-2014

## Detail to be presented to TAC 11/18

| CC | Topic | Activity | Date |
|---|---|---|---|
| 1 | Initiate discussion on DWF concept | | T Oct 1 |
| 2 | Establish Research Plan format | | Th Oct 24 |
| 3 | Initiate discussion regarding identification of prospective partners and roles | Planning with TAC | M Nov 18 |
| 4 | Initiate discussion regarding identification of prospective site(s) | | T Dec 17 |
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| 9 | Receive, discuss comments on draft Plan | Review by TAC | T May 20 |
| 10 | Preview and submit final Plan | | T Jun 17 |
| | Submit Final Research Plan | Final by CH2MHILL | F Jul 25 |
| | Discuss/Determine next steps for DWF Implementation/Partnerships | | |

*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

# Technical Advisory Committee (TAC) Meeting #4

**December 17, 2013**
(Via Teleconference)

# <u>Meeting Notes</u>

**Attendees (checked box indicates attendance):**

| | | |
|---|---|---|
| ☒ Andy Hamilton/BLM | ☒ Jane Vorpagel/CA DFG | ☒ Linda Prendergast/PacifiCorp |
| ☐ Beth Bendickson/PacifiCorp | ☒ Jared Bottcher/KBRT | ☐ Maia Singer/Stillwater Sciences |
| ☒ Bob Gearhart/HSU | ☒ Jed Redwine/SF Environments | ☒ Mary Grainey/OWRD |
| ☒ Brittany Hughes/CH2M HILL | ☒ Jim Bays/CH2M HILL | ☐ Micah Gibson/Yurok Tribe |
| ☒ Chauncey Anderson/USGS | ☒ Jessica Asbill-Case/USBR | ☒ Mike Deas/Watercourse Eng |
| ☒ Chris Stine/ODEQ | ☒ John Hamilton/USFWS | ☒ Nell Kolden/KBRT |
| ☒ Clayton Creager/CA RWQCB | ☒ Kathleen Sloan/Yurok Tribe | ☐ Rick Carlson/USBR |
| ☐ Crystal Bowman/Karuk Tribe | ☒ Ken Carlson/CH2M HILL | ☒ Ted Wise/ODFW |
| ☒ Eli Asarian/Riverbend Sciences | ☒ Kris Fischer/Klamath Tribe | ☒ Tim Hemstreet/PacifiCorp |
| ☒ Heather Hendrixson/TNC | ☒ Kyle Gorman/OWRD | |
| ☒ Jake Kann/AES | ☒ Kurt Carpenter/USGS | |

## 1. Introductions

Jim Bays/CH2M HILL opened the meeting by reiterating the purpose of Interim Measure 11, Study 2. The mission of the study is to plan and design a demonstration wetland facility (DWF). Jim reviewed the agenda for today's meeting.

## 2. Purpose, Progress and Activity Review

Jim Bays reviewed the schedule for Study 2 and what has been discussed on past calls. TAC previously had an initial discussion reviewing a draft outline of the DWF research and implementation plan. Input on the draft outline is always welcome. Based on TAC discussions, more detailed information will start being added to the draft outline. Discussion has been initiated regarding identification of prospective partners and roles. We are looking for partners amongst the stakeholders, landowners, agencies, realizing sites may be difficult to find. We are also looking for partnerships in funding and establishing research objectives. Potential site location(s) will be a continuing discussion point.

All information gathered through the TAC meetings is intended to accumulate into a draft research and implementation plan with opportunities for input along the way. The schedule is to complete the plan by summer 2014.

Discussion of DWF site attributes will include construction requirements for a fully functional site (accessibility), type of wetland, potential partners (research and funding), permitting (NEPA, EIS, etc), groundwater input, water rights and the ability to convey water to/from site, and proximity to power.

## 3. Lake Response to Changes in Inflow Loading-Jake Kann

Jake Kann/AES presented to the TAC on recent work he's been doing researching nutrient balances and lake response to phosphorus load reductions in Upper Klamath Lake.

Upper Klamath Lake is the focus point of the research as it serves as a receiving water for the upper watershed areas and as headwaters for the Klamath River. Data from a network of sampling sites maintained by Klamath Tribes was used. Information on both phosphorus and nitrogen was examined. The goal of the study was to observe all sources contributing these nutrients to the lake and all the sources leaving the lake and examine the change in phosphorus and nitrogen mass in the lake.

Net nutrient retention was calculated as the sum of the tributary and atmospheric inputs minus the outputs and change in lake storage.

A lot of phosphorus is "recycled". (Internal loading and recycling are synonymous.) A model was built to model phosphorus and algae in the lake. Data from an expanded monitoring network and additional data from 1999 to 2010 was added to the model. Results of the model will be analyzed more thoroughly in 2014.

The initial estimate was 39% of phosphorus load was coming from external sources, 61% was recycled. The watershed and lake are coupled systems which result in a variety of potential mechanisms controlling the internal recycling.

Charts also show negative retention- meaning recycling is occurring (generally happens between the months of May and September).

Research also showed that nitrogen is coming into the lake and then flowing downstream (it is not retained as was observed with phosphorus).

The TMDL model was run for 200 years- with no reduction in external loads, equilibrium is around 100 ppb; with 40% reduction in external loads, equilibrium drops to 55 ppb.

External loading of phosphorus is coming from a variety of sources- Williamson River (26%), Sprague River (18%), Wood River (29%), Sevenmile Canal (11%), pumped directly to the Lake (9%), and through springs, ungagged tributaries, and groundwater (7%).

A lot of pumping directly to the lake has been curtailed. It is important to note that the small drainage areas (such as the Wood River) are large contributors to phosphorus loading.

Study revealed that phosphorus outflow loads and concentrations appear to respond relatively rapidly (one-year lag time) to changes in external loading.

The study concluded that implementing water quality improvements upstream of Klamath Lake will have greater impacts (on both the Lake and downstream river) than implementation of improvements downstream of the Lake.

There are a multitude of solutions that can be implemented. The Wood River seems to be a good place to start. Wetlands are good for phosphorus mass reduction with a high throughput.

Chauncey Anderson/USGS asked if the same load reductions could be seen with nitrogen. Jake Kann/AES said that nitrogen does show a similar result, but it is hard to tell if it's driven by nitrogen loading itself (higher biomass).

Eli Asarian/Riverbend Sciences asked if there are implications for the time of year of loading. Reducing loading in the spring prior to the growing season would affect loading. Decreasing the concentration during the growing season would benefit the Lake.

Loading to wetlands should be designed to track the change in mass loading coming from the lake (downstream), would like to validate mass reduction during high export periods as a desirable near term goal. Hydraulics would need to be dynamic.

Clayton Creager/CA RWQCB noted that the delay in lake response for having the project above the lake is not a driver for site selection (California is a potential funding partner even if projects are above Klamath Lake). If wetlands can help the Lake reach equilibrium, may not need to maintain wetlands for a long period of time.

4. **Williamson River Delta Work-Heather Hendrixson**

Heather Hendrixson/TNC presented the work The Nature Conservancy (TNC) has been doing at the Williamson River Delta (WRD).

TNC purchased property in 1996 and planned for breaching of levees and flooding of properties. Nutrient and toxin studies were done. Hydrologic modeling was also completed to figure out most effective breach locations. In the fall of 2007, levees were breached on Tulana (north part of WRD). The breached levees resulted in the flooding of 5500 acres; some of the area in Tulana is open water and the rest are all wetlands. Multiple Monitoring locations in Tulana and Goose Bay were set-up, providing stratified sampling based on wetland zones- open water, deep water, emergent, transitional, and upload. TNC has 5 years of monitoring data.

There was a high release of phosphorus with initial levee breach (breach was completed in October). About 2 tons were released from flooding, however this was less than what was predicted. TNC also looked at sucker threshold exceedances. Exceedances have gone down over a 4 year time period following the levee breaches. As wetlands grow and mature, conditions are becoming more favorable for suckers.

At the sonde sites, temperature was measured every hour from April to November mid-water column. In the early spring when sucker larvae is using the wetland, wetlands are a bit warmer than lake. Have seen wind direction and strength dictate flow through wetland.

TNC is also planning restoration activities along the NRCS easement along Sevenmile Canal. Plan to build a berm on the property to build-up water to encourage wetland vegetation growth. Will reduce loads in Sevenmile Canal. No pumping of water is planned.

Area above Barnes/Agency Lake Ranch is set for rehabilitation. Barnes/Agency Lake Ranch will be starting an EIS process soon to look at options. Alternative designs can be introduced in the EIS process.

There are a range of opinions in USFWS about the types of treatment wetlands that are appropriate for sites. There is a lot of support in considering a more active type of treatment wetland. TNC became involved in this area since these properties would be breached. Tribes are very interested in breaching and more passive restoration. Option of a treatment wetland is worthwhile exploring.

John Hamilton/USFWS will find out who from USFWS is a contact regarding potential pilot project sites. Names mentioned included Ron Cole, Greg Austin, Dan Blake, Matt Barry, Ron Larsen and Laurie Sada.

Sevenmile Canal, West Canal, Fourmile Creek and the Wood River flow into Barnes and Agency Lake Ranch.

Chauncey Anderson/USGS and Kurt Carpenter/USGS mentioned that there is funding from Bureau of Reclamation to begin planning for future research. Funding would be provided in 2014 to complete a literature review about what's been done at the Wood River and do some pilot testing or reconnaissance work. This will be about a one-year effort. Literature review would include recent data from Bureau of Land Management since they started to irrigate, showing sequestration and secretion of soils and nutrient uptake changes over time. Will also examine how water depth influences phosphorus release. The goal is to develop a proposal for multi-year study looking at multiple type of wetlands around Upper Klamath Lake.

## 5. Discussion and Identification of Prospective Sites

Jim Bays/CH2M HILL observed that strong cases can be made for trying to site wetlands around Upper Klamath Lake based on the information that was provided today from Jake Kann and Heather Hendrixson. There is a previous 2009 CH2M HILL Report that also lists sites downstream of the Lake. Those sites will remain on the list of sites for consideration.

## 6. TAC for Nutrient Reduction Study (Interim Measure 11, Activity 7)

Ken Carlson/CH2M HILL introduced Activity 7. Proposal is to have participants from this TAC participate on the TAC for Activity 7. An initial draft of the Initial Testing Approach and Procedures was sent out to the IMIC and TAC a few weeks ago. The TAC for Activity 7 would discuss specific approaches to nutrient reduction, identify technical expertise, partnerships, etc. for conducting a pilot study using chemical agents for coagulation, binding, and sequestration. One of the recommendations that emerged from the 2012 Water Quality Workshop in Sacramento was to use alum micro-flocculation in concert with aeration to reduce nutrients in Keno Reservoir. Some groups have been more receptive than others to the use of chemical agents. The draft Initial Testing Approach and Procedures plan that was submitted was the first step in using a bench-scale test to determine candidate agents. TAC members should review and provide comments via email or on the next TAC call for Activity 7.

Linda Prendergast/PacifiCorp suggested we could have a short discussion on Activity 7 draft plan at the end of our next TAC Call (extend it by 30 minutes).

Chauncey Anderson/ USGS mentioned that there may be other people from USGS who should be involved as a part of the Activity 7 discussion- Nancy Simon, Tammy.

Jim Bays/CH2M HILL suggested that technology of chemical addition may speak to needing different people to be involved. Folks governing or regulating biological water quality might want to be involved in the call.

John Hamilton/USFWS suggested the Klamath Falls sucker folks should participate on the Activity 7 call.

The intent for Activity 7 is to develop a plan for bench/lab testing. Bench/lab testing could be done late spring, summer of 2014. Testing of various treatments/chemical agents does not mean that the treatment/chemical agent is endorsed for use.

TAC members to provide names of any additional people who they believe should participate in the Activity 7 discussion.

The Tribes are very interested in sucker population rehabilitation. There is a sense of urgency (10 years). The Tribes are open-minded about use of chemical additives if it will help the suckers.

## 7. Action Items

- John Hamilton/USFWS will find out who from USFWS is a contact regarding potential project sites.
- TAC members to provide input to Jim Bays/CH2M HILL on potential wetland sites and partners.
- TAC members to provide names of any additional people who they believe should participate in the Activity 7 discussion.
- Interested TAC members should review the Activity 7 draft study plan and provide comments to Ken Carlson/CH2M HILL by January 21, 2014.

CH2MHILL

*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

Technical Advisory Committee
(TAC) Meeting #4
December 17 2013

BUILDING SUSTAINABLE SOLUTIONS

## Agenda

1. Introductions
2. Purpose, Progress and Activity Review
3. Lake Response to Changes in Inflow Loading-Jake Kann
4. Williamson River Delta Work-Heather Hendrixson
5. Discussion and Identification of Prospective Sites
6. TAC for Nutrient Reduction Study (Interim Measure 11, Study 7)

BUILDING SUSTAINABLE SOLUTIONS 2

## Study Schedule: 2013-2014

| CC | Topic | Activity | Date |
|---|---|---|---|
| 1 | Initiate discussion on DWF concept | Planning with TAC | T Oct 1 |
| 2 | Establish Research Plan format | | Th Oct 24 |
| 3 | Initiate discussion regarding identification of prospective partners and roles | | M Nov 18 |
| 4 | Initiate discussion regarding identification of prospective site(s) | | T Dec 17 |
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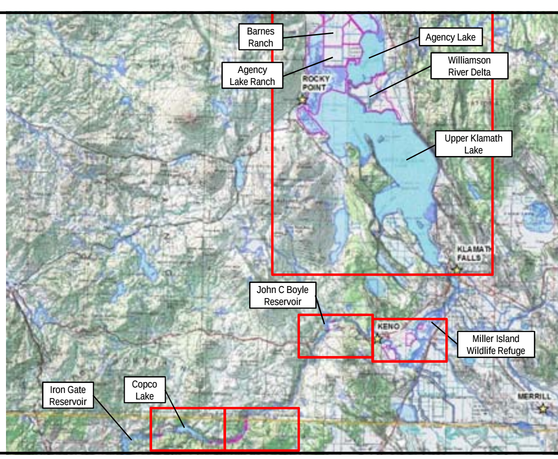
| | Submit Final Research Plan | Final by CH2MHILL | F Jul 25 |
| | Discuss/Determine next steps for DWF Implementation/Partnerships | | |

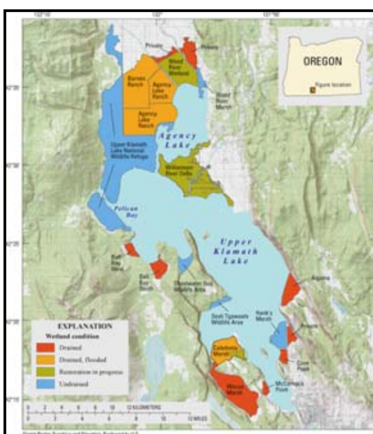
BUILDING SUSTAINABLE SOLUTIONS 3

## Conceptual Site Attributes

- Construction requirements for a fully functional site
- Type of wetland
- Potential partners
  - Research
  - Funding partners
- Permitting (NEPA, EIS, etc.)
- Groundwater input
- Ability to convey water to/from site
- Proximity to power

BUILDING SUSTAINABLE SOLUTIONS 4



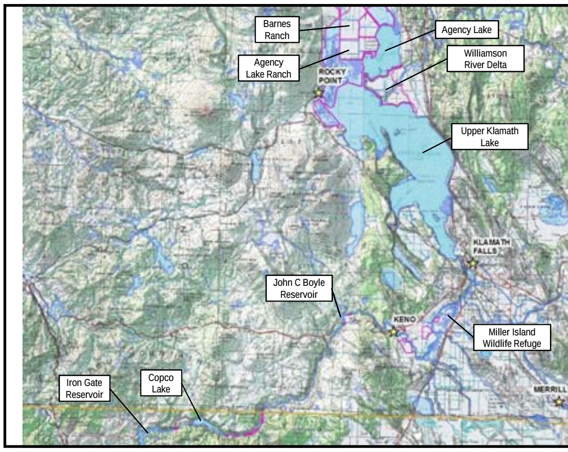

Sites near Upper Klamath Lake

**Pers.comm. Hendrickson 2013**

## Sites Discussed Previously in TAC Calls

| Site Name | Address/Location | Ownership | Area (ac) | Existing Wetland Site? Y/N |
|---|---|---|---|---|
| Barnes Ranch | Upper Klamath Lake | | | Y |
| Sevenmile Canal | Upper Klamath Lake | | | |
| BLM Wood River Wetland | Upper Klamath Lake | Bureau of Land Management | | Y |
| Agency Lake | Upper Klamath Lake | Bureau of Reclamation | | |
| Keno Canal? | Near the Link River Dam | PacifiCorp | | |
| Williamson River Delta | Upper Klamath Lake, downstream of Upper Klamath Lake | The Nature Conservancy | | Y |
| KBRT Wood River Valley Sites? | | | | |
| K&K Ranch | | | | |
| Miller Island Wildlife Refuge | East of Keno on Klamath River | State Owned | | |



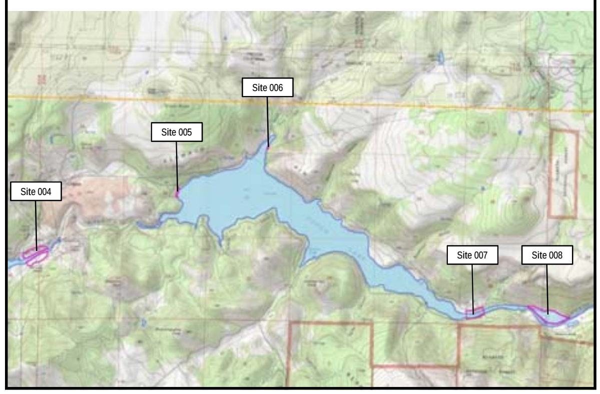



## Sites from Past Reports (CH2MHILL 2009)

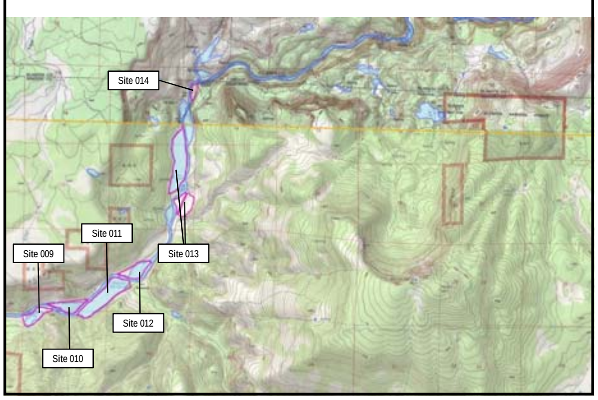
| Site Name | Address/Location | Ownership | Area (ac) | Existing Wetland Site? Y/N |
|---|---|---|---|---|
| Site 004 | Upstream end of Iron Gate Reservoir | PacifiCorp | 19.4 | N |
| Sites 005 - 007 | Along Copco Lake | | 51.1 | N |
| Sites 008 - 014 | Along Klamath River just upstream of Copco Lake | | 253.1 | N |
| Sites 015 - 017 | Along John C. Boyle Reservoir | PacifiCorp | 26 | N |
| Site 018 | Klamath River in Keno | Privately Owned | | N |
| Sites 019 - 022 | Lower Klamath National Wildlife Refuge between Keno and Klamath Falls | Privately Owned, State Owned | 1284 | N |



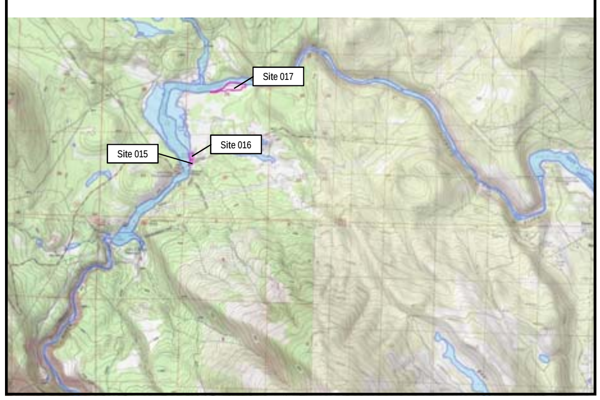
## Sites near Copco Lake




## Sites upstream of Copco Lake



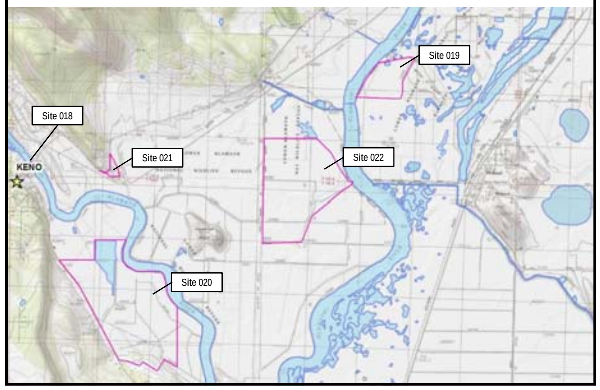

## Sites near John C. Boyle Reservoir



Mahugh et al 2008

**Figure 2. Potential pilot-scale wetland treatment locations (outlined in red) (see *Mahugh et al., 2008 for specific site details*).**

## Sites near Keno, OR




## Next Steps

1. Action Item Review
2. Comments and suggestions- please send re:
   - Prospective study sites & attributes/constraints
   - Prospective partners and modes of partnering
   - Draft outline of contents
3. Next Meeting : January 21 2014

BUILDING SUSTAINABLE SOLUTIONS 15

*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

# Technical Advisory Committee (TAC) Meeting #5

**January 21, 2014**
(Via Teleconference)

## Meeting Notes

**Attendees:**

- ☐ Andy Hamilton/BLM
- ☐ Beth Bendickson/PacifiCorp
- ☒ Bob Gearhart/HSU
- ☒ Brittany Hughes/CH2M HILL
- ☒ Chauncey Anderson/USGS
- ☒ Chris Stine/ODEQ
- ☐ Clayton Creager/NCRWQCB
- ☒ Crystal Bowman/Karuk Tribe
- ☒ Eli Asarian/Riverbend Sciences
- ☐ Heather Hendrixson/TNC
- ☒ Jake Kann/AES
- ☒ Jane Vorpagel/CDFW
- ☐ Jared Bottcher/KBRT
- ☒ Jed Redwine/SF Environments
- ☐ Jessica Asbill-Case/USBR
- ☒ Jim Bays/CH2M HILL
- ☒ John Hamilton/USFWS
- ☐ Kathleen Sloan/Yurok Tribe
- ☒ Ken Carlson/CH2M HILL
- ☐ Kris Fischer/Klamath Tribe
- ☒ Kyle Gorman/OWRD
- ☒ Kurt Carpenter/USGS
- ☒ Linda Prendergast/PacifiCorp
- ☒ Maia Singer/Stillwater Sciences
- ☒ Mary Grainey/OWRD
- ☒ Micah Gibson/Yurok Tribe
- ☒ Mike Deas/Watercourse Eng
- ☒ Nell Kolden/KBRT
- ☒ Rick Carlson/USBR
- ☒ Ted Wise/ODFW
- ☐ Tim Hemstreet/PacifiCorp

### 1. Introductions

Jim Bays/CH2M HILL opened the meeting by reviewing the agenda for the call. The call today will cover several items for the TAC to provide input on related to the research topics that should be studied, site locations, and partnerships for the Demonstration Wetland Facility (DWF). The intent of the TAC meetings is to lay out useful directions for the DWF project and provide TAC input on DWF features in advancing water quality in the Klamath Basin.

### 2. Purpose, Progress and Activity Review

Jim Bays/CH2M HILL reviewed topics of past calls including the DWF concept, research plan format, identification of prospective partners and roles, and identification of prospective sites. Today the call will focus on key topics and analysis approach. CH2M HILL will be starting the write-up of a draft of the DWF research and implementation plan, and this conference call is an opportunity for the TAC to provide new input and to review and confirm input from past conference calls. Upcoming calls are scheduled on a monthly basis.

### 3. Review and Discussion: Partnerships and Sites

Jim Bays/CH2M HILL noted that Jake Kann's presentation on the last call was very helpful. Based on the previous discussion, Jim indicated that the Wood River Wetland site owned by the Bureau of Land Management (BLM) may be a particularly good candidate location for the DWF because: (1) the watershed loadings are high and influential; (2) it’s an ongoing full-scale wetland site already; and (3) the site is accessible, has power, and includes features you’d want to build in to the DWF. However, it is not clear where exactly in the Wood River Wetland area the DWF would be located. Other sites will also be considered.

Kurt Carpenter/USGS noted that there was a pretty extensive 3-year monitoring period completed prior to changes BLM made in water level management at the Wood River wetland area. The Wood River Wetland has a strong groundwater input into both the north and south unit and the site has quite a bit of orthophosphate and ammonia.

Jake Kann/AES mentioned that the Agency Lake and Barnes Ranch areas could be another potential site for treating Sevenmile Canal if for some reason the Wood River Wetland area is not a good site.

Linda Prendergast/PacifiCorp noted that the Agency Lake and Barnes Ranch areas are moving through the NEPA process and are looking at doing passive dike breaching. Linda is under the impression that any sort of wetland facility in this area is off the table. John Hamilton/USFWS mentioned that Clayton Creager was going to talk with Matt Barry/USFWS about the status of the Agency Lake and Barnes Ranch areas. John will follow-up and provide updated information to the TAC on the next TAC conference call in February.

The Agency Lake Ranch, Barnes Ranch, and Wood River Wetland sites all have fish screens installed at their intakes. Kurt Carpenter/USGS mentioned that there are also a number of piezometers available at the sites for tracking water levels.

Jim Bays/CH2M HILL noted that DWF test cells could be built to control water/mass balance.

Bob Gearhart/HSU asked if it is of interest to have landscape similitude to be able to learn from the DWF site and apply to other similar sites. Jim Bays/CH2M HILL responded that he believes they should complement each other.

Jane Vorpagel/CDFW asked if the expectation is that partners would pay for and operate the DWF or if PacifiCorp would be running the DWF for a number of years. Linda Prendergast/PacifiCorp noted the implementation and operation of the DWF would be based on partnerships with stakeholders, potentially including PacifiCorp as long as there is still some money available under Interim Measure 11. Clayton Creager has been looking at some grants, but that is all that we know of at this time. BLM would be a partner if the DWF is on their land.

Ted Wise/ODFW mentioned that he can begin asking more questions within his agency if Miller Island is a potential DWF site that we want to seriously pursue. ODFW would need to consider how the DWF would work with its management objectives. The site itself seems to be well suited, but it is below Upper Klamath Lake (UKL). Ken Carlson/CH2M HILL noted that the further up in the watershed that the site can be located, the better. However, previous Keno area wetland studies were focused on organic matter removal, since organic matter loading to Keno from UKL can be substantial. A site at Miller Island would pose a distinct and separate issue compared to an upper basin site about how wetlands could be used to treat removal of organic matter.

Kurt Carpenter/USGS mentioned the DWF would take up soluble nutrients, but could also be used to reduce particulate matter. Algae harvesters probably remove some phosphorus. Jake Kann/AES noted that the amount of phosphorus harvesters remove is a tiny fraction. It would be more effectively accomplished in a river.

Jim Bays/CH2M HILL noted that we have been thinking about lake input control, but not outputs. Miller Island should stay on the table as a possible site, but may have different objectives than a site above UKL.

Ted Wise/ODFW mentioned he could talk conceptually to his colleagues about Miller Island as a potential site, but will need specifics to get past the conceptual level of conversation within his organization.

Jim Bays/CH2M HILL covered partnership concepts, including collaborative research between agencies, site access, land purchase, design and construction, operation, monitoring and management, and lab sample analysis. Jim asked the TAC how they might see partnerships working on the project.

Kurt Carpenter/USGS inquired about how much the DWF would cost. Jim Bays/CH2M HILL commented that construction would be a significant investment and there would need to be funding associated with operation and monitoring.

Jane Vorpagel/CADFG noted that education is key. The facility should be a good neighbor to communities by helping educate them about the benefits of wetland treatment systems.

Kurt Carpenter/USGS mentioned the TAC could consider focusing on smaller areas where nutrient storage is occurring, such as the Sevenmile Canal area.

Jim Bays/CH2M HILL noted that the concept of building/studying diffuse treatment wetlands in the basin is already planned to occur as a result of efforts by the Klamath Basin Rangeland Trust (KBRT). As such, the DWF will have the most benefit by focusing on different aspects other than the diffuse treatment wetlands.

Kyle Gorman/OWRD said he would make contact with the Oregon Watershed Enhancement Board to find out about additional funding that may be available to support the DWF.

## 4. Discussion of Key Topics

Jim Bays/CH2M HILL put together a list of key topics that could be a focus of the DWF and asked the TAC to consider if the list encompasses the wetland research goals for the DWF. The key topics include:

1. Phosphorus reduction, storage and cycling- process and parameters
2. Loading Rates- effect of hydraulic and mass loading
3. Vegetation community- structure and effects
4. Soil/Water Interactions
5. Water Balance- loss rates
6. Community Metabolism- effect on P cycling
7. Mercury Transformation- process and parameters
8. Aim to complement research by others

Eli Asarian/Riverbend Sciences noted that previous calls contained discussion around the type of wildlife habitat that could be provided by the DWF. Jim Bays/CH2M HILL responded that this has not been resolved as to how best incorporate habitat as a specific wetland feature when water quality treatment is the primary driver.

Mike Deas/Watercourse Eng mentioned that in his experience on previous wetlands design work there were entities that were concerned about endangered species inhabiting a DWF because the species presence may limit what work could be done in/with the DWF.

Jed Redwine/SF Environments described an example of operation of a treatment wetland in Florida that was found to have an initial direct negative impact on endangered species. However, over time, a net positive effect was observed.

Bob Gearhart/HSU asked how long it takes from time zero until the DWF would be operational in terms of monitoring. If planting is involved, there can be a tremendous amount of pressure from wildlife and grazers on newly planted material. Grazing impacts can be significant.

Maia Singer/Stillwater Sciences noted that while we often think about rearing and spawning habitat in rivers and lakes, it may not be beneficial to open up the DWF to juvenile suckers right away. The project could outline habitat suitability requirements and make sure testing requirements overlap with habitat suitability. Waterfowl is a concern and interest for the U.S. Fish and Wildlife Service (USFWS). The DWF could be designed to test bird use at a small scale.

Ted Wise/ODFW noted that bird life shouldn't be excluded from the DWF because implementation on a larger scale will include bird life. To address the concern regarding the introduction of ESA-listed species to the DWF, the USFWS can incorporate a caveat into the permit that gives an exemption on any impacts for the DWF project.

Jim Bays/CH2M HILL noted that such exemptions can be issued, such as a "Safe Harbor Agreement". Regulatory approvals and permits will be key items in the approval of a DWF facility, and will also be driven by DWF features and site characteristics.

Kurt Carpenter/USGS recommended the DWF examine both nitrogen and phosphorus. Realizing the focus of monitoring will be on phosphorus, there would be little additional effort required to also monitor nitrogen.

Linda Prendergast/PacifiCorp noted that water rights will be a crucial part in selection of a site.

Maia Singer/Stillwater Sciences asked if there is still an interest in looking at amendments to address phosphorus loading. Jim Bays/CH2M HILL responded that amendments to strip phosphorus from water would be studied under Activity 7. Ken Carlson/CH2M HILL confirmed that Activity 7 would be a laboratory-based study to assess use of amendments (e.g., alum) to reduce nutrients in example water samples from the area. However, Ken noted that soil amendments that might be considered for use in the DWF would need to be addressed under Activity 2.

Jim Bays/CH2M HILL noted that it would be useful to operate the system with the native soil for a period of time (2-3 years) and then amend the soil. Maia Singer/Stillwater Sciences concurred that it would be important to understand what the native soils can do on their own and also what amendments can do to enhance or benefit the system.

John Hamilton/USFWS mentioned he would talk to his colleagues regarding their opinions on the concept of amended soils or alum use and how that might impact the suckers. Jim Bays/CH2M HILL will provide additional information he has on amendments to John Hamilton and noted that mesocosms are a great place to try influent amendments while avoiding potential effects to biota.

Kyle Gorman/OWRD asked if the parameters for site selection and cost effectiveness will be part of research plan or done as a separate assessment. Jim Bays/CH2M HILL said site selection will be part of the research and implementation plan.

Kurt Carpenter/USGS mentioned a report done by Dan Snyder where soil cores were analyzed that would provide a good framework for expected soil characteristics.

Jim Bays/CH2M HILL noted that the DWF may need to have a liner to control the water balance. Mesocosm studies have shown varying lengths of time (in some cases taking more than two years) for phosphorus to bleed out.

Jane Vorpagel/CDFW asked if mercury transformation monitoring is expensive. Jim Bays/CH2M HILL noted that mercury transformation monitoring is expensive, but it is doable.

Linda Prendergast/PacifiCorp asked if mercury was seen as an issue in UKL. Chauncey Anderson/USGS said that literature indicates there is reason to be concerned about methyl mercury. Chauncey will track down more information on methyl mercury and provide it to the TAC. The way the water is managed with respect to aerobic and anaerobic processes may be critical.

Jed Redwine/SF Environments noted that the presence of methyl mercury is highly influenced by sulfur content.

Jim Bays/CH2M HILL noted that wetland treatment technology is advanced enough to help us understand these issues, and there are ways we can design a system around them.

Bob Gearhart/HSU asked what environmental process would be required to implement the plan. Jim Bays/CH2M HILL noted that the permitting timeline has not been determined yet.

Chris Stine/ODEQ noted that UKL is not 303(d)-listed for mercury, but that’s not to say that it won’t be an issue. The plan will need to consider all the parameters that apply to the methyl mercury formation issue.

Chauncey Anderson/USGS mentioned that a lot of set-up for the pilot tests can be done through soil sampling, bench scale tests and basic calculations.

Ken Carlson/CH2M HILL suggested that a lot of the issues that have been discussed could be used to build a matrix to list and then rate the relevance and importance of these issues for determining the features and components of the DWF. This sort of matrix could reveal the need to have sub-facilities (e.g., mesocosms, bench testing capability) within the larger DWF.

Jim Bays/CH2M HILL introduced his thoughts on the DWF configuration conceptual criteria which included basic features and advanced features. The basic features included multiple cells (3), 0.5-1 acres, depth of 0-5 ft, level slope, inflow of 1-10 cm/d, parallel flow with series option, local and native vegetation, access walkways, and liner. The advanced features included multiple inflow sources, multiple substrate sources, subsurface piping to simulation infiltration and groundwater upwelling, sedimentation marker strata, vegetation/open water interspersion, interpretive/public access, and more replication. Jim then asked the TAC what else should be considered.

Jane Vorpagel/CDFW asked about the inflow rate. Mike Deas/Watercourse Eng offered that 0.5 cfs is consistent flow for a 1-acre wetland. Jim Bays/CH2M HILL also mentioned that the Everglades wetland systems have 2-3 cm/d loading, which is about 2 days of residence time (depending on depth). It would be important to be able to control the grade/water level in the DWF so it could be run at 1-ft depth or 3-ft or more for submersed aquatics. This would also allow examination of the effects of water depth on vegetation.

Jed Redwine/SF Environments asked if the mesocosms and bench scale testing would be small enough that they could be applied at any site. Jim Bays/CH2M HILL responded that there is definitely a benefit to having separate mesocosms to study the effects of different parameters. There could be a small bank of mesocosms constructed at any site.

Jed Redwine/SF Environments mentioned it would be useful to study how rapidly microbial communities take up or process phosphorus or other nutrients during different temperature gradients. Jim Bays/CH2M HILL agreed that the facilities will need to be able to operate year-round to study transitional seasons.

Maia Singer/Stillwater Sciences asked if it is difficult to retrofit sites for liners if you're working within a system (like Wood River) that is an existing wetland. Jim Bays/CH2M HILL responded that a liner can be put down in an existing wetland and then have fill placed on top of it. It is also possible to berm off part of an existing wetland or to pick a site upland of a wetland and pump water from the existing wetland into DWF. Army Corp permitting might be required (or approval might be required) to put fill in a wetland area.

Kyle Gorman/OWRD asked if a 3-acre DWF is really scaleable to much larger full-size facilities. Jim Bays/CH2M HILL noted that we know from project history that pilot scale studies (1 acre or larger) are scaleable to full size facilities. Jim will send additional information to Kyle Gorman/OWRD. Jed Redwine/SF Environments noted that while there is a long history of using small scale studies and then replicating them at a large scale, small scale studies can't take into effect drought or climate effects.

## 5. TAC for Nutrient Reduction Study (Interim Measure 11, Activity 7)

Ken Carlson/CH2M HILL provided a status update on Activity 7. The purpose of Activity 7 is to complete a lab-based pilot study of influent amendments. A draft test plan was distributed to the TAC back in December. The IMIC is also reviewing the draft test plan and will be providing comments by the end of January. The initial testing plan is focused on phosphorus removal, but the complete suite of nutrients will be monitored. TAC members need to provide input on the amendments/agents that will be tested in the lab as well as the source waters to test (UKL, Keno Reservoir, etc.). It is expected that the timing of source water collection would occur when nutrient levels are at their highest.

## 6. Action Items

1. John Hamilton/USFWS will follow-up and provide information to the group on the status of the Agency Lake and Barnes Ranch areas on the February call.
2. Kyle Gorman/OWRD will make contact with the Oregon Watershed Enhancement Board to find out about additional funding that may be available.
3. Jim Bays/CH2M HILL will provide any additional information he has on amendments to John Hamilton/USFWS.
4. Chauncey Anderson/USGS will track down information on methyl mercury and provide it to the TAC.
5. Jim Bays/CH2M HILL will send additional information to Kyle Gorman/OWRD regarding the scaling of pilot studies to large scale facilities.

CH2MHILL

*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

## Technical Advisory Committee (TAC) Meeting #5
## January 21 2014

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## Agenda

1. Introductions
2. Purpose, Progress and Activity Review
3. Review and Discussion: Topics and Sites
4. Discussion of Key Topics
5. TAC for Nutrient Reduction Study (Interim Measure 11, Study 7)

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## Study Schedule: 2013-2014

| CC | Topic | Activity | Date |
|---|---|---|---|
| 1 | Initiate discussion on DWF concept | Planning with TAC | T Oct 1 |
| 2 | Establish Research Plan format | | Th Oct 24 |
| 3 | Initiate discussion regarding identification of prospective partners and roles | | M Nov 18 |
| 4 | Initiate discussion regarding identification of prospective site(s) | | T Dec 17 |
| 5 | Review key topics and analysis approach | | T Jan 21 |
| 6 | Finalize topics, sites and partners | Draft by CH2MHILL | T Feb 18 |
| 7 | Mid-point progress update on Plan | | T Mar 18 |
| 8 | Preview and submit draft Plan | | T Apr 20 |
| 9 | Receive, discuss comments on draft Plan | Review by TAC | T May 20 |
| 10 | Preview and submit final Plan | | T Jun 17 |
| | Submit Final Research Plan | Final by CH2MHILL | F Jul 25 |
| | Discuss/Determine next steps for DWF Implementation/Partnerships | | |

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## Demonstration Wetland Research Goals: Are These the Basic Questions?

- Phosphorus reduction, storage and cycling – process and parameters
- Loading rates - effect of hydraulic and mass loading
- Vegetation community – structure and effects
- Soil – water interactions
- Water balance – loss rates
- Community metabolism – effect on P cycling
- Mercury transformation - process and parameters
- *Aim to complement research by others*

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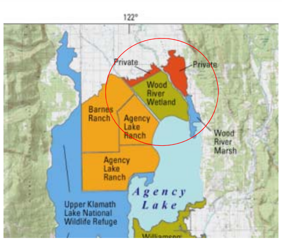
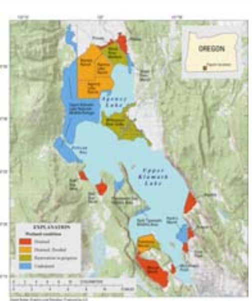
## Current Site Preference – Can the Wood River Be an Appropriate Location?



✓Watershed loadings
✓Full-scale demonstration
✓Access, power, security

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## Wetland Demonstration Facility Configuration Conceptual Criteria: What Else Should Be Considered?

**Basic Features**
- Multiple cells: 3
- Size: 0.5-1 acre
- Depth control: 0 – 5 ft
- Grade: level slope
- Inflow HLR: 1-10 cm/d
- Flow: parallel with series option
- Vegetation: local, native
- Marsh access: walkways
- Liner: Yes

**Advanced Features**
- Multiple inflow sources
- Multiple substrate sources
- Subsurface piping
  - Simulating infiltration
  - Simulating groundwater upwelling
- Sedimentation marker strata
- Vegetation/open water interspersion
- Interpretative/public access
- More replication

## Partnership Concepts: Are These All of The Opportunities?

- Collaborative Research between Agencies
  - Complementary to WRD, KBRT, other projects
- Site Access
- Land Purchase
- Design and Construction
- Operation, Monitoring and Management
- Laboratory Sample Analysis

## Next Steps

1. Action Item Review
2. Comments and suggestions- please send re:
   - Topics, sites and approaches
   - Prospective study sites & attributes/constraints
   - Prospective partners and modes of partnering
   - Draft outline of contents
3. Next Meeting : February 18 2014

*Interim Measure 11 Activity 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

# Technical Advisory Committee (TAC) Meeting #6

**February 18, 2014**
(Via Teleconference)

## <u>Meeting Notes</u>

**Attendees (checked box indicates attendance):**

| | | |
|---|---|---|
| ☐ Andy Hamilton/BLM | ☒ Jane Vorpagel/CA DFG | ☒ Linda Prendergast/PacifiCorp |
| ☐ Beth Bendickson/PacifiCorp | ☐ Jared Bottcher/KBRT | ☒ Maia Singer/Stillwater Sciences |
| ☒ Bob Gearhart/HSU | ☒ Jed Redwine/SF Environments | ☐ Mary Grainey/OWRD |
| ☒ Brittany Hughes/CH2M HILL | ☐ Jessica Asbill-Case/USBR | ☐ Micah Gibson/Yurok Tribe |
| ☒ Chauncey Anderson/USGS | ☒ Jim Bays/CH2M HILL | ☒ Mike Deas/Watercourse Eng |
| ☐ Chris Stine/ODEQ | ☒ John Hamilton/USFWS | ☒ Nell Kolden/KBRT |
| ☒ Clayton Creager/CA RWQCB | ☒ Kathleen Sloan/Yurok Tribe | ☒ Rick Carlson/USBR |
| ☒ Crystal Bowman/Karuk Tribe | ☒ Ken Carlson/CH2M HILL | ☒ Ted Wise/ODFW |
| ☐ Eli Asarian/Riverbend Sciences | ☒ Kris Fischer/Klamath Tribe | ☒ Tim Hemstreet/PacifiCorp |
| ☒ Heather Hendrixson/TNC | ☒ Kurt Carpenter/USGS | |
| ☒ Jake Kann/AES | ☒ Kyle Gorman/OWRD | |

### 1. Introductions

Jim Bays opened the meeting by reviewing the agenda for the call. The call today will review the list of key documents that have been gathered to-date (based on a previous literature review and additional documents provided by TAC members). The key documents list it is intended to reflect current or recent work. The call will also review configuration concepts. Ken Carlson will provide an update on Activity 7.

### 2. Purpose, Progress and Activity Review

Jim Bays commented that past calls have helped build familiarity with issues and with the team. An outline for the study plan has been developed and reviewed on a past call. Prospective sites, key topics, and approaches to study have been discussed. CH2M HILL is moving toward developing a final list of topics to incorporate into the study plan based on TAC input. It is important to keep a few sites in mind that are good candidates for a demonstration wetland facility (DWF). Writing of the research and implementation plan will begin soon, with a draft plan ready for review by the TAC in a few months.

### 3. Key Document Overview

Jim Bays highlighted the key reference documents and noted that a lot of work has been done and is being done in the Klamath Basin. Highlights of the key documents included the new documents that have been provided by TAC members on work completed since the literature review in *Approaches to Water Quality Treatment by Wetlands in the Upper Klamath Basin* prepared by CH2M HILL for PacifiCorp in 2012.

Much of the research in the Klamath Basin is being completed simultaneously and the DWF research and implementation plan needs to reflect recent findings. The DWF should be designed to serve a broad need for focused research across the watershed. There have been some detailed studies done at a large-scale on restored wetlands. The DWF will provide a place where variables can be controlled and specific questions can be studied in a controlled environment. Documents provided by the TAC members include:

1. *A thesis- An Assessment of Carbon, Nitrogen, and Phosphorus Storage and the Carbon Sequestration Potential in Arcata's Constructed Wetlands for Wastewater Treatment*- written by Mary Burke, provided by Bob Gearhart.
2. *Keno Reservoir Wetlands Feasibility Study, Phase III: Organic Matter Removal Using Treatment Wetland in the Upper Klamath Watershed: Pilot-Scale Treatment Wetland Pre-design Assessment*- provided by Mike Deas. This document has a good literature review and a good summary of what pilot wetlands can cover.
3. *Selected Water Quality Dynamics and Horizontal Zonation of Water Quality in Hanks Marsh, Upper Klamath Lake, Oregon*- provided by Bob Gearhart.
4. *Horizontal zonation of Periphyton in Hanks Marsh, Upper Klamath Lake, Oregon*- a Master's thesis written by Margaret Forbes and provided by Bob Gearhart.
5. Jim Bays had a conversation with Andy Hamilton and got a good summary of work that has been done and is being done in the Wood River Wetlands. Andy provided a provisional report: *BLM Wood River Wetland Studies- 2013 Summary Report.*
6. Heather Hendrixson provided two reports on the work being done in the Williamson River Delta by The Nature Conservancy: *Water Quality Conditions on the Williamson River Delta, Oregon: Four Years Post-Restoration (2011 Annual Data Report)* and *Water Quality Conditions on the Williamson River Delta, Oregon: Five Years Post-Restoration (2012 Annual Data Report).*
7. Andy Hamilton also provided an additional document *Subsidence Reversal in a Re-established Wetland in the Sacramento-San Joaquin Delta, California, USA.*
8. Mike Deas provided an additional report: *Evapotranspiration from marsh and open-water sites at Upper Klamath Lake, Oregon, 2008–2010.* This report has information that will be useful for restoration work and determining constraints.

Kurt Carpenter mentioned there had been some recent work done by Oregon State University Professor Desiree Tullos and Carla Stevens that examined phosphorus release. The 2011 paper investigated the relationships between temperature and soil characteristics of restored wetlands to identify management strategies that would minimize external phosphorus loading to Upper Klamath and Agency Lakes.

Kurt also noted that modeling of phosphorus sequestration in an Upper Klamath Basin wetland was completed by Emily Mulford in 2012. Kurt will send links to the two papers to the TAC.

Rick Carlson noted that Kann and Walker's work on nutrient budgets in Klamath Basin was not included on the list. Jake Kann will send to paper to Jim Bays. The paper includes a 20-year analysis of loading with water and nutrient balances for Upper Klamath Lake.

4. **Configuration Concepts**

Jim Bays reviewed the following research goals with the TAC:

- Phosphorus reduction, storage and cycling- process and parameters
- Loading Rates- effect of hydraulic and mass loading
- Vegetation community-structure and effects
- Soil-water Interactions
- Water Balance- loss rates
- Community metabolism- effect on P cycling
- Mercury Transformation- process and parameters

Clayton Creager noted there may be other topics to cover in addition to those described by Jim. Those topics include subsidence and the importance of soil accretion in the wetlands helping mitigate subsidence. Also, if the DWF is planned to be near the edge of the lake, its effect on water storage in the lake should be considered.

Chauncey Anderson noted that there could be some point in the development of the DWF research and implementation plan where various objectives are in competition with each other. Doing one thing to achieve a certain objective may conflict with other objectives. The research and implementation plan should weigh the importance of all objectives.

In the Interim Measure 10 Report, the issue of storage in the lake came up due to location and owner of the property. The mission of the land owner will be an important consideration when deciding the location of the DWF. The objectives may be different between a constructed wetland and management of a natural wetland.

Soil accretion and long-term phosphorus storage is critical. The DWF will need to be able to test and control variables that are associated with the catchment.

Jim Bays reviewed the following concepts with the TAC:

- Phosphorus Removal- Vegetation Type and Background Phosphorus: more and more influence of soil and water interactions as levels decrease. Background phosphorus will vary based on local soil types, stored phosphorus, vegetation retention and cycling, etc. Understanding factors that contribute to background phosphorus will be critical.
- Hydrology- Consumptive Loss and Groundwater Influence: Critical because of consumptive losses. Measure of groundwater influence.

- Accretion (Soil Rebuilding)- Vegetation type effect, hydroperiod effect: plant uptake and growth/root development, the wetland's ability to trap and settle organic solids and decaying matter over time- related to hydroperiod.

Jim Bays shared some additional thoughts and pictures of test cells. The DWF could be a bank of test cells, resembling DWFs constructed in other locations. The DWF would receive water by gravity from tank, with the water level being experimentally adjusted. Soils are brought in, elevations and plant communities are adjusted. Systems are allowed to reach equilibrium and then testing is completed. The DWF can then be used to study various questions. The DWF is a very "engineered" system. All cells are lined, preventing groundwater interaction.

For example, in Sacramento, the SRWW Demonstration Wetlands looked at metals and nitrogen reduction. Each cell was about 0.75 ac (0.3 ha) in size, lined, and hydrology was controlled.

Kurt Carpenter noted that the groundwater in the Upper Basin has high levels of ammonia and phosphate. In terms of phosphorus reduction, constructing a treatment wetland that mimics natural conditions (with groundwater seepage) may be important.

Jim Bays responded that while the test cells would be lined, local soils would need to be imported for the facility. If nutrients are coming in through groundwater, an unlined, bermed system could be a control or comparison that looks at groundwater as an active part of the hydrology.

Kurt Carpenter also noted that there are several artesian wells in upper basin (UKL and further up into watershed). The flux of groundwater through pumice layers could represent a huge phosphorus load to the Lake.

Kyle Gorman mentioned there are probably more than 100 artesian wells, but less than 1000 in the Wood River Valley and that not all of the artesian wells have high nutrient levels. Groundwater flows north to south through the valley and discharges in the wetland areas through artesian wells. In general, high nutrient groundwater discharges in the wetland areas, and not into the lake itself. Now that the wetlands are no longer pumped, it is unclear whether the nutrient load actually reaches the lake. If this is not the case and we're missing a significant input to the lake, it should show up in the nutrient budget. The research and implementation plan will need to determine whether treatment is focused around groundwater or tributary inputs into the lake.

Clayton Creager commented that removal efficiency for the different treatment systems should be examined to determine the most cost efficient way to reduce phosphorus. May also consider if there an opportunity for interception of phosphorus or ammonia flux through or under the wetlands.

Jim Bays showed a hypothetical wetland cell example where regionally dominant species are studied- cattail cell, bulrush cell, etc. - to determine removal rate for community type. The hydrology and nutrient content in the DWF can be controlled and flows and depths can be managed.

The research and implementation plan should also consider the temperature at which soils are flooded, natural soil recession, export of phosphorus from areas, and how all those items are managed. If water is brought on during a warm soil period, the microbial biomass breaks down organics resulting in a net generation of phosphorus, but the microbes are using the phosphorus when algae is trying to use it.

Jed Redwine noted he would add two elements to the research and implementation plan: temperature effects on phosphorus and a range of soil types. It will be important to consider how survivable the plants are in systems and how well they respond to changes in water depth across the growing season. May want to think about different locations for test cells to meet different goals.

Jim Bays commented that in order to test various soil types, soils could be brought in from different locations. This would allow for DWF to remain in one location, but would create the ability to test different soils from different locations.

Chauncey Anderson noted that the facilities shown in Jim's examples are in parallel. It might make sense to design the DWF such that the test cells could also be run in series.

Jim Bays commented that the installation of a subsurface piping network to simulate groundwater input into a lined system may also be considered. The intent of the DWF is to be able to control as many input/output variables as possible. A seasonal hydrograph could be used, with inflow rates being pumped into the wetland to match seasonal flows. The DWF is not something that is built for one year- this would be a long term (5-year) study plan to allow the system to reach equilibrium and then begin the study.

Another picture shown by Jim Bays presented the mesocosms set-up in Oxnard, CA using fruit bins. Mesocosms offer the opportunity for less expensive operations for studies that can be replicated at a large scale. In the Klamath Basin, the mesocosms would need to be hardened or protected from weather due to harsh weather conditions.

The study may also consider the variable volume of nutrients that the treatment wetlands will be able to process. The study could be used to determine the upper threshold on amount of nutrients that can pass through the wetlands and still get a large amount of treatment.

### 5. Sites

Jim Bays noted that the Wood River Wetlands seem to be an attractive site as they are located in the Upper Klamath Basin and a significant nutrient contributor to the lake. The wetlands have a site that's already been operating for period of time. The Agency Lake and Barnes Ranch sites have similar attractiveness.

Kurt Carpenter noted that there is a difference between soils at Agency Lake/Barnes Ranch sites versus the Wood River site which has to do with the amount of root material and microbes. The soils had a big effect on phosphorus removal.

Heather Hendrixson mentioned the Williamson River Delta has wide range of soil types due to how the river used to flow through the area.

When comparing inorganic to organic soils, inorganic soils have more capacity for absorbing phosphorus.

Maia Singer commented that a matrix may be useful in looking at the various inputs- soils, range of phosphorus, etc. Is there a limit to number of test cells and questions that we'll be able to study?

Jim Bays noted that there will be an inherent variation in how wetlands grow and work. Inputs would need to be resolved down to a small number of key site variables- soil, vegetation, etc. The nutrient load could be varied over time. With a good set of test cells, studies could vary over time to achieve useful, basin-specific answers (not just based on literature). Pilot studies are completed to learn things about basin-specific parameters.

Chauncey Anderson asked what the timeframe would be for design and construction of a DWF. Jim Bays/CH2M HILL responded that the research and implementation plan would be completed by mid-summer. Once the plan has been completed, partnerships would need to be solidified. Design wouldn't begin until late 2014 and construction could be at least a year away. The research and implementation plan will lay the groundwork for what will be studied with the DWF. The federal fiscal year and long range planning may also affect the schedule.

Kurt Carpenter noted that 2012 work completed by Andy Hamilton evaluated the storage capacity of vegetated nutrient stocks around Upper Klamath Lake. Work might have good information about how to monitor treatment wetlands over time.

TAC members should send Jim Bays any additional thoughts or other papers that are relevant to discussion on Activity 2.

6. **TAC for Nutrient Reduction Study (IM 11, Activity 7)**

Ken Carlson introduced Activity 7. An action item from the last TAC meeting was a call for comments on study plan that was sent out to the TAC in December. CH2M HILL has received 5 comment letters: USGS (Nancy Simon), RWQCB (Clayton Creager), USFWS (John Hamilton), CDFW (Jane Vorpagel), and Karuk Tribe (Crystal Bowman). A comment letter from ODEQ (Chris Stine) is expected soon.

Ken Carlson mentioned that some of the comment letters indicated that chemical treatment is not an appropriate strategy in the long term. They are in no way a substitute for use of wetlands. The intent of the bench-scale testing is to determine if there may be one more option for nutrient removal. Ken indicated that, regarding the proposed Activity 7 study, it should be clearly understood that use of agents/amendments for nutrient reduction is not a replacement or substitute for restoration of wetlands or application of other BMPs. However, use of agents/amendments is another “tool in the box”, particularly in the interim before restored wetlands and other BMPs are implemented and fully effective.

Ken Carlson mentioned that some of the comment letters indicated an impression that dosing of the whole lake is the focus; for example, an impression that study plan is moving toward dosing the whole of UKL with alum. Ken said that, in preparing this draft study plan, we by no means are recommending or endorsing any specific agent, amendment, or application.  In particular, we are not in any way recommending or otherwise moving in the direction of dosing the whole of Upper Klamath Lake with alum. This study plan is simply for a straightforward laboratory-based bench study of example agents/amendments applied to example waters from the basin. How this information is used and where the potential uses of such agents go are later steps down the line to be decided by stakeholders (including appropriate authorizing regulatory agencies).

Linda Prendergast reiterated that this study plan is for a bench test study to determine the most appropriate agents (if they are used). This is just a small step of many steps that would have to be taken before chemical agents would be considered for use. PacifiCorp is not endorsing any type of amendment nor are they endorsing dosing the entirety of Upper Klamath Lake. The goal of the study and use of an amendment is to increase the efficiency of phosphorus removal without increasing the treatment footprint.

Ken Carlson mentioned that the Karuk Tribe’s comments included concerns of high cost and unintended toxic effects when using chemical agents. This comment letter stated that these concerns would need to be addressed before widespread chemical treatment could occur. The Karuk Tribe recommended cost be included as a part of study.

Ken Carlson indicated that the proposed study plan is not making any assumptions about “widespread chemical treatment”. How and where the potential uses of agents (like alum) go are later steps down the line to be decided by various stakeholders (including appropriate authorizing regulatory agencies). If and when such agents are used in the future, costs and prevention of potential toxicity would be two of several factors that would need to be assessed and weighed to determine ultimate feasibility for a given proposed application. For this particular study, bioassay and toxicity tests are not proposed. Toxicity testing would be something that should be done in the future and would be more appropriate once a specific agent or group of agents have been identified. The bench scale study will look at residual aluminum, ionized ammonia and the information gathered could be used to inform potential toxicity issues. Ken also mentioned that information could be provided on the costs of the agents (price per unit of material) purchased for this study. This could provide a relative sense of costs for the agents when scaled-up.

Chauncey Anderson noted that the proposed bench scale tests are all water tests, no sediment is involved. Chauncey indicated that tests that include sediment should probably be included in subsequent toxicity testing.

Ken Carlson commented that alum is not toxic by its very nature, although over-dosage or misapplication can cause issues. Alum has been used for decades to treat drinking water as a clarifying amendment. Alum has been applied in many lakes across the country. The North American Lake Management Society (NALMS) has issued a position statement on use of alum. NALMS position is that alum is a safe and effective method to mitigate for phosphorus in lakes and reservoirs. Ken will provide the NALMS position statement to the TAC.

Jed Redwine noted that, if there is a group or body of people who feel that alum is safe, they should compile all the evidence and allow it to be reviewed. Maia Singer responded that, while there is no comprehensive safety review of applications, there have been many applications of alum in lakes over the past four decades. Maia indicated that textbook chapters are available that give good background on alum use and effectiveness (e.g., Ch.8, in Cooke et al. 2005. Restoration of Lakes and Reservoirs, 3rd Ed., CRC Press, FL).

Linda Prendergast will provide abstracts on the use of alum from her attendance at the recent NALMS annual conference in San Diego. She also noted that Lake Oswego in Oregon has used alum for years.

Chauncey Anderson noted that alum wouldn't be applied to the whole lake as it would be prohibitively expensive. There is also a general understanding that alum was least effective in the past in shallow lakes, so it may not make sense to use in Upper Klamath Lake.

Linda Prendergast commented that the bench scale testing would be used to determine if the use of alum is even applicable.

Ken Carlson reiterated that the use of alum is not being advocated, and recognizes there is a need to be cautious based on alum's history of use and cost. However, it is included on the list for the Activity 7 study given its relatively long history of use and effectiveness in treating phosphorus.

John Hamilton asked whether alum has been used in the Everglades. Jim Bays confirmed that alum has been investigated in Everglades Test Cells and in field mesocosms in other wetlands in that area. Low intensity chemical dosing studies were completed in mesocosms. A low rate of alum application has shown to be effective for phosphorus reduction. It has been tested as a surface soil amendment during initial flooding. The application of alum has not been implemented as a full scale solution, only studied.

Ken Carlson mentioned that some of the Karuk Tribe comment letter included recommendations on source waters locations and timing to be used for the

Activity 7 study. The Karuk Tribe indicated that it is important for the source water to be collected from places that offer the most potential benefit for full-scale implementation. This means that either the sources waters should have very high P concentrations and also be located far upstream or have a strong direct effect on Keno Reservoir. Based on these criteria, the best locations would be Seven Mile Canal, Wood River, and Link Dam. The Karuk Tribe also offered that, in Upper Klamath Lake tributaries, the best times would be spring through early summer. Below Upper Klamath Lake, the best time would be early summer through late summer. Ken Carlson indicated that these suggestions were appreciated and would be highly considered

Ken Carlson mentioned that Nancy Simon provided comments suggesting that struvite precipitation should perhaps be considered, which would involve removing phosphate by precipitation of struvite or magnesium ammonium phosphate (MAP). Nancy Simon thinks we might do a more efficient job of lowering the concentration of P in lake water by using a process in which struvite is formed in water traveling in canals that deliver P into the lake. Ken Carlson said that this recommendation offers an interesting idea that is possibly worthy of further consideration. However, CH2M HILL's experience suggests that the struvite technique would likely not be as straightforward to study and potentially implement as the other agents/amendments under consideration.

CH2M HILL also received some good suggestions on things to include in the lab analysis that would likely be adopted into the Activity 7 study plan.

TAC members should provide any additional comments they have to Ken Carlson. Ken will summarize any additional comment and our next call will discuss the decisions needed to proceed with implementing the Activity 7 study based on the comments provided.

Ken Carlson will forward the comments provided by USGS on Activity 7 to the TAC members.

## 7. Action Items

Kurt Carpenter will send links to the papers written by Desiree Tullos, Carla Stevens, and Emily Mulford to the TAC.

Jake Kann will send to paper on nutrient budgets in Klamath Basin to Jim Bays/CH2M HILL.

TAC members will send Jim Bays any additional thoughts or other papers that are relevant to discussion on Activity 2.

Ken Carlson will provide the official position statement on alum application from NALMS to the TAC.

Linda Prendergast will provide abstracts on the use alum from her attendance at a recent conference.

TAC members will provide any additional comments they have on the Activity 7 study plan to Ken Carlson.

Ken Carlson will forward the comments provided by USGS on Activity 7 to the TAC members.

CH2MHILL

*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility Adjacent to the Klamath River*

## Technical Advisory Committee (TAC) Meeting #6 February 18 2014



## Agenda

1. Introductions
2. Purpose, Progress and Activity Review
3. Discussion: Document Review
4. Discussion: Configuration Concepts
5. Discussion: Sites
6. Update: TAC for Nutrient Reduction Study (Interim Measure 11, Study 7)



## Study Schedule: 2013-2014

| CC | Topic | Activity | Date |
|---|---|---|---|
| 1 | Initiate discussion on DWF concept | Planning with TAC | T Oct 1 |
| 2 | Establish Research Plan format | | Th Oct 24 |
| 3 | Initiate discussion regarding identification of prospective partners and roles | | M Nov 18 |
| 4 | Initiate discussion regarding identification of prospective site(s) | | T Dec 17 |
| 5 | Review key topics and analysis approach | | T Jan 21 |
| 6 | Finalize topics, sites and partners | Draft by CH2MHILL | T Feb 18 |
| 7 | Mid-point progress update on Plan | | T Mar 18 |
| 8 | Preview and submit draft Plan | | T Apr 20 |
| 9 | Receive, discuss comments on draft Plan | Review by TAC | T May 20 |
| 10 | Preview and submit final Plan | | T Jun 17 |
| | Submit Final Research Plan | Final by CH2MHILL | F Jul 25 |
| | Discuss/Determine next steps for DWF Implementation/Partnerships | | |



## Key Documents

| # | Author(s) | Year | Title |
|---|---|---|---|
| 1 | Akins, G.J. | 1970 | The effects of land use and land management on the wetlands of the Upper Klamath Basin. |
| 2 | Aldous, A.R., C.B. Craft, C.J. Stevens., M.J. Barry, and L.B. Bach. | 2007 | Soil phosphorus release from a restoration wetland, Upper Klamath Lake, Oregon. Wetlands. |
| 3 | Aldous, A. | 2009 | Nitrogen and phosphorus loading to and from Sycan Marsh, Oregon |
| 4 | Boyd, M., S. Kirk, M. Wiltsey, and B. Kasper. | 2002 | Upper Klamath Lake drainage total maximum daily load (TMDL) and water quality management plan (WQMP) |
| 5 | Burke, M.C. | 2011 | An Assessment of Carbon, Nitrogen, and Phosphorus Storage and the Carbon Sequestration Potential in Arcata's Constructed Wetlands for Wastewater Treatment |
| 6 | Carlson, J.R. | 1993 | The evaluation of wetland changes around Upper Klamath Lake, Oregon, using multitemporal remote sensing techniques, in Campbell, S.G |



## Key Documents

| # | Author(s) | Year | Title |
|---|---|---|---|
| 7 | Carpenter, K.D., Snyder, D.T., Duff, J.H., Triska, F.J., Lee, K.K., Avanzino, R.J., and Sobieszczyk, S. | 2009 | Hydrologic and water-quality conditions during restoration of the Wood River Wetland, upper Klamath River basin |
| 8 | Deas, M.L. and J. Vaughn. | 2006 | Characterization of Organic Matter Fate and Transport in the Klamath River below Link Dam to Assess Treatment/Reduction Potential |
| 9 | Deas, M.L., Vaughn, J., Limanto, E., Willis, A., Bale, A., Rabe, A. | 2012 | Keno Reservoir Wetlands Feasibility Study, Phase III: Oreganic Matter Removal Using Treatment Wetland in the Upper Klamath Watershed: Pilot-Scale Treatment Wetland Pre-design Assessment |
| 10 | Forbes, M. | 1997 | Horizontal zonation of periphyton in Hanks Marsh, Upper Klamath Lake, Oregon. |



## Key Documents

| # | Author(s) | Year | Title |
|---|---|---|---|
| 11 | Forbes, M., Sartoris, J. and Sisneros, D. | 1998 | Selected Water Quality Dynamics and Horizontal Zonation of Water Quality in Hanks Marsh, Upper Klamath Lake, Oregon. Bureau of Reclamation, Technical Memorandum No. 8220-98-11. |
| 12 | Gearheart, R.A., Anderson, J.K., Forbes, M.G., Osburn, M., and Oros, D. | 1995 | Watershed strategies for improving water quality in Upper Klamath Lake, Oregon |
| 13 | Geiger, S.N. | 2001 | Reassociating wetlands with Upper Klamath Lake to improve water quality: Klamath Fish and Wildlife Management Symposium, Arcata, Calif., May 22–25, 2001. |
| 14 | Hamilton, A. | 2013 | BLM Wood River Wetland Studies- 2013 Summary Report- Provisional |
| 15 | Hayden, N., H. Hendrixson | 2012 | Water Quality Conditions on the Williamson River Delta, Oregon: Four Years Post-Restoration (2011 Annual Data Report) |

## Key Documents

| # | Author(s) | Year | Title |
|---|---|---|---|
| 16 | Hayden, N., Hendrixson, H. | 2013 | Water Quality Conditions on the Williamson River Delta, Oregon: Five Years Post-Restoration (2012 Annual Data Report) |
| 17 | Independent Multidisciplinary Science Team (IMST). | 2003 | IMST Review of the USFWS and NMFS 2001 Biological Opinions on Management of the Klamath Restoration Project and Related Reports. |
| 18 | Kadlec, R. H. and R L. Knight. | 1996 | Treatment Wetlands |
| 19 | Kuwabara, J.S., Topping, B.R., Carter, J.L., Wood, T.M.., Parchaso, F., Cameron, J.M., Asbill, J.R., Carlson, R.A., and Fend, S.V. | 2012 | Time scales of change in chemical and biological parameters after engineered levee breaches adjacent to Upper Klamath and Agency Lakes, Oregon: U.S. Geological Survey Open-File Report 2012-1057 |



## Key Documents

| # | Author(s) | Year | Title |
|---|---|---|---|
| 20 | Lyon, S., A. Horne, J. Jordahl, H. Emond, and K. Carlson. | 2009 | Preliminary Feasibility Assessment of Constructed Treatment Wetlands in the Vicinity of the Klamath Hydroelectric Project. |
| 21 | Lytle, C.M. | 2000 | Water Quality Data Review and Wetland Size Estimate for the Treatment of Wastewaters from the Klamath Straits Drain |
| 22 | Mahugh, S, M.L. Deas, R.A. Gearheart, J. Vaughn, R. Piaskowski, and A. Rabe. | 2008 | Keno Reservoir Feasibility Study, Phase II – Identification and Assessment of Potential Treatment Wetland Sites in the Upper Klamath River. |
| 23 | Mayer, T.D. | 2005 | Water-quality impacts of wetland management in the Lower Klamath National Wildlife Refuge, Oregon and California, USA |
| 24 | Miller, R., M. Fram, R. Fujii, G. Wheeler | 2008 | Subsidence Reversal in a Re-established Wetland in the Sacramento-San Joaquin Delta, California, USA |



## Key Documents

| # | Author(s) | Year | Title |
|---|---|---|---|
| 25 | North Coast Regional Water Quality Control Board. | 2010 | Final Staff Report for the Klamath River Total Maximum Daily Loads (TMDLs) and Action Plan Addressing Temperature, Dissolved Oxygen, Nutrient, and Microcystin Impairments in California, the Proposed Site Specific Dissolved Oxygen Objectives for the Klamath River in California, and the Klamath River and Lost River Implementation Plans. |
| 26 | Perdue, E.M., Lytle, C.R., Sweet, M.S., and Sweet, J.W. | 1981 | The chemical and biological impact of Klamath marsh water on the Williamson River, Oregon |
| 27 | Snyder, D.T., and Morace, J.L. | 1997 | Nitrogen and phosphorus loading from drained wetlands adjacent to Upper Klamath and Agency Lakes, Oregon |
| 28 | Stannard, D.I., Gannett, M.W., Polette, D.J., Cameron, J.M., Waibel, M.S., and Spears, J.M. | 2013 | Evapotranspiration from marsh and open-water sites at Upper Klamath Lake, Oregon, 2008–2010 |



## Key Documents

| # | Author(s) | Year | Title |
|---|---|---|---|
| 29 | Wong, S. and C. Bienz. | 2011 | Summary of Water Quality Sampling at Sycan Marsh, Oregon, 2010–2011 |
| 30 | Wong, S. and H. Hendrixson. | 2011 | Water Quality Conditions on the Williamson River Delta, Oregon: Three Years Post-Restoration. 2010 Annual Data Report. |
| 31 | Wong, S., M. Barry, N. Rudd, H. Hendrixson and C. Doehring. | 2011 | Nutrient Release from a Recently Flooded Delta Wetland: Comparison of Field Measurements to Laboratory Results. |



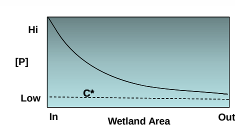
## Demonstration Wetland Research Goals: Are These the Basic Questions?

- Phosphorus reduction, storage and cycling – process and parameters
- Loading rates - effect of hydraulic and mass loading
- Vegetation community – structure and effects
- Soil – water interactions
- Water balance – loss rates
- Community metabolism – effect on P cycling
- Mercury transformation - process and parameters
- *Aim to complement research by others*



## Conceptual Demonstration Facility Preliminary Hypotheses and Factors

- Phosphorus Removal
  - Vegetation type
  - Background P
- Hydrology
  - Consumptive loss
  - Groundwater influence
- Accretion (Soil Rebuilding)
  - Vegetation type effect
  - Hydroperiod effect




## Constructed Wetland Test Cell: Examples

STA-1W North Test Cells

Sacramento Regional Wastewater Demonstration Wetlands

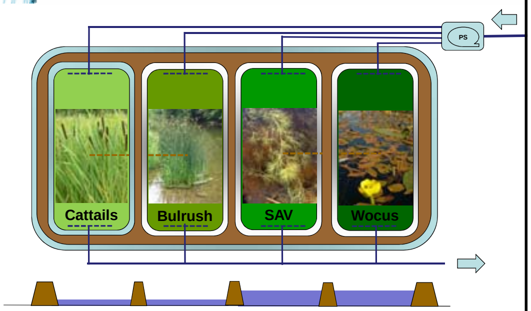


## Conceptual Demonstration Facility Basic Components

- Multiple wetland "cells" – allows side by side testing
  - 0.5 to 1.0 acre each, with liner
- Vegetation type – control for competitive interactions
  - Regionally dominant species
- Wide depth range – comparable to field gradient
  - 0 to 6 feet
- Wide hydraulic load range – for seasonal adjustment
  - 1-10 cm/d = ~7-70 gpm @ 1-ac cell
  - Total combined flow <300 gpm



## Conceptual Facility Layout






## Conceptual Demonstration Facility Preliminary Enhancements

- Groundwater interaction
  - Subsurface piping network
    - Allow drainage to simulate infiltration
    - Allow parallel inflow subsurface to simulate groundwater flux
- Seasonal hydrograph
  - Pump inflow at rates indexed to seasonal flows
- Range of P concentrations
  - Local well for high P; surface flow for lower P



## Wetland Mesocosms: Opportunities for Replicated Investigations

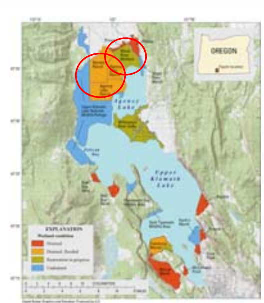
Demonstration Wetlands
Oxnard CA

Everglades Mesocosms
West Palm Beach FL



## Preliminary Sites

✓Watershed loadings
✓Full-scale demonstration
✓Access, power, security



## Partnership Concepts: Are These All of The Opportunities?

- Collaborative Research between Agencies
  - Complementary to WRD, KBRT, other projects
- Site Access
- Land Purchase
- Design and Construction
- Operation, Monitoring and Management
- Laboratory Sample Analysis



## Next Steps

1. Action Item Review
2. Comments and suggestions- please send re:
   - Comments on conceptual configuration
   - Topics, sites and approaches
   - Prospective study sites & attributes/constraints
   - Prospective partners and modes of partnering
   - Draft outline of contents
3. Next Meeting : March 18 2014

*Interim Measure 11 Activity 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

# Technical Advisory Committee (TAC) Meeting #7

**March 18, 2014**
(Via Teleconference)

# Meeting Notes

**Attendees (checked box indicates attendance):**

| | | |
|---|---|---|
| ☒ Andy Hamilton/BLM | ☒ Jane Vorpagel/CA DFG | ☐ Maia Singer/Stillwater Sciences |
| ☐ Beth Bendickson/PacifiCorp | ☐ Jared Bottcher/KBRT | ☒ Mary Grainey/OWRD |
| ☒ Bob Gearhart/HSU | ☒ Jed Redwine/SF Environments | ☐ Micah Gibson/Yurok Tribe |
| ☒ Brittany Hughes/CH2M HILL | ☐ Jessica Asbill-Case/USBR | ☐ Michael Hughes/OIT |
| ☒ Chauncey Anderson/USGS | ☒ Jim Bays/CH2M HILL | ☒ Mike Deas/Watercourse Eng |
| ☒ Chris Stine/ODEQ | ☒ John Hamilton/USFWS | ☐ Nell Kolden/KBRT |
| ☒ Clayton Creager/CA RWQCB | [\] Kathleen Sloan/Yurok Tribe | ☒ Rick Carlson/USBR |
| ☐ Crystal Bowman/Karuk Tribe | ☒ Ken Carlson/CH2M HILL | ☒ Ron Larson/USFWS |
| ☒ Dan Blake/USFWS | ☐ Kris Fischer/Klamath Tribe | ☒ Ted Wise/ODFW |
| ☐ Eli Asarian/Riverbend Sciences | ☒ Kurt Carpenter/USGS | ☐ Tim Hemstreet/PacifiCorp |
| ☒ Heather Hendrixson/TNC | ☒ Kyle Gorman/OWRD | |
| ☒ Jake Kann/AES | ☒ Linda Prendergast/PacifiCorp | |

## 1. Introductions

Jim Bays opened the meeting by reviewing the agenda for the call. The call today is the seventh in a series of calls that have been held over the last few months. Since the last call, CH2M HILL has been working on concepts and plan development for a demonstration wetland facility (DWF) in the Upper Klamath Basin. The TAC call provides an opportunity to share ideas about a DWF that can then be included in the draft research and implementation plan. An update on Activity 7 will also be provided at the end of the call.

## 2. Purpose, Progress and Activity Review

Jim Bays commented that the call will focus on two things: the process for selecting conceptual sites and the preliminary layouts and conceptual details associated with a DWF. A general map of conceptual site locations for a DWF will be presented to promote a discussion about the questions we want to research with regards to wetlands in the watershed. The call will also cover conceptual layout concepts for a DWF to gather TAC thoughts and explain our ideas that will either help confirm or identify concept revisions. Ken Carlson will provide an update on Activity 7 at the end of call.

Minutes from last month's call and additional information on use of alum treatment were provided last week via email. The TAC is welcome to bring up discussion on that topic today.

With this being our seventh call, we've been making steady progress and have converged on a series of topics on conceptual sites and ideas. CH2M HILL plans to use that information to begin writing a draft plan that will be sent out prior to the next call. The TAC will have opportunities to provide comments on the draft plan.

### 3. Discussion: Conceptual Site Locations- Screening Approach

Jim Bays noted that CH2M HILL has completed work on conceptual siting following the last TAC call. We've received useful inputs from Jake Kann, Heather Hendrixson, Andy Hamilton, and Kurt Carpenter on water quality issues and the potential for the Agency Lake Ranch, Barnes Ranch, and Wood River Wetland sites for treating inflows to Upper Klamath Lake. These sites have the potential to help address water quality issues. CH2M HILL put together a map of potential sites to review with the TAC. This is not a final list of sites, but was a way to look at attributes of a potential site, to see if it fit as a conceptual site, and to demonstrate a process on how a conceptual site can be identified. The main goal was to show the process of determining site characteristics.

Multiple inflow sources, access and power, and grade elevations were key criteria used in identifying concept sites. Grade elevations are preliminary, but were used to determine if sites may be more wetland sites, or upland sites.

Jim Bays has had several conversations since the last TAC call with Bob Gearhart, Jake Kann, Kurt Carpenter, and Andy Hamilton about concepts and sites and would be happy to talk to others who know about other sites in the local area.

The sites covered on the call today are located on Agency Lake Ranch, Barnes Ranch, and in the Wood River Wetland. The goal is to discuss the advantages and disadvantages of each site to determine what attributes are important for the siting of a DWF. The sites shown illustrate a compact site of approximately 4 acres. The sites have 8 cells, 0.5 ac in size, are lined, built with local soils, and each cell might be planted with one type of vegetation- wocus, bulrush, cattail, etc.

Rick Carlson commented that some Agency Lake Ranch sites are close to the existing intake which has a fish screen on it already. Rick will provide a mark-up of features such as fish screens and intake to Jim Bays.

Jane Vorpagel asked if there are certain sites that already have access. The Wood River Wetland site 2 is accessible from park that is to the east of site 2. Public access is limited to foot traffic. The park has a parking lot where visitors may leave their vehicles and then walk the road out to the wetland.

Dan Blake asked if anyone has spoken with the Upper Klamath Lake National Wildlife (UKLNW) Refuge about these sites. Jim noted that no discussions with landowners have taken place; however, landowners are an important constraint to consider. The goal of what is being presented today is to try to identify sites that are valuable from an ecological or water quality perspective.

Heather Hendrixson commented that she has pointed out challenges with the Agency Lake Ranch and Barnes Ranch sites on past TAC calls, so was surprised to see them on the map today. She doesn't recommend those sites as a path we should pursue due to permitting challenges. Conversations with U.S. Fish and

Wildlife Service (USFWS) are just starting. The NEPA process was initiated once the Bureau of Reclamation (BOR) stopped using those sites as pumped storage. Levee breaching options were to be considered once pumped storage ended. There are long standing partnerships at the Agency Lake Ranch and Barnes Ranch sites. A lengthy EIS process would be required for any DWF site at Agency Lake Ranch or Barnes Ranch.

Ron Larson mentioned that he had talked to Greg Austin (who is the acting UKLNW Refuge manager). Greg stressed that the refuge has specific purposes/goals such as waterfowl management that are the refuge's primary concern. The refuge would not allow something to be done on their property that might limit their ability to use the property to achieve the specific purposes for the refuge.

Jim Bays noted that all the sites shown have theoretical merit with regard to identifying what would be beneficial to understanding phosphorus removal and using wetlands for treatment. Real constraints may remove these sites from consideration, but we want to be able to say we've looked at all possible options.

Mary Grainey asked about the possibility of locating a site immediately upstream of the Agency Lake Ranch, Barnes Ranch, and Wood River Wetlands sites. Heather Hendrixson noted that there would be landowner constraints. The Klamath Basin Rangeland Trust (KBRT) has been working with a private landowner and will be installing 6 diffuse source wetlands on a property upstream on Sevenmile Creek. The Nature Conservancy (TNC) also owns acreage just north of Agency Lake Ranch that is enrolled in the NRCS Wetland Reserve Program. Due to its enrollment in the NRCS program, it will not be eligible for the development of a DWF; however, TNC will be working on restoring the property. The site was formerly known as Bengard Ranch, TNC is now calling it Fourmile Wetland. While there is an opportunity to do monitoring on the property, TNC does not currently have a specific plan for water quality monitoring of Fourmile Wetland once restoration has begun. The Tribes may do monitoring in Sevenmile Canal.

Ted Wise asked if TNC believes a 4-acre DWF is out of the question. Heather Hendrixson confirmed that due to the property's enrollment in the NRCS Wetland Reserve Program, infrastructure required for a DWF is not allowed to be built. TNC tried to accommodate a few ponds at Williamson River Delta, and NRCS wouldn't allow them to be constructed.

Mary Grainey noted that putting water on the Fourmile Wetland acreage would provide an opportunity for water quality monitoring to determine the restoration benefits.

Due to the conversation regarding challenges with siting a DWF at Agency Lake Ranch and Barnes Ranch, Jim Bays suggested that the rest of the discussion on this topic at today's meeting should focus on the Wood River conceptual locations. Brittany Hughes then introduced and described the DWF conceptual locations for the Wood River Wetlands.

Wood River Wetland Site 1 is the lowest elevation of the conceptual sites shown. It is a wetland, a sump has been created in the Site 1 location, and a drainage pump is located there that pumps water out of the wetlands into Sevenmile Canal. The site has existing power and would be accessible to the public (foot traffic). This site provides the opportunity to use both Sevenmile Canal water and Lake water; however, there is a backwater effect on the canal at times. There are also seasonal changes in water quality. Andy Hamilton mentioned that another source of water is the wetland itself. The Bureau of Land Management (BLM) is managing the site as a wetland, and treatment is occurring. Jim Bays noted that this site is a good location in terms of the variety of water sources, but there may be more construction effort due to the elevation of the site.

Chauncey Anderson noted that there is a new stream gage and turbidity gage near the Wood River. It is a very recent installation. Chauncey will send link to the new gages.

Andy Hamilton asked if it would be a challenge to construct and operate a DWF at Site 1 due to everything being so wet. Jim Bays noted that fill may need to be brought in in order for this site to be functional as a DWF.

Jane Vorpagel asked if fill would have to be brought in to build a DWF at every location. Jim Bays noted that some sites are more upland than others and may not require as much fill.

Wood River Wetland Site 2 is the closest site to the park, thus being the most accessible to the public. Underground power runs past this site and there is an existing junction box in the vicinity. This site provides the potential to pick and choose water sources using pipes, pumps, and intakes. Water sources include wetland itself, the Wood River, and the Lake.

Bob Gearhart noted that Site 2 is considerably higher than Site 1. It is less subsided, containing more river deposits.

Wood River Wetland Site 3 would provide access to Wood River and internal wetland canal water. The canal would provide range of water qualities. The site is still centrally located and has overhead power. It is near an existing pump station.

Andy Hamilton noted that Wood River Wetlands sites 3 and 4 are within probable critical habitat for the Oregon Spotted Frog. The habitat would include the entire floodplain for the Wood River, but would not affect Site 2.

Wood River Wetland Site 4 is the most upland of all the sites. Water could be used from the Wood River, the internal canals, and also an artesian well that is in the area. The well is monitored by USGS, has a high nutrient concentration, and has a valve on it that is only opened when samples are taken. The well is drilled through to the lower aquifer. The site does not currently have a power source.

Kurt Carpenter noted that USGS monitoring is just measuring flow from the well, not chemistry. There have been eight measurements of nutrients collected. Nutrient concentrations are pretty steady at 6.2 mg/L SRP and ammonia is 6 mg/L.

Andy Hamilton noted there are also piezometer wells near the artesian well where higher nutrient concentrations are found.

Jim Bays commented that the DWF could use a rich or dilute source of water for testing in the treatment wetlands.

Wood River Wetland 5- This site has overhead power available. BLM also has a good working relationship with the landowner to the North. Water sources available include Sevenmile Canal (which has inputs from the Wood River) and the water from the internal canal system in the Wood River Wetland. Andy Hamilton noted that the site wouldn't be accessible in the winter, and wouldn't be accessible to the public. It is at the location of BLM's legal point of diversion and there is a fish screen. Once water is inside the wetland, BLM can choose how it is used. If any additional points of diversion are needed, coordination with OWRD would be needed. Sevenmile Canal is fish habitat.

Andy Hamilton also mentioned that BLM completed a Resource Management Plan about 20 years ago which included an alternative in the EIS for a small treatment wetland. The permitting may then not be as challenging if the DWF is located in the Wood River Wetland.

John Hamilton noted that in order to consider Agency Lake Ranch for conceptual DWF locations, a conversation will need to occur with the Refuge and the DWF would need to meet the purpose/goals of the Refuge when planning is completed. John Hamilton will follow up with Ron Larson and Dan Blake and will then talk to Greg Austin.

Jed Redwine mentioned that almost all DWFs in Florida are located on the same lands as stormwater treatment areas where they are testing active restoration. Might have 4-10 acres for research facility. Jed will send the LILA fact sheet as an example. There are many opportunities on Wood River Wetland site, and it is rare to have a DWF inside a refuge.

Kurt Carpenter asked if it might make sense to look at properties further upstream on Sevenmile Canal or the Wood River to see if there might be some parcels worth setting up monitoring on. A lot of the canals are already functioning as wetlands. Might need to take an approach that many small wetlands might be another strategy for nutrient removal.

Heather Hendrixson mentioned that KBRT is working on 6 diffuse source treatment wetlands upstream of the Wood River Wetland. All 6 wetlands will be on one landowner's property. They will be small wetlands. If we looked at properties further upstream on Sevenmile Canal or the Wood River, most of the land is private ownership and a diffuse source treatment wetland may be more acceptable to a landowner. KBRT is involved in the Klamath Tracking and Accounting Program (TAP) which defines a consistent accounting system that links conservation actions to watershed needs by quantifying ecosystem benefits from conservation projects. The Klamath TAP's goal is to increase the pace, and reduce the cost, of improving Klamath Basin water quality to support all beneficial uses, including, but not limited to recovery of native fish. There are also other tools available for use (such as the nutrient trading tool).

Jake Kann mentioned his work on the Wood River pertains to understanding the hydrology and movement of water. The Tribes will start collecting nutrient data in more of the canals in the coming year. Sevenmile Canal nutrient concentrations increase greatly from upstream to downstream, with West Canal being a big nutrient contributor.

Clayton Creager noted that progress has been made in engineered solutions so the values of fish and vegetation are supported through design. Engineered treatment wetlands are able to minimize the area required and maximize phosphorus removal. Water quality problems seem to be impacting fisheries and possibly waterfowl. Today we've discussed things that might be real deal-breakers for some of the conceptual sites. It would be useful to have additional discussion after today on the sites that remain.

Jim Bays mentioned that even if we end up rejecting sites, or find them unsatisfactory, it is beneficial to go through this discussion process. There are a lot of different plans for restoration in the general area. These restoration projects will provide a wealth of knowledge about wetlands and their benefits. The piece that is missing is a more controlled facility. In Jim's view, the value of a controlled, engineered demonstration wetland facility stands out even more after our discussion today.

### 4. Discussion: Conceptual Configuration- Preliminary Layout and Details

Jim Bays highlighted the key factors that a DWF might be used to study based on our conversations from past TAC calls. These factors include the effects of vegetation and background phosphorus on phosphorus removal, hydrology (including consumptive loss and groundwater influence), and the effect of vegetation and hydroperiod on accretion.

Clayton Creager noted that he agreed with the key factors as Jim has presented, but would also include biodiversity, as it seems to be consistent with the mission of some of the landowners. Jim Bays responded that studying impacts on wildlife by comparing bird density, invertebrates, and other communities has been done at other DWFs.

Jim Bays mentioned that timing is another thing we'll want to consider. Seasonal changes in water quality may be important to track in order to understand how wetland treatment cells work under different treatment conditions and are able to respond to changes in flow and pulses in nutrient load.

Being able to parse out each different variable to determine its effects on the system is important. Groundwater can be a source of nutrients through upwelling and a loss of water. Trying to engineer that into a treatment system would be useful to be able to control different variables in order to develop an understanding of its impacts.

Multiple cells side-by-side would make for a compact facility and allows for the testing of key variables.

Cold climate considerations also need to be taken into consideration. The DWF needs to be accessible or be able to survive the winter. Jim shared two examples with the TAC- one in New York and one in Nova Scotia- that were designed to be under snow for more than 3 months out of the year.

Brittany Hughes presented an overview of the conceptual layout and cross-sections of one of the DWFs and the different components including pumps, inlet piping and flow meters, access roads and platforms, sedimentation forebay, sump, outlet, and water level control structure with a meter. Eight test cells would allow for testing of different variables. At this location, two years would likely be required for the system to establish. Capturing flows throughout the year is important because of changes in forms and concentration of phosphorus; for example, spring flow of particulate matter provides a high phosphorus load. By lining the cells and measuring inflow and outflow with meters, the water balance can be characterized.

Jim Bays highlighted the potential hydrologic inputs and outputs that could be quantified in the DWF which include precipitation, evaporation, berm runoff, flow in and out, infiltration and upwelling. Jim showed a summary of results from a CH2M HILL project where a demonstration wetland analysis was completed to establish the wetland water balance.

A subsurface piping network could be built in the DWF to study infiltration or upwelling of water through the treatment bed, simulating groundwater inputs and outputs.

Kurt Carpenter mentioned that he thinks subsurface piping is good idea and asked if we would need to know the rate of groundwater upwelling occurring at the site or if it has been studied elsewhere. There are hydrologists that might be taking measurements in the area. Kurt Carpenter will talk with Jim Bays offline about additional testing.

Jim noted that the forebay can be designed to study accretion rates, transition and storage of phosphorus, and subsequent recycling over the course of the year. Sampling water at the inlet, middle, and outlet of the test cell would provide data for calibrating models. Boardwalks allow access to the interior. One could also drain the test cells to allow for sampling before filling back up again.

Being able to get back to a baseline is the best way to look at soil accretion over time.

It is also useful to repeat these measures outside of the test cell to understand how representative the test cells are of a natural system.

Mesocosms could also be used- inside or outside- but would need to be made to withstand winter conditions.

CH2M HILL will start drafting the elements of the research and implementation plan. TAC members should send any additional comments to Jim.

### 5. TAC for Nutrient Reduction Study (IM 11, Activity 7)

Linda Prendergast mentioned that the comment responses to the draft study plan for Activity 7 were emailed out to the TAC last week. TAC members should contact Ken or Linda by email or phone with any questions.

### 6. Action Items

- Rick Carlson will provide a mark-up of location of features such as fish screens and intakes to Jim.
- Chauncey Anderson will send link to the new gages near Wood River.
- John Hamilton will follow up with Ron Larson and Dan Blake and will then talk to Greg Austin about the Agency Lake Ranch sites.

- Jed Redwine will send the LILA fact sheet as an example to the TAC.
- Kurt Carpenter will talk with Jim Bays about additional testing of groundwater upwelling.

CH2MHILL

*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

Technical Advisory Committee
(TAC) Meeting #7
March 18 2014

BUILDING SUSTAINABLE SOLUTIONS

## Agenda

1. Introductions
2. Purpose, Progress and Activity Review
3. Discussion: Conceptual Site Locations – Screening Approach
4. Discussion: Conceptual Configuration – Preliminary Layout and Details
5. Update: TAC for Nutrient Reduction Study (Interim Measure 11, Study 7)

BUILDING SUSTAINABLE SOLUTIONS 2

## Study Schedule: 2013-2014

| CC | Topic | Activity | Date |
|---|---|---|---|
| 1 | Initiate discussion on DWF concept | Planning with TAC | T Oct 1 |
| 2 | Establish Research Plan format | | Th Oct 24 |
| 3 | Initiate discussion regarding identification of prospective partners and roles | | M Nov 18 |
| 4 | Initiate discussion regarding identification of prospective site(s) | | T Dec 17 |
| 5 | Review key topics and analysis approach | | T Jan 21 |
| 6 | Finalize topics, sites and partners | Draft by CH2MHILL | T Feb 18 |
| 7 | Mid-point progress update on Plan | | T Mar 18 |
| 8 | Preview and submit draft Plan | | T Apr 20 |
| 9 | Receive, discuss comments on draft Plan | Review by TAC | T May 20 |
| 10 | Preview and submit final Plan | | T Jun 17 |
| | Submit Final Research Plan | Final by CH2MHILL | F Jul 25 |
| | Discuss/Determine next steps for DWF Implementation/Partnerships | | |

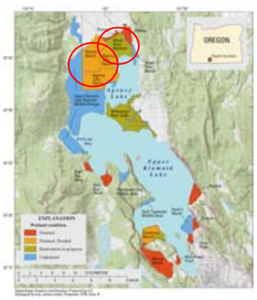
BUILDING SUSTAINABLE SOLUTIONS 3

## Conceptual Siting: Wood River Wetlands, Agency Lake/Barnes Ranch

✓Purpose:
- ✓Initial screening
- ✓Demonstrate process
- ✓Identify concerns

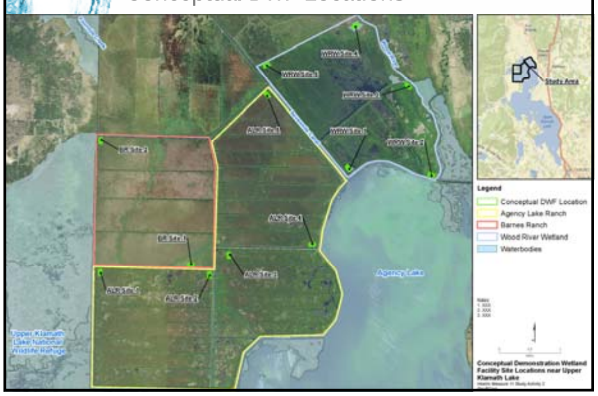
✓Key Criteria:
- ✓Multiple inflow sources
- ✓Access and power
- ✓Grade elevations

✓Local Experts Consulted



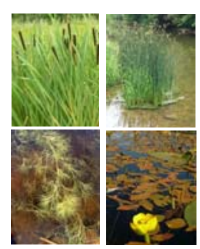
BUILDING SUSTAINABLE SOLUTIONS 4

## Conceptual DWF Locations



## Conceptual Demonstration Facility Configuration: Key Factors

- Phosphorus Removal
  - Effects of vegetation type
  - Background P
- Hydrology
  - Consumptive loss
  - Groundwater influence
- Accretion (Soil Rebuilding)
  - Vegetation
  - Hydroperiod effect



BUILDING SUSTAINABLE SOLUTIONS 6

## Constructed Wetland Test Cell: Multiple Simultaneous Comparisons

STA-1W North Test Cells

Sacramento Regional Wastewater Demonstration Wetlands



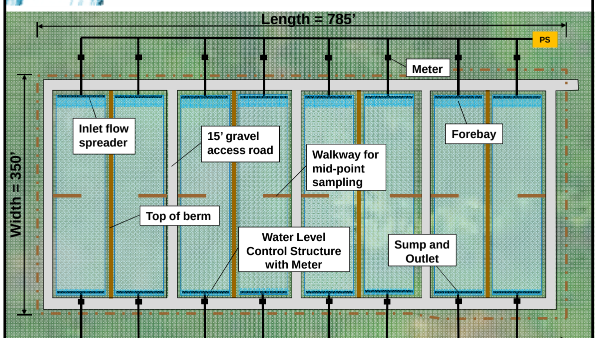
## Constructed Wetland Test Cell: Cold Climate, Technology Demonstrators

Onondaga County, NY

Nova Scotia

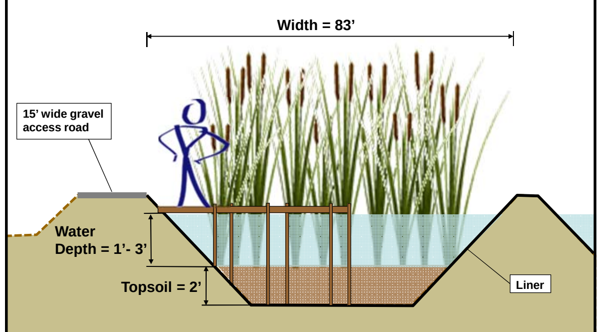


## Conceptual Facility Layout- (8) 0.5 ac Test Cells



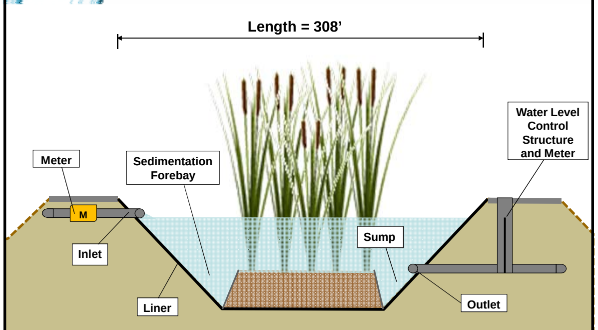



## Cross-Section View of Conceptual Layout



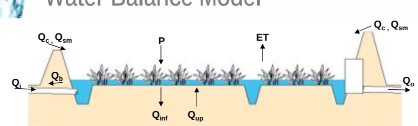



## Profile View of Conceptual Layout






## Hydrologic Interactions Estimated by Water Balance Model




**Dynamic Water Balance**

$$\frac{dV}{dt} = Q_i - Q_o + Q_c - Q_b - Q_{gw} + Q_{sm} + PA - ETA$$

Where:

V=water storage in wetland, m$^3$
T=time, d
✓ $Q_i$=input water flow rate, m$^3$/d
✓ $Q_o$=output wastewater flow rate, m$^3$/d
$Q_c$=catchment runoff rate, m$^3$/d
$Q_b$=bank loss rate, m$^3$/d
✓ $Q_{gw}$=infiltration to groundwater, m$^3$/d
✓ $Q_{sm}$=snowmelt rate, m$^3$/d
✓ **P**= precipitation rate, m/d
✓ **ET**=evapotranspiration rate, m/d
**A**=wetland surface area, m$^2$

**Periodic Water Balance**

$$\Delta V_{stored} = V_i - V_o + V_c - V_b - V_{gw} + V_{sm} + V_r - V_e$$

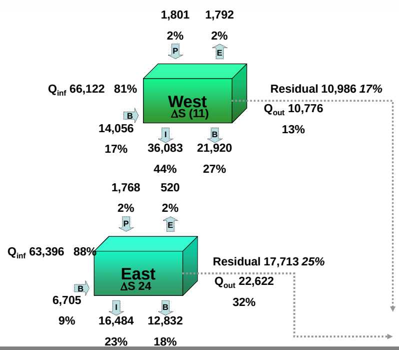
Where:

$\Delta V_{stored}$=change in water storage in wetland, m3
$V_i$=input wastewater volume, m$^3$
$V_o$=output wastewater volume, m$^3$
$V_c$=catchment runoff volume, m$^3$
$V_b$=bank loss volume, m$^3$
$V_{gw}$=volume of infiltration to groundwater, m$^3$
$V_{sm}$=snowmelt volume, m$^3$
$V_r$= rain volume, m$^3$
$V_e$=evaporated volume, m$^3$

IWA, 2000

## Example: Demonstration Wetland Analysis Establishes Wetland Water Balance

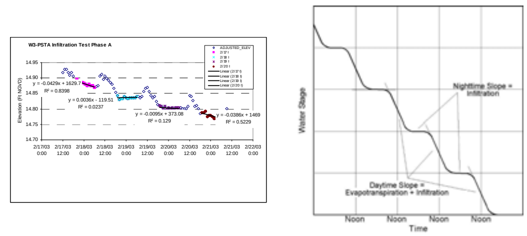
P Precipitation
E Evapotranspiration
I Infiltration
B Berm loss
R Residual
$Q_{inf}$ = inflow
$O_{out}$ = outflow
S Storage


CH2MHILL 2003



## Continuous Water Balance Estimates Daily Storage and Evapotranspiration



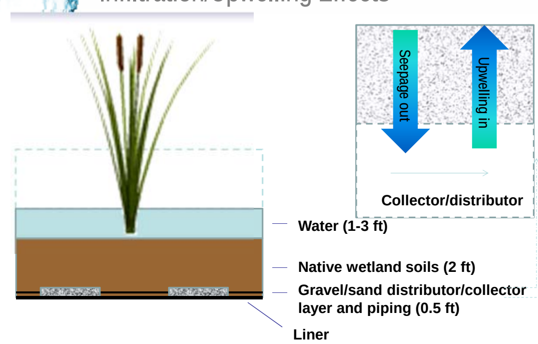



## Conceptual Demonstration Facility Preliminary Enhancements

- Groundwater interaction
  - Subsurface piping network
    - Allow drainage to simulate infiltration
    - Allow parallel inflow subsurface to simulate groundwater flux
- Seasonal hydrograph
  - Pump inflow at rates indexed to seasonal flows
- Range of P concentrations
  - Local well for high P; surface flow for lower P



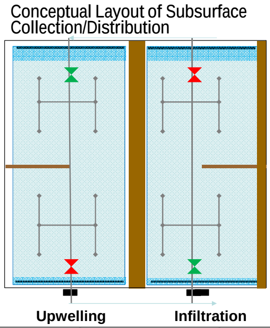
## Conceptual Approach to Estimating Infiltration/Upwelling Effects



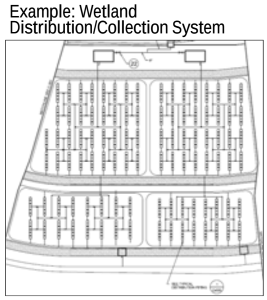



## Conceptual Configuration Test Cell Infiltration/Upwelling Analysis

Conceptual Layout of Subsurface Collection/Distribution




Example: Wetland Distribution/Collection System

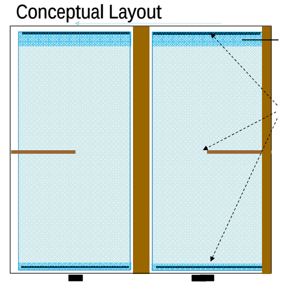


CH2MHILL 2013



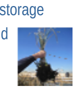
## Conceptual Configuration Supports Research Focus Activities

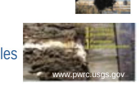
Conceptual Layout




Areas of Focus

- Forebay
  - Sedimentation rates/ Seasonal P deposition/ transformation
- P profile – in, mid, out
- Vegetation cover and biomass
  - Seasonal and long-term P storage
  - Controlled water depths and boardwalks for access
- Soil Accretion
  - Feldspar horizon
  - Soil elevation tables
  - P storage





## Wetland Mesocosms – Factoring Climate into Planning Considerations

Outdoor Mesocosms

Greenhouse: Year-Round Study

BUILDING SUSTAINABLE SOLUTIONS 19

## Next Steps

1. Draft Plan Preparation
2. Comments and suggestions- please send re:
   - Comments on conceptual configuration
   - Topics, sites and approaches
   - Prospective study sites & attributes/constraints
   - Prospective partners and modes of partnering
   - Draft outline of contents
3. Next Meeting : April 22 2014

BUILDING SUSTAINABLE SOLUTIONS 20

*Interim Measure 11 Activity 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

# Technical Advisory Committee (TAC) Meeting #8

**April 22, 2014**
(Via Teleconference)

# <u>Meeting Notes</u>

**Attendees (checked box indicates attendance):**

| | | |
|---|---|---|
| [x] Andy Hamilton/BLM | [x] Jake Kann/AES | [x] Maia Singer/Stillwater Sciences |
| [ ] Beth Bendickson/PacifiCorp | [x] Jane Vorpagel/CA DFG | [x] Mary Grainey/OWRD |
| [x] Bob Gearhart/HSU | [ ] Jared Bottcher/KBRT | [x] Micah Gibson/Yurok Tribe |
| [x] Brittany Hughes/CH2M HILL | [x] Jed Redwine/SF Environments | [ ] Michael Hughes/OIT |
| [ ] Chauncey Anderson/USGS | [ ] Jessica Asbill-Case/USBR | [x] Mike Deas/Watercourse Eng |
| [x] Chelsea Aquino/BLM | [x] Jim Bays/CH2M HILL | [x] Nell Kolden/KBRT |
| [x] Chris Stine/ODEQ | [x] John Hamilton/USFWS | [ ] Rick Carlson/USBR |
| [ ] Clayton Creager/CA RWQCB | [\] Kathleen Sloan/Yurok Tribe | [ ] Ron Larson/USFWS |
| [ ] Crystal Bowman/Karuk Tribe | [x] Ken Carlson/CH2M HILL | [x] Tara Jane Campbell Miranda/USBR |
| [ ] Dan Blake/USFWS | [ ] Kris Fischer/Klamath Tribe | [x] Ted Wise/ODFW |
| [ ] Eli Asarian/Riverbend Sciences | [x] Kurt Carpenter/USGS | [x] Tim Hemstreet/PacifiCorp |
| [x] Elizabeth Vasquez/USBR | [x] Kyle Gorman/OWRD | |
| [x] Heather Hendrixson/TNC | [ ] Linda Prendergast/PacifiCorp | |

## 1. Introductions

Jim Bays opened the meeting by reviewing the agenda for the call. The call today is the eighth in a series of calls that have been held over the last 7 months. Since the last call, CH2M HILL has prepared a draft Research and Implementation Plan (Plan) for the demonstration wetland facility (DWF). The draft Plan will not be discussed in detail on the call today. An outline of what is included in the Plan will be reviewed. The overall schedule and research objectives input matrix will also be reviewed. Activity 7 will then be discussed at the end of the call.

## 2. Purpose, Progress and Activity Review

The TAC has invested a lot of time over the past 7 months to talk and think through a variety of wetland facility ideas. Per the schedule, an overview of the draft Plan will be presented today. The intent of this overview is to give the TAC an idea about what has been included in the Plan and following the call the TAC members should take time to review and comment on the Plan. The draft Plan is a compilation of the ideas discussed over the past 7 months on the planning and components of the facility. CH2M HILL fully expects to receive a lot of comments from the TAC that will help to further shape the Plan.

On the next call (originally scheduled for May 20$^{th}$, but we will probably reschedule to coincide with an in-person meeting), we plan to discuss the comments received in detail to think and talk through any issues. Consideration is being given to holding an in-person meeting in early June with as many people as can be available face-to-face in Klamath Falls. The intent is to get close to a final Plan by June, with a final Plan in July.

### 3. Discussion: Research Objectives Input Matrix

Tim Hemstreet and Linda Prendergast met with stakeholders in Klamath Falls on April 3, 2014. There was a general discussion in the Klamath Falls meeting about the need to assess the correspondence between the draft Plan for the DWF and the driving interests and needs of those on the TAC. The matrix that was sent out to the TAC in the Meeting 8 Materials email was a result of this conversation.

The matrix condenses key technical issues into topics that include nutrient removal and retention, hydrology and water balance, soils and accretion, biodiversity, and others. Many attributes of the DWF lend themselves to the different needs and interests of the TAC members. PacifiCorp wants to understand the level of interest in each of the topics listed in the matrix. TAC members should fill out the research objectives input matrix and send it to Brittany for compilation.

Jim Bays noted that the DWF is meant to be a controlled environment where research can be completed.

Bob Gearhart asked what drove the need for the matrix. Tim Hemstreet noted that some of the feedback received at the April 3 Klamath Falls meeting was that the DWF didn't fit the mission of their agency or isn't consistent with management objectives for land that the agency has available. PacifiCorp wants the DWF to be useful and to align with agency's objectives and goals. The DWF needs to be designed such that it is eligible for support from partnerships with other agencies, so the matrix is being used to identify attributes that will make it more attractive to partnering agencies.

Jane Vorpagel commented that even though she works for the California Department of Fish and Wildlife (CDFW), she put a low priority on the potential wildlife attribute due to the relatively small (4-acre) proposed size of the DWF. Tim Hemstreet noted that there are DWF attributes that may or may not be important to the agency, but PacifiCorp wants to figure out how to make the DWF more relevant. The TAC is requested to provide any input on how the DWF can be designed to make it attractive for different funding sources.

Jed Redwine noted that the OIT proposals put together by Michael Hughes were most closely aligned with what is being proposed for the DWF.

Ken Carlson mentioned the DWF topic was also brought up at the IMIC Meeting last week. Ken mentioned that Clayton Creager had noted that the IM10 Report contained a concept for a DWF based on a variety of closed and open wetland cells.

### 4. Discussion: Draft Plan Review

Jim Bays started off the discussion about the draft Plan by noting that the Plan focuses on the Wood River Wetlands. The Wood River Wetlands are a long term restoration area known by many of the TAC members. By working through the siting process within the Wood River Wetlands, a model can be developed about how a DWF can be located in a restored area. This includes a process for selecting sites based on identifying constraints and concerns about specific locations. Although the draft Plan examines potential sites within the Wood River Wetlands, the draft Plan still contains enough detail around desirable site characteristics that could be used to identify other potential sites throughout the watershed. These characteristics include multiple water sources with different nutrient concentrations, a wide range of elevations and plant communities, accessibility, etc. In general, all sites will have some desirable characteristics as well as potential constraints.

The draft Plan outlines a description of a multiple cell facility (8 cells) which allows for replicates of 4 different types of plant communities and 2 sets of depths (shallow and deep). It is a pumped system from an existing water source with inflow and outflow metered to understand the water balance. Included in the draft Plan are plan and section views of the DWF that provide a sense of scale and operability.

Section 1 of the draft Plan contains background information, a conceptual site description, the organization of the Plan, and the TAC composition. The relationship of the DWF project to the KHSA is described and an overview of a DWF is provided.

Section 2 of the draft Plan contains a concise literature review. It discusses the phosphorus removal process, design factors affecting wetland performance, similar wetland treatment projects, and work being done in the Klamath River Basin. By summarizing the key findings on work in the Klamath Basin, the report provides context for how the results from a DWF can be reviewed and compared against other work.

Section 3 of the draft Plan covers the key hypotheses identified for study at the DWF as well as research and design factors. The DWF system is meant to be built to provide the researcher with experimental control over loading rates and other factors.

Section 4 of the draft Plan describes the proposed DWF layout and features, and includes conceptual plan and section views of the facility. It also discusses the proposed approach to DWF construction and operations. An estimated cost for DWF construction and operations has not yet been developed at this time. Conceptual site locations within the Wood River Wetland and their constraints are discussed.

Section 5 of the draft Plan details the potential for research and experimental design of the DWF. With different cells side-by-side, one can compare the difference in performance of different treatments and evaluate influential factors in wetland performance. The draft Plan is not meant to provide only a description of the facility. The document should be used to guide the operator as to the features required to be built into a facility that make it useful. The DWF is designed to be versatile. The draft Plan will not capture everything, but the facility should be designed such that other hypotheses not listed can also be studied.

Tim Hemstreet noted that some of the conceptual diagrams of the DWF from the draft Plan were shared with stakeholders at the April 3 Klamath Falls meeting.

Initial feedback received was that different DWF configurations may be used to evaluate effectiveness of passive restoration. The DWF could contain cells to evaluate passive-type restoration. The TAC should provide feedback if they have ideas about how the DWF can meet more passive approaches.

Sections 6 through 8 of the draft Plan include sample collection and data analysis, reporting, as well as an Appendix (that was not sent out to the TAC) on parameters.

Jane Vorpagel mentioned that she is interested in the QA/QC appendix which has not yet been included. Jim Bays noted that it will be provide out to TAC for review and comment before it is finalized.

Kurt Carpenter asked if the intent is to construct the DWF in the multiple locations shown on at the Wood River Wetland, or if it would just be one site. Jim Bays noted that one location would be chosen that gives us the most versatility for the site.

Bob Gearhart commented that he saw a poster presentation of a study on wocus plantings while meeting at OIT last week. The presentation discussed the difficulty in moving and growing wocus. Jim Bays noted that he's experienced challenges with growing some types of wetland vegetation in the past and that we want to learn from local experience. This may result in choosing a different vegetation type, however we do want to capture a range of depths for a system. There are diffuse treatment concepts being planned in the watershed. These are critical because they can be implemented at a range of scales. However, the missing piece is a facility like this that provides a benchmark on phosphorus performance that can be dialed in under controlled conditions.

John Hamilton asked how long it would be before you could get some meaningful data following start-up of the DWF. Jim Bays commented that maturation of cells is important to track, so data immediately following start-up is meaningful. It may take up to 2 summers before vegetation is grown in, but the phosphorus removal process can be studied during the establishment period for vegetation.

Jed Redwine noted that in his experience in the Everglades, they could re-vegetate 2,000 ac in about 1.5 months. Vegetation management focused on how to keep the vegetation in check (i.e. preventing woody vegetation from taking over).

Bob Gearhart noted that planting density will make a difference too. Consider planting the facility in the late fall to get a jump start on growth of the system.

Heather Hendrixson noted that in farmed/flooded areas, the Nature Conservancy (TNC) started with dock and other pioneer species, which then succeeded to other emergent species.

Kurt Carpenter recommended talking with Andy Hamilton about the planting of Wood River Wetland.

Jed Redwine asked what the expected duration was for the DWF. Jim Bays responded that his vision for the facility is that it be something that could run for decades with refurbishment from time to time.

Jed Redwine noted that he agreed with the long-term vision of the site and using it for multiple decades. This provides the opportunity to maximize learning. Jed's comments on the draft Plan will be focused on maximizing the DWF structure such that it can be used for many years.

The TAC will provide comments on the draft Plan to Brittany and Jim over the next few weeks.

Jim Bays commented that our upcoming call was originally scheduled for May 20th. There has been some discussion about having an in-person meeting in Klamath Falls after TAC members have had a chance to review the draft Plan. The meeting would be used to discuss comments on the draft Plan and visit the potential sites. Tim Hemstreet noted that he received comments from several attendees at the April 3 Klamath Falls meeting about how productive it was to be able to meet face-to-face. The meeting would need to be a combination of meeting/teleconference and visits to potential DWF sites over a couple of days.

Jane Vorpagel noted she has a conflict on that date with a water rights meeting and Kurt Carpenter noted that there is a joint aquatics meeting in Portland that week (May 18-23). Jim Bays noted that the week with Memorial Day Weekend should also be considered when scheduling the in-person meeting.

CH2M HILL will propose a meeting time and place to determine the availability of TAC attendees. Current thinking is that the meeting would be in the first week of June.

**5. Discussion: Partnerships**

Jim Bays noted that it is important to think ahead to partnerships. Partners will be needed to help fund, construct, and operate the DWF. Tim and Linda participated in the initial April 3 Klamath Falls meeting. There is a need to clarify the DWF nexus with the missions and objectives of potential partnering organizations. The draft Plan will be revised with suggestions made by the TAC on how to better align the Plan with the missions or objectives of potential partnering agencies.

**6. TAC for Nutrient Reduction Study (IM 11, Activity 7)**

Ken Carlson provided an update to the TAC on Activity 7. A review draft of the "Initial Testing Approach and Procedures" plan (Testing Plan) was issued in December to the TAC for a laboratory bench-scale study to assess the effects of treating water using chemical agent applications to reduce nutrient concentrations through flocculation, binding, or sequestration.

The Testing Plan was subsequently revised based on the TAC discussions and comment letters that were provided. The revised Testing Plan was sent out to the TAC by Tim Hemstreet on April 22, 2014. Comments consisted of concerns and recommendations on agents to be tested (or not) and recommendations on source waters and timing of sample collection. Major concerns had to do with chemical treatment not being feasible at a large scale and the toxicity of the chemical agents being studied.

Ken noted that this is the very first step of the study process- a laboratory-based study. With regards to concerns raised about toxicity, that topic is not the focus of this particular study. There will be data collected to evaluate whether there are changes in potentially toxic substances, such as dissolved aluminum. Concerns were also raised about cost. The use of chemical agents on a large scale could certainly be expensive; however, it's not yet been determined how these agents might be used (if at all).

The revised Testing Plan lists four chemical agents that will be tested: Lanthanum-modified bentonite clay (Phoslock™), aluminum-modified zeolite (Z2G1 or Aqual P™), polyaluminum hydroxychloride (PaCl), and alum (aluminum sulfate buffered with sodium aluminate). Ken acknowledged the concern of some TAC members with potential alum use. However, Ken said that, even if not favored for potential use in this case, alum has long history of use elsewhere and serves as a sort of baseline for evaluating the effectiveness of other agents in comparison to alum.

The three water sources proposed for testing include the Wood River, Upper Klamath Lake near Link River, and Keno Reservoir near Miller Island. These locations offer relatively high nutrient profiles, a spatial mix of locations, and represent areas with the possibility for a future in-field application.

Collection of source waters would be completed in the late spring or early summer to hit the peak nutrient profile. Samples would then be transported to the applied sciences lab in Corvallis for bench testing. Methodology for how tests will be conducted are outlined in the plan. Testing would be completed in June/July with a report to be issued in early fall.

The revised Testing Plan (which was sent out to the TAC by Tim Hemstreet on April 22, 2014) is considered final, but if there are major concerns by TAC, please provide comments.

Kurt Carpenter noted that given the amount of groundwater in the Klamath Basin, PacifiCorp may want to consider a groundwater source. Ken Carlson mentioned that the source water could easily be changed from the Wood River to a different source.

Jake Kann would recommend collection of Sevenmile Canal water, however the ability to test both (Sevenmile Canal and Wood River) would be best. Sevenmile Canal has high particulate matter. The Wood River has a higher nutrient load, but lower nutrient concentration. Jake Kann will look up Sevenmile Canal and Wood River nutrient concentrations and provide to Ken Carlson and the group.

Kurt Carpenter commented that having information about how to deal with the exceedingly high nutrient concentrations in the groundwater may be helpful.

Jake Kann noted that Sevenmile Canal first flush events show large amounts of total phosphorus being flushed from fields. Sevemile Canal is more indicative of return flow. The mean concentration is 133 ppb on Sevenmile Canal and 103 ppb on the Wood River. The Wood River has a high nutrient loading rate at its mouth. Selection of the source waters could incorporate a water with a natural high level background of phosphorus (Wood River), water with influence from return flows (Sevenmile Canal), and lake water (from Upper Klamath Lake or Keno Reservoir).

Ken Carlson commented that more thought will be given to the source water selection and Ken will then circle back with the TAC.

## 7. Action Items

TAC members should fill out the research objectives input matrix and send it to Brittany for compilation.

The TAC will provide comments on the draft Plan to Brittany and Jim over the next few weeks.

CH2M HILL will propose a time and place for a face-to-face meeting in Klamath Falls to determine level availability of attendees.

Jake Kann will look up Sevenmile Canal and Wood River nutrient concentrations and provide to Ken Carlson and the group.

Ken Carlson will give more thought to the source water selection and will then circle back with the TAC.

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*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility Adjacent to the Klamath River*

## Technical Advisory Committee (TAC) Meeting #8
## April 22, 2014

BUILDING SUSTAINABLE SOLUTIONS

## Agenda

1. Introductions
2. Purpose, Progress and Activity Review
3. Discussion: Research Objectives Input Matrix
4. Discussion: Draft Report Review
5. Discussion: Partnerships
6. Update: TAC for Nutrient Reduction Study (Interim Measure 11, Study 7)

BUILDING SUSTAINABLE SOLUTIONS 2

## Study Schedule: 2013-2014

| CC | Topic | Activity | Date |
|---|---|---|---|
| 1 | Initiate discussion on DWF concept | Planning with TAC | T Oct 1 |
| 2 | Establish Research Plan format | | Th Oct 24 |
| 3 | Initiate discussion regarding identification of prospective partners and roles | | M Nov 18 |
| 4 | Initiate discussion regarding identification of prospective site(s) | | T Dec 17 |
| 5 | Review key topics and analysis approach | | T Jan 21 |
| 6 | Finalize topics, sites and partners | Draft by CH2MHILL | T Feb 18 |
| 7 | Mid-point progress update on Plan | | T Mar 18 |
| 8 | Preview and submit draft Plan | | T Apr 22 |
| 9 | Receive, discuss comments on draft Plan | Review by TAC | T May 20 |
| 10 | Preview and submit final Plan | | T Jun 17 |
| | Submit Final Research Plan | Final by CH2MHILL | F Jul 25 |
| | Discuss/Determine next steps for DWF Implementation/Partnerships | | |

BUILDING SUSTAINABLE SOLUTIONS 3

## DWF Key Investigative Topics: Current Basis for Draft Study Plan

- Nutrient Removal & Retention
  - Effects of Vegetation Type
  - Site Factors Effects
- Hydrology & Water Balance
  - Consumptive loss
  - Groundwater influence
- Soils & Accretion (Soil Rebuilding)
- Biodiversity
  - Habitat quality and use
- Others
  - E.g., pre-treatment techniques

BUILDING SUSTAINABLE SOLUTIONS 4

## More Factors Can Affect DWF Project Value : DWF Attributes Matrix

| Pilot Wetland Attribute |
|---|
| Assessing/Monitoring Passive Wetland Performance |
| Assessment of Pre-Treatment Benefits |
| Diffuse Source Treatment Wetlands Assessment |
| Engineered Wetlands Assessment |
| Facility Siting on Private Land |
| Facility Siting on Public Land |
| Groundwater Interaction |
| Habitat Benefits / Biodiversity |
| Nutrient Removal Capability (as Opposed to Research/Study) |
| On-Farm Suitability |
| Passive Restoration |
| Rate of Soil Rebuilding |
| Scalability |
| Scientific Research |
| Water Consumption/Consumptive Loss |

- Need to assess correspondence between DWF attributes and agency/organization missions
- Need TAC input:
  - Determine if list is complete
  - Weight by High, Moderate, and Low ratings?
  - Look for concurrence on areas of greatest value

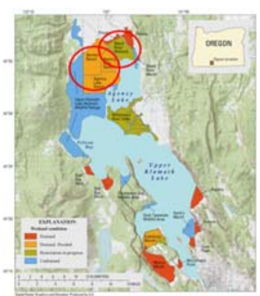
BUILDING SUSTAINABLE SOLUTIONS 5

## Conceptual Siting: Wood River Wetlands

✓Purpose:
- ✓Initial screening
- ✓Demonstrate process
- ✓Identify concerns

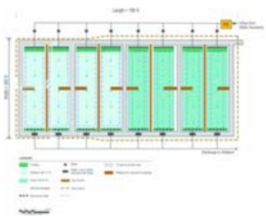
✓Key Criteria:
- ✓Multiple inflow sources
- ✓Access and power
- ✓Grade elevations

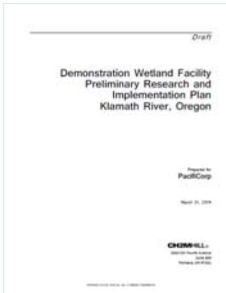
✓Local Experts Consulted




BUILDING SUSTAINABLE SOLUTIONS 6

## Preliminary Draft Research and Implementation Plan: Need TAC Comment




Draft

Demonstration Wetland Facility
Preliminary Research and
Implementation Plan
Klamath River, Oregon

Prepared for
PacifiCorp

CH2MHILL



## Overview of Preliminary Research and Implementation Plan

- Section 1 - Introduction
  - Background
    - "…to investigate site-specific requirements, effectiveness, feasibility and costs of wetlands technologies…improve water quality in the Upper Klamath Basin…"
  - Conceptual Site Description
  - Research Plan Organization
  - TAC Composition and Role



## Overview of Preliminary Research and Implementation Plan

- Section 2 – Relevant Research and Technical Review
  - Treatment Wetlands P Removal Process
  - Design Factors Affecting Wetland Performance
  - Similar Wetland Treatment Projects (9 selected)
  - Klamath River Basin Research (9 selected)
    - Hydrology
    - Chemistry
    - Vegetation/Wildlife



## Overview of Preliminary Research and Implementation Plan

Section 3 – Klamath River Wetland Research and Design Issues

- Key Factors
  - Regionally specific design criteria
  - Groundwater interactions
  - Vegetation type effects
  - Community composition and wildlife
- Experimental Design
  - Hydraulic Loading
  - Water Depth
  - Inlet Concentration
- Key Hypotheses
  - Nutrient Removal and Retention
  - Water Balance Effects
  - Vegetation Effects
  - Soil Accretion Rates
  - Biodiversity
- Other Potential Topics



## Overview of Preliminary Research and Implementation Plan

- Section 4 – Demonstration Wetland Facility Description
  - Facility Size and Configuration
  - Construction
  - Operation
  - Cost
  - Conceptual Site Locations



## Overview of Preliminary Research and Implementation Plan

- Section 5 – Experimental Design
  - Paired Comparisons
  - Strengths
  - Limitations
  - Identification of Treatment Effects
  - Evaluation of Causative Factors

## Overview of Preliminary Research and Implementation Plan

- Section 6 – Sample Collection and Data Analysis
- Section 7 – Project Reports
- Section 8 – References
- Appendices
  - A. Monitoring Parameters Sampling Plans



## Prospective Partnering

- Need to identify partners to help fund, construct, and operate DWF
- Initial meeting held on April 3, 2014 in Klamath Falls
- Need to clarify DWF nexus with missions and objectives of potential partnering organizations
  - Additional polling and information gathering from TAC
  - DWF revisions possible to better align with partner preferences



## Next Steps

1. Review and Provide Comments on Draft Research and Implementation Plan
2. Next Scheduled Conference Call: May 20th, 2014
   - Consider In-Person Meeting

*Interim Measure 11 Activity 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

# Technical Advisory Committee (TAC) Meeting #9

**June 17, 2014**
(Via Teleconference)

# <u>Meeting Notes</u>

**Attendees (checked box indicates attendance):**

| | | |
|---|---|---|
| ☐ Andy Hamilton/BLM | ☐ Jake Kann/AES | ☒ Linda Prendergast/PacifiCorp |
| ☐ Beth Bendickson/PacifiCorp | ☒ Jane Vorpagel/CA DFG | ☐ Maia Singer/Stillwater Sciences |
| ☒ Bob Gearhart/HSU | ☐ Jared Bottcher/KBRT | ☒ Mary Grainey/OWRD |
| ☒ Brittany Hughes/CH2M HILL | ☒ Jed Redwine/SF Environments | ☐ Micah Gibson/Yurok Tribe |
| ☐ Chauncey Anderson/USGS | ☐ Jessica Asbill-Case/USBR | ☐ Michael Hughes/OIT |
| ☒ Chelsea Aquino/BLM | ☒ Jim Bays/CH2M HILL | ☒ Mike Deas/Watercourse Eng |
| ☒ Chris Stine/ODEQ | ☒ John Hamilton/USFWS | ☒ Nell Kolden/KBRT |
| ☒ Clayton Creager/CA RWQCB | ☒ Kathleen Sloan/Yurok Tribe | ☒ Rick Carlson/USBR |
| ☐ Crystal Bowman/Karuk Tribe | ☒ Ken Carlson/CH2M HILL | ☐ Ron Larson/USFWS |
| ☐ Dan Blake/USFWS | ☒ Kris Fischer/Klamath Tribe | ☒ Susan Corum/Karuk Tribe |
| ☐ Eli Asarian/Riverbend Sciences | ☐ Kurt Carpenter/USGS | ☐ Ted Wise/ODFW |
| ☒ Heather Hendrixson/TNC | ☒ Kyle Gorman/OWRD | ☐ Tim Hemstreet/PacifiCorp |

## 1. Introductions

Jim Bays opened the meeting by reviewing the agenda for the call. The in-person meeting originally scheduled for May will be rescheduled. Also, CH2M HILL has received several responses on the matrix of attributes, those results will be reviewed on the call and used to further develop the draft Research and Implementation Plan (Plan). We will also go through a high-level summary of the comments received on the plan thus far. The goal is to continue to push forward with revisions to the Plan, focusing revisions such that the Plan is applicable and/or useful to a greater audience.

## 2. Purpose, Progress and Activity Review

Jim Bays reviewed the study schedule. The final Plan will be submitted by the end of August. Responses to comments will be provided and will be folded into next version of the Plan.

## 3. Discussion: Re-planning of the Site Meeting

Brittany Hughes has set-up Doodle Poll for 3 periods in July. TAC Members should respond to know who can attend the in-person meeting. The general format of the meeting will be the same as previously planned- a short meeting and then site visit to Wood River Wetlands on first day. The second day will include a teleconference call with TAC as a whole. TAC members must respond to the Doodle Poll by end of week.

## 4. Discussion: Matrix of Facility Attributes – Results Summary

CH2M HILL received 12 responses on the matrix of attributes where those who responded assigned scores relative to the general importance of the draft Plan attributes. The matrix was a good way to look at general trends, as some attributes are viewed by the TAC as having greater importance than others. CH2M HILL took the results of the matrix responses and looked for general areas of agreement. The Plan will focus on agreement areas supported by most of TAC to make it most useful.

To summarize the results, everyone agreed the key attribute of the project is to demonstrate nutrient removal & retention. There was a general grouping of rankings of the importance of the other topics, with a lot of interest in engineered systems, scaling, vegetation, and loading rate effects. Lower importance was placed on the Plan being used to study wetlands for biodiversity and habitat and soil rebuilding.

Clayton Creager commented that within the choices of the survey, he ranked the choices relative to one another. He noted that there is an urgency to address the effects water quality pollutants are having across the entire region, so the idea of a smaller footprint for a facility may enable the facility to be built more quickly. He thought it was more important to focus on the water quality aspects than biodiversity, even though water quality benefits will affect wildlife. He noted that there is also a need to understand challenges with meeting landowner and/or stakeholder needs.

Bob Gearhart noted there may not be much applicability of the type of information you would receive at such a small scale facility with regards to biodiversity.

Jane Vorpagel commented that wildlife ranked low in her assessment due to the size of wetlands. Also, if amendments are considered for research, may not want wildlife as a part of the facility.

Jim Bays noted that based on the matrix rankings, 3 "top" tiers were identified to help focus the plan.

Tier 1 included nutrient removal and retention, assessment of more designed/ engineered systems, and the ability to scale up. We generally see economy of scale- there is a lower unit cost for bigger facilities.

Tier 2 topics included vegetation type and loading rates and how they affect nutrient removal and retention, site factors affect background nutrient concentrations, assess diffuse source treatment wetlands, determine O&M requirements and costs, and incorporate scientific research opportunities. Comments also have been provided that the Plan needs to be cognizant of system variability.

Tier 3 topics included groundwater upwelling and losses affect nutrient removal and retention, hydrology and water balance, vegetative cover and loading rate affect water loss, assess passively restored systems, assess pre-treatment techniques to enhance nutrient removal and retention, assess on-farm suitability. The updated Plan may include half of the wetland cells as unlined to mimic the existing system and to build a comparison between and engineered and passively restored system.

With regards to lower tier items, though they are not unimportant, they wouldn't be the sole focus of a specific test/pilot.

Clayton Creager commented that he is getting much closer to acquiring funding for diffuse source treatment pilot wetlands, and may have funding for up to 6 separate pilots. He's had discussions with Klamath Basin Rangeland Trust (KBRT) to get help in identifying landowners where these pilots could be completed. Clayton wants to coordinate as the pilots move forward to see if there are hypotheses identified in the Plan that can be tested in the diffuse source pilots.

Jim Bays noted that there is a linkage in monitoring. The facility shown in the Plan is more controlled, but can be operated to mimic a diffuse source system. The Plan can be modified to describe in more detail how it could be used in a diffuse source system. Track seasonality of flow in a diffuse system. Show in the plan more detail on how match can be made.

Clayton Creager commented that the final discretionary funding plan is authorized after a legislature vote. He has requested $200,000 of funding. There may also be matching funding available. Clayton sees linkages between hypotheses outlined in the plan and the pilot systems he will be working on. Engineered systems are more expensive and require more permitting timing, such that discretionary spending wouldn't be able to fund due to the need of immediacy of implementation of projects.

Nell Kolden noted that KBRT's approach is to do smaller projects and intensely monitor them to see what works and what doesn't work. While KBRT is completely supportive of a larger demonstration facility, they do not have the capacity to do something larger-scale. KBRT wants to share all the data they collect with partners to learn and improve upon their approaches.

Clayton commented that he took ideas from the Plan on hypotheses that he plans to include into the diffuse wetland system pilots.

Jim Bays will follow up with Clayton Creager and Nell Kolden to coordinate their upcoming pilot project with the information in the draft Plan. It is critical to be sure the Plan is in agreement with other parties to ensure collection of data is consistent so data/results from various studies are comparable. The Plan should be a platform for incorporating research in developing plans for restoration.

Chris Stine noted that some of the attributes that ranked as lower tier items could be addressed incidentally through research that addressed higher tier items. Focusing on the top tier items will not preclude work on lower ranked topics.

## 5. Discussion: Draft Plan Comments

CH2M HILL received specific review comments from a number of TAC members who've reviewed the draft Plan. Comment format ranged from comments provided on a separate page to detailed mark-ups of Plan. Jim Bays summarized the topics that were repeated in several comments for discussion on the call today. These included:

- Groundwater effects (lined vs unlined cells): An adjustment will be made to the Plan to account for various interests.
- Generality of application (e.g. diffuse vs. point, private vs public, passive vs engineered): As researched-focused as this site could be, the Plan needs to be more general to cover many different applications. The Plan needs to explain how the results can be more generally applied to a more regional or on-farm facility.
- Scale-up of results and costs (e.g. subdivide cells; liners): Eli Asarian had a good suggestion on subdividing cells.
- Natural vegetation community vs. monoculture
- Focus on phosphorus removal processes vs wildlife issues
- Factor in load seasonality and inter-annual effects: There are key seasonal processes. Most wetlands will receive flow related to early spring/summer inputs. Performance from one year in DWF cell may affect subsequent years. This is something that needs to be tracked and understood.
- Role of PacifiCorp: PacifiCorp is helping to organize thinking and put together the Plan. What evolves over the future is up to anyone who wants to take the Plan and use it as a basis for creating a study facility.

Jed Redwine worked with Eli Asarian and Jake Kann to put together comments on the Plan to represent input from the Tribes. Jed will forward those comments on plan.

Kyle Gorman and Mary Grainey will be coordinating to provide response to plan this week.

Jim Bays noted that an in-person meeting in July will be used to flesh out some of these comments in more detail. The matrix has provided a structure with which to respond. After the July meeting, CH2M HILL will move forward with revisions to the draft Plan and will provide a "final" Plan for last review/comments in late July, with completion of the Plan in August.

## 6. TAC for Nutrient Reduction Study (IM 11, Activity 7)

Ken Carlson provided an update to the TAC on Activity 7. Samples will be taken in early July for the bench-scale test. A change was made in the study to select Sevenmile Canal instead of Wood River as a sample point. CH2M HILL is working out the logistics with PacifiCorp. If anyone has questions or additional thoughts, send them to Brittany Hughes or Ken Carlson.

## 7. Action Items

TAC Members to respond to the Doodle Poll by end of week regarding availability for the in-person meeting.

Jim Bays will follow up with Clayton Creager and Nell Kolden to coordinate their upcoming pilot project with the information in the draft Plan.

Jed Redwine/Susam Corum and Mary Grainey/Kyle Gorman to provide comments on the draft Plan.

CH2MHILL

*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

## Technical Advisory Committee (TAC) Meeting #9
## June 17 2014



## Agenda

1. Introductions
2. Purpose, Progress and Activity Review
3. Discussion: Re-planning the Site Meeting
4. Discussion: Matrix of Facility Attributes – Results Summary
5. Discussion: Draft Plan Comments
6. Update: TAC for Nutrient Reduction Study (Interim Measure 11, Study 7)



## Study Schedule: 2013-2014

| CC | Topic | Activity | Date |
|---|---|---|---|
| 1 | Initiate discussion on DWF concept | Planning with TAC | T Oct 1 |
| 2 | Establish Research Plan format | | Th Oct 24 |
| 3 | Initiate discussion regarding identification of prospective partners and roles | | M Nov 18 |
| 4 | Initiate discussion regarding identification of prospective site(s) | | T Dec 17 |
| 5 | Review key topics and analysis approach | | T Jan 21 |
| 6 | Finalize topics, sites and partners | Draft by CH2MHILL | T Feb 18 |
| 7 | Mid-point progress update on Plan | | T Mar 18 |
| 8 | Preview and submit draft Plan | | T Apr 20 |
| ~~9~~ | ~~Receive, discuss comments on draft Plan – on-site meeting~~ | Review by TAC | ~~W Jun 3~~ |
| 9 | Receive, discuss comments on draft Plan | | T Jun 17 |
| 10 | Receive, discuss comments on draft Plan – on-site meeting | | Jul 14-15 |
| 11 | Preview and submit final Plan | | T Jul 22 |
| | Submit Final Research Plan | Final by CH2MHILL | F Aug 29 |



## Discussion: Matrix of Preferred Attributes of a Demonstration Wetland Facility

| **Pilot Wetland Attribute** |
|---|
| Assessing/Monitoring Passive Wetland Performance |
| Assessment of Pre-Treatment Benefits |
| Diffuse Source Treatment Wetlands Assessment |
| Engineered Wetlands Assessment |
| Facility Siting on Private Land |
| Facility Siting on Public Land |
| Groundwater Interaction |
| Habitat Benefits / Biodiversity |
| Nutrient Removal Capability (as Opposed to Research/Study) |
| On-Farm Suitability |
| Passive Restoration |
| Rate of Soil Rebuilding |
| Scalability |
| Scientific Research |
| Water Consumption/Consumptive Loss |



## Matrix Response Overview

- Assign score of 1, 2 and 3 to L, M and H response
- Sum scores for each topic
- Scale to 100 (where 100 is highest priority)



## Distribution of Matrix Responses

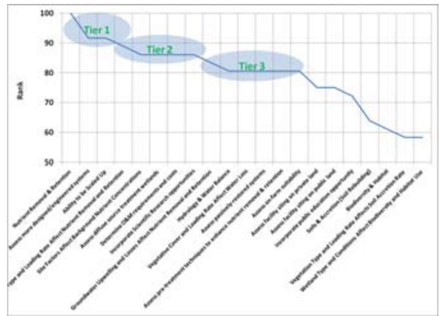
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Key Topics Priority | | | | | | | | | | | | |
| Nutrient Removal & Retention | H | H | H | H | H | H | H | H | H | H | H | H |
| Hydrology & Water Balance | H | M | L | H | M | H | H | L | M | H | H | H |
| Soils & Accretion (Soil Rebuilding) | M | H | L | H | L | M | M | H | M | M | L | L |
| Biodiversity & Habitat | L | M | L | L | H | M | H | L | L | H | M | M |
| Hypotheses to be Evaluated | | | | | | | | | | | | |
| Site Factors Affect Background Nutrient Concentrations | H | H | M | H | L | H | H | H | M | H | M | H |
| Vegetation Type and Loading Rate Affect Nutrient Removal and Retention | H | H | M | H | M | H | H | M | H | H | M | H |
| Vegetative Cover and Loading Rate Affect Water Loss | H | H | L | H | M | H | H | L | M | H | M | H |
| Groundwater Upwelling and Losses Affect Nutrient Removal and Retention | H | H | H | H | M | H | H | L | M | H | L | H |
| Vegetation Type and Loading Rate Affects Soil Accretion Rate | M | H | L | H | L | M | M | L | M | M | L | L |
| Wetland Type and Conditions Affect Biodiversity and Habitat Use | L | M | L | L | H | M | H | L | L | H | L | M |
| DWF Features & Operations | | | | | | | | | | | | |
| Assess passively-restored systems | H | H | H | H | L | H | H | H | M | M | M | L |
| Assess more designed/engineered systems | H | L | H | H | H | H | M | H | H | H | H | H |
| Assess pre-treatment techniques to enhance nutrient removal & retention | M | H | L | H | M | H | H | H | L | H | H | M |
| Assess diffuse source treatment wetlands | H | H | H | H | L | H | H | H | H | M | M | M |
| Determine O&M requirements and costs | H | H | M | L | H | H | M | M | H | H | H | H |
| Ability to be Scaled Up | H | M | H | M | H | H | H | H | H | H | M | H |
| Assess facility siting on private land | H | H | L | M | H | M | M | L | H | H | M | M |
| Assess facility siting on public land | H | H | L | H | L | M | M | M | H | H | M | M |
| Assess on-farm suitability | H | H | M | H | H | M | H | L | M | M | H | M |
| Incorporate public education opportunity | L | H | M | M | M | H | M | M | L | H | M | H |
| Incorporate Scientific Research opportunities | H | M | H | H | L | H | M | H | H | H | M | H |

## Matrix Results, Ranked

| Key Topics Priority | Ranks |
|---|---|
| Nutrient Removal & Retention | 100 |
| Assess more designed/engineered systems | 92 |
| Ability to be Scaled Up | 92 |
| Vegetation Type and Loading Rate Affect Nutrient Removal and Retention | 89 |
| Site Factors Affect Background Nutrient Concentrations | 86 |
| Assess diffuse source treatment wetlands | 86 |
| Determine O&M requirements and costs | 86 |
| Incorporate Scientific Research opportunities | 86 |
| Groundwater Upwelling and Losses Affect Nutrient Removal and Retention | 83 |
| Hydrology & Water Balance | 81 |
| Vegetative Cover and Loading Rate Affect Water Loss | 81 |
| Assess passively-restored systems | 81 |
| Assess pre-treatment techniques to enhance nutrient removal & retention | 81 |
| Assess on-farm suitability | 81 |
| Assess facility siting on private land | 75 |
| Assess facility siting on public land | 75 |
| Incorporate public education opportunity | 72 |
| Soils & Accretion (Soil Rebuilding) | 64 |
| Biodiversity & Habitat | 61 |
| Vegetation Type and Loading Rate Affects Soil Accretion Rate | 58 |
| Wetland Type and Conditions Affect Biodiversity and Habitat Use | 58 |



## Ranked Priorities Suggest Topic Groupings by Priority






## Tier 1 Topics (Rank Score 91-100)

- Nutrient Removal & Retention
- Assess more designed/engineered systems
- Ability to be scaled up



## Tier 2 Topics (Rank Score 86-90)

- Vegetation Type and Loading Rate Affect Nutrient Removal and Retention
- Site Factors Affect Background Nutrient Concentrations
- Assess diffuse source treatment wetlands
- Determine O&M requirements and costs
- Incorporate Scientific Research opportunities



## Tier 3 Topics (Rank Score 81-85)

- Groundwater Upwelling and Losses Affect Nutrient Removal and Retention
- Hydrology & Water Balance
- Vegetative Cover and Loading Rate Affect Water Loss
- Assess passively-restored systems
- Assess pre-treatment techniques to enhance nutrient removal & retention
- Assess on-farm suitability



## Lower Tier (Rank Score 58-80)

- Assess facility siting on private land
- Assess facility siting on public land
- Incorporate public education opportunity
- Soils & Accretion (Soil Rebuilding)
- Biodiversity & Habitat
- Vegetation Type and Loading Rate Affects Soil Accretion Rate
- Wetland Type and Conditions Affect Biodiversity and Habitat Use

## Discussion: Technical Comments

- Detailed comments received from five reviewers.
- Several topics were repeated in multiple comments:
  - Groundwater effects (lined vs. unlined cells).
  - Generality of application: e.g., diffuse vs point, private vs. public, passive vs. engineered
  - Scale-up of results and costs (e.g., subdivide cells; liners)
  - Natural vegetation community vs. monoculture
  - Focus on P removal processes vs. wildlife issues.
  - Factor in load seasonality and inter-annual effects
  - Role of Pacificorp

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## Discussion: Technical Comments

- Please share your comments with group, by email, or phone
- Looking for final comments back by Friday June 20.

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## Next Steps

1. Submit Comments on Plan by June 20
2. Revise Plan based on
   1. Matrix results
   2. TAC comments
3. Site Meeting - TBD
4. Next Meeting: July 22 (as currently scheduled – subject to change)

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*Interim Measure 11 Activity 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

# Technical Advisory Committee (TAC) Meeting #10

**July 2, 2014**
(In-person and via Teleconference)

# Meeting Notes

**Attendees (checked box indicates attendance):**

- ☐ Andy Hamilton/BLM
- ☐ Beth Bendickson/PacifiCorp
- ☒ Bob Gearhart/HSU
- ☒ Brittany Hughes/CH2M HILL
- ☒ Chauncey Anderson/USGS
- ☒ Chelsea Aquino/BLM
- ☒ Chris Stine/ODEQ
- ☒ Clayton Creager/CA RWQCB
- ☐ Crystal Bowman/Karuk Tribe
- ☐ Dan Blake/USFWS
- ☐ Eli Asarian/Riverbend Sciences
- ☒ Heather Hendrixson/TNC
- ☒ Jake Kann/AES
- ☒ Jane Vorpagel/CA DFG
- ☐ Jared Bottcher/KBRT
- ☐ Jed Redwine/SF Environments
- ☐ Jessica Asbill-Case/USBR
- ☒ Jim Bays/CH2M HILL
- ☒ John Hamilton/USFWS
- ☐ Kathleen Sloan/Yurok Tribe
- ☒ Ken Carlson/CH2M HILL
- ☐ Kris Fischer/Klamath Tribe
- ☒ Kurt Carpenter/USGS
- ☒ Kyle Gorman/OWRD
- ☒ Linda Prendergast/PacifiCorp
- ☒ Maia Singer/Stillwater Sciences
- ☒ Mary Grainey/OWRD
- ☐ Micah Gibson/Yurok Tribe
- ☒ Michael Hughes/OIT
- ☐ Mike Deas/Watercourse Eng
- ☐ Nell Kolden/KBRT
- ☐ Rick Carlson/USBR
- ☒ Rob Ronniger/BLM
- ☐ Ron Larson/USFWS
- ☒ Susan Corum/Karuk Tribe
- ☒ Ted Wise/ODFW
- ☒ Tim Hemstreet/PacifiCorp

## 1. Introductions

Jim Bays opened the meeting by reviewing the agenda for the call. Some TAC members were able to participate at the meeting in-person in Klamath Falls and attended a site visit to the Wood River Wetlands yesterday. Plan to discuss the results of the site visit on the call today as well as capture any additional comments on the study plan. Call today will discuss attributes and features of the sites.

## 2. Purpose, Progress and Activity Review

This is the tenth TAC meeting. On the call today, the TAC will discuss the site visit. There are some thoughts about which sites are better than others after visiting the sites yesterday. CH2M HILL is still taking inputs from the site meeting and TAC calls and will revise the draft plan toward the end of the month. Any additional comments need to be received by July 11. Some TAC members have provided comments on the plan. TAC members are welcome to share any additional comments throughout the call today.

## 3. Discussion: Site Visit July 1, 2014

The preliminary criteria for site selection included attributes such as multiple water sources, previous disturbance, and berm access. TAC members that attended the in-person meeting in Klamath Falls were able to visit all five sites at the Wood River Wetland. The following discussion incudes observations made during the site visit yesterday:

- **Site 1:** This site is located in the southwest corner of the Wood River Wetlands near Sevenmile Canal. There are existing wetlands at the site with dense vegetation. The site has multiple water sources available including Sevenmile canal, the wetland, and Agency Lake. It is not identified as Oregon Spotted Frog critical habitat. There is an existing berm at the site. The site has power, is accessible, and has diverse, mixed emergent and deep water species. The footprint of the concept site is about equal to the bermed wetland area. The demonstration wetland facility (DWF) cell configuration could be modified to fit within the bermed area. Public access for education and recreation in this area would be very much in the public eye. There are also existing pumps near the site that are being used to pull water out of the wetlands. Construction of a DWF at this site would need to prevent interference with existing pumping for wetlands. Also, impacts on the DWF with regards to future plans for restoration of the wetland would need to be considered.

  Chauncey Anderson asked how much water the DWF could treat relative to the flow in Sevenmile Canal and how one would decide what source of water would be used in the DWF. Jim Bays noted that the flow required for the DWF is fairly small compared to the flow in Sevenmile Canal. Linda Prendergast also noted that this is a conceptual plan, so there is a desire to have a full range of options for differing water sources available for study in the DWF.

  The DWF would be used to tell us what we could expect for phosphorus reduction in larger restoration projects. In thinking of next phases, future restoration projects can use data from this facility to understand what could be expected for future projects.

- **Site 2:** This site is located in the southeast corner of the Wood River Wetlands near the Wood River. The existing wetlands are productive. Water sources at the site include the wetland itself, the Wood River, and Agency Lake. This site is the most accessible of all the sites. Impacts on the DWF with regards to future plans for restoration of the wetland would need to be considered (should berms be breached in the future). There is no option for the facility to receive water directly from Sevenmile Canal. The site is also very visible to the public and may therefore be under a lot of public scrutiny with regards to construction activities in the wetland.

- **Site 3**: This site is centrally located on the east side of the Wood River Wetlands adjacent to the Wood River. It is also in Oregon Spotted Frog critical habitat which could result in a significant effort in terms of permitting, regulatory, and environmental documentation. Potential sources of water include water from the wetland itself or the Wood River. Examined the possibility of using water from existing wells near the site as a potential source for high ranges of mass loads, however comments suggest the wells are capped. If wells are valved, that may be optimum, as the flow from the wells could be easily accessed. Some improvements for long term access may be required. Power is close in proximity to the site. Oregon Spotted Frog critical habitat affects sites 2, 3, and 4. Site 2 is less of an issue than sites 3 and 4. Threats to Spotted Frog include predation and habitat so construction impacts of the DWF would need to be addressed.

There are currently nine Oregon Spotted Frog populations in the Klamath Basin. The Wood River is one of larger populations and considered the most stable. Attempts to expand the Oregon Spotted Frog habitat have not been successful. Bull Frogs, rather than Spotted Frogs, tend to take over the new habitat, and Bull Frogs are a predator of the Oregon Spotted Frog. Would need to consider how initial construction of the DWF, operations and monitoring activities including diverting water, driving vehicles in and out, etc. would disrupt proposed critical habitat.

The Wood River is also proposed critical habitat for Bull Trout and the Lost River and Shortnose Sucker.

Ken Carlson asked what the risk is to a demonstration wetland facility being able to be constructed if facility is not in critical habitat, but is located near it. Rob Ronniger noted that the final listing of Oregon Spotted Frog will occur on August 23rd. The current plan is to list it as threatened, and will not have separate, distinct population sections. Critical habitat units will come out on the same date in the Register. There is a court mandate to get the Oregon Spotted Frog listed, so dates will not be delayed. Ron doesn't believe the listing would be a deal breaker for facility siting. None of the polygons are actually directly within the critical habitat unit, but are close or adjacent to the habitat. If outside critical habitat boundary, mitigation requirements may be tough to meet. Oregon Spotted Frog habitat is a risk factor that should be focused on.

In terms of restoration projects that cause short term disruptions, working very early on with environmental groups in the development of project has been very helpful in terms of addressing concerns which results in a less contentious permitting process.

- **Site 4:** This site is located in the northeast corner of the Wood River Wetlands, adjacent to the Wood River at the confluence of the North Canal and the Wood River. It is very different from Sites 1, 2, and 3. This site is the highest in elevation within the Wood River Wetlands and has upland vegetation. There are no deep, emergent plant communities at the site. This site would have minimal construction impact. Water sources available at the site include the wetland itself, the Wood River, the upstream pasture, Sevenmile Canal and a pond. The site is accessible by road, however there is no power at the site. Overhead power would need to be brought in. Future Wood River Wetland restoration, if it included breaching the levees, would have least effects on a DWF located at this site. The site is also adjacent to Oregon Spotted Frog critical habitat which could result in a significant effort in terms of permitting, regulatory, and environmental documentation.

  There is an artesian well in the area, but this was not included in the list of water sources available at the site. The well has a pressure gage and ball valve, and has not been decommissioned. This well could be a potential source of water, although it is a distance from the facility.

- **Site 5:** This site is located in the northwest corner of the Wood River Wetlands, adjacent to Sevenmile Canal. Water is also available from the North Canal. This site is the least accessible. The site is 2-3 feet in depth, has power, and a fish screen. This site is outside of Oregon Spotted Frog habitat.

  Michael Hughes commented that the plan should consider space in addition to just the footprint of the cells. Include areas for staging, storage, analytical capability, etc. next to wetland. Consider using Arcata as a potential model. Would be helpful to have some place where work can be sorted, coordinated, etc. Need to discuss capacity of facility in report, providing places for agencies, professors, and volunteers to work together.

**4. Discussion: Site Characteristics and Ranking**

Jim Bays discussed the basis for ranking sites is to determine a preferred site following the previous discussion. Several different attributes were examined including:

- Water sources
- Oregon Spotted Frog critical habitat
- Vegetation

Water rights will be an issue for every site.

Oregon Spotted Frog habitat affects sites 2, 3, and 4. Permitting for the Oregon Spotted Frog habitat is a process that can be gone through but may be more cumbersome for some sites than others.

Constructability makes the sites on north side of the Wood River Wetlands more attractive. Sites 1 and 2 are more accessible. Jim Bays noted that he favors sites 2, 4, and 5.

Sites closer to Sevenmile Canal are preferable as they already have fish screens in place.

Ability to also take water from the pasture north of the Wood River Wetlands would be beneficial.

Rob Ronniger noted that we might consider a “Site 6” alternative along the north road, outside of critical habitat.

Site 5 has strong attributes that set it apart from others. Northerly sites are good from a standpoint of any future levy breaches for wetland restoration.

Chauncey Anderson noted that the TAC may want to consider getting data on nutrient concentrations of different source water. Might not always get high nutrient water at Site 5. Pasture water may be high in nutrients. Jim Bays noted that the draft report does include a summary of Jake Kann and Kurt Carpenter’s work with regards to nutrient concentrations in different source waters.

Jim Bays commented that he'd like to see the facility operated year-round. Spring and summer loading is a major influence of nutrients, other sources could be tested as well. Sevenmile runs consistently high in nutrient concentrations during major irrigation season.

Jane Vorpagel noted that people have a certain passion for the Wood River Wetland. Consider locating the facility along Sevenmile Canal where it is less visible to the public. Consider public perception of taking away beautiful natural wetland and replacing it with mechanical enhancement. By moving the facility further away from public eye, it may make project less controversial.

Michael Hughes noted that the facility is a safe place to conduct science for the public good and Bob Gearhart followed up that the concern about public perception may be overstated. Need to make sure to involve people in the process to have a successful outcome.

Cost may be a driver for site selection. The cost estimate for construction should include costs to de-water, construct berms, and remove vegetation versus sites where this isn't required. It will be difficult to pinpoint costs around permitting. Could look at costs for completing permitting on previous projects.

Chelsea Aquino noted that she likes site 5 due to fish screens, etc.

### 5. Discussion: Draft Plan Comments

Based on all the varying kinds of comments received, Jim Bays want to evolve current plan to include unlined cells as a way to examine how groundwater effects nutrient input. Couple different processes- groundwater discharge, might not be as much on North end as there is closer to lake, could also be oxidized peat soil.

Maia Singer noted that the groundwater question is important, but questioned whether this is the right facility for studying the topic. Unlined cells would reduce the capability of those cells for study. Should also consider whether the approach is pertinent to the overall management plan for the Wood River Wetland.

Jim Bays also noted comments were received (and will be incorporated into the Plan) regarding break-up of vegetation by depth rather than monoculture cells, using sub-cells for replicated testing, groundwater effects by difference, and local reference sites.

### 6. Action Items

Brittany Hughes to send out meeting invite for next TAC meeting scheduled for July 22$^{nd}$ at 1:30 PM PST.

CH2MHILL

*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

Technical Advisory Committee
(TAC) Meeting #10
July 2 2014



## Agenda

1. Introductions
2. Purpose, Progress and Activity Review
3. Discussion: Site Visit July 01 2014
4. Discussion: Site Characteristics and Ranking
5. Discussion: Draft Plan Comments
6. Update: TAC for Nutrient Reduction Study (Interim Measure 11, Study 7)

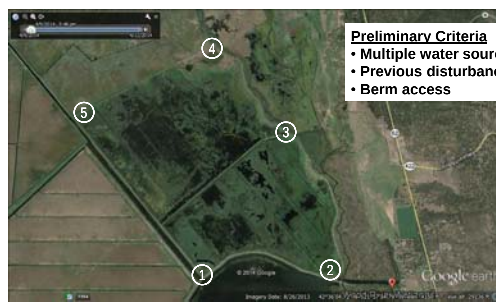


## Study Schedule: 2013-2014

| CC | Topic | Activity | Date |
|---|---|---|---|
| 1 | Initiate discussion on DWF concept | Planning with TAC | T Oct 1 |
| 2 | Establish Research Plan format | | Th Oct 24 |
| 3 | Initiate discussion regarding identification of prospective partners and roles | | M Nov 18 |
| 4 | Initiate discussion regarding identification of prospective site(s) | | T Dec 17 |
| 5 | Review key topics and analysis approach | | T Jan 21 |
| 6 | Finalize topics, sites and partners | Draft by CH2MHILL | T Feb 18 |
| 7 | Mid-point progress update on Plan | | T Mar 18 |
| 8 | Preview and submit draft Plan | | T Apr 20 |
| ~~9~~ | ~~Receive, discuss comments on draft Plan – on-site meeting~~ | Review by TAC | ~~W Jun 3~~ |
| 9 | Receive, discuss comments on draft Plan | | T Jun 17 |
| 10 | Receive, discuss comments on draft Plan – on-site meeting | | Jul 01-02 |
| 11 | Preview and submit final Plan | | T Jul 22 |
| | Submit Final Research Plan | Final by CH2MHILL | F Aug 29 |



## Wood River Wetlands Conceptual Site Locations

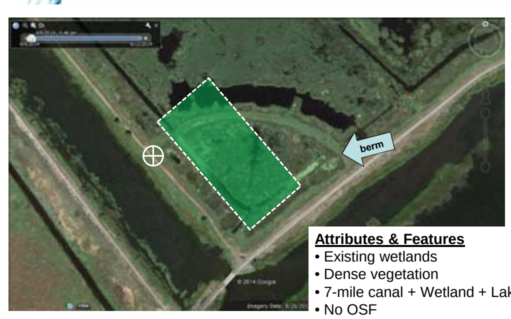





## Site Visit




## Site 1 Southwest 7-mile Canal




**Attributes & Features**
- Existing wetlands
- Dense vegetation
- 7-mile canal + Wetland + Lake
- No OSF
- Existing berm
- Good road

## Site 1



## Site 2 Southeast Wood River


**Attributes & Features**
- Existing wetlands
- Dense vegetation
- Wetland + River + Lake
- No OSF
- Good road



## Site 3 Center Wood River

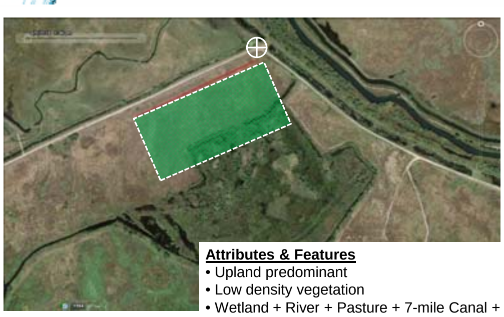
**Attributes & Features**
- Existing wetlands
- Less dense vegetation
- Wetland + River + Well
- OSF
- Fair road



## Site 3



## Site 4 North Wood River



**Attributes & Features**
- Upland predominant
- Low density vegetation
- Wetland + River + Pasture + 7-mile Canal + Pond
- Not OSF
- Fair road



## Site 4

## Site 5: NW Corner by 7-mile Canal

**Attributes & Features**
- Upland/wetland combination
- Lower density vegetation
- Wetland + Pasture + 7-mile Canal
- Not OSF
- Fair road



## Site 5



## Conceptual Site Attributes and Ranking (draft)

| Site | Description | Conceptual Water Sources | | | | | Water Rights | OSF | Vegetation Type/density | Access | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | R | W | L | P | | | | | |
| 1 | SW 7-mile Cnl | x | | x | x | | | N | W - high | G | |
| 2 | SE WR | | x | x | x | | | N | W - high | G | |
| 3 | E WR | | x | x | | | | Y | W - high | F | |
| 4 | NE WR | x | x | | | x | | Y | U - low | F | |
| 5 | NW 7-mile Cnl | x | | | | x | | Y | W- low | F | |



## Discuss Technical Comments: Changes to Plan Under Consideration

- Unlined cells, fewer lined cells
- Mixed vegetation communities
- Two depth ranges
- Sub-cells for replicated testing
- Groundwater effects by difference
- Local reference sites



## Discussion: Technical Comments

- Please share your comments with group, by email, or phone
- Looking for final comments back by Friday July 11.



## Next Steps

1. Submit Comments on Plan by July 11
2. Revise Plan based on
   1. Matrix results
   2. TAC comments
   3. Site visit
3. Next Meeting: July 22

*Interim Measure 11 Activity 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

# Technical Advisory Committee (TAC) Meeting #11

**July 22, 2014**
(Via Teleconference)

## Meeting Notes

**Attendees (checked box indicates attendance):**

| | | |
|---|---|---|
| ☐ Andy Hamilton/BLM | ☒ Jane Vorpagel/CA DFG | ☒ Mary Grainey/OWRD |
| ☐ Beth Bendickson/PacifiCorp | ☐ Jared Bottcher/KBRT | ☐ Micah Gibson/Yurok Tribe |
| ☒ Bob Gearhart/HSU | ☐ Jed Redwine/SF Environments | ☐ Michael Hughes/OIT |
| ☒ Brittany Hughes/CH2M HILL | ☐ Jessica Asbill-Case/USBR | ☒ Mike Deas/Watercourse Eng |
| ☒ Chauncey Anderson/USGS | ☒ Jim Bays/CH2M HILL | ☐ Nell Kolden/KBRT |
| ☐ Chelsea Aquino/BLM | ☒ John Hamilton/USFWS | ☒ Rick Carlson/USBR |
| ☒ Chris Stine/ODEQ | ☐ Kathleen Sloan/Yurok Tribe | ☐ Rob Ronniger/BLM |
| ☐ Clayton Creager/CA RWQCB | ☒ Ken Carlson/CH2M HILL | ☐ Ron Larson/USFWS |
| ☐ Crystal Bowman/Karuk Tribe | ☐ Kris Fischer/Klamath Tribe | ☐ Susan Corum/Karuk Tribe |
| ☐ Dan Blake/USFWS | ☐ Kurt Carpenter/USGS | ☒ Ted Wise/ODFW |
| ☐ Eli Asarian/Riverbend Sciences | ☒ Kyle Gorman/OWRD | ☒ Tim Hemstreet/PacifiCorp |
| ☐ Heather Hendrixson/TNC | ☒ Linda Prendergast/PacifiCorp | |
| ☒ Jake Kann/AES | ☐ Maia Singer/Stillwater Sciences | |

### 1. Introductions

Jim Bays opened the meeting by reviewing the agenda for the call. The call today is a follow-up from the site meeting. We will be reviewing the site characteristics of the preferred/short list of sites at the Wood River Wetland and narrow it down to a preferred site. Discussion will walk through how the preferred site was selected in order to understand how the preferred site was chosen. Ideas on how the demonstration wetland facility (DWF) sketch in the report can be modified based on inputs received will also be discussed.

### 2. Purpose, Progress and Activity Review

The schedule of calls has been extended. There will be a call in August and possibly a final call in September. The final draft of the plan will be submitted for review in the next month.

### 3. Discussion: Site Characteristics and Ranking

Five sites at the Wood River Wetland were selected as potential locations for a DWF. Site 1 and 2 are located by Agency Lake. Sites 3 and 4 are located by the Wood River, and Site 5 is in the Northwest corner of the Wood River Wetlands. From the site visit, a list of attributes was developed and discussed during the on-site meeting and teleconference call. Jim Bays used these attributes to develop a table of attributes for each site.

Site 1 is located in the southwestern corner of the Wood River Wetlands. The site has access to multiple potential water sources including Agency Lake and water from the wetland itself. The range of available water sources and water qualities provides more flexibility in testing opportunities. There is a pump station at the site with power available. A solar-powered facility could be built if needed, but would not be required at this site. The public can access this facility, but not as readily as Site 2, so public access potential was characterized as moderate in range. The DWF will provide an educational facility that is important to the community, but at the same time, we may be creating an impact that may cause public concern. Also, the DWF should not impact BLM's operations. This site has the potential to impact operations. The Post-KBRA Effect is a future setting where dikes have been breached and the lake is entering the wetland areas. Sites closest to the lake may be impacted the most due to their lower elevation levels. Protected species issues rose to prominence during the on-site meeting - both for Oregon Spotted Frog and Fish. Site 1 is outside of spotted frog habitat, but we would need to be sure we could protect suckers. Site 1 is a well-established emergent wetlands with a well-developed stand of vegetation. Any work done to construct a DWF at this site would impact existing vegetation. The site is readily accessible by dike roads.

Bob Gearhart noted that groundwater availability was not included in the list of potential water sources. Jim Bays responded that conversations surrounding the wells have noted that the wells have been capped and are not being used, although there may still be some opportunity for use.

Site 2 has three potential water sources as well as power. Site 2 is the most accessible and visible to the public. A DWF at this location wouldn't impact BLM operationally. However, Site 2 would be impacted by post-KBRA effects. The site is located in Oregon Spotted Frog habitat and may potentially impact suckers.

Site 3 only has two potential water sources- the Wood River and the wetland itself. The site is located near a pump station, so power is available. The roads out to the site were a little sandy, and need to be improved if a facility is built at this location. The site is located in Oregon Spotted Frog habitat and may potentially impact suckers. The vegetation is dense. The site is not as accessible or visible as Sites 1 and 2.

During the site visit at Site 4, the outlet from cross canal was visible and a high sediment load had built up in the outlet. There is high nutrient content water coming in at the north end of the canal. The canal is directly connected to the inlet structure that takes in water from the northwest corner of the site. Site 4 doesn't have power and it is not very accessible to public, so public access was rated as moderate. Operational impacts to BLM are viewed as low. There is no existing facility or berm structure. The site is higher in elevation, so it would be the least effected by the post-KBRA effect. It is located in an area where Oregon Spotted Frog and Suckers may be impacted. Site 4 has lower density vegetation.

Site 5 is located in the Northwestern corner of the wetland. Water is available from the canal itself, longitudinal canals in the Wood River Wetland, and pasture overflow that flows into the cross-canal. Seasonally-varied sources are available for use. Site 5 has power and is out of the public eye. There would be no operational impacts to BLM and the post-KBRA effect would have a minimal impact. Oregon Spotted Frog and Suckers would not be impacted. The intake at Site 5 has a fish screen. Vegetation density is low. The site is hydrated, but not as wet as the sites closer to the lake. The site access is rated as fair. Dike roads may require improvements.

Jim Bays ranked the sites based on their attributes. No weighting was used, all attributes are ranked equally. They are all equally important. The theory behind rankings include:

> -5 water sources were identified. An optimal site would be able to take water from all sites. Summed sources of water for each site to get a total point value.
>
> -Power: A site either has power (1 pt) or no power (0 pts).
>
> -Public access: Areas further away from public access were ranked higher. Rankings from 1 to 3 pts. Site 2 ranked as a 1 (most accessible, Site 5 ranked as a 3 (least accessible by public).
>
> -Operational Impact: The site location either impacts BLM operations (0 pts) or will not (1 pt).
>
> -KBRA Impact: The site will either be impacted by the KBRA restoration plans (0 pts) or not (1 pt).
>
> -Oregon Spotted Frog and Suckers: The site will either impact the species (0 pts) or will not (1 pt).
>
> -Vegetation Type: The site either impacts existing thick vegetation (0 pts) or does not (1 pt).
>
> -Site Access: If the site is easily accessible (2 pts), less accessible (1 pt).

A correction to the rankings was identified. Jim Bays will update the slides and send out correction to the TAC. Site 5 ends up ranking highest.

In terms of public access, the thought is that building a facility like this may be viewed as impactful, and therefore raise concerns of people who use the wetland. “Public Access” attribute might be better labeled as “public visibility”. The public views the wetland as a pristine area.

The general trend in elevations at the Wood River Wetland is that sites are deeper toward the south of the wetland.

The research and implementation plan needs to be flexible and versatile if Site 5 is not selected.

Rick Carlson noted that a weighting scheme based on site attributes might be better. Some attributes seem like they may be more important than others. Figuring in species impact may be the most important factor in site selection.

Chauncey Anderson asked if there will be an overall agency review of document. The different agencies represented may want a chance to weigh-in. Ken Carlson stated that the idea about this research and implementation plan is that it is a conceptual plan. A more formalized review is potentially a step for the next phase. There is hope that the TAC is a fair representation of agencies. TAC member’s participation is in no way a formal approval, but we're getting a screening level input from TAC members.

Chauncey Anderson noted that there still might be some things in the report that need to be discussed over more than just a conference call. Jim Bays commented that we've received good advice from TAC members and this process has been helpful in identifying important factors that make some sites more feasible than others.

Jane Vorpagel noted that water rights were not considered as an attribute in the rankings. Jim Bays commented that in talking with Kyle Gorman, given the relatively small flows, allocations appear to be available for the site. Kyle said there is probably a way to get the water rights established. Water rights will be discussed in the plan. Mary Grainey noted that OWRD can issue limited licenses for up to 5 years for short term uses. If longer-term operations are expected, water rights can be addressed at that time.

**4. Discussion: Revised Conceptual Plan**

Slide 7 shows a conceptual layout to illustrate the general footprint at Site 5. An area is included where trailers could be installed for testing, storage, maintenance, a pump station, etc. The pump intake could go directly from the main canal or from an internal canal. Also included is a reference or comparison site to study the Wood River Wetland. The reference site would be marked and monuments would be installed at the corners, but wouldn't be built up. The site is similar in elevation to the demonstration facility.

The proposed concept changes include 2 outer cells as unlined cells, 4 deep cells and 4 lined half-size cells. The smaller cells are intended for use for replicated testing of special topics. Every cell would include a boardwalk for access/testing, inlet/outlet controls, an inflow pump for each cell, subsurface piping, and would be planted with a diverse mix of native, local species. The intent of the combination of lined and unlined cells is to find a balance at this facility that allows control over the groundwater influence on wetland performance.

Mary Grainey noted that it would be useful to have flexibility in the facility and to complete a cost estimate based on the flexible design.

Bob Gearhart commented that he believes this a good end point.

In his comments, Chris Stine had voiced some concern about unlined cells. They are valuable in terms of looking at groundwater influence, but increase the complexity of the design. Jim's description of the unlined cells shows their usefulness. Any linkage providing a real-world example of wetland function adjacent to DWF is extremely valuable component of the design. Making reference to natural conditions in the area would require additional ambient monitoring such as groundwater levels and quality. May save in upfront construction costs due to lack of liner, but more intensive testing would be required for the unlined cells.

Jim commented that one goal of the project should be to make BLM's wetland monitoring complement and provide reference data for what a specific researcher could study at the DWF.

Bob Gearhart mentioned that if surface water instead of artesian well water is being used for groundwater input, this may alter results from what is actually happening in nature. Without the same groundwater source, we might not see much of an effect. If we can't simulate groundwater conditions using surface water, is it worth including the underground piping? May get all the information you need from the unlined and reference cells and wouldn't need to include subsurface piping. Jim Bays noted that maybe subsurface piping could be limited to the smaller test cells instead of larger cells. One could create a high nutrient feed solution to simulate groundwater quality.

Nested piezometers would be installed in each of the unlined cells near the boardwalks to allow detailed measurement of stage, artesian influence, and response to water balance inputs and outputs (e.g., precipitation, evaporation, change in storage, etc.). The net flux of groundwater in the unlined cells would have to be estimated from the piezometer data and corroborated against the residual of other components that could be measured directly. The intent would be for the DWF to be able to quantify all the water balance terms to find the total water balance for system on day-to-day or yearly basis. We need to build in features that allow us to measure all of these items directly or indirectly.

Net flux of groundwater is commonly the residual variable in the water balance equation. Are other water balance terms measured with any certainty that would extend the certainty to the groundwater term? Every term has an error attached to it. Inflow/outflow are the most precisely measured. Errors aggregate, one term can influence the other term, which increases the potential for inflating the error. The difference between lined and unlined cells gives you a way to compare and measure these terms. Kurt's previous work can be used as a comparison. Groundwater input is also seasonal.

## 5. TAC for Nutrient Reduction Study (IM 11, Activity 7)

Ken Carlson updated the TAC on the Nutrient Reduction Study. Scheduled to obtain source water samples by the beginning of next week. Trying to determine sample collection timing. We may need to allow additional time for lab set-up. Ken will provide more updates as things are accomplished.

The sample volumes that are being obtained are several gallons (5 gallons) per site. The sites are Sevenmile Canal above Agency Lake, Upper Klamath Lake at the Link River Dam, Keno Reservoir near Miller Island. As soon as more information becomes available, Ken will notify the TAC. Sample collection will be between 0.5 and 3 meters in depth. Not trying to homogenize the sample.

## 6. Next Steps

CH2M HILL is revising the research and implementation plan to reflect the new configuration. There will be more written description on the site selection process. The update will also fold in earlier comments on the matrix.

The next TAC call is Tuesday, August 26th. Brittany to send out invite for next TAC call. CH2M HILL will send the revised draft ahead of time to give everyone 10 days of review time.

## 7. Action Items

Jim Bays will update the slides and send out correction to the TAC.

Brittany to send out invite for next TAC call.

CH2M HILL will send the revised draft ahead of time to give everyone 10 days of review time.

CH2MHILL

*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

## Technical Advisory Committee (TAC) Meeting #11
## July 22 2014

BUILDING SUSTAINABLE SOLUTIONS

## Agenda

1. Introductions
2. Purpose, Progress and Activity Review
3. Discussion: Site Characteristics and Ranking
4. Discussion: Revised Conceptual Plan
5. Update: TAC for Nutrient Reduction Study (Interim Measure 11, Study 7)

BUILDING SUSTAINABLE SOLUTIONS 2

## Study Schedule: 2013-2014

| CC | Topic | Activity | Date |
|---|---|---|---|
| 1 | Initiate discussion on DWF concept | Planning with TAC | T Oct 1 |
| 2 | Establish Research Plan format | | Th Oct 24 |
| 3 | Initiate discussion regarding identification of prospective partners and roles | | M Nov 18 |
| 4 | Initiate discussion regarding identification of prospective site(s) | | T Dec 17 |
| 5 | Review key topics and analysis approach | | T Jan 21 |
| 6 | Finalize topics, sites and partners | Draft by CH2MHILL | T Feb 18 |
| 7 | Mid-point progress update on Plan | | T Mar 18 |
| 8 | Preview and submit draft Plan | | T Apr 20 |
| ~~9~~ | ~~Receive, discuss comments on draft Plan – on-site meeting~~ | Review by TAC | ~~W Jun 3~~ |
| 9 | Receive, discuss comments on draft Plan | | T Jun 17 |
| 10 | Receive, discuss comments on draft Plan – on-site meeting | | Jul 01-02 |
| 11 | Receive, discuss comments on draft Plan – on-site meeting | | T Jul 22 |
| 12 | Submit Final Research Plan | CH2MHILL | F Aug 29 |

BUILDING SUSTAINABLE SOLUTIONS 3

## Wood River Wetlands Conceptual Site Locations


BUILDING SUSTAINABLE SOLUTIONS 4

## Conceptual Site Attributes and Ranking (draft)

| Site | Description | Conceptual Water Sources | | | | | Power | Public Access | Operation Impact | Post-KBRA Effect | OSF | Sucker | Vegetation Type/density | Site Access | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | R | W | L | P | | | | | | | | | |
| 1 | SW 7-mile Cnl | x | | x | x | | x | M | Y | H | N | Y | W - high | G | |
| 2 | SE WR | | x | x | x | | x | H | N | H | Y | Y | W - high | G | |
| 3 | E WR | | x | x | | | x | M | N | L | Y | Y | W - high | F | |
| 4 | NE WR | x | x | | | x | | M | N | L | Y | Y | U - low | F | |
| 5 | NW 7-mile Cnl | x | | x | | x | x | L | N | L | N | N | W- low | F | |

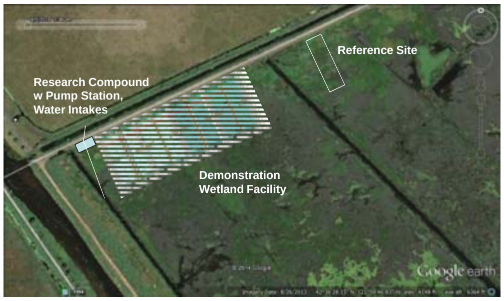
BUILDING SUSTAINABLE SOLUTIONS 5

## Preliminary Site Ranking (Unweighted)

| Site | Description | Conceptual Water Sources | Power | Public Access | Operation Impact | Post-KBRA Effect | OSF | Sucker | Vegetation Type/density | Site Access | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | SW 7-mile Cnl | 3 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 2 | 9 |
| 2 | SE WR | 3 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 8 |
| 3 | E WR | 2 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 1 | 8 |
| 4 | NE WR | 3 | 0 | 2 | 1 | 1 | 0 | 0 | 1 | 1 | 9 |
| 5 | NW 7-mile Cnl | 3 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 13 |
| Optimum | | 5 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 2 | 16 |

BUILDING SUSTAINABLE SOLUTIONS 6

## Site 5: NW Corner by 7-mile Canal Conceptual Placement and Scale



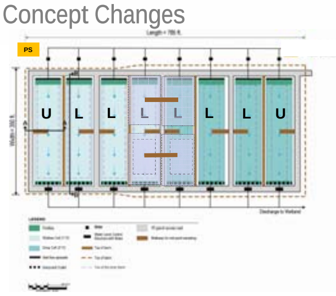



## Site 5 – Conceptual Placement



## Proposed Concept Changes

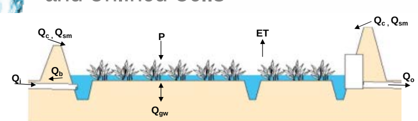
- Cells w/o bottom liner - 2
- Lined cells – 4
- Duplicate lined sub-cells - 4
- Deep water vegetation (>3 ft)
  - e.g., SAV, Wocus
- Shallow water vegetation (<3 ft)
  - e.g., Cattail, Bulrush, Bur-reed
- Local reference sites
- Research facility compound




**L Lined**
**U Unlined**



## Dynamic Water Balance Model for Lined and Unlined Cells




**Dynamic Water Balance**

$$\frac{dV}{dt} = Q_i - Q_o + Q_c - Q_b - Q_{gw} + Q_{sm} + PA - ETA$$

Where:

V=water storage in wetland, $m^3$
T=time, d
$Q_i$=input water flow rate, $m^3/d$
$Q_o$=output water flow rate, $m^3/d$
$Q_c$=catchment runoff rate, $m^3/d$
$Q_b$=bank loss rate, $m^3/d$
$Q_{gw}$=net flux of groundwater, $m^3/d$
$Q_{sm}$=snowmelt rate, $m^3/d$
**P**= precipitation rate, m/d
**ET**=evapotranspiration rate, m/d
**A**=wetland surface area, $m^2$

**Periodic Water Balance**

$$\Delta V_{stored} = V_i - V_o + V_c - V_b - V_{gw} + V_{sm} + V_r - V_e$$

Where:

$\Delta V_{stored}$=change in water storage in wetland, m3
$V_i$=input water volume, $m^3$
$V_o$=output water volume, $m^3$
$V_c$=catchment runoff volume, $m^3$
$V_b$=bank loss volume, $m^3$
$V_{gw}$=volume of groundwater flux, $m^3$
$V_{sm}$=snowmelt volume, $m^3$
$V_r$= rain volume, $m^3$
$V_e$=evaporated volume, $m^3$

IWA, 2000



## Next Steps

1. Submit Comments on Plan by July 11
2. Deliver Revised Draft Plan based on
   1. Matrix results
   2. TAC comments
   3. Site visit
3. Next Meeting: Aug 26

*Interim Measure 11 Activity 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

# Technical Advisory Committee (TAC) Meeting #12

**October 21, 2014**
(Via Teleconference)

# Meeting Notes

**Attendees (checked box indicates attendance):**

| | | |
|---|---|---|
| ☐ Andy Hamilton/BLM | ☒ Jane Vorpagel/CA DFG | ☐ Mary Grainey/OWRD |
| ☐ Beth Bendickson/PacifiCorp | ☐ Jared Bottcher/KBRT | ☒ Micah Gibson/Yurok Tribe |
| ☒ Bob Gearhart/HSU | ☐ Jed Redwine/SF Environments | ☐ Michael Hughes/OIT |
| ☒ Brittany Hughes/CH2M HILL | ☐ Jessica Asbill-Case/USBR | ☒ Mike Deas/Watercourse Eng |
| ☐ Chauncey Anderson/USGS | ☒ Jim Bays/CH2M HILL | ☐ Mike Hiatt/ODEQ |
| ☒ Chelsea Aquino/BLM | ☐ John Hamilton/USFWS | ☐ Nell Kolden/KBRT |
| ☒ Chris Stine/ODEQ | ☐ Kathleen Sloan/Yurok Tribe | ☐ Rick Carlson/USBR |
| ☒ Clayton Creager/CA RWQCB | ☒ Ken Carlson/CH2M HILL | ☐ Rob Ronniger/BLM |
| ☐ Crystal Bowman/Karuk Tribe | ☐ Kris Fischer/Klamath Tribe | ☐ Ron Larson/USFWS |
| ☐ Dan Blake/USFWS | ☐ Kurt Carpenter/USGS | ☒ Susan Corum/Karuk Tribe |
| ☒ Eli Asarian/Riverbend Sciences | ☒ Kyle Gorman/OWRD | ☒ Ted Wise/ODFW |
| ☒ Heather Hendrixson/TNC | ☒ Linda Prendergast/PacifiCorp | ☐ Tim Hemstreet/PacifiCorp |
| ☒ Jake Kann/AES | ☒ Maia Singer/Stillwater Sciences | |

## 1. Introductions

Jim Bays opened the meeting by reviewing the agenda for the call. The call today is the last in the series held during the development of the demonstration wetland facility research and implementation plan (Plan). The call will include a quick recap of accomplishments to-date and include discussions on the final Plan. The meeting minutes prepared for the call will provide an opportunity to clarify or expand on the Plan. TAC comments on the draft Plan have been incorporated, and modifications were made based on the July site visit. Today's discussion will be centered on ways to implement the Plan, identification of partners, funding, and other potential wetland projects and locations in the area where parts of the plan could be transferable. One of the goals in the development of the Plan was to make it generally useful for a multitude of projects. Ken Carlson will also provide an update on the Nutrient Reduction Study.

## 2. Purpose, Progress and Activity Review

Jim Bays noted that over the past year, we have come a long way on this project. The input and effort from all the TAC members over the past year has been very much appreciated. The TAC has had the opportunity to determine the focus of the Plan, taken part in the Plan review cycle, and participated in a detailed site meeting. All of these activities have brought new information into final version of Plan. With the Plan finalized, next steps will be discussed.

## 3. Final Study Plan Discussion:

The introduction and background sections of the Plan focused on key processes for phosphorus reduction, design factors affecting performance, and similar projects/missions in other parts of the world. The issues affecting the Klamath Basin are not unique, there are projects all over the world that are studying the effectiveness of wetlands for nutrient reduction. However, there are several important factors affecting wetland performance that are unique to the Klamath Basin, particularly though the combination of hydrogeology, geochemistry, land use history and climate. Investigation of these Basin-specific factors is a large part of the rationale for the need for Demonstration Wetland Facility (DWF).

The Plan includes sections discussing research and design priorities. These priorities include nutrient removal and retention, water balance effects on performance and sizing, vegetation effects on nutrient removal and retention, and habitat quality and faunal use. The Plan is designed to provide a research platform to identify and investigate key sources and inputs into the system, including ranges of concentrations from the contributing watersheds, seasonality, and significant interrelations with groundwater and watershed, among others. The Plan also includes a simplified but broadly representative vegetation design to study plant performance. Focusing on nutrient removal is the key priority of the facility; however, ancillary information collected on habitat is also beneficial.

In the DWF description section, more detail and new information was added in this final version. The facility is meant to be compact, but big enough that the scale of the study is meaningful. The larger cells within the DWF layout allow for study of changes in water depth and nutrient loads. The preferred location for the DWF is in the Wood River Wetlands at a site that was determined to be the least problematic in terms of environmental permitting while enabling a range of phosphorus input concentrations. A construction cost estimate for the facility has been incorporated. The Plan also includes detail on experimental design, and research needs and priorities.

Five conceptual site locations within the Wood River Wetlands were evaluated and ranked. Site 5 near the northwest corner of the wetlands was identified as the most implementable site location after the site visit and comparison. The site is close to Sevenmile Canal, and has various water sources and qualities available. The site could be fenced off and turned into a compound. The site would be able to take water in from multiple locations and distribute flow equally across cells. A reference system/site has also been included. The reference site would not be fenced-in or impounded but would be marked in the field for comparison with the treatment cells. Hydrologic monitoring would be installed to create a basis of comparison between natural wetland function and the DWF facility experiment results.

The DWF is designed to be a multi-celled facility with 4 shallow cells and 4 deep cells. The two outermost cells are unlined. The unlined cells include nested piezometers to allow groundwater flux to be estimated. The facility is an impoundment with control structures, but upwelling of groundwater or infiltration of groundwater can be examined in the outside, unlined cells. The interior cells are lined. Hydrologic inputs into the lined cells include pumped inflows and precipitation inputs. A subsurface piping system is included in the smaller cells to simulate natural groundwater inputs and losses under controlled conditions.

If groundwater quality is identified as a critical issue to study, the smaller cells in the facility also have a component where water with high nutrient concentration could be pumped into the subsurface piping system as groundwater to study effects of high-nutrient groundwater.

A research compound was also included in the conceptual DWF layout. This includes a trailer for research, a work area, sample processing, equipment storage, etc. Other projects have had similar systems built to serve as field headquarters.

This final version of the Plan also includes information on the construction cost for the DWF that is estimated to be $2.275M (which includes a contingency). The cost estimate is consistent with a Class 4 estimate as determined by the American Association of Cost Estimators International (AACEI), meaning that the DWF as proposed in the Plan includes detailed bases for estimates of earthwork volumes for berms, and costs associated with liners, structures, piping, etc. The Class 4 estimate is better than a rough magnitude estimate, but still has a wide range of accuracy (+50% to -30%). The estimate also takes into account a regional adjustment factor to account for geographic differences in labor and materials. The cost does not include operations and maintenance (O&M) costs. O&M costs would be dependent upon the partners, nature of studies/projects, etc.

Eli Asarian noted that it would be helpful to include an order of magnitude estimate of expected O&M costs in the Plan. For planning purposes, having some range of numbers would be helpful for budget planning. Assumptions would need to be stated around the cost range that is provided.

Bob Gearhart also added that having a funding partner who can cover background O&M costs for the facility would be beneficial to maintain continuity of the system operation.

Clayton Creager noted that construction costs in the Plan are specific to this facility and do not represent the cost to implement a full-scale treatment wetland. What is learned from this facility may reduce costs to build wetlands at full scale in the future. For example, pumping costs are related to experiment cost. There is an economy of scale with regards to operations.

Jim Bays noted that O&M costs would be in tens of thousands of dollars a year to operate. The reason for not incorporating O&M costs into the Plan was to preserve complete flexibility for future researchers to determine costs associated with research to be completed at the facility. Every study will be different and costs will vary for testing. However, Jim offered to provide some additional information on the possible range of O&M costs. Jim suggested that, rather than revising the final version of the Plan, this additional information will be incorporated into these project meeting minutes, and the meeting minutes will be included as an appendix to the final version of the Plan (including the minutes for all the TAC meetings).

In response to the request for additional information on possible O&M costs, Table 1 summarizes preliminary estimates of baseline annual O&M costs, which have been prepared based on the following assumptions:

- Continuous operation and maintenance of a water pump station at an average rate of 300 gpm
- Daily site inspections, coordination, and maintenance by a locally-based part-time supervisor, nominally assumed to be half-time
- Seasonal repairs to berms, fences, etc., and associated equipment rental
- Periodic upkeep and miscellaneous repairs, septic tank maintenance, etc.
- 10% contingency.

TABLE 1
**Preliminary Baseline Operation and Maintenance Costs, Demonstration Wetland Facility**

| Item | Criteria | Quantity | Basis | Cost per Unit | Estimated Cost |
|---|---|---|---|---|---|
| Energy | Scaled from 100 HP for 800 gpm system | 31 | Prior Experience | $0.10 per KW hr | $24,497 |
| Equipment Maintenance (pumps) | 2.5% of equipment capital cost | 1 | Prior Experience | 2.5% | $125 |
| Replacement | Fencing and gates - annual repairs | 100 | CPES | $31.00 | $3,100 |
| Labor - Site Supervisor | Half-time (4 hr/d for hydraulic maintenance, site overview, coordination, etc.) | 1040 | CH2M HILL OMI | $62.85 per hr | $65,364 |
| Labor - Maintenance Only | 16 hrs 3x/year berm maintenance | 96 | CH2M HILL OMI | $62.85 per hr | $6,034 |
| Equipment Rental | Repairs to access roads, berms, and physical facilities | 6 | Internet | $260 per day | $1,560 |
| Septic Tank Pumping | Quarterly pumping | 4 | Internet | $275 per trip | $1,100 |
| Miscellaneous | Vegetation control, cables, wires, etc; windows, building repairs | 1 | Allowance | $2000 per year | $2,000 |
| | | | | Subtotal: | **$104,000** |
| | | | | Contingency (10% estimated cost): | $10,400 |
| | | | | **Total Cost:** | **$114,000** |

For a preliminary estimate of possible costs of a basic monitoring program (annually or per-year of research activity), the following criteria were assumed:

- Analyte list: total phosphorus, dissolved reactive phosphorus, particulate phosphorus, total Kjeldahl nitrogen, ammonia-nitrogen, oxidized nitrogen, calcium, aluminum, iron, total organic carbon.
- Sampling frequency: biweekly.
- Samples:
  - Inflow: once per event
  - Mid-station: 10 per event (2 unlined cells, 4 lined cells, and 4 sub-cells)
  - Outflow:10 per event
  - Surface sediment: 2 per cell, once per year
  - Vegetation: 3 per cell, twice per year.
- Sampling labor: 2 person-days per event.

This basic monitoring program is intended to describe a generally-focused sampling program characterizing water quality for all 10 cells without a particular research emphasis other than evaluating nutrient removal. Table 2 summarizes the components of the sampling program and the associated preliminary estimate of costs. We emphasize that this preliminary estimate of monitoring costs represents only a potential baseline for comparison. The actual sampling programs eventually undertaken at the DWF could require more or less effort and cost, and may focus on different objectives and parameters as assumed here. As such, a potential wide range in monitoring costs should be expected, and would be reflection of the versatility of this research platform.

TABLE 2
**Preliminary Baseline Monitoring Costs, Demonstration Wetland Facility**

| Analytical Parameter | EPA Method | Unit Cost ($) | No. of Samples | Unit Cost ($) |
|---|---|---|---|---|
| **Surface Water** | | | | |
| Total Phosphorous | EPA 365.4 | $30 | 572 | $17,160 |
| Dissolved reactive (ortho) phosphorous | Filtration[1]/EPA 365.1 | $18 | 572 | $10,296 |
| Particulate (ortho) phosphorous | EPA 365.1 | $18 | 572 | $10,296 |
| TKN | EPA 351.2 | $30 | 572 | $17,160 |
| Ammonia | EPA 350.1 | $16 | 572 | $9,152 |
| Oxidized nitrogen (NO2 + NO3) | EPA 353.2 | $18 | 572 | $10,296 |
| Total Calcium, Iron | EPA 200.7 | $30 | 572 | $17,160 |
| Total Aluminum | EPA 200.8 | $20 | 572 | $11,440 |
| TOC | SM 5310B | $30 | 572 | $17,160 |
| | | | **Subtotal:** | **$20,120** |
| **Surface Sediments** [2] | | | | |
| Total Phosphorous | EPA 365.4 | $45 | 20 | $900 |
| Reactive (ortho) phosphorous | EPA 365.1 | $28 | 20 | $560 |
| TKN | EPA 351.2 | $45 | 20 | $900 |

TABLE 2

**Preliminary Baseline Monitoring Costs, Demonstration Wetland Facility**

| Analytical Parameter | EPA Method | Unit Cost ($) | No. of Samples | Unit Cost ($) |
|---|---|---|---|---|
| Ammonia | EPA 350.1 | $31 | 20 | $620 |
| Oxidized nitrogen (NO2 + NO3) | EPA 353.2 | $33 | 20 | $660 |
| Total Calcium, Iron | EPA 200.7 | $30 | 20 | $600 |
| Total Aluminum | EPA 200.8 | $20 | 20 | $400 |
| TOC | Lloyd Kahn | $55 | 20 | $1,100 |
| Bulk Density | | $40 | 20 | $800 |
| | | | **Subtotal:** | **$6,540** |
| **Vegetation** [3] | | | | |
| Total Phosphorous | EPA 365.4 | $50 | 60 | $3,000 |
| TKN | EPA 351.2 | $50 | 60 | $3,000 |
| % Solids | | $20 | 60 | $1,200 |
| | | | **Subtotal:** | **$7,200** |
| | | | **Total:** | **$133,860** |
| | Shipping, coolers, ice, miscellaneous allowance | | | $ 2,000 |
| | | | Labor[4] | $ 70,200 |
| | | | **Total:** | **$206,060** |

[1] Assuming field filtered

[2] Report on dry weight basis

[3] Report as received

[4] $75/hr x 2 staff x 12 hrs event x 26 events

Finally, costs for the data management, analysis, and reporting of the study will vary, but a preliminary placeholder value would be expected to be in the range of $150,000 per year. Under the assumptions provided here, the total costs of operation, maintenance, monitoring and reporting (as presented above) yield an approximate total of about $470,000 annually (or per-year of research activity).

- **How to identify partners for implementation?**

Bob Gearhart recommended a governing structure for the DWF be created. This is an important consideration, in that it preserves the research and demonstration potential of the DWF equally now and into the future for all potential users in the Basin.

Clayton Creager discussed that work is beginning on a more-structured watershed stewardship process in the Basin. The intent is to provide a structure for multiple entities who have common or overlapping management objectives, research goals, and operational outcomes. Clayton is organizing a workshop in November 2014 as a way to move beyond typical collaboration to a more direct and purposeful collaboration. Clayton plans to email invitations and additional information on the planned workshop to all TAC members.

Clayton noted that there is a lot of work is going on in the watershed that would benefit from a more formal, coordinated effort. There are opportunities for project partnerships and monitoring optimization. A more collaborative funding strategy could be defined. The overall scope of the planned November 2014 workshop is broad.

Linda Prendergast noted that Clayton has received a grant for implementation of diffuse treatment wetlands in the Basin, and asked Clayton what are the next steps?

Clayton indicated that the next steps for the diffuse wetland treatment grant is to get contracting done this winter, with design work following shortly after contracting. Plan is to begin construction work next spring in the Wood River.

Jim Bays noted that BLM could potentially be a site maintenance partner if the DWF is constructed within the Wood River Wetlands (as assumed in the Plan). Jim Bays noted that based on earlier conversation with Andy Hamilton (former TAC member representing BLM), BLM was open-minded to it, but would need to ensure that the DWF is compatible with historic environmental planning for the site.

Chelsea Aquino (current TAC member representing BLM) noted that there is precedent for BLM's approval of a wetland research facility within the Wood River Wetlands. Chelsea commented that there is language in the Wood River Wetland EIS for a "temporary research facility" about 5 acres in size. The EIS was completed in 1995/96, and it would be up to decision makers to decide whether the EIS is still valid. If so, this would potentially expedite the NEPA process that would be required for a DWF project at the site. No further discussion of the DWF as proposed in the final Plan has occurred at the BLM management level, but BLM management will need to weigh in if further planning of the DWF continues to assume siting within the Wood River Wetlands.

Jim Bays agreed and emphasized that, although this final version of the Plan for a DWF at the Wood River Wetland has been completed, additional approvals would be needed and details about how BLM might be a partner in monitoring/maintaining the site would need to be determined.

- **How to obtain funding for implementation?**

Kyle Gorman applauded the TAC and the DWF plan and hopes funding partners can be found – he suggested that entities such as OWEB and NRCS be contacted as possible funding sources.

Jim Bays noted that the DWF will require an agency/organization to own the daily maintenance have some authority over what happens at the site, as suggested by Bob Gearhart. This could be an agency that folds costs into annual programs of water quality improvement, or seen as something that is supported by grants to a university to sustain its research site. Soft funding (grants) can vary with administrations and economic conditions. The DWF could also be maintained/owned by a separate entity that is funded by separate donations or grants.

- **Are elements of the DWF plan transferrable to other potential sites?**

Clayton commented that much of the DWF Plan can be implemented at another site. As members of the TAC encounter other research opportunities, there may be pieces of the DWF Plan that can be used. Transfer of knowledge that has been learned through this process needs to continue.

Jim concurred and elaborated that the Plan outlines principals of treatment wetland planning and design that are transferable to other sites. Phosphorus removal occurring naturally even in restoration sites can be described using the information provided in the report. An engineered system will optimize, but is not required for phosphorus removal. The DWF system layout as provided in the Plan could be applied identically to other sites as a template or a beginning concept. Even the conceptual siting process applied here to define a potential site can be applied to other sites. An important step in the process is to find a place to build a controllable facility to use as a control milestone, but this should not impede progress of other work going on in the watershed. Building aspects of the DWF Plan into other plans/facilities within the watershed is encouraged.

4. **Discussion: Next Steps**

There is no plan to reconvene the TAC going forward. The workshop Clayton is organizing may result in next steps. The Interim Measures Implementation Committee (IMIC), which the TAC was formed to represent, is meeting this Thursday (October 23), and will also discuss next steps regarding the proposed DWF.

5. **TAC for Nutrient Reduction Study (IM 11, Activity 7)**

Ken Carlson provided an update on Activity 7. Tests were completed with 4 different agents: Lanthanum-modified bentonite clay (Phoslock™), aluminum-modified zeolite (Z2G1 or Aqual P™), polyaluminum hydroxychloride (PaCl), and alum (aluminum sulfate buffered with sodium aluminate), and 3 different water sources: the Wood River, Upper Klamath Lake near Link River, and Keno Reservoir near Miller Island. Source water collection occurred on July 29th, 2014 and then delivered to the CH2M HILL Applied Sciences Laboratory in Corvallis for bench-scale testing that was completed over the next 2 days.

The data resulting from the laboratory testing is now being analyzed. Of the sources waters that were collected, all 3 had relatively high nutrients as desired for this testing. Total and soluble phosphorus were near peak levels (based on comparison with levels previously measured at the source water locations in other studies). Nitrogen was at slightly higher than average level. There appeared to be a strong algal bloom going on in Upper Klamath Lake, as the source water samples at that location showed a lot of chlorophyll a.

Preliminary data comparisons indicate that all 4 agents that were tested are effective in reducing phosphorus. The preliminary results will be presented to the IMIC on Thursday, October 23. PowerPoint slides presented to the IMIC will be provided to the TAC. The report is scheduled to be completed in late December 2014 or early January 2015. The report will be sent out a report in draft form for comments.

CH2MHILL

*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility Adjacent to the Klamath River*

Technical Advisory Committee (TAC) Meeting #12
October 21 2014

BUILDING SUSTAINABLE SOLUTIONS

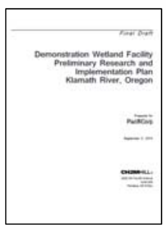
## Study Schedule: 2013-2014

| CC | Topic | Activity | Date |
|---|---|---|---|
| 1 | Initiate discussion on DWF concept | Planning with TAC | Oct 1 |
| 2 | Establish Research Plan format | | Oct 24 |
| 3 | Initiate discussion regarding identification of prospective partners and roles | | Nov 18 |
| 4 | Initiate discussion regarding identification of prospective site(s) | | Dec 17 |
| 5 | Review key topics and analysis approach | | Jan 21 |
| 6 | Finalize topics, sites and partners | Draft by CH2MHILL | Feb 18 |
| 7 | Mid-point progress update on Plan | | Mar 18 |
| 8 | Preview and submit draft Plan | | Apr 20 |
| 9 | Receive, discuss comments on draft Plan | Review by TAC | Jun 17 |
| 10 | Receive, discuss comments on draft Plan – on-site meeting | | Jul 01-02 |
| 11 | Receive, discuss comments on draft Plan | | Jul 22 |
| | Submit Final Research Plan | CH2MHILL | Sep 16 |
| 12 | Discuss Final Research Plan & Next Steps | TAC | Oct 21 |

BUILDING SUSTAINABLE SOLUTIONS 2

## DWF Preliminary Research and Implementation Plan - Contents

- Introduction & Background Review
  - Nutrient Removal Processes
  - Design Factors Affecting Performance
  - Similar Wetland Treatment Projects
- DWF Research and Design Priorities
  - Nutrient Removal and Retention
  - Water Balance Effects on Performance and Sizing
  - Vegetation Effect on Nutrient Removal and Retention
  - Habitat Quality and Faunal Use




BUILDING SUSTAINABLE SOLUTIONS 3

## DWF Preliminary Research and Implementation Plan - Contents

- Demonstration Wetland Facility Description
  - Facility Features, Size, & Configuration
  - Construction & Operation
  - Conceptual Site Locations
  - Costs
- Experimental Design, Data Collection & Analysis
  - Research Needs & Priorities
  - Specific Parameters of Interest
  - Data Analysis

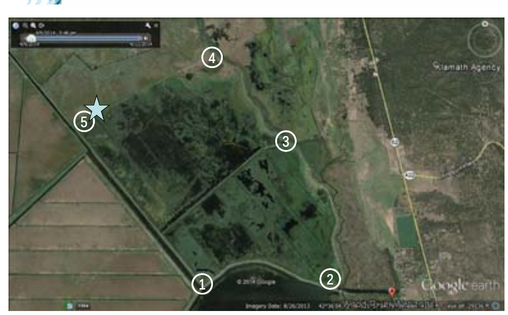
BUILDING SUSTAINABLE SOLUTIONS 4

## TAC Participants – Excellent Coordination & Input!

- **Chauncey Anderson:** US Geological Survey
- **Eli Asarian:** Riverbend Sciences
- **Jessica Asbill-Case:** US Bureau of Reclamation
- **Chelsea Aquino:** US Bureau of Land Management
- **Jim Bays:** CH2M HILL
- **Dan Blake:** US Fish and Wildlife Service
- **Jared Bottcher:** Klamath Basin Rangeland Trust
- **Crystal Bowman:** Karuk Tribe
- **Ken Carlson:** CH2M HILL
- **Rick Carlson:** US Bureau of Reclamation
- **Kurt Carpenter:** US Geological Survey
- **Clayton Creager:** California Regional Water Quality Control Board
- **Mike Deas:** Watercourse Engineering
- **Kris Fischer:** Klamath Tribe
- **Bob Gearhart:** Humboldt State University
- **Micah Gibson:** Yurok Tribe
- **Kyle Gorman:** Oregon Water Resources Dept
- **Mary Grainey:** Oregon Water Resources Dept
- **Andy Hamilton:** Humboldt State University
- **John Hamilton:** US Fish and Wildlife Service
- **Tim Hemstreet:** PacifiCorp
- **Heather Hendrixson:** The Nature Conservancy
- **Brittany Hughes:** CH2M HILL
- **Michael Hughes:** Oregon Institute of Technology
- **Ron Larson:** US Fish and Wildlife Service
- **Jacob Kann:** Aquatic Ecosystem Sciences
- **Nell Kolden:** Klamath Basin Rangeland Trust
- **Linda Prendergast:** PacifiCorp
- **Jed Redwine:** SF Environments
- **Maia Singer:** Stillwater Sciences
- **Kathleen Sloan:** Yurok Tribe
- **Chris Stine:** Oregon Department of Environmental Quality
- **Jane Vorpagel:** California Division of Fish and Wildlife
- **Ted Wise:** Oregon Division of Fish and Wildlife

BUILDING SUSTAINABLE SOLUTIONS 5

## Wood River Wetlands Conceptual Site Locations Were Evaluated and Ranked



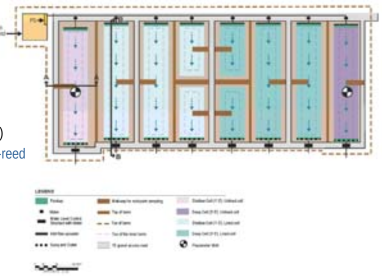

BUILDING SUSTAINABLE SOLUTIONS 6

## DWF Conceptual Placement and Scale




## Multi-Celled Facility to Enhance Research & Demonstration

- Cells w/o bottom liner - 2
- Lined cells – 4
- Duplicate lined sub-cells - 4
- Deep water vegetation (>3 ft)
  - e.g., SAV, Wocus
- Shallow water vegetation (<3 ft)
  - e.g., Cattail, Bulrush, Bur-reed
- Local reference site
- Research facility compound
- Piezometer wells





## Planning-Level Conceptual Cost Estimate

- Total Construction Cost Estimate: $2,275,000
- Class 4 estimate (AACEI): +50% to -30% (in 2016)
- Costs would be refined during further design
- Within cost range of other similarly-sized facilities, but toward the higher part of the range
- Costs can vary significantly based on many factors
  - e.g., construction conditions, earthwork, liner system
- Annual O&M costs not estimated
  - Depends on partners, participants, research projects, etc.



## Next Steps

- This phase of DWF planning is now completed
  - *Thanks again to the TAC!*
- Additional discussion by IMIC is recommended
  - How to identify partners for implementation?
  - How to obtain funding for implementation?
  - Other potential DWF sites?



## Update Nutrient Reduction Study

- Update: TAC for Nutrient Reduction Study (Interim Measure 11, Study 7)



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*Interim Measure 11 Study 2:*
*Planning and Design for a Demonstration Wetlands Facility*
*Adjacent to the Klamath River*

Thank you