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Water Quality Studies for Year 2008
for the Klamath Hydroelectric Project

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PacifiCorp Energy (PacifiCorp) is planning to conduct several water quality studies in the vicinity of the Klamath Hydroelectric Project (Project) from April through December 2008. These studies are described below and include study purpose, approach, and schedule. The studies described in this document will provide information for PacifiCorp's on-going assessment of reservoir management plan (RMP) actions in support of PacifiCorp's applications to the California State Water Resources Control Board (SWRCB) and the Oregon Department of Environmental Quality (DEQ) for water quality certifications for the Project.

The proposed studies described in this document include:

1. Constructed Wetlands Feasibility and Design Assessment
2. Design and Implementation Planning of an Air Injection Diffuser System in J.C. Boyle Reservoir
3. Testing of Turbine Venting for Dissolved Oxygen Enhancement at Iron Gate Powerhouse
4. Additional Pilot Testing of Solar-Powered Circulators in Copco Reservoir
5. Effectiveness Testing of Sodium Carbonate Peroxyhydrate (PAK™27) Applications in Copco and Iron Gate Reservoirs
6. Water Quality Protection (Curtain) in Iron Gate Reservoir in the Vicinity of the Dam Intake
7. Basic Water Quality Monitoring
8. Microcystis and Microcystin Environmental Sampling
9. Automated Continuous Sampling in the Klamath River below Iron Gate Dam

These studies, although listed as discrete elements, have considerable overlap and are intended to be complimentary and integrative where applicable. Further, the field components of these studies may be modified in response to additional information and field conditions experienced during the monitoring.

1. Constructed Wetlands Feasibility and Design Assessment

Purpose

This study will evaluate the feasibility of using constructed wetlands as a potential means for helping to process and reduce loads of nutrients and organic matter to the Project reservoirs from upstream sources. It is the first step in the evaluation process of potentially using constructed wetlands to enhance the water quality in the Klamath River. Prior to any design and construction, this assessment will evaluate site conditions to assess the efficacy of the proposed constructed wetlands.

Approach

The primary focus of the wetlands feasibility assessment is potential treatment wetland sites at the shallower upper ends or embayments of J.C. Boyle, Copco, and Iron Gate reservoir as a potential means for helping to process and reduce a portion of nutrients and organic matter loads to the Project reservoirs from the inflowing river.

Activities performed under this task will include:

- A desk-top analysis and reconnaissance site visit will be conducted to develop a preliminary (rough) estimate of the wetland types, sizes, and locations. The preliminary analysis will also include an associated rough order-of-magnitude estimate of costs. No detailed design, analysis, or testing activities will be performed under this task.

- A site reconnaissance will be done to visit the area and view potential wetlands sites to discuss opportunities and constraints of each potential site. Information gathered at this time will be used to identify preliminary wetland locations for the project. The preliminary wetland locations are subject to revisions based on other site features during the soils and hydro-geological site characterization and modeling results.

- To help characterize the sites of potential treatment wetlands, a review of basic information concerning soil and hydrogeologic characteristics in the potential wetlands areas will be conducted. This information will be obtained through data available from the NRCS soil survey and Final License Application (FLA) materials. To help identify any areas of potential concern to constructed treatment wetlands placement, available information will be reviewed for the possible presence of existing wetlands or sensitive flora and fauna on potential sites.

- A water balance of potential wetlands will be estimated to quantify the water inflows to the constructed wetlands systems from the river and the outflows, including the net losses through evapotranspiration. It is assumed that what is not evapotranspired will be returned to the river (or reservoir) through surface water discharge or indirect discharge through groundwater.

- The treatment capabilities and potential capacity of a constructed wetlands system will be estimated using a numerical wetlands performance model calibrated with applicable Northwest treatment wetlands data, and evaluated based on the layout and the results of the water balance modeling. The treatment modeling will evaluate the

reduction of such parameters as biochemical oxygen demand (BOD) and total suspended solids (TSS). Treatability will be estimated by percent concentration reduction as well as mass load of each constituent into and out of the wetlands.

- Once the various components of the evaluation are complete, results will be analyzed to identity the potential capacity of a treatment wetlands system and the opportunities and constraints associated with that approach to water quality treatment. A preliminary concept layout for the project will be developed for the recommended alternative. An order of magnitude construction cost estimate will be prepared based on the preliminary concepts.

- A technical report of findings and recommendations, including a conceptual layout of the proposed system, will be prepared. The conclusions and recommendations of the feasibility study will serve as a guide for the next phase of project development and construction.

Schedule

Initial assessment period	Spring 2008
Wetland site suitability assessment	Spring 2008
Pre-design, feasibility, and concept development	Summer 2008
Technical report	Fall 2008

2. Design and Implementation Planning of an Air Injection Diffuser System in J.C. Boyle Reservoir

Purpose

This study will develop a conceptual design and implementation plan for an air injection diffuser system in J.C. Boyle reservoir to improve dissolved oxygen and pH in the reservoir's bottom waters. Air injection diffuser systems are the most common water column circulation method (also known as "destratification"). Water column circulation (or destratification) is a technique to improve water quality by eliminating vertical density gradients that lead to low dissolved oxygen concentration in the bottom waters.

Approach

Activities performed under this task will include:

- The spatial variability of dissolved oxygen in J.C. Boyle reservoir will be assessed on two occasions during summer 2008 (i.e., July, August). Systematic in-situ measurements of dissolved oxygen will be collected in J.C. Boyle reservoir to characterize this spatial variability. This data and information will support the conceptual design analysis for the air injection diffuser system.

- The feasibility of oxygenating shallow regions of J.C. Boyle reservoir will be assessed. This assessment will be based on the areas in the reservoir where dissolved oxygen can be enhanced by the air injection diffuser system. These areas will be characterized using the dissolved oxygen spatial data, and other previously collected water quality data and bathymetry. The amount of oxygen and mixing in those areas needed to supply dissolved oxygen demand will be estimated. Recommendations will be developed of estimated times of aeration (e.g., day and/or night, pulses) and locations (e.g., depths, spacing, mixing cell size calculations based on depths).

- Information on a conceptual design for the air injection diffuser system for J.C. Boyle reservoir will be prepared (approximately equivalent to no more than a 15 percent design completion level). The conceptual design will include initial specifications of pipe length, aerator types, and compressor sizes. The conceptual design will depict the size and shape of the aeration array using existing information on the upper reservoir bathymetry and known dissolved oxygen conditions. Initial estimates will be made of air needs, power needs, air compressor sizes and numbers, likely location of compressor(s), and lengths and diameter of air lines.

- A technical report of findings and recommendations, including a conceptual layout of the proposed system, will be prepared. The conclusions and recommendations of the feasibility study will serve as a guide for the next phase of project development and construction.

Schedule

Consultation	Spring 2008
System design and planning	Summer-Fall 2008
Technical report	Winter 2009

3. Testing of Turbine Venting for Dissolved Oxygen Enhancement at Iron Gate Powerhouse

Purpose

In 2005, a turbine venting system was modeled at the Iron Gate powerhouse to estimate air admission rates, dissolved oxygen uptake, and potential total dissolved gas (TDG) for the observed powerhouse operating conditions. Modeled estimates of turbine air admission indicated dissolved oxygen uptake of 1.5 to 2.7 mg/L depending on turbine headcover valve operation and the potential inclusion of baffles. Such uptake could provide an appreciable increase to dissolved oxygen concentration in the tailwaters of Iron Gate dam.

The Final Environmental Impact Statement (FEIS) for the Project issued by the Federal Energy Regulatory Commission (FERC) in November 2007 concluded that turbine

venting would be effective in achieving increases in dissolved oxygen in the Klamath River downstream of Iron Gate dam. On this basis, FERC recommended a measure to include turbine venting and follow-up dissolved oxygen monitoring at Iron Gate. Further testing and evaluation of a turbine venting system at the Iron Gate powerhouse will be conducted to field test and verify air flow and dissolved oxygen increases, and to quantify the effects of the increased air flow on turbine efficiency.

Approach

Activities performed under this task will include:

- Field tests of turbine venting at the Iron Gate powerhouse will be conducted to assess the turbine venting capability and the effect of venting on turbine generator performance. The work includes measurements and analyses to assess turbine efficiency, power output, and turbine venting air flows. It assumed that performance and air admission tests will be conducted at one head. At this head, an efficiency curve of the unit will be developed over a range of gate openings. At each test point, efficiency will be assessed with air admission to the unit off and on, so that the effect of air admission on performance can be quantified.

- During tests, turbine discharge will be measured using either existing Winter-Kennedy taps, or by use of an acoustic flowmeter. Power will be measured using existing plant instrumentation. Air will be admitted to the unit through the headcover using the existing vacuum breaker system, with the air valve control unlinked from the gate ring so that manual control can be achieved. Air flow will be measured using the existing bellmouth intake as a flowmeter.

- During tests, simultaneous measurements will be taken of dissolved oxygen, total dissolved gas (TDG), and water temperature in the Project tailwaters and in the river just downstream. These measurements will provide information on the effectiveness of turbine venting in enhancing water quality.

- A technical report of findings and recommendations will be prepared that compiles the information developed during the turbine venting tests and discusses the results of the turbine venting tests. The conclusions and recommendations of the report will serve as a guide for potential implementation of turbine venting, including recommendations on modifications of valves or intake piping that would be needed to permanently increase turbine venting capacity.

Schedule

Consultation and final planning of tests	Spring 2008
Turbine venting tests and monitoring	Summer 2008
Technical report	Fall 2008

4. Additional Pilot Testing of Solar-Powered Circulators in Copco Reservoir

Purpose

This study will be a pilot-scale testing of solar-powered circulators in Copco reservoir to gain better reliability and effectiveness information for this technology. It will assess operational consistency and reliability in field conditions, and assess water quality improvement in the "treated" area relative to other "untreated" areas, particularly in controlling blooms of blue-green algae such as *Microcystis*.

Approach

Activities performed under this task will include:

- Twelve solar-powered circulators will be deployed in upper Copco reservoir from mid- April through mid-October. Water quality and the presence of *Microcystis* and microcystin will be measured before, during, and after deployment of the circulators in the "treated" and "untreated" areas in Copco reservoir to test for the effectiveness of the circulator's lateral mixing and circulation.
- A technical report of findings and recommendations will be prepared. The conclusions and recommendations of the report will serve as a guide for potential future expanded deployment of circulators in Copco and Iron Gate reservoirs.

Schedule

Final planning of circulator pilot tests	March-April 2008
Circulator deployment, testing, and monitoring	April-October 2008
Technical report	Winter 2009

5. Effectiveness Testing of Sodium Carbonate Peroxyhydrate (PAK™27) Applications in Copco and Iron Gate Reservoirs

Purpose

This study will test sodium carbonate peroxyhydrate (PAK™27) applications as an algaecide in Copco and Iron Gate reservoirs for controlling blooms of blue-green algae such as *Microcystis*. Algaecides are widely used to control algal blooms in reservoirs throughout the United States as well as other countries. Algaecides for the purposes of this study are to assess management of bloom conditions in certain areas of system reservoirs and not elimination of algae. For decades copper-based algaecides were applied to the nation's reservoirs, but recent concerns about metals contamination as well as the non-specific treatment, have led to new technologies. PAK-27 is the outgrowth of such technical advances. PAK-27 is a non-copper based treatment method that targets blue-green algae and acts as both an algaecide and an algaestat (retarding and preventing new growth).

Approach:

Studies will include bench test analyses and local tests at Copco reservoir. Activities will include:

- Bench tests will include applications of PAK-27 to water column samples selected from Copco Reservoir. Replicate samples will be treated with various levels of PAK-27 (and potentially other commercially-available forms of peroxide-based algaecides), and include a blank. Fate of phytoplankton species and microcystin toxin will be assessed, as well as physical and chemical analysis to characterize potential effects on nutrient and dissolved oxygen conditions.
- Tests at Copco reservoir may include use of segregated enclosures adjacent to the reservoir (e.g., limnocorrals, temporary test pools/containers). These tests will be completed with similar measurements to bench tests. This will be used to determine any variability between bench tests and field with varying field conditions.
- A technical report will be prepared to present findings and recommendations. The conclusions and recommendations of the report will serve as a guide for potential future expanded applications of sodium carbonate peroxyhydrate (PAK™27) in Copco and Iron Gate reservoirs.

Schedule

Consultation and final planning	Spring 2008
Test applications and monitoring	Summer 2008
Technical report	Fall 2008

6. Water Quality Protection in Iron Gate Reservoir in the Vicinity of the Dam Intake

Purpose

This task involves the installation of a barrier curtain at the log boom in Iron Gate reservoir in the vicinity of the dam intake. The primary emphasis of this measure will be to enhance water quality near the dam and reduce the potential entrainment into the dam intake of biomass from blooms of blue-green algae such as *Microcystis* and potential associated algal toxins (i.e., microcystin). Water quality will be monitored (as part of the Basic Water Quality Monitoring – see Task 7) during implementation of this measure within and outside of boomed areas in the lower part of the Iron Gate reservoir near the dam intake and downstream of the powerhouse discharge to assess the effectiveness of this measure.

Approach

The technique will involve deployment of a floating boom and barrier curtain upstream of the intake (at the log boom) to prevent drift and accumulation of algae biomass into the reservoir area upstream of the dams and in the vicinity of the dam intake. The curtain will consist of connected panels of impermeable geotextile material suspended to a depth of about 12 feet from a floating boom at the reservoir surface. The boom and curtain will extend across the entire width of the reservoir (approximately 1100 feet) at the current log boom location, which is about 1800 feet upstream of the dam. The curtain is intended to provide a barrier to drift and accumulation near the dam (and power intakes) of algae biomass in the reservoir's photic zone, and especially buoyant algae bloom material at the water surface.

Mechanical removal and disposal of accumulated algae on the upstream side of the boom and barrier curtain may also be needed if appreciable accumulation occurs. If needed, PacifiCorp will ensure timely and proper disposal of accumulated algae materials that are collected.

A technical report will be prepared to present findings and recommendations. The conclusions and recommendations of the report will serve as a guide for potential future continued use of this technique.

Schedule

Final planning and design	March-May 2008
Implementation and monitoring	June-October 2008
Technical report	Winter 2009

7. Basic Water Quality Monitoring

Purpose

This study will monitor basic water quality as a continuation of work carried out since 2001 to describe water quality conditions in the vicinity of the Klamath Hydroelectric Project. The basic monitoring is included as one of the primary water quality measures as described in the J.C. Boyle Reservoir Management Plan and the Copco/Iron Gate Reservoir Management Plan. These RMPs are part of the revised Applications for Water Quality Certification under CWA Section 401 for the Project submitted by PacifiCorp on February 22, 2008. This monitoring will provide additional information for PacifiCorp's on-going assessment of RMP actions in support of water quality certifications for the Project from the California State Water Resources Control Board (State Water Board) and the Oregon Department of Environmental Quality (DEQ).

Approach

Basic water quality monitoring will be conducted to describe water quality conditions in the Project vicinity and to monitor water quality during the performance of other field studies (as described above). Basic water quality monitoring will be conducted at 13 locations, consisting of nine river sites and four reservoir sites, including:

- Link River
- Klamath River below Keno dam
- Klamath River above J.C. Boyle reservoir
- J.C. Boyle reservoir at the lower end near the log boom
- Klamath River below J.C. Boyle powerhouse
- Klamath River above Copco reservoir (above Shovel Creek)
- Copco reservoir at the lower end near the log boom
- Klamath River below Copco No. 2 powerhouse
- Iron Gate reservoir at the lower end near the log boom
- Iron Gate reservoir inside the log boom near the dam[1]
- Klamath River below Iron Gate dam
- Klamath River at the I-5 rest area
- Klamath River at Walker Road Bridge

Samples and measurements will be taken at 13 sites once per month in April, May, October, November, and December, and twice per month (i.e., every other week) in June through September. There will be a total of 14 sampling events. Sampling will include instantaneous acquisition of physical parameters (with multi-probe instrumentation) at each of the 13 sampling sites. The acquisition of physical parameters will include measurements of water temperature, dissolved oxygen, pH, and specific conductance. These measurements will be taken at the reservoir sites as profiles (at 1 to 3-meter intervals depending on total depth) and at the river sites just beneath the surface (approximately 0.5 m depth). Secchi disk measurements will also be taken at reservoir sites.

Sampling also will include grab samples immediately following the physical measurements at the 13 sites for laboratory analysis of water chemistry. Water chemistry samples from the river sites will be taken in the current at approximately 0.5 meter below the surface. Water chemistry samples from J.C. Boyle reservoir will be taken from two depths: at approximately 0.5 meter below the surface and at a depth approximately 1 meter above the bottom. Water chemistry samples from Copco reservoir will be taken from four depths: at approximately 0.5 meter below the surface and at depths of approximately 9, 18, and 27 meters. Water chemistry samples from Iron Gate reservoir will be taken from five depths: at approximately 0.5 meter below the surface and at depths of approximately 10, 20, 30, and 40 meters. Water chemistry samples will be analyzed for nutrients, including ammonia (NH3), nitrate + nitrite (NO3 + NO2), total nitrogen (TN) (or total Kjeldahl nitrogen [TKN]), total phosphorous (TP), and

[1] The site in Iron Gate reservoir inside the log boom near the dam is a new site being added in 2008 to the Basic Water Quality Monitoring program to monitor conditions inside the barrier curtain that PacifiCorp plans to deploy at the log boom during 2008 to enhance water quality in the vicinity of the power conduit intake (see Task 6).

orthophosphate (OP). These samples will also be analyzed for total suspended solids (TSS), volatile suspended solids (VSS), dissolved organic carbon (DOC), turbidity (TURB), apparent color (COLORA), and total alkalinity (ALKT).

Sampling also will include grab samples for laboratory analysis of phytoplankton at nine of the 13 sites, including six of the nine river sites and three of the four reservoir sites. The six river sites include Link River, below Keno, above Shovel Creek, below Iron Gate dam, at the I-5 Rest area, and at Walker Road Bridge. The three reservoir sites include the site in Copco reservoir and both sites in Iron Gate reservoir. (Note: Additional samples will be taken at other sites in Copco and Iron Gate reservoirs to monitor the presence and quantities of *Microcystis* and associated microcystin toxins as described in Task 8 below). Phytoplankton samples from the river sites will be taken as grab samples offshore in the current at approximately 0.5 meter below the surface. At each of the reservoir sites, two phytoplankton samples will be taken: (1) an integrated vertical sample from the surface, and (2) a horizontal integrated below the surface. Grab samples for laboratory analysis of phytoplankton will be analyzed for chlorophyll-*a*, algae speciation, density, and biovolume, as well as microcystin (using the ELISA method).

A memorandum summarizing the results of the most recent chlorophyll-*a*, *Microcystis*, and microcystin sample analysis will be produced every two weeks (see Task 8: *Microcystis* Sampling). A final technical report describing the results and interpretation of data will be prepared after the conclusion of the sampling effort. The results of the monitoring program will be used to assess the water quality conditions in the Project area and to examine trends and relationships in these water quality conditions.

Schedule

Planning and preparation	Spring 2008
Monitoring and analysis	April 2008-Winter 2009
Technical report	Winter 2009

8. *Microcystis* and Microcystin Environmental Sampling

Purpose

This study will monitor the presence and quantities of *Microcystis* and associated microcystin toxins in conjunction with the Basic Water Quality Monitoring (Task 7) in the vicinity of the Klamath Hydroelectric project.

Approach

Microcystis and microcystin levels will be monitored in conjunction with the Basic Water Quality monitoring (Task 7). The Basic Water Quality monitoring will test for *Microcystis* and microcystin at nine sites as described above in Task 7. Under Task 8, additional focused monitoring of *Microcystis* and microcystin will occur at 12 additional sites, including:

- Four shoreline sample locations in coves in Copco and Iron Gate reservoir (i.e., two cove sites in each reservoir). These will be similar to sites as monitored in previous years by the Karuk Tribe.
- Four shoreline sample locations in selected coves in the lower basin of Upper Klamath Lake.
- Four open-water sample locations in the vicinity of solar-powered circulators deployed in the upper end of Copco reservoir during 2008 (in conjunction with Task 4: Additional Pilot Testing of Solar-Powered Circulators in Copco Reservoir).

Samples will be taken at the shoreline cove sites in the reservoirs and lake once per month in April, May, November and December, and twice per month in June through September. At these shoreline cove sites, grab samples will be taken at the water surface.

Samples from the open-water sample locations in the vicinity of solar-powered circulators in Copco reservoir will be taken once per month in April, May, June, November and December, and twice per month in July through September. At each of these open-water locations, two phytoplankton samples will be taken: (1) an integrated vertical sample from the surface, and (2) a horizontal integrated transect below the surface..

Phytoplankton samples will be analyzed to enumerate *Microcystis*, as well as other species (e.g., *Aphanizomenon flos-aquae*). The samples will also be analyzed for microcystin content using the ELISA immunoassay method. The microcystin samples will be analyzed within 48 hours, allowing for prompt assessment of conditions in Copco and Iron Gate reservoirs.

A memorandum summarizing the results of the most recent *Microcystis* and microcystin sample analysis will be produced every two weeks (see Task 7: Basic Water Quality). A final report of the results and interpretation of data will be prepared after the conclusion of the sampling effort.

Schedule

Planning and preparation	Spring 2008
Monitoring and analysis	April 2008-Winter 2009
Technical report	Winter 2009

9. Automated Continuous Sampling in the Klamath River Below Iron Gate Dam

Purpose

An automated sampling station will be installed in the Klamath River below Iron Gate dam to continuously measure water and record water quality data on an hourly basis via a multi-parameter datasonde (e.g., YSI 6920V2).

Approach

The datasonde will be equipped to measure water temperature, pH, dissolved oxygen, conductivity, and blue-green algae (using a phycocyanin fluorescence sensor). The datasonde will be downloaded on a weekly to twice-monthly basis. Data will be compiled into a database or spreadsheet format, and will be posted on PacifiCorp's relicensing website on a monthly basis. (Note: posted data will be provisional pending final quality review and notification).

A report will be prepared that presents and discusses the data and summarizes pertinent data issues. The report will include tabulations and plots of the data, such as hourly time-series plots of the data and plots or tables of daily maximum, mean, and minimum values calculated from the hourly data.

Schedule

Planning and preparation	Spring 2008
Installation, monitoring, and analysis	April-November 2008
Technical report	Winter 2009