TECHNICAL MEMORANDUM

Interim Measure 11, Activity 7 – Assessment of Potential Algae Harvesting and Removal Techniques at Link River Dam

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1.0 Introduction

The Klamath Hydroelectric Settlement Agreement (KHSA) includes Interim Measure 11 (Interim Water Quality Improvements), which is intended to address water quality improvement in the Klamath River during the interim period leading up to potential dam removal. Several Interim Measure 11 activities were conducted during 2015 and extending into 2016, which included Activity 7 "Assessment of Potential Algae Harvesting and Removal Techniques at Link River Dam". Link River Dam is located at the outflow of Upper Klamath Lake at River Mile (RM) 254.3. The discharges from Link River Dam enter the short 1.2-mile Link River and then into Keno reservoir, which is located on the upper Klamath River from RM 233.0 (at Keno dam) to RM 253.1 (Figure 1). The technical memorandum describes the approach and results of IM 11 Activity 7.

1.1 Purpose

The purpose of Activity 7 was to conduct an assessment of potential algae harvesting and removal techniques at Link River Dam as a possible method for enhancing water quality in Keno reservoir and the downstream Klamath River. Algae harvest is a topic of interest to the Interim Measures Implementation Committee (IMIC) as a potential means to improve quality of water being released from Upper Klamath Lake. The removal of organic matter loads (from the harvesting of algae) emanating from Upper Klamath Lake could provide substantial water quality improvements in the Klamath River, and especially in Keno reservoir, which is just downstream of Upper Klamath Lake (Figure 1).

1.2 Background

As stated above, algae harvest at Link River Dam is of interest to the IMIC as a possible method for reducing organic matter loads emanating from Upper Klamath Lake with the intent of improving water quality improvement in Keno reservoir and the downstream Klamath River. This section provides background on conditions in Keno reservoir, where water quality conditions are most severely affected by these algae-based organic matter loads.

Keno reservoir extends 20 miles from the headwaters of Lake Ewauna (RM 253.4) to Keno dam (RM 233.3). The impoundment is generally a broad, shallow body of water. The width of the reservoir in this reach ranges from several hundred to over 1,000 feet, with maximum depths along its length ranging from less than 6 feet to approximately 20 feet (Eilers 2005). Municipal, industrial, and agricultural activities are located along this reach (ODEQ 2010).

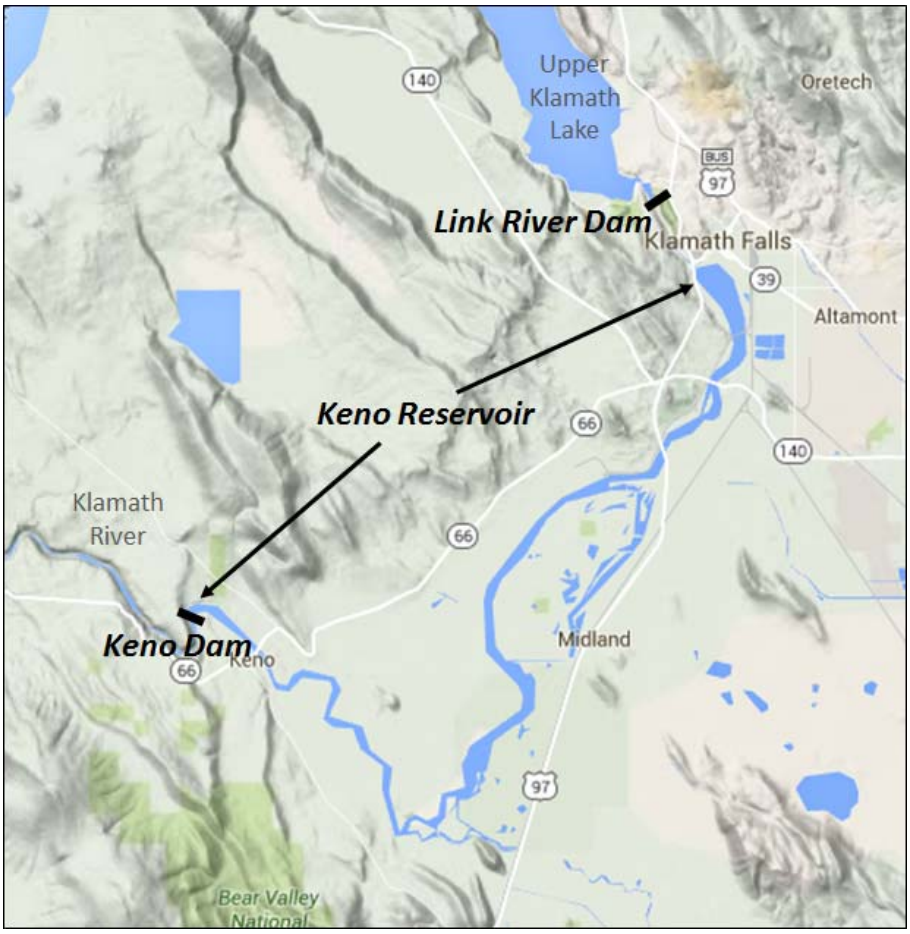

Figure 1. Link River Dam and Keno Reservoir Locations

Currently, Keno reservoir experiences severe seasonal water quality impairment. These impairments include summer and fall anoxia in the reservoir caused primarily by the substantial oxygen demand from the large organic matter loading from Upper Klamath Lake (Sullivan et al. 2010; Sullivan et al. 2011; Sullivan et al. 2013). In addition to the organic matter loading from Upper Klamath Lake, the agricultural return flows from the U.S. Bureau of Reclamation's Klamath Project also contribute loads (although lesser) of nutrients, total dissolved solids, and biochemical oxygen demand (BOD; ODEQ 2010).

Sullivan et al. (2010) report that the large organic matter loading causes substantial oxygen demand in Keno reservoir. Sullivan et al. (2010) measured large oxygen demand values in Keno reservoir, including 5-day BOD values ranging from 4.2 to 26.5 milligrams per liter (mg/L) and 30-day BOD values ranging from 13.6 to 55.4 mg/L. Most pristine rivers have a 5-day BOD below 1 mg/L, and moderately productive rivers generally have a BOD value in the range of 2 to 8 mg/L (Manivanan 2008). Typical treated municipal sewage has values of about 10 to 40 mg/L (Spellman 2013).

The substantial oxygen demand in Keno reservoir has been well-documented previously. In 1955, the State of Oregon (Oregon State Sanitary Authority et al. 1955) concluded that the large nutrient load and oxygen demand from the Upper Klamath Lake outflow cause severe downstream impacts that are "equivalent to the raw sewage from a population of more than 240,000 persons" but that "94 percent of BOD is derived from natural causes" where the term "natural causes" was referring to algae bloom materials.

The large organic matter loading from Upper Klamath Lake to Keno reservoir also has important implications for processing of nutrients and growth of algae in Keno reservoir (Sullivan et al. 2010). The

organic matter takes on one of several forms (labile, refractory, particulate, and/or dissolved), and includes organic forms of nutrients (nitrogen and phosphorus). These nutrients are transported downstream and upon decay of the organic matter are released and available for uptake by local phytoplankton and benthic algae populations (Sullivan et al. 2010, Sullivan et al. 2011). One of the most notable aspects of the reach is the large amount of inorganic nutrients present during periods of anoxia (e.g., total inorganic nitrogen [nitrate and ammonia] is in excess of 1 mg/L, and orthophosphate values are in excess of 0.5 mg/L) (Deas 2008).

During summer and early fall, Keno reservoir can experience extensive algal standing crop. This standing crop benefits from in-reservoir processing of nutrients, as well as wash-in of algae from Upper Klamath Lake. Maximum concentrations of chlorophyll *a* at Link River can reach 250 micrograms per liter (µg/L), while concentrations in the Klamath River downstream of Keno dam are generally well under 100 µg/L (Deas 2008, Sullivan et al. 2010, Sullivan et al. 2011).

2.0 Approach

PacifiCorp, in consultation with the IMIC, determined that the evaluations necessary for Activity 7 would benefit from an initial investigation and information gathering exercise along with stakeholder outreach to answer key questions before proceeding to more-detailed study or pilot assessment, if warranted. This investigation focused on those questions necessary to address: (1) the overall feasibility of algae harvest at Link River Dam (Priority 1 Questions: Drivers of Feasibility): (2) the types and sizes of systems need to accomplish the algae harvest (Priority 2 Questions: Drivers of Scope, Size, and Type of System Needed); and (3) the various process steps needed to implement the algae harvest and determine disposition of harvest materials (Priority 3 Questions: Important Process-Related Steps).

A Technical Advisory Committee (TAC) subgroup of the IMIC was convened to provide input on the Priority 1, 2, and 3 questions. TAC meetings (conference calls) were held on August 20, 2015, September 17, 2015, February 11, 2016, and March 2, 2016 to discuss answers to these questions. All TAC meetings were facilitated and documented by CH2M. An additional meeting (conference call) was held on September 3, 2015 by a TAC sub-group to specifically address potential regulatory requirements of the Endangered Species Act (ESA) that may be applicable to an algae harvesting endeavor. TAC meeting participants are listed in Table 1. Detailed notes from each TAC meeting are attached in Appendix A.

Based on the above activities, this technical memorandum has been prepared to describe information and input obtained on the Priority 1, Priority 2, and Priority 3 questions, and other related findings or recommendations. A draft of this report was circulated to the IMIC for review on April 13, 2016. Comments subsequently received from IMIC members were reviewed by PacifiCorp and the draft report was revised as appropriate; all comments and responses are included in Appendix B.

Table 1. Participants in TAC Meetings

Participant	Organization
Jake Kann	Aquatic Ecosystem Sciences (AES)
Jim Carpenter	Carpenter Design
Brittany Hughes	CH2M
David Austin	CH2M
Ken Carlson	CH2M
Susan Corum	Karuk Tribe
Doug Jackson	New Earth
Jerry Anderson	New Earth
Clayton Creager	North Coast Regional Water Quality Control Board (RWQCB)
Elyse Will	North Coast Regional Water Quality Control Board (RWQCB)
Chris Stine	Oregon Department of Environmental Quality (ODEQ)
Mike Hiatt	Oregon Department of Environmental Quality (ODEQ)
Ted Wise	Oregon Department of Fish and Wildlife (ODFW)
Mary Grainey	Oregon Water Resources Department (OWRD)
Demian Ebert	PacifiCorp
Tim Hemstreet	PacifiCorp
John Rueter	Portland State University (PSU)
Eli Asarian	Riverbend Sciences
Parker Thaler	State Water Resources Control Board (SWRCB)
Maia Singer	Stillwater Sciences
Rick Carlson	U.S. Bureau of Reclamation (USBR)
Dan Blake	U.S. Fish and Wildlife Service (USFWS)
Darrick Weissenfluh	U.S. Fish and Wildlife Service (USFWS)
John Hamilton	U.S. Fish and Wildlife Service (USFWS)
Chauncey Anderson	U.S. Geological Survey (USGS)
Mike Deas	Watercourse Engineering
Micah Gibson	Yurok Tribe

3.0 Assessment Findings

Assessment findings are described in the following sections by question within the Priority 1, Priority 2, and Priority 3 groups of questions. Findings are described in bulleted statements with references to source information, including reports and specific TAC meetings when discussed. Additional details are provided in the notes of the TAC meetings themselves (Appendix A).

3.1 Priority 1 Questions: Drivers of Feasibility

3.1.1 What quantity of algae biomatter would need to be removed to significantly reduce loading and enhance water quality?

- As used in this question, "enhance[ment]" of water quality refers to reductions in organic matter that are sufficient to decrease nutrients and biochemical oxygen demand to levels that demonstrably improve dissolved oxygen (DO) and lessen enrichment downstream. (TAC Meeting of August 20, 2015)
- The TAC discussed that algae harvest and removal at Link River dam would be just one of many technologies that likely will need to be used to enhance water quality in the Klamath River. Algae harvest and removal at Link River dam would not itself resolve the DO or downstream nutrient-loading problems, but could provide some incremental improvement. (TAC Meeting of August 20, 2015)
- Eli Asarian (Riverbend) mentioned that the TAC might want to consider several different end points for the nutrient and organic matter reduction at the outlet of Keno dam. The report by Sullivan et al. (2013) has tables in the appendices that talk about the nutrients. This would result in a range of outcomes rather than a set number. A good outcome would be removal of 50 percent of the organic matter; however, we're likely going end up doing as much as is feasible. A substantial portion of the nutrients are in dissolved form, so even substantial removal of algae may not result in significant nutrient reductions. (TAC Meeting of September 17, 2015).
- Regarding the suggestion of removing as much organic matter as feasible, John Rueter (PSU) said that there may be a scale of an activity that is more feasible than another. For example, regarding algae biomass removal, the size of the operation could become infeasible at some point because of material disposal and transport requirements. (TAC Meeting of September 17, 2015).
- Mike Deas (Watercourse) said that the previous model simulations (as presented by Sullivan et al. 2013) found that organic matter reductions in the 5-8 percent range didn't demonstrably improve water quality, but with removal in the 15-25 percent range, there was a notable effect downstream. (TAC Meeting of August 20, 2015)
- Sullivan et al. (2013) used hydrodynamic and water-quality modeling to study how various actions could affect water quality in the reach from Link River dam to Keno dam. The study used a previously developed and calibrated CE-QUAL-W2 model of the Link-Keno reach developed by the U.S. Geological Survey (USGS), Watercourse Engineering Inc., and the Bureau of Reclamation for calendar years 2006–09 (referred to as the "USGS model"). One of the actions evaluated included Scenario 6, which assumed a decrease of 25 to 90 percent of algae and particulate organic matter in Link River to assess downstream water quality effects. Model results indicated that removal of algae and particulate organic matter at the Link River inflow could improve water quality in the Link-Keno reach, appreciably increasing dissolved oxygen and decreasing nutrients and chlorophyll a. However, the model results indicated downstream pH may remain high in summer.

- Scenario 6 (Sullivan et al. 2013) includes results only for assumed removal period of June 15-October 31, because removing material for the entire year had only a small additional benefit compared to treatment for the primary growth period of June–October.
- Scenario 6 (Sullivan et al. 2013) modeling results indicate appreciable dissolved oxygen improvements, including increasing concentrations by up to 0.9 mg/L with 25 percent removal, up to 1.9 mg/L with 50 percent removal, and up to 3.9 mg/L with 90 percent removal (Table 2). The model results also suggest that if Link River particulate removal was the selected treatment option, removal of close to 90 percent of material, depending on year, may be required to bring Keno reach DO concentrations to meet the DO criteria.
- Scenario 6 (Sullivan et al. 2013) modeling also predicts decreased concentrations in most nutrients. At 25 percent algae and particulate load removal, total phosphorus (TP) concentrations are predicted to decrease by up 7 percent, total nitrogen (TN) by up to 9 percent, ammonia (NH3) by up to 10 percent, and orthophosphate (PO4) by up to 4 percent (Sullivan et al. 2013, Table A6). At 50 percent algae and particulate load removal, TP concentrations are predicted to decrease by up 14 percent, TN by up to 18 percent, NH3 by up to 24 percent, and PO4 by up to 7 percent (Sullivan et al. 2013, Table A6). At 90 percent algae and particulate load removal, TP concentrations are predicted to decrease by up 25 percent, TN by up to 34 percent, NH3 by up to 49 percent, and PO4 by up to 14 percent (Sullivan et al. 2013, Table A6). With assumed algae and particulate load removal, nitrate (NO4) concentrations are predicted to increase, by up to 25, 48, and 67 percent at 25, 50, and 90 percent-removals, respectively, due to more prevalent oxic conditions that would occur with removal.

Table 2. Summary of June 15-October 31 Scenario 6 Model Results from Sullivan et al. (2013) (The load-related values of algae and particulate organic matter (in metric tons) are in terms of dry weight and do not include any associated water weight).

Year	Scenario	Total Load (metric tons)	Percent Removal	Load Decrease (metric tons)	Load Decrease (metric tons/day)	Dissolved oxygen (mg/L)	pH	Total P (mg/L)	Total N (mg/L)	Chlorophyll a (µg/L)
2006	Base case	4,792	0	0	0.0	4.4	8.3	0.224	2.270	84.1
2006	25% decrease	4,792	25	1,198	8.6	5.2	8.5	0.215	2.120	66.9
2006	50% decrease	4,792	50	2,396	17.2	5.9	8.7	0.206	1.950	48.8
2006	90% decrease	4,792	90	4,313	31.0	7.1	8.9	0.192	1.660	16.5
2007	Base case	4,717	0	0	0.0	4.6	8.2	0.247	2.500	85.0
2007	25% decrease	4,717	25	1,179	8.5	5.4	8.4	0.237	2.320	68.2
2007	50% decrease	4,717	50	2,359	17.0	6.2	8.6	0.226	2.130	50.0
2007	90% decrease	4,717	90	4,245	30.5	7.5	8.9	0.210	1.760	15.6
2008	Base case	7,080	0	0	0.0	3.2	8.4	0.217	2.320	67.0
2008	25% decrease	7,080	25	1,770	12.7	4.0	8.6	0.204	2.130	53.8
2008	50% decrease	7,080	50	3,540	25.5	5.1	8.9	0.191	1.920	39.8
2008	90% decrease	7,080	90	6,373	45.8	6.9	9.3	0.170	1.550	13.7
2009	Base case	7,520	0	0	0.0	2.9	8.2	0.194	2.200	43.3
2009	25% decrease	7,520	25	1,880	13.5	3.7	8.4	0.180	2.010	35.3
2009	50% decrease	7,520	50	3,760	27.1	4.8	8.6	0.167	1.810	26.8
2009	90% decrease	7,520	90	6,768	48.7	6.8	9.0	0.145	1.450	10.8

- Watercourse Engineering (2015) assessed the feasibility of using continuous deflective separation (CDS) technology to remove particulate organic matter (primarily consisting of algae biomatter) from the Klamath River just downstream of Link Dam. CDS separators are gravity-driven separators consisting of a specifically-designed round vault and screen through which

treated waters travel in a circular (vortex) fashion to effectively screen, separate, and trap suspended material. CDS separators are most commonly employed in municipal stormwater treatment systems to remove coarser particulates.

- Watercourse Engineering (2015) tested a prototype CDS system and concluded that a full-scale CDS removal system assumed to be operating for several months at flow rates typical of Link River in the algae growth period (e.g., 1,000 cubic feet per second [cfs]) could remove a considerable mass of particulate organic matter on the order of 15 to 25 percent.
- Watercourse used modeling to assess the potential water quality effects of 20-, 30-, and 40-percent reductions. Spatially, modeling indicates that positive impacts on the reservoir are in the same ballpark as those presented in Sullivan at al. (2013), but the Watercourse (2015) report presents some different spatial and temporal information.
- The Watercourse (2015) modeling results suggest that while the reductions in carbon are notable, on the order of hundreds of tons. Locations in Keno Reservoir near Link River have the largest changes for all modeled constituents except DO. The model estimates reductions in BOD, TN, and TP on the order of 15 to 25 percent. Increases in DO of over 1 to 2 mg/L in lower reaches of Keno Reservoir represent a notable improvement in water quality for the reservoir given the very low DO concentrations (including anoxia) that can be observed in Keno Reservoir during the algae growth season. However, even at the highest assumed 40-percent reduction, these modeling results suggest that other actions will likely be needed in addition to particulate organic matter (algae biomatter) removal in order to achieve significant and lasting water quality improvements in Keno Reservoir and downstream Klamath River reaches.
- **Answer:** Modeling (Watercourse 2015; Sullivan et al. 2013) showed a notable downstream improvement in water quality at the 25 percent removal level. However, modeling also indicates that removal of close to 90 percent of material, depending on year, may be required to bring Keno reach DO concentrations in compliance with the DO criteria, if Link River particulate removal were the sole treatment approach. Therefore, as the TAC presumes, algae harvest and removal at Link River dam would be just one of many technologies that likely will need to be used to enhance water quality in Keno reservoir and the Klamath River. Removing 50 percent or more of the material would likely require an extensive facility capable of handling this increased volume. As discussed in section 3.1.2 below, for planning purposes it may be worth considering just the 25 percent removal rate since the 50 percent facility would occupy a large area that is not immediately available.

3.1.2 Are technologies or types of systems available to remove algae biomatter at the scale required?

- Doug Jackson (New Earth) said that an algae harvesting collection system was built in the 1990s at a location where A Canal ends and splits into the B and C canals. Average flow was about 750 cfs and the peak flow was about 1,000 cfs. The facility operated from June to October each year. The average harvest of algae biomass was about 200,000 pounds per day (ppd). Doug said that the 200,000 ppd is the wet weight, with about 94 percent of the extracted algal material consisting of intracellular liquid. (TAC Meeting of August 20, 2015)
- Doug Jackson (New Earth) said that the A Canal algae harvesting collection system included a dewatering process whereby the water was filtered through an initial mechanical screen, which produced a slurry with about a 1 percent solids concentration (about the consistency of honey). An additional dewatering step was then used to further concentrate the material to a thick paste at about 6 percent solids concentration. (TAC Meeting of August 20, 2015)

- Regarding screen sizes needed to target algae removal, Doug Jackson (New Earth) commented that there will be a need to examine the mix of algae collected and that there will be variation in the mix depending upon the time of year. The percent solids and toxin levels will also vary seasonally because the process would remove all different kinds of algae at the same time. Removal of the zooplankton *Daphnia*, which is a food source for fish, will likely be unavoidable and the effects may also need to be examined. (TAC Meeting of August 20, 2015)

- Jerry Anderson (New Earth) commented that removal of 20 percent of the algae may be achievable, however 50 percent may not be (it's a question of system efficiency and economics). The benefit of doing the algae removal at the Link River is the narrow channel that allows easier removal of the algae material. Harvested biomass may have commercial applications such as health supplement, food ingredient, livestock feed and/or soil amendment. Biomass commercial use is highly dependent on the biomass composition. Jerry and Doug have recently developed a new proprietary screening technology (patent pending) and could look at adapting that technology to a stationary site such as at Link River dam. There would be a dewatering process required. (TAC Meeting of September 17, 2015).

- Doug Jackson (New Earth) indicated that he is not aware of a system that is available or has been used that might remove loads at 20 to 25-percent range of the algae biomatter load (as dry weight) that is in the discharge from Upper Klamath Lake. Doug said that the A Canal harvesting system was the largest system he is aware of, harvesting at a rate of about 200,000 pounds per day of wet algae biomass, which is estimated to be equivalent to about 12,000 pounds dry weight, by processing 1,000 cfs. (TAC Meeting of February 11, 2016). This is roughly equivalent to about 2 to 4 tanker trucks per day (assuming tanker trucks with typical capacities ranging from 5,500 to 11,600 gallons).

- Harvesting at a rate of 12,000 pounds per day of algae biomass (in dry weight) is equivalent to about 5.4 dry metric tons per day. By comparison, the Sullivan et al. (2013) model results indicate that an average of about 10.8 dry metric tons per day of algae and particulate organic material would needed to be removed to generate a 25 percent reduction (i.e. average of 1,506 metric tons load decrease at 25 percent removal as listed in Table 2 divided by the number of days from June 15 to October 31). Therefore, the system described by Doug Jackson (New Earth) is roughly half of the processing capacity needed to achieve the 25 percent reduction level as assumed by Sullivan et al. (2013).

- Ken Carlson (CH2M) said that the technological means are probably available to build a system to remove 20 to 25-percent if money were no object. As such, feasibility probably comes down to cost rather than available technological capability. Ken also noted that there is more to an algae harvest strategy than just the removal piece. Processing, transportation, and disposal are all crucial items. It appears 20 to 25-percent removal may be feasible, but 50-percent is likely not because it would require removal of about 21.7 dry metric tons per day of material (i.e. average of 3,014 metric tons load decrease at 50 percent removal as listed in Table 2 divided by the number of days from June 15 to October 310). This is equivalent to a system with about 4-times the processing capacity of that described by Doug Jackson. (TAC Meeting of February 11, 2016).

- Tim Hemstreet (PacifiCorp) commented that the logical next step is to lay out what would be required for a pilot and to understand how you assess whether a pilot project would be useful. We need to understand what a system would look like and require (including for transport, disposal, permitting, etc.) to achieve 20 to 25-percent algae removal. (TAC Meeting of February 11, 2016).

- **Answer:** The technology is available to build a system to remove 20 to 25-percent of the algae load. This basically includes a fish-screened intake, water/algae separation screens, slurry

handling pumps, etc. Overall feasibility will probably come down to cost and space for a facility rather than available technological capability. Processing, transportation, and disposal are all crucial items that need to be factored into an overall feasibility discussion.

3.1.3 What would be the disposition or disposal needs of the removed algae biomatter? Is release to the A Canal an acceptable approach? Are there other options (e.g., land application) to dispose of the removed algae biomatter?

- The TAC discussed that the A Canal is already an impaired waterway. Any additional load from the harvested algae biomatter that goes into A Canal could generate water quality issues. The additional load to the Lost River system would need to be evaluated with the existing loading. To add additional substantial volume of biomass in the Lost River system could lead to additional water quality impairment in that system. Overall, A Canal was not considered a feasible option for disposal. (TAC Meeting of August 20, 2015)
- Jerry Anderson (New Earth) commented that some times of the year the species of algae that is removed from the water could be used commercially. However, there are other times of the year where there may be toxic algae present and disposal would need to be considered. Doug Jackson (New Earth) said that the mix of algae would depend on the time of year, and there is a potential for toxins to be involved. Jerry Anderson said that if algal toxins are present, the handling and disposal of the removed material is more challenging. (TAC Meeting of September 17, 2015).
- Mike Hiatt (ODEQ) said that there is another possible option for disposal of the material. A composting facility is being proposed just north of the state-line along the highway. It would be a large facility. Mike has spoken with the individual who is putting the facility together. It would be a little bit of a drive for transportation (17 miles). The composting facility has people who want the material to amend their soil and they are currently putting together a list of what the facility would accept. Ken Carlson asked if the facility is being set-up to take algal material. Mike Hiatt said the facility is being proposed with a large lagoon system and a compost pile that is composed of manure and other materials received throughout the area. Lagoon materials would be used to apply to the compost pile to help with the degradation process. Mike Hiatt said he would check in with the composting facility and get some further information and details on how this material looks to them and if they might be interested in a pilot study on toxin degradation. Mike said he believes toxins would be broken down through the composting process. The end user is the agricultural community. (TAC Meeting of February 11, 2016).
- **Answer:** Because of water quality concerns, disposal of algae slurry to A Canal is not considered a feasible option. Other options for disposal include a commercial composting facility that is being planned nearby, commercial uses (see Section 3.2.4), or commercial landfill. Knowing the long-term toxicity of harvested algae would help refine these answers.

3.1.4 What is the potential for take of ESA-listed species associated with algae removal? Can incidental take authorization be obtained and what would be the likely mitigation requirements?

- Incidental take authorization or permit (ITP) would be needed for a proposed action with the potential to affect an ESA-listed species. The need for an ITP and the associated type of ESA-related analysis will depend on the type and location of the proposed action to be taken. For example, where would the proposed action be located relative to presence of adult or juvenile suckers? How might the proposed action affect habitat and water quality conditions for adult or juvenile suckers? (TAC Meeting of August 20, 2015; TAC subgroup conference call with U.S. Fish and Wildlife Service (USFWS), September 3, 2015)

- Incidental take authorization would be obtained using one of two ESA-related processes. If a federal agency takes the lead, consultation under Section 7 of the ESA would be used, involving preparation of a Biological Assessment (BA) by the federal lead agency (or their designated representative) and the preparation of a Biological Opinion (BO) by USFWS. For an action lead by a non-federal entity, consultation would occur under the ESA Section 10 process, involving preparation of a Habitat Conservation Plan (HCP) by the non-federal entity and the preparation of a BO by USFWS. In approximate terms, the ESA Section 7 process could be expected to take about 5 months and the ESA Section 10 process about 2 years, so the proposed action would need to plan for this in the overall timeline. (TAC subgroup conference call with USFWS, September 3, 2015)
- The USFWS BO would estimate incidental take at the individual and cumulative population levels. As part of the consultation process, the USFWS would determine if there would be potential for the action to jeopardize continued existence of the species. Algae removal could cause harm (e.g., via screening and entrainment) but should also benefit suckers by improving downstream water quality conditions, so analysis of the action should account for both positive and negative effects. If strong benefits can be shown, then incidental take authorization is more likely but USFWS would require a level of confidence and certainty about the benefits shown. (TAC subgroup conference call with USFWS, September 3, 2015)
- From the standpoint of a conceptual algae harvest/removal facility located at or near the Link Dam outlet, the concerns would be primarily the entrainment of juvenile/larval suckers emigrating from Upper Klamath Lake. It would be prudent to think of what could be done with the conceptual facility design and operations to avoid or minimize potential entrainment and screening of juvenile/larval suckers. Conceptually, a pilot project would have a relatively small level of take and could perhaps be authorized. A full scale system would have a proportionately higher level of take and require substantially more time and work to authorize. (TAC subgroup conference call with USFWS, September 3, 2015)
- Some already-developed tools are available from USFWS for estimating potential entrainment and take based on conceptual flow volumes that might be screened by an algae harvest/removal system. These tools would provide an initial estimate of negative effects of alternative systems that could be used for planning purposes. There are no existing tools to assess potential positive effects, making this portion of the evaluation more challenging. (TAC subgroup conference call with USFWS, September 3, 2015)
- The fate of larvae and juveniles that pass downstream of Link River dam is not well known, but as they move further downstream the suckers are considered lost from the reproducing population. Because the suckers downstream of Link River dam are considered lost, this impact to the population from an algae harvest/removal facility may be lower at this location. On the other hand, an algae harvest/removal system located on the open lake would potentially affect the reproducing population and could have a correspondingly higher level of impact. Even if a proposed project does have a high enough level of effect to lead the USFWS to make a jeopardy determination, the USFWS BO will contain appropriate terms and conditions that the proposed project that would need to be complied with. (TAC subgroup conference call with USFWS, September 3, 2015)
- Darrick Weissenfluh (USFWS) commented that it is important to realize that Upper Klamath Lake, Link River, and Keno Reservoir are considered critical sucker habitat. It is too early for USFWS to make an effective assessment of impacts to the suckers but the USFWS should be involved through the whole process. Darrick mentioned that USFWS is developing some analytical tools that could be used to help assess the level of impact. (TAC Meeting of September 17, 2015).

- Derrick Weissenfluh (USFWS) said that the State of Oregon has specific screening requirements for fish that would come into effect. A follow-up with Oregon Department of Fish and Wildlife (ODFW) is suggested. The state will want to see screening for other native fish species in addition to suckers. (TAC Meeting of September 17, 2015). USFWS screening requirements to prevent entrainment of fish would require screen mesh size of no greater that 3/32nds of an inch and approach velocities of no more than 0.33 feet per second. (TAC Meeting of February 11, 2016).
- **Answer:** The TAC concluded that the ESA issue isn't necessarily a fatal flaw, but it will be important to coordinate with USFWS as algae harvest/removal system alternatives continue to be discussed and developed. Also, the algae harvest/removal system planning and development (including for a possible pilot project) needs to allow for the 5-month to 2-year timeline for ESA-related consultation processes.

3.1.5 What are other approval steps (e.g., legal, regulatory, financing) that would be needed, and what are the potential constraints that could be imposed from these approvals?

- The TAC concluded that approval steps (including permit types and timelines) would likely be different between pilot- and full-scale implementation. This should be kept in mind when considering this question. (TAC Meeting of September 17, 2015).
- From a water rights perspective, Mary Grainey (OWRD) said that at least a limited license for a pilot project would probably be needed, which is easier to obtain than a regular water rights permit. At the point where water is being taken, it would be beneficial to get an agreement from the Bureau of Reclamation that it's not injurious to them. This might be harder at a location on Upper Klamath Lake. For a full scale project, Mary indicated that the more the potential project is non-consumptive, the better. There is a high level of interest in seeing the water quality improvement, so that should carry weight in terms of needed regulatory approvals. (TAC Meeting of September 17, 2015).
- Clayton Creager (RWQCB) said that, if the siting of algae harvest facilities involved impacts to wetlands, such impacts can be mitigated. A compliance schedule can be developed for a restoration project that has short-term water quality impacts. In California, there is criteria to evaluate long-term benefits if a compliance schedule is developed with USFWS. (TAC Meeting of September 17, 2015).
- Eli Asarian (Riverbend) asked if anyone had talked to any of the wastewater treatment plants about TMDL compliance to see they might want to be partners and a part of the discussion. Mike Hiatt (ODEQ) indicated that the wastewater treatment plants are still waiting on the finalized TMDL. Once the TMDL is updated, permits would be renewed; this likely will not happen until 2017 at the earliest. (TAC Meeting of February 11, 2016).
- Eli Asarian (Riverbend) commented that the intent of a pilot study was to understand the quantity of algae that could be removed. Secondarily, it allows us to test out every step of the process to determine necessary permits, work on end uses, etc. One significant gap is the fate of algal toxins – how long do they last? Toxins may degrade over time, but maybe we should do some pilots studies or do a literature review. For human health, a pure algae stream would be required. With dirty algae streams, how do we get toxins out and get it into an animal food stream? Is there anywhere in the world where algae is being used for animal feed and have toxins been addressed? (TAC Meeting of February 11, 2016).
- **Answer:** Nothing the TAC has discussed from a regulatory and permitting perspective has seemed to pose a fatal flaw. However, answers to questions do reveal that regulatory authorization and permits, such as related to ESA and water rights, could take a significant effort and time to successfully complete.

3.2 Priority 2 Questions: Drivers of Scope, Size, and Type of System Needed

3.2.1 What system components or steps would be required to remove the desired amount of algae biomatter (e.g., screening, filtration, centrifugal, sedimentation, flotation, flocculation, dewatering, drying, transport, disposal)?

- Doug Jackson and Jerry Anderson (New Earth) explained that steps would include: (1) a primary in-water harvest screening that would result in algal mass material of 1 percent solids; (2) a secondary on-shore dewatering step to concentrate the algal material to about 6 percent solids (with the extra water returned to the river); and, (3) loading of the 6 percent concentrated product into tanker trucks (or other transport approach). The 6 percent solids product is a very thick paste that is hard to pump even though it is still 94 percent water. Because of this it takes a long time to fill a tanker truck. However, it is hard to find effective ways to move this material other than by tanker truck. Based on the other ideas listed in the question (filtration, centrifuges, flocculation), screening out the material is the most preferential from an ease and expense of process standpoint. Once the 6 percent solids material is loaded into a tanker truck, it is then transported to its use or disposal site; however, it takes a long time to drain out of the truck. It would be hard to burn it as a potential fuel without going through a drying step. New Earth would batch freeze the 6 to 7 percent sludge and then dry it. When dried, the algae has a high protein content and lipids are as high as they will get, although lipid content likely still inadequate for potential biofuel use. (TAC Meetings of February 11, 2016 and March 2, 2016).
- Regarding fish screening that New Earth has used in the past, Doug Jackson (New Earth) said one screening method is very similar to what most small irrigation districts have used for screening fish out of their intake and uses a rotating drum screen. The screen rotates for cleaning purposes and in open water fish can simply avoid the screen. Screening should be reviewed (in terms of required openings, flow, approach velocity, and other criteria) with the approach evaluated during the design phase. (TAC Meeting of February 11, 2016).
- John Hamilton (USFWS) noted that a fish screen is already in place at the entrance to the A Canal making this a location to consider implementation of an algae harvesting pilot study, if pursued. (Comment letter on IM 11 Draft Reports from John Hamilton to Tim Hemstreet/PacifiCorp dated May 26, 2016).
- Doug Jackson (New Earth) said that during the algae removal process the water screened from the algae is sent back to the lake. They do not make any additions to the water after screening out the algae. Doug Jackson noted that New Earth does not have a permit that is specific for return of the water to the lake. Other than screening out the algae, they don't take any additional water out of the lake. Mike Hiatt said that from an ODEQ standpoint, it's cleaner water being discharged to the lake than what was originally taken out. Mike thinks that no National Pollutant Discharge Elimination System (NPDES) permits would be needed. (TAC Meeting of February 11, 2016).
- Doug Jackson (New Earth) said the facility on the A Canal in the 1990s had discharge permits through ODEQ. Monitoring occurred at inspection stations (vaults). The Oregon Department of Agriculture was a regulator for the lake process because it was a food-based product. (TAC Meeting of February 11, 2016).
- Mary Grainey (OWRD) commented that a system at A Canal may need to be a large system; for example, to screen 1,000 cfs. A system at Link River dam may have to be a much smaller system. Space requirements need to be determined to see if there is room for a fish and algae screen at Link River dam. (TAC Meeting of February 11, 2016).

- Tim Hemstreet (PacifiCorp) noted that the stormwater separator work with Watercourse (2015) revealed that for 200-300 cfs, there is not a large screen or space requirement. Such a system could pump water or use the East Side forebay space - a footprint of 200 feet long and 30 to 40 feet wide just downstream of Link River Dam. (TAC Meeting of February 11, 2016).
- **Answer:** The system steps to remove the desired amount of algae would include: (1) a primary in-water harvest screening that would prevent the entrainment of fish and result in algal mass material of 1 percent solids; (2) a secondary on-shore dewatering step to concentrate the algal material to about 6 percent solids (extracted water would be returned to the source water body); and, (3) loading of the 6 percent concentrated product into tanker trucks for transport. Once the 6 percent solids material is loaded into a tanker truck, it is then transported to its use or disposal site. Monitoring for algae species and/or toxin concentrations could be required at different steps in the process depending on the destination and end use of the product.

3.2.2 What quantity of algae biomatter would be available or could alternative systems potentially remove (i.e. at Link River dam)?

- Doug Jackson (New Earth) said that their experience relates to screening flow with a certain type of system, which may or may not be the right system for the situation at Link River dam envisioned by the TAC. In the 1990s, New Earth was able to screen out approximately 200,000 wet pounds per day (estimated at about 12,000 dry pounds per day of biomatter) using their harvesting system on the A Canal, which filtered a large portion of the water passing through that location. Doug commented that a pilot study would help determine the type and size of the system required before a large scale system is designed and constructed. The pilot study could also be used to test for: (1) the amount/rate of biomass removal, (2) potential fish entrainment effects; and (3) speciation, toxins, and weights of the algae biomass. Location of the system could be a determining factor in the selection of the methods used for algal removal. (TAC Meeting of March 2, 2016).
- Doug Jackson (New Earth) indicated that New Earth has extensive experience in engineering algae harvesting techniques and equipment, most of which could be transferrable to a pilot project. One of the goals of a pilot project would be to look at the amount of biomass removal. Doug Jackson noted that the East Side and West Side forebays and penstocks at Link River dam might lend some advantages on how an algal removal system could be engineered. A pilot should also look at a system to be placed in the Link River upstream of the dam. (TAC Meeting of March 2, 2016).
- Tim Hemstreet (PacifiCorp) commented that the use of the East Side and West Side forebays and canals may be possible in terms of space, depth of water, etc. On the East Side, it is also private access and there are currently no public nature trails where people would be walking by the operation. The East Side forebay is larger than West Side. PacifiCorp could potentially allow use in that area although that would need to be coordinated with proposed plans for decommissioning those facilities. (TAC Meeting of March 2, 2016).
- Mary Grainey (OWRD) asked how much instrumentation is needed when algae is being removed from the water. Is algae being weighed and tested? Doug Jackson (New Earth) noted that a lot of testing is completed on the biomass including speciation, toxin presence, weight, etc. (TAC Meeting of March 2, 2016).
- **Answer:** The previous algae removal facility on the A Canal removed about 200,000 wet pounds per day (90.7 wet metric tons per day; 12,000 dry pounds per day; 5.4 dry metric tons per day), 24 hours a day, from mid-June through October by processing 1,000 cfs. For scaling purposes, this volume of material converts to about 200 wet pounds per day per cfs (0.09 wet metric tons per day per cfs; 5.4 dry kilograms per day per cfs).

3.2.3 How might the approach to algae biomatter removal at Link River dam be affected by (or integrated with) other efforts in the basin to reduce nutrient and algae loads in Upper Klamath Lake and the Klamath River?

- Clayton Creager (RWQCB) indicated that the Stillwater et al. (2013) report did not include algal biomass removal among the water quality improvement techniques examined for the Upper Klamath Basin. Rather, the Stillwater et al. (2013) report focused on a range of other approaches for dissolved oxygen improvement in Keno reservoir and treatments to reduce nutrient loads coming into Upper Klamath Lake. Clayton likes the idea of modeling the entire basin. Current TAC discussions have been focusing on the Link-Keno segment of the basin rather than the basin as a whole. A Soil & Water Assessment Tool (SWAT) model of the watershed is currently being developed and should help quantify the impact of land management practices in the basin. Rosemary Records (a PhD graduate student at Colorado State University) is creating a SWAT model that looks at all the inputs from the upper watershed. However, the model may be limited to the Sprague River basin instead of the whole Upper Klamath basin. Documentation related to a presentation of her model can be found at http://www.kbmp.net. Clayton doesn't think that the current approach addresses how to apportion improvements across the projects. (TAC Meeting of March 2, 2016).
- Clayton Creager (RWQCB) indicated that efforts directly within Upper Klamath Lake to reduce nutrient and algae would be quite complex. The most effective and resilient way to affect algal populations (and loads) moving downstream from the lake is to correct phosphorus input into the lake. This thinking resulted in a push to consider use of treatment wetlands upstream of the lake. (TAC Meeting of March 2, 2016).
- **Answer:** The answer to this question is unclear at this time. The TAC exhibited some reluctance to extrapolate from the theoretical construct of algae removal at Link River dam to Upper Klamath Lake conditions and other watershed management actions. Given the large nutrient loads in Upper Klamath Lake, it seems unlikely that in-lake conditions would improve so substantially over the life-span of an algae removal facility that the facility would no longer be needed. Meanwhile removal of adequate material could improve water quality downstream of the facility.

3.2.4 What are the potential commercial uses and quantities of the harvested algae biomatter?

- Jerry Anderson (New Earth) commented that harvested biomass may have commercial applications such as health supplement, food ingredient, livestock feed, and/or soil amendment. Biomass commercial use is highly dependent on the biomass composition. (TAC Meeting of September 17, 2015).
- Ken Carlson (CH2M) described that other potential uses have been discussed by the TAC and include potential use for pharmaceuticals and biofuels. However, the algae material from Upper Klamath Lake likely does not have an adequate amount of lipid content for use as a biofuel (Simon et al. 2013). (TAC Meeting of March 2, 2016).
- Jerry Anderson (New Earth) indicated that when there is no toxin in the biomass, there are uses available for it. However, when toxins are present, it is difficult to find uses. Another key question to answer is what to do with the material when toxins are present. The presence of toxins varies from year to year. (TAC Meeting of March 2, 2016).
- Doug Jackson (New Earth) commented that most everybody refers to the material in a dry powder sense. The cost to get algae to that point can be very high. The value of the dried powder product might not justify the high costs of getting the algae to that state. (TAC Meetings of February 11, 2016 and March 2, 2016).

- Rick Carlson (USBR) suggested the report by Simon et al. (2013) be added as a citation in answering these questions (included in section 4 below). The Simon et al. (2013) report notes the high protein and low lipid content of the algae. (TAC Meeting of February 11, 2016).
- **Answer:** While there are a variety of commercial uses, the suitability depends on the toxin levels in the harvested algae. Possible uses for harvested algae include as health supplements, food ingredients, livestock feed, soil amendment, compost products, and pharmaceuticals. Because toxins are known to be present, the most likely uses are those where toxin levels are not an issue (e.g., compost). The use of harvested algae as a biofuel is unlikely given the low lipid content of algae typically found in Upper Klamath Lake.

3.2.5 Could algae biomatter removal quantities (as estimated above) be sufficient to affect oxygen depletion at the sediment/water interface? If so, is information available to estimate this effect?

- Clayton Creager (RWQCB) indicated that he raised this question initially, and his question pertained more to potential algal biomass removal in Upper Klamath Lake itself and removal of phosphorus from sediments. With focus on Keno reservoir (based on removal at Link River dam), the question may not be as relevant now. Clayton suggests that further work on this question perhaps be deferred to the USGS/Watercourse model of Keno reservoir to determine if and to what extent algae biomatter removal would affect sediment oxygen demand (SOD). (TAC Meeting of March 2, 2016).
- **Answer:** With the focus on removal at Link River dam, this question was not relevant and could be deferred to evaluation of benefits as illustrated in existing water quality models for Keno reservoir.

3.2.6 If release of additional algal loads to the A Canal is an acceptable approach, what potential effect would that have on Lost River water quality?

- **Answer:** A Canal and the Lost River system already have high levels of organic matter and nutrients, there are anoxic dissolved oxygen conditions, and overall water quality is poor. For these reasons, it would be difficult to obtain regulatory approvals to dispose of removed material to A Canal or Lost River because it could exacerbate already poor water quality conditions. Because of this, disposal to A Canal was dropped from consideration (see previous discussion in Section 3.1.3.

3.2.7 If other disposal is required, where would that occur?

- Ken Carlson (CH2M) asked: for algae biomass that is collected and can't be used, where would disposal of that biomatter occur? Mike Hiatt talked about a composting facility on a previous TAC call. Doug Jackson commented that he would encourage the group to find a way to dispose of the material and not count on finding a commercial use for the product. (TAC Meeting of March 2, 2016).
- Eli Asarian (Riverbend) commented that he had talked with Jake Kann after the last TAC call regarding the use of algae as animal feed. The Oregon Health Authority (OHA) or some other entity has an allowable concentration of microcystin which is similar to human consumption. Eli also left a message with the Oregon Institute of Technology (OIT) agriculture extension office. (TAC Meeting of March 2, 2016).
- **Answer:** A variety of options were discussed (e.g., animal feed, composting, etc.) but a specific answer was not developed. To a degree, disposal depends on the toxin levels and end use of the product. That is, more information on toxin levels and potentially viable end uses may need to be developed before disposal requirement and options can be determined.

3.3 Priority 3 Questions: Important Process-Related Steps

3.3.1 What are the specific process steps and methods needed to dewater or dry the harvested algae biomatter?

- Jerry Anderson (New Earth) indicated that there are different ways of dewatering. New Earth has a method they use that works well for them with no additives. The process removes a little more water (not intracellular) that is present in algae slurry (river/lake water) so there is no disposal issue for that water. This dewatering would take place on the side of the river. Drying is a whole separate topic that would depend entirely on specific end use (human, animal, etc.). In any event, drying would not take place on the side of the river; the material would have to be trucked to an offsite location for drying. If the end use has to have good a nutrient profile of the algae to have value, it's like harvesting milk. You have to be able to process the material in a short amount of time in order to maintain its nutrient value. The material may not have enough value if it is dried in a cheap way. Low temperature drying is expensive. Drying requires specialized process/equipment that can deliver the right temperatures for drying. (TAC Meeting of March 2, 2016).
- Ken Carlson (CH2M) asked if the material has a commercial use as a dried powder product, would the entity that is doing harvesting offer to sell or transport slurry to whoever wants the product and they would do the drying. Or would drying have to occur prior to make the product commercially attractive? Doug Jackson (New Earth) indicated that an end use needs to be identified because that defines the quality and drying parameters. (TAC Meeting of March 2, 2016).
- Jerry Anderson (New Earth) indicated that end uses such as animal feed or soil amendments don't sell for a lot of money. Drying is one of the more expensive parts of the process. (TAC Meeting of March 2, 2016).
- Ken Carlson (CH2M) asked if dewatering is an expensive part of the process as compared to screening. Doug Jackson (New Earth) indicated that it depends on the approach and the equipment chosen for the step. It may require personnel to monitor and process. Other equipment may cost a little more, but require less manpower to operate. Dewatering is not cheap, but it is not as expensive as initial removal from the lake itself. Jerry Anderson noted that if you can dewater on-site in a manner that doubles your solids content, you have a lot less drying that you have to do subsequently. (TAC Meeting of March 2, 2016).
- **Answer:** Dewatering is accomplished through screening processes that gradually remove more water. This water is then returned to the lake. The upper limit is about 6-7 percent algae by weight because of the consistency of the concentrated product. Drying could require a relatively rapid processing time to retain nutrients. If nutrients are not important, a slower, less expensive drying option may be feasible, but the process is ultimately driven by the end-use of the product.

3.3.2 Would the operational requirements be for a batch or continuous mode harvesting system?

- **Answer:** New Earth's operation on the A Canal in the 1990s went 24 hours a day, 7 days a week from July 4th to Oct 15th when the canal shut down. The process can easily be a continuous process. New Earth operates daylight hours only for their open lake facility. Shore-side facilities can run on constant through-put mode until loading into tankers is completed. Loading is more of a batch process. (TAC Meeting of March 2, 2016).

3.3.3 What specific process steps are needed to detoxify algae biomatter?

- Doug Jackson (New Earth) indicated that New Earth avoids toxins up-front by doing testing ahead of time and then not harvesting when toxins are present. (TAC Meeting of March 2, 2016).

- Clayton Creager (RWQCB) commented that Nancy Simon (USGS) was looking at an enzyme treatment to reduce toxicity of microcystin. If you can address the toxicity issue, might be able to use algae as a feed source. (TAC Meeting of March 2, 2016).
- Eli Asarian (Riverbend) commented that there is a fine line between reuse and disposal. Eli finds it hard to believe that composting is not going to destroy the algal toxin; rather, it will be a condition of the time scale of how long it takes for toxins to break down. This is a critical question we need to figure out – exploring degradation of toxins in a variety of field conditions. (TAC Meeting of March 2, 2016).
- Ken Carlson (CH2M) and Jerry Anderson (New Earth) commented that they had heard that exposure of collected biomatter to sunlight (such as in a land-based drying step) breaks down microcystin toxins, so this may be worth looking into. (TAC Meeting of March 2, 2016).
- The Karuk Tribe provided the following additional information on detoxification of algae biomatter (in a letter from Susan Corum to the IMIC dated May 17, 2016):

  > "Degradation rates for cyanotoxins are highly dependent on conditions. Mechanisms for removal include photochemical degradation by ultraviolet radiation (e.g. sunlight), adsorption onto sediments or suspected particles, and biodegradation by micro-organisms (Corbel et al. 2014b). Microcystin added to surface sediment samples from Taihu Lake and incubated at 20°C degraded rapidly due to favorable conditions for bio-degrading bacteria, reducing by more than 90% loss in 4 days and reaching levels at or near zero within 7 days (Chen et al. 2008). Conversely, crusts of dried *Microcystis aeruginosa* collected on the shore of an Australian lake that were 5-6 months old still contained high levels of microcystins (Jones et al. 2005). If applied to land and not degraded, microcystins have the potential to contaminate groundwater and can be uptaken by terrestrial plants including agricultural crops (Chen et al. 2012; Corbel 2014a, 2014b, 2016).
  >
  > "Due to high moisture content and low porosity, algae are challenging to compost alone but can be mixed together with other materials (Han et al. 2014). When blue-green algal sludge from Taihu Lake (China) was mixed with mature chicken manure compost and composted (including turning once per day) under mesophilic (moderate temperature) conditions, microcystin was reduced to non-detectible amounts within seven days (Huang et al. 2014). In addition, plants grown in soil supplemented with the algal/chicken compost mixture grew faster than plants supplemented with chicken compost alone (Huang et al. 2014). Another experiment combining cattle manure compost, blue-green algal sludge, and plant growth-promoting rhizobacteria (PGPR) for six days of solid-state fermentation yielded similarly promising results (Zhang et al. 2014). Solely considering the value of the final product alone, harvest and land application of algae and aquatic plants a[re] unlikely to compete well economically with other fertilizers; however, environmental benefits may be considerable (Quilliam et al. 2015)."

- **Answer:** The literature indicates that mechanisms for degradation of algae toxins are possible, but the specific process to detoxify microcystin from material potentially harvested at Link River dam is unclear at this time. Companies currently harvesting algae in Upper Klamath Lake simply avoid the toxins and cease operations when toxins are present. It may be feasible compost the product, thereby breaking-down the toxin, but specific requirements for this process are unknown.

3.3.4 What specific process steps are needed to transport or dispose of harvested algae biomatter?

- **Answer:** For commercial use, tankers would have to be the approach. For non-commercial uses, pumping to another location is a possible approach; however, based on possible facility location at Link River dam and proximity of homes, a tanker truck may be the only option for transport or disposal of algae. (TAC Meeting of March 2, 2016).

3.3.5 What are the estimated energy consumption demands, and/or costs or cost ranges of the above?

- Ken Carlson (CH2M) commented that it is likely possible to engineer a full-scale system that could remove large quantities of algae biomatter, but ultimately costs would become so high that they will become limiting or unfeasible. A cost effective approach is necessary because funds will be limited. (TAC Meeting of March 2, 2016).
- Doug Jackson (New Earth) commented that drying costs are by far the largest. If taking the product to a dry form is needed, drying costs would be the driver. (TAC Meeting of March 2, 2016).
- Jerry Anderson (New Earth) said that there would be significant electrical costs associated with the screening process. (TAC Meeting of March 2, 2016).
- **Answer:** Major costs are associated with electricity for screening and dewatering the algae. If the final product is to be dried, these costs would be the largest associated with the process. Specific estimates of energy consumption were not made.

3.3.6 Based on the answers to the above, what are some example conceptual layouts for an algal biomass harvesting system?

- Jerry Anderson (New Earth) noted that the conceptual layout will have two potential paths depending on whether the collected algae biomatter will: (1) be a usable product; or (2) is material to be disposed. (TAC Meeting of March 2, 2016).
- Mary Grainey (OWRD) suggested that the TAC should perhaps follow-up by developing an estimate on square footage of screens needed for 100 cfs. What screen size do you need for the first step? (TAC Meeting of March 2, 2016). Regarding size, Doug Jackson (New Earth) commented that if the scale is too small, there is a lot more room for error and misunderstanding of the system's effectiveness and potential impacts. It will be important to set out an objective for the approximate size of the envisioned full-scale system, and then determine the size of the pilot project that would be needed to help evaluate the system's effectiveness and potential impacts. (TAC Meeting of March 2, 2016).
- Eli Asarian (Riverbend) commented that the TAC needs to understand the cost per unit removal. Ken Carlson (CH2M) said that coming up with reliable costs at this point would be a big challenge given that any such cost estimates would be very broad until certain decisions can be made with regard to key elements of the system. For example, how big of a system is needed, what size, how and where to dispose, are there commercial uses, etc.? The specific answers on these elements will factor heavily into cost estimates. Might be the basis of next round of work. (TAC Meeting of March 2, 2016).
- Clayton Creager (RWQCB) commented that he is unsure whether it is worth moving this IM Activity 7 study further into the pilot phase, or whether we use the available IM 11 study funds for other methods that have a bigger "bang-for-buck" on water quality. Clayton is thinking about this particular algae harvesting approach in relationship to other potential approaches – known

benefits of some of other methods and approaches may be more worthwhile pursuing. (TAC Meeting of March 2, 2016).

- **Answer:** Conceptual layouts have not been developed. They would be driven by the answers to questions regarding the fate of the harvested algae. Substantial differences in facility design are likely depending on if and how much of the harvested material is usable, wet or dry, or simply needs to be disposed. Once the fate of the harvest material is known and a specific site is identified, then conceptual layouts can be developed.

3.4 Remaining Areas of Uncertainty

The TAC spent a considerable amount of time addressing the questions in the previous three sections. There are some questions to which an answer is unclear. Yet, that lack of clarity should not preclude further evaluation. For example, how a removal system would fit into other nutrient and algae management efforts for Upper Klamath Lake is not known (Section 3.2.3), but it is reasonable to expect that any such facility would be complimentary to other efforts.

There are some key areas of uncertainty that may merit continued investigation.

- What happens to toxins after the material is harvested? Further investigation into the fate of toxins could be conducted to evaluate their lifespan in wet and dry material, potential treatment options, and the fate of toxins when subjected to commercial composting, drying, or other processes.
- Once the toxin question has been answered it should be possible to more accurately characterize commercial use and disposal options. Questions that could be addressed include: Is the material suitable as animal feed? Is there an economic way to dry the material for use as a supplement or fertilizer? What are disposal fees at commercial landfills (and if the material cannot be detoxified, does it have to go to a special landfill)?
- Once the toxin and commercial use/disposal questions have been addressed, a conceptual layout could be developed that would allow a more accurate feasibility discussion.

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Appendix A: TAC Meeting Notes

Interim Measure 11 of the Klamath Hydroelectric Settlement Agreement
Activities 4 and 7

Technical Advisory Committee Meeting #1

MEETING DATE: August 20, 2015

MEETING TIME: 9:00 AM – 11:00 AM

LOCATION: Teleconference; Conference Call In: 1-855-559-2426;
Conference ID: 865-9083

ATTENDEES (checked box indicates attendance):

☒ Brittany Hughes/CH2M	☒ Jake Kann/AES	☐ Micah Gibson/Yurok Tribe
☒ Chauncey Anderson/USGS	☐ Jerry Anderson/New Earth	☒ Mike Deas/Watercourse
☒ Chris Stine/ODEQ	☒ Jim Carpenter/Carpenter Design	☒ Mike Hiatt/ODEQ
☒ Clayton Creager/CA RWQCB	☐ Joe Eilers/MaxDepth Aquatics	☒ Parker Thaler/CA RWQCB
☒ Dan Blake/USFWS	☐ John Hamilton/USFWS	☐ Rick Carlson/USBR
☐ Darrick Weissenfluh/USFWS	☒ John Rueter/PSU	☒ Susan Corum/Karuk Tribe
☐ David Austin/CH2M	☒ Ken Carlson/CH2M	☐ Tammy Wood/USGS
☒ Demian Ebert/PacifiCorp	☒ Kyle Gorman/OWRD	☒ Ted Wise/ODFW
☒ Doug Jackson/New Earth	☐ Larry Dunsmoor/Klamath Tribes	☒ Tim Hemstreet/PacifiCorp
☒ Eli Asarian/Riverbend	☒ Maia Singer/Stillwater Sciences	
☒ Elyse Will/CA RWQCB	☐ Mary Grainey/OWRD	

Meeting Notes

1. Introductions and Agenda Review

Ken Carlson opened the meeting by reviewing the agenda for the meeting. Ken and David Austin will be moderating the technical advisory committee (TAC) meetings. The call today is the first in a series of calls that will be used to discuss Activities 4 and 7 of the 2015 Interim Measure (IM) 11 Study Plan of the Klamath Hydroelectric Settlement Agreement (KHSA).

2. TAC Purpose, Activities, and Future Schedule

The purpose of the TAC is to provide technical guidance and input. The TAC is composed of a group of people who are knowledgeable technically of the issues that underlie Activities 4 and 7. PacifiCorp and CH2M will look to the TAC to provide input for these activities through monthly phone calls and on deliverables as they are developed.

The future schedule for teleconferences will be discussed at the end of the call. Calls will be held once a month, or more frequently if warranted. Each teleconference will be used to discuss both Activity 4 and Activity 7. The agenda for the meeting will be provided prior to

the call and will outline specific times such that TAC members who are only interested in one activity may call-in and drop off as needed.

Chauncey Anderson noted that federal government employees are forbidden from using Skype for Business due to security concerns. Brittany Hughes will determine an alternative meeting format to enable all TAC members to participate both by phone and in viewing the meeting materials live.

3. Activity 4: Conceptual Feasibility Study of Oxygenation at Keno Reservoir

The purpose of Activity 4 is to complete a conceptual feasibility study of a potential oxygenation system to supplement in-situ oxygen levels in Keno Reservoir. The addition of oxygen would improve dissolved oxygen (DO) conditions for fish in Keno Reservoir and help to offset oxygen demand in Keno Reservoir from large loads of organic matter that originate from Upper Klamath Lake.

The TAC reviewed the handout (sent out before the meeting) titled "Some Background Information on Dissolved Oxygen (DO) Conditions in Keno Reservoir". Keno Reservoir represents an area continually challenged by DO impairment in the Klamath system. Recent work by USGS confirms that large organic matter loading into Keno Reservoir from Upper Klamath Lake is the major contributor to the substantial oxygen demand in the reservoir. Agricultural return flows also contribute to loading in the reservoir. Oxygen levels in the reservoir can be close to zero or anoxic from July to mid-October. There is evidence that some oxygen recovery occurs by the time the water reaches the downstream end of the reservoir at Keno Dam. Conditions in the river downstream of Keno Dam are usually improved by turbulent reaeration in the river downstream of the dam.

The handout also contains information on the applicable standard for DO in Oregon. The Klamath River between Keno Dam and Upper Klamath Lake is designated for cool water species. The applicable DO criterion for this reach of the river is 6.5 mg/L year-round (per Oregon Administrative Rules [OAR] 340-041-0016).

Chris Stine contributed information on ODEQ's consideration of the 6.5 mg/L DO criterion, and indicated that it is seldom that a deviation from the 6.5 mg/L criterion for DO is allowed. ODEQ realizes that under certain conditions, there can be deviations through natural variations that still support beneficial uses under those conditions. If sufficient information is available, then temporary lower levels can be supported. There is not enough experience to characterize the conditions in which lower numbers would be acceptable.

Chris indicated that the standard provides that 4 mg/L DO is the absolute minimum level at which acute effects of low DO on aquatic species are assumed to occur. Per the handout, it is clear that DO levels less than 4 mg/L occur consistently in Keno Reservoir from July to mid-October. Therefore, a lot of work will be required just to increase DO levels to 4 mg/L. Excursions to levels lower than the 4 mg/L absolute minimum criterion are intended to reflect potential natural variations (that could occur under some circumstances) that aquatic species could tolerate for a short period of time. It is not clear how those would apply to Keno Reservoir. At this point, Chris suggested that the DO criterion of 6.5 mg/L should be the year-round target per the Oregon standard.

Chauncey Anderson noted that the data from Miller Island shows that Keno Reservoir stratifies periodically and that DO can be worse at the bottom than at the top of the

Reservoir (it is not necessarily well-mixed). Ken Carlson reiterated that the data shown on graphs is from a single grab location in Keno Reservoir upstream of the dam and is not necessarily representative of the overall reservoir vertically or longitudinally.

Ken Carlson indicated that achieving the 6.5 mg/L DO criterion may be aspirational for now given the larger basin issues that contribute to water quality impairment in Keno Reservoir. Therefore, the goal of the study of a potential oxygenation system in Keno Reservoir may need to consider both the regulatory standard for DO in the Reservoir and perhaps an interim DO goal, such as one aimed at seasonal fish use or movement. Ken asked the TAC if the study should consider such an interim DO goal, especially given there is a total maximum daily load (TMDL) in place and other factors driving DO in Keno Reservoir that could take many years to address. Are there specific DO objectives for fish protection or the ability for fish to move through Keno Reservoir that may be less than the 6.5 mg/L criterion, but would allow fish a migratory corridor?

Clayton Creager discussed Table 16 shown in the handout, which is from a report completed by his colleague Katherine Carter. The table was completed as a part of the TMDL effort, which determined site-specific objectives for DO saturation. The DO levels in the table attempt to consider organic matter impacts on DO. It is not just the milligrams of DO, but also percent saturation that should be considered.

Parker Thaler noted that, if the TAC considers achieving a DO level of less than 6.5 mg/L in Keno Reservoir, a DO level of 4 mg/L could be okay for fish, but really only if other factors (e.g., temperature, food supply) are in real good condition. Otherwise, lower DO levels would be problematic for fish.

Chris Stine commented that Table 16 in the handout illustrates increased impairment and mobility of aquatic species and adds an additional stressor. The 6.5 mg/L criterion is intended to provide full-function in terms of cool water species, but it also recognizes that under certain conditions, lower levels of DO may be ok. There is a need to maintain full support of cool water species through the 6.5 mg/L DO level.

In a temporary migratory situation, the TAC should consider an example of what might be considered an appropriate lower 30-day mean numeric criterion. If the TAC considers the reservoir as a 20-mile long low-velocity, highly-impaired waterbody, the objective for this discussion needs to have a 6.5 mg/L DO criterion. When addressing percent saturation in developing the criterion, the TAC must recognize under certain conditions the DO level is highly influenced by percent saturation.

Clayton Creager noted that when you use percent saturation as a criterion, you can take temperature and elevation into consideration. There are some assumptions about the effect of decomposition in terms of setting a percent saturation criterion that would need to be verified. Clayton indicated that percent saturation values may not be the criteria to use, but that is it worthy of discussion. Also, the DO standards were based on a sampling program that was done in the middle of the day. The sampling program has since been refined.

Ken noted that the study will start with some preliminary modeling runs by Watercourse Engineering using the existing CE-QUAL-W2 model developed by USGS and Watercourse for previous USGS studies of Keno Reservoir. This preliminary modeling would seek to “bound

the problem" and start by assuming the use of side-stream oxygenation where supersaturated water is injected into Keno Reservoir at various locations and over a range of oxygen-delivery quantities. Mixing effectiveness of the side-stream injection technology might mean that there is ample DO in a portion of the reservoir, but not the entire reservoir. Ken asked the TAC if they thought it would be acceptable as part of an interim goal to have a continuous part of the reservoir where DO conditions are ok, but perhaps not the entire reservoir.

Parker Thaler noted that he would be hesitant to recommend anything short of full compliance with Oregon's standard as a final objective.

Eli Asarian commented that he supports analysis based on full water quality compliance and then another analysis using an objective that assumes DO conditions are sufficient to allow for fish passage at appropriate times of the year.

Tim Hemstreet noted that full compliance with water quality standards is the ultimate goal of water quality improvement efforts, but asked if the study should consider a focus on key time periods where oxygenation would be useful in helping fish get through the reservoir. Tim said that oxygenation in only one of multiple activities that will need to occur to improve water quality conditions in Keno Reservoir and that it is probably not realistic for the study to assume that potential oxygenation would be used as the ultimate, comprehensive solution to DO in Keno Reservoir.

Clayton Creager commented that there is some flexibility in terms of how DO improvement in Keno Reservoir is accomplished over time. Development of a compliance schedule that factors in the multiple activities being completed to improve water quality would allow for a broader look at long-term restoration of the basin.

Chris Stine commented that from the ODEQ perspective, the TAC should maintain the overall objective for meeting 6.5 mg/L DO criterion, recognizing that there a number of activities will need to occur to reach the 6.5 mg/L level. Oxygenation is one technique that may offer some movement toward achieving that objective, but it is not the sole tool to reach compliance. Other additional technologies/solutions will also be needed to ameliorate the conditions that cause the problem. Beyond the Activity 4 study, there will be a further need to look at this issue from a number of different perspectives in order to reach compliance in the most expedient manner.

Tim Hemstreet reiterated that he is supportive of Eli's suggestion that the analysis assume an interim objective that provide DO conditions sufficient to create a fish passage corridor in the reservoir at appropriate times of the year. The TAC will need to understand the feasibility of this technology to achieve a passage corridor objective as well as total compliance with the water quality standard.

Ken reiterated that the study analysis will start with some preliminary modeling by Watercourse (as noted above) to initially assess how and where in the reservoir the oxygen injection would improve the DO levels. Ken suggested that for initial discussion purposes, an adequate fish passage corridor could perhaps be defined as an area of connected water in the reservoir where there is adequate DO and of an approximate size similar to the downstream river reach. For analysis purposes, this definition would serve as an assumed interim objective. Using a corridor approach, oxygenation could focus on continuous-spatial

distribution of DO during the season when DO is low and fish are migrating through the reservoir (June through mid-October period that is the focal point for impairment). Otherwise, for the other full compliance scenario, the goal would simply be to maintain the DO levels of 6.5 mg/L throughout the reservoir over the entire year.

Ted Wise noted that ODFW could support an approach where the focus is on DO levels during the migratory fish season as a starting point. In terms of looking at potential for reintroduction, the season where fish are moving upstream and downstream is a key objective.

In reviewing the handout, the period of low DO is pretty well defined and repeatable year after year (mid-July through October). So, this provides a well-defined timeframe when supplemental oxygen would be needed. Another way to define a timeframe would be to align it with fish migration.

Ted Wise said that ODFW could provide the information about the most opportune time to oxygenate as a part of adult (upstream) move-in and downstream juveniles. Ted will discuss with colleagues and send information. Ted asked if the goal was to come up with a continuous timeframe or if the plan would be to start up and turn off the oxygenation system. It may be easier to keep the system running at a constant rate rather than turning it on and off several times a year.

Ken noted that the detail around how the oxygenation system may be operated is undefined at this time. We may assume a constant operation at the time and locations that we're evaluating as a starting place for modeling. Depending on the results of the modeling, adjustments to the system operation could then be made.

Mike Deas commented that a cross-section of Keno Reservoir shows the reservoir has shallow benches on each side and then has a very rectangular cross section in the middle of the reservoir. It is often seen that there is decent DO in these shallow bench areas (2-4 feet of depth), but the bulk of reservoir (90%) is where the oxygen issues occur.

Chauncey Anderson asked whether the side-stream injected super-saturated water would remain in these shallow benches or would there be enough mixing to provide good oxygenation throughout the reservoir?

Mike Deas commented that one might expect the oxygenated water to hug the bank for a ways, but previous work has shown that inputs from the drains to Keno reservoir mix well after entering the reservoir.

Ken summarized that based on this TAC discussion, two different objective scenarios will be examined: standard compliance and a migratory fish passage corridor. Ken will put together a description of these scenarios and send them out to the TAC for additional feedback. Ken will also list out the initial modeling assumptions about what Mike Deas will do to help scope the modeling process.

Ted Wise noted that we may need to consider juxtaposing the thermal profile of the reach with the DO. Oxygenation may solve the DO issue, but a temperature barrier in the reservoir may prevent fish from migrating upstream.

4. Activity 7: Conceptual Assessment of Algae Removal at Link River Dam

Ken introduced the purpose of Activity 7 which is to assess potential algae harvesting and removal techniques at Link River Dam as a possible method for enhancing water quality in the Klamath River downstream of the dam. Initially when this was discussed with the Interim Measures Implementing Committee (IMIC), there were some people who felt we should proceed with pilot testing of some systems. For example, Joe Eilers/Jerry Anderson had proposed an algae removal system that might be used. However, PacifiCorp felt that there were still some basic questions that needed to be answered before proceeding with pilot testing.

During 2015, Activity 7 will focus on consulting with the TAC to answer several key questions. Answers to those questions will allow us to bound the problem and provide background context to inform appropriate future steps of assessment, including additional studies or testing that should be conducted.

As a starting point, Ken provided a suggested list of key questions to the TAC for discussion. Ken asked that the TAC read through the list of key questions and their prioritization. The questions address feasibility of a system (Priority 1), technologies as related to scope size and type of system (Priority 2), and process steps (Priority 3). Does this list capture all the important questions that need to be answered, and are any of the questions listed unimportant?

Clayton Creager noted that there is a need to define “water quality enhancement” in Priority 1, Question 1 (“What quantity of algae biomatter would need to be removed to significantly reduce loading and enhance water quality?”). Ken Carlson commented that enhancement of water quality would be a reduction in biochemical oxygen demand which would result in DO improvements downstream.

Mike Deas noted that there are two processes that are related: reduction in nutrients and organic matter. If you rely solely on algae removal, it is probably going to be expensive. Watercourse previously performed some model simulations of Keno Reservoir (in support of the previous studies) that assumed some substantial magnitude of organic matter removal. Those model results indicated that such removals do not resolve the DO or downstream nutrient-loading problems, but do provide some incremental improvements. One challenge is to understand the role in space and time of organic matter reductions for improving DO and reducing downstream nutrient-loading.

Ken Carlson indicated that Priority 1, Question 1 seeks to identify the quantity of algae biomatter that would need to be removed to have a beneficial impact on downstream DO concentrations. Algae harvest and removal likely will be just one of many technologies that will need to be used to enhance water quality.

Mike Deas said that the previous model simulation found that organic matter reductions in the 5-8% range didn’t demonstrably improve water quality, but with removal in the 15-25% range, there was a notable effect downstream.

Eli Asarian commented that he believes the question related to the potential take of Endangered Species Act (ESA) listed species is the most important question to answer. A conversation with USFWS will be needed to understand how to balance algae removal and

the potential take of ESA-listed species (primarily listed suckers). If take is likely to occur, can we even implement algae removal?

Dan Blake noted that when algae was harvested from Upper Klamath Lake in the past, there were probably smaller fish that were taken some of which were probably listed suckers. Authorization for incidental take will most likely be needed. USFWS would need to understand what would be gained from algae removal in order to determine if some incidental take is justified.

Demian Ebert commented that removal of algae from behind a screened intake may reduce ESA impacts which would make choosing a location of an algae removal facility important.

Doug Jackson noted that he thinks all five Priority 1 questions are valid. In the 1990s, an algae harvesting collection system was built where A Canal ends and splits into the B and C Canals. Average flow was about 750 cubic feet per second (cfs). The facility operated from June to October every year. The peak flow was about 1,000 cfs, and from that flow, the average harvest of algae biomass was about 200,000 pounds per day (ppd). About 94% of the extracted material is intracellular liquid. After a dewatering process, the end product was a thick paste with 6% solids concentration, which would then require disposal. There are some uses for the end product, but putting it back in the A Canal could be a problem if there are toxins present.

Doug noted that 200,000 ppd is the wet weight. It is about the consistency of honey and specialized pumps have to be used to move the waste. On the A Canal site, the water was filtered through an initial mechanical screen, which produced a slurry with about a 1% solids concentration. It then takes additional dewatering to further concentrate the material to the 6% solids concentration.

Clayton Creager commented that the DO levels in the Lost River this time of year are definitely impaired. Any additional load of pollutants that goes through A Canal may be an issue. The US Bureau of Reclamation (USBR) has been doing water quality monitoring in this area.

Mike Deas noted that he has reservations about diverting into the A Canal because it is already an impaired waterway. The final decision would be made by USBR. The additional load to the Lost River system would need to be evaluated with the existing loading. To add additional substantial volume of biomass in the Lost River system could lead to more severe water quality problems in that system.

The harvested algae biomaterial could be used for composting. A proposal for a nearby composting facility has come up in the last few weeks. It is uncertain if the algae harvesting biomass is something that would be provided to the compost facility or if the facility would have the capacity to handle the volume of material. There are many individuals in the basin who want compost for soil amendments.

Eli Asarian commented that differentiating between pilot- and full-scale implementation may be something that should be thought about when addressing Priority 1, Question 5 (“What are the regulatory approval steps that would be needed, and what are the potential constraints that could be imposed from these approvals?”).

Chauncey Anderson asked if screen sizes need to vary at different times of year or whether screen size will matter later into the year. Also, what impacts will screen size have to the design? Should we target *Microcystis* in the removal?

Doug Jackson commented that there will be a need to examine the mix of algae collected and that there will be variation in the mix depending upon the time of year. The percent solids and toxin levels will also vary. Basically, the process would remove all different kinds of algae at the same time. Removal of the zooplankton *Daphnia*, which is a food source for fish, may also need to be examined.

Jake Kann noted that *Microcystis* concentrations have been higher this year than in recent years.

Doug Jackson commented that this year is trending very similar to 1996 when they were operating the algae removal facility on the A canal.

Ken Carlson will revise the list of questions a bit as a result of the TAC discussion today. The next TAC meeting will focus on Priority 1 questions. Based on today's discussion, Ken will include some preliminary answers or observations in bullet-form under each of the Priority 1 questions for the next meeting and will send out to TAC group in advance of the next meeting.

Eli Asarian suggested that a subcommittee be formed to work on answering the ESA-related permitting question prior to the next call. Ken Carlson will coordinate a separate phone conversation with Dan Blake, Darrick Weissenfluh, and Eli Asarian.

Tentative dates of Sept 17th and 24th were discussed for the next call. The TAC decided to tentatively schedule the next meeting on Sept 17th.

5. Follow-up Action Items & Adjourn

a) Brittany Hughes will determine an appropriate alternative meeting format to enable all TAC members to participate both by phone and in viewing the meeting materials live.

b) Ted Wise will discuss with colleagues and send information about the most opportune time to oxygenate Keno Reservoir as a part of adult upstream migration and downstream juvenile movements.

c) Ken Carlson will put together a description of the two different objective scenarios that will be examined as a part of Activity 4 and that will include a list of the initial modeling assumptions.

d) Ken Carlson will revise the Priority 1 key questions as a result of the meeting today and include some preliminary answers or observations to the questions for the next meeting. This will be sent out to the TAC group in advance of the next meeting.

e) Ken Carlson will coordinate a separate phone conversation with Dan Blake, Darrick Weissenfluh, and Eli Asarian to discuss ESA-related permitting for algae removal.

f) Brittany Hughes will send out a meeting invitation for the next TAC meeting.

Interim Measure 11 Activities 4 and 7 Technical Advisory Committee (TAC)

IM 11 Activity 7 Priority 1 Question 4 Follow-up with U.S. Fish and Wildlife Service (USFWS)

MEETING DATE: September 3, 2015

MEETING TIME: 10:00 AM – 11:00 AM

LOCATION: Teleconference; Conference Call In: 1-855-559-2426; Conference ID: 370-4351

ATTENDEES: Demian Ebert/PacifiCorp; Ken Carlson/CH2M; Dan Blake/USFWS; Eli Asarian/Riverbend

Conference Call Notes

6. Purpose of Call and Background

The purpose of this conference call was to address an action item from previous TAC meeting (August 20, 2015) to assess probable Endangered Species Act (ESA)-related permitting requirements of algae removal at Link River Dam. The potential take of ESA-listed species is a key question to answer. At the previous TAC meeting (August 20, 2015), Dan Blake (USFWS) indicated that authorization for incidental take will most likely be needed. USFWS would need to understand what would be gained from algae removal in order to determine if some incidental take is justified.

The key ESA-listed species of concern related to potential algae harvest at Link River Dam are the Lost River sucker and shortnose sucker. The majority of Lost River sucker and shortnose sucker spawning occurs in tributaries to Upper Klamath Lake from March to early-May (for Lost River sucker) and early-April to mid-May (for shortnose sucker). Soon after hatching, sucker larvae move out of the gravel; larvae generally spend relatively little time upriver before passively drifting downstream. Larval sucker outmigration from spawning sites begins in April and is generally completed by mid-July. Peak migration occurs in June. Downstream movement generally takes place at night and near the water surface. After emigrating from the parental spawning sites in late spring, larval and juvenile Lost River and shortnose suckers inhabit near shore waters, primarily less than 20 inches in depth, throughout the summer months. Juvenile suckers emigrate from Upper Klamath Lake during the July through October period, with a peak in August and September.

7. Notes from the Call

Ken Carlson (KC): Background and introduction. How would we determine the level of take, what approvals would be required, timelines, what the requirements might be (mitigation/monitoring)? This would apply to both the pilot level and full-scale study.

Eli Asarian (EA): Two issues: 1) biology/ecology of suckers and potential impact, 2) how is that impact addressed from the regulatory perspective. We can't do everything here, but need to look at both items. Think about the different life-stages that could be affected and how they'd be affected. What's the fate of fish that make it to the downstream end of Upper Klamath Lake and then move on downstream? What happens to them? The recovery plan has different goals for different populations.

Demian Ebert (DE): We need to have a discussion about the life-stages and their distribution and then likelihood of entrainment/impact to fish that can be used for the evaluation of the different options for algae removal.

KC: Let's go back up a level and look at the overall goals from the USFWS regulatory perspective.

Dan Blake (DB): Where we go and type of analysis depends entirely on the type of action to be taken. It's possible that there's some action that doesn't require much consultation. A facility on the lake for example could be directly affecting juvenile suckers. We would also have to address other species, but we don't know for sure what those are until the action is actually proposed. The analysis would also depend on who's doing the action. You need a federal lead agency to use the Section 7 consultation process which would determine the level of take. This would require a biological opinion (BO) in a formal consultation and would need to plan for this in the overall timeline. The BO would do both the individual level of analysis as well as the cumulative population level effects. The USFWS would determine if there's a jeopardy determination to be made for continued existence of the species. If there is not a federal lead agency then we'd have to do a Section 10 consultation for which the timeline is typically longer. Algae removal is something we should be doing to benefit suckers, so the analysis will have to include that benefit as well. Determining the benefit will probably require that we pull other fish-experts into the analysis.

DE: Is there some flexibility in permitting that could let us do a test/pilot project? DB: There might be something that would let us work this action through. We could look at existing BOs and see if this fits within an existing BO. Also have consult with Bureau of Reclamation with water management. It would be worth looking into these as we move forward.

KC: What types of Terms and Conditions would be required? DB: That typically depends on the project and the action that's being proposed. It is best if we're involved in the project development so that the terms and conditions are minimized.

EA: What are the details of Reclamation's consultation for A Canal, Eastside/Westside, and on-the-lake algae harvesters? DE: The HCP/and ITP for PacifiCorp's facilities cover operations/maintenance of the Eastside, Westside, and JC Boyle facilities. The Eastside/Westside are basically shut down at this point, but we do operate them intermittently. KC: The HCP does specify a certain level of take for which PacifiCorp is authorized but it doesn't really include an algae harvesting/removal system. I guess that the HCP would need to be modified. DB: That's my understanding as well. We'd probably need to modify the PacifiCorp HCP to cover algae removal. That might be easier than doing a brand-new consultation but it depends on how big the change is. KC: Either way, there's a BO and timeline involved, and we'll have to build that requirement into the pilot end of the project. DB: An HCP is a couple of years. A Section 7 is a five month process once all the paperwork is complete. KC: But we'd have to include a federal agency to use the Sec 7 process. DB: The Reclamation consultation is focused on the management of their water system and analysis of lake levels and river flow. There is some take in their BO as well. On the lake, there's been no Section 7 or 10 consultations as far as I know. They are probably working without authorization.

KC: Conceptual project would be some kind of facility located at or near the lake outlet to reduce downstream biomatter loading. If it were located at Link Dam and operating summer-early fall then the concerns would be primarily juvenile sucker emigration from Upper Klamath Lake which peaks at the same period of time. Is it fair then to say that the focus is on juvenile/larval entrainment? DB: Seems like that would be most of it. We don't know exactly where the adults would be and would have to consider other species too. Entrainment would be an issue and the most significant portion. Would want to look at what's going through the 'screen'

EA: Does anyone have a sense of the fate of larvae and juveniles that go downstream of Link Dam? DB: We don't know, but as they move further downstream the suckers are considered more 'lost' from the reproducing population. There is some movement back upstream, but it's poorly understood. DW would know more and be helpful to have them involved in the development of the alternatives. EA: Is the Link River fish ladder passable to suckers? DB: Yes and it gets some use, but not a lot of use. It's unclear why it's used the way it is. We don't know if there is some problem with the ladder or if fish simply aren't

trying to use it. We are installing a PIT array across Link River later this fall that should help us gather more information.

KC: In terms of a concept at Link Dam, depending on the size, could a system trip a jeopardy opinion or is there a size that would simply have terms and conditions. A pilot project would have a small (relatively) take which perhaps could be authorized. But as we scale that up to a larger system, the level of take goes up but these are mostly juvenile and larval which are 'lost' to the population. DB: Because the area downstream of Link Dam is considered lost, then jeopardy becomes harder to get to. If you had a larger system on the open lake then conditions could be different and a jeopardy opinion perhaps more likely. We still need to address the take that's occurring.

EA: Hypothetically say the project would kill 75% of the larvae/juveniles at Link Dam but the remaining 25% would have their survival increased by 100 times because of better water quality downstream. Under these hypothetical conditions, the biological effect could be a net positive. Could something like this be approved? DB: That's the type of analysis that would occur. We need a level of confidence and certainty about the benefit. It's possible that something like this could be approved. We have to look at individuals but also at the populations and individual health of fish that do survive interaction with a facility. KC: The calculation of take would be important. The science might not exist in a way that provides a lot of confidence of this which could generate a range of take but would also generate a range of benefits as well. Sounds like jeopardy may not be an issue, but the issue could be more the terms and conditions. DB: Want to make sure that we plan timeframes correctly. Planning already includes the goal of improving conditions for suckers.

DE: Can we use the already developed tools for entrainment and take based on conceptual volume to screen the different alternatives? KC: A spreadsheet was used in the PacifiCorp HCP that we worked with the USFWS on that's based on volume of water and related entrainment. That would put the minus side pretty well in hand. The benefit side would be new and would have to be developed. Perhaps for initial screening the entrainment side could be used. DB: Those are estimates of entrainment but are the best we know now. Looking at the improvement side would also be looking for science/research to support the change and relative benefit to the species. KC: There is a little bit of information available on dissolved oxygen and survival of suckers. Perhaps a reduction in organic matter that led to an increase in dissolved oxygen could be an acceptable benefits analysis. DB: That's the kind of beneficial analysis that we'd need to do. Overall the regulatory process doesn't kill the idea, it just needs to be planned for.

DE: In terms of a summary of the process to the TAC we can say that:

- Consultation will be required for a pilot and full-scale facility and that process could take 5 months to 2 years.
- Take is a concern and has to be minimized but a jeopardy opinion is a remote possibility.
- We can use existing entrainment calculation methods for screening but need to look at the benefits to the species from a science-supported perspective

KC: We need to look at how a system could be built that would reduce to the extent feasible that we could the level of entrainment. The ESA issue isn't necessarily a fatal flaw but need to plan for the 5-month to 2-year process and need to work with USFWS in system development.

EA: Are there technology effects that we could be looking at? For example: 1. Taking water that's already screened (A Canal). 2. Divert at Upper Klamath Lake outlet and then return to river 3. Rotating screens that 'scrape' algae from the surface at the Fremont Bridge. Is there a depth where suckers are not as prevalent? DB: Not sure I can answer the depth question. There probably is a difference of top versus bottom intake. EA: would be helpful as we move forward as choosing technologies. DB: A Canal is already screened so you would only be entraining fish that had passed the screen. EA: As you get downstream in A Canal there's less prevalence of suckers. What's the opinion of larvae/juveniles that

end up in A Canal? DB: I would have to look at the BO. We do salvage there, but there is definitely some loss as they get further down the canal. There are suckers throughout the canal system too. They don't all die, but many probably do. There are return flows back into the river so return to the population is possible, but we don't really know if it happens.

KC: Other than the PacifiCorp HCP and BO, are there other Section 7 biological assessments, HCPs, or other information that would help with the latest biology or terms and conditions? DB: Those are really the key documents that are the most appropriate at this point. There may be some older stuff, but the information could be quite dated and of limited use because our understanding of suckers has increased over the years. KC: Might be interesting to see the older algae harvesting BO from the lake since that action is the closest to what is being discussed here. DB: Haven't seen that one, but can try to find it.

Interim Measure 11 of the Klamath Hydroelectric Settlement Agreement
Activities 4 and 7

Technical Advisory Committee Meeting #2

MEETING DATE: September 17, 2015

MEETING TIME: 9:00 AM – 11:00 AM

LOCATION: Teleconference; Conference Call In: 1-855-559-2426;
Conference ID: 865-9083

ATTENDEES (checked box indicates attendance):

☒ Brittany Hughes/CH2M	☒ Jake Kann/AES	☐ Micah Gibson/Yurok Tribe
☐ Chauncey Anderson/USGS	☒ Jerry Anderson/New Earth	☒ Mike Deas/Watercourse
☐ Chris Stine/ODEQ	☐ Jim Carpenter/Carpenter Design	☒ Mike Hiatt/ODEQ
☒ Clayton Creager/CA RWQCB	☐ Joe Eilers/MaxDepth Aquatics	☐ Parker Thaler/CA RWQCB
☐ Dan Blake/USFWS	☒ John Hamilton/USFWS	☒ Rick Carlson/USBR
☒ Darrick Weissenfluh/USFWS	☒ John Rueter/PSU	☐ Susan Corum/Karuk Tribe
☒ David Austin/CH2M	☒ Ken Carlson/CH2M	☒ Tammy Wood/USGS
☒ Demian Ebert/PacifiCorp	☐ Kyle Gorman/OWRD	☐ Ted Wise/ODFW
☐ Doug Jackson/New Earth	☐ Larry Dunsmoor/Klamath Tribes	☒ Tim Hemstreet/PacifiCorp
☒ Eli Asarian/Riverbend	☒ Maia Singer/Stillwater Sciences	
☒ Elyse Will/CA RWQCB	☒ Mary Grainey/OWRD	

Meeting Notes

8. Introductions and Agenda Review

Ken Carlson opened the Technical Advisory Committee (TAC) meeting by reviewing the agenda for the meeting. This meeting (conference call) is a continuation of the conversations from the first TAC meeting (conference call) held on August 20, 2015 to discuss Activities 4 and 7 of the 2015 Interim Measure (IM) 11 Study Plan of the Klamath Hydroelectric Settlement Agreement (KHSA).

Ken introduced David Austin, who will be moderating the TAC meetings with Ken. David is an environmental engineer and aquatic ecologist. He has been involved in both analysis and design of remediation for reservoirs, including implementation of oxygenation systems.

9. **Review of TAC Meeting #1 Notes and Action Items**

Ken asked if there were any comments on the meeting notes from the August 20 TAC meeting. There were none. Ken invited TAC members to provide any comments by email.

The following are the action items from the previous August 20 TAC meeting:

g) *Brittany Hughes will determine an appropriate alternative meeting format to enable all TAC members to participate both by phone and in viewing the meeting materials live.*

Brittany is looking into 3rd party software for the meeting to enable the group to share screens in addition to phone conferencing. For now, meeting materials will be provided to each TAC member prior to calls and referenced on the call as it is discussed.

h) *Ted Wise will discuss with colleagues and send information about the most opportune time to oxygenate Keno Reservoir as a part of adult upstream migration and downstream juvenile movements.*

Ted was not on the call today. Ken Carlson will follow-up with Ted for status on this item.

i) *Ken Carlson will put together a description of the two different objective scenarios that will be examined as a part of Activity 4 and that will include a list of the initial modeling assumptions.*

Ken provided this information to the TAC via email a week ago and it will be reviewed on the TAC call today.

j) *Ken Carlson will revise the Priority 1 key questions as a result of the meeting today and include some preliminary answers or observations to the questions for the next meeting. This will be sent out to the TAC group in advance of the next meeting.*

Ken provided information listing the key questions and status of answers to this point to the TAC via email a week ago and it will be reviewed on the TAC call today.

k) *Ken Carlson will coordinate a separate phone conversation with Dan Blake, Darrick Weissenfluh, and Eli Asarian to discuss ESA-related permitting for algae removal.*

A separate call was held regarding ESA-related permitting for algae removal and the results of that call will be discussed with the TAC today.

10. Activity 4: Conceptual Feasibility Study of Oxygenation at Keno Reservoir

a. Review "Initial Criteria and Assumptions of Analysis"

Ken Carlson emailed a document called "Initial Criteria and Assumptions of Analysis" to the TAC. It is intended that this initial analysis will "bound the problem", after which refinements in the analysis would be further pursued, including possible adjustments to the initially-used criteria and assumptions. The Initial Criteria and Assumptions of Analysis document provides an extensive description of the problem in Keno reservoir. Keno reservoir experiences severe seasonal water quality impairment. Summer and fall anoxia in the reservoir is found to be caused primarily by the substantial oxygen demand from the large organic matter loading from Upper Klamath Lake.

The modeling of the reservoir will be used to estimate the size an oxygenation system that would be needed in Keno reservoir to achieve assumed objectives as laid out in the "Initial Criteria and Assumptions of Analysis" document. The results of the modeling will help to guide subsequent estimates of installation, operational requirements, and approximate costs of an oxygenation system.

During the August 20 TAC meeting, two criteria as proposed in the "Initial Criteria and Assumptions of Analysis" document were discussed:

- Criterion 1 is based on the state water quality standard applicable to Keno Reservoir. The applicable dissolved oxygen (DO) water quality criterion for the reservoir is 6.5 mg/L year-round (OAR 340-041-0016(3)). The 6.5 mg/L criterion applies as a 30-day mean minimum, with a 7-day minimum mean of 5.0 mg/L and an absolute minimum of 4.0 mg/L. For purposes of Activity 4, the analysis will focus on the summer/fall period (July through October) where DO conditions are less than the criterion. Given the severe seasonal DO impairment in Keno reservoir (driven by large organic matter loading from Upper Klamath Lake), Ken Carlson indicated that Criterion 1 may be difficult (if not impossible) to achieve, particularly during summer, without larger basin improvements. As such, Criterion 1 is considered as more of an aspirational goal under existing conditions.
- Criterion 2 is based on a fish passage protection objective. The overall goal is to provide adequate DO to support fish passage. Given the presumed difficulty of achieving Criterion 1, the fish passage objective is intended to provide sufficient DO conditions in Keno reservoir to support fish passage, particularly for redband trout and the potential future presence of anadromous salmonids. Criterion 2 assumes that 5.0 mg/L of DO would be adequate to support passage at the times of year when trout (and possibly salmon in the future) would be migrating through Keno reservoir.

For purposes of Activity 4, it will be assumed that the above Criterion 2 would apply to a "migratory corridor" through Keno reservoir. For initial modeling purposes, the "migratory corridor" will be assumed as a continuous and connected area through the length of the reservoir, and that has width-depth dimensions that are similar to river reaches upstream (i.e., Link River) or downstream (i.e., Klamath River downstream of Keno dam) of Keno reservoir.

Ken Carlson noted that the model is still being developed by Mike Deas. TAC members are still welcome to submit input for the modeling criteria and assumptions. Input can be submitted by email or a call to Mike Deas, Ken Carlson, or Brittany Hughes. A few locations need to be identified where different rates of oxygenation could be tested to determine the effects on the reservoir. One goal is to examine how differing rates of oxygenation impact the water in the reservoir as it is conveyed downstream and how long the increased oxygen level persists. In order to fulfill Criterion 1 or Criterion 2, multiple input locations may be needed.

David Austin commented that we can use the model to look at defined injection quantities of oxygen at points within the reservoir, ideally creating a consistent oxygen gradient that we are assuming fish can follow. In looking at the injection quantities and locations, it is important to consider the technologies available to inject oxygen. Linear diffusers are used for hypolimnetic oxygenation projects. In an anoxic zone, 7 or 8 meters of depth is needed for oxygen transfer efficiency. Another efficient way to transfer oxygen is with a side-stream oxygenation system. A Speece cone is a large (12-foot diameter) stainless steel cone where oxygen is injected at the top of the cone. Speece cones are better for oxygen transfer in shallow water. However, in terms of project cost, Speece cones are expensive. Thus, depending on the number of cones, the project costs can become prohibitively high.

David Austin also noted that it will be important to understand the oxygen transfer zones when reviewing the model. If the total quantity of oxygen that is needed is on the high side (10-20

tons of oxygen per day), then liquid oxygen becomes more economical to consider. At an even higher oxygen demand, construction of an oxygen plant may need to be considered. The largest oxygen system currently in existence produces about 100 tons of oxygen per day.

Clayton Creager thanked David for providing a big picture summary of oxygenation systems noting that the infrastructure and maintenance of an oxygenation system is humbling. Clayton reminded the TAC about the Klamath Water Quality Improvement Workshop where design charrettes were held and hypothetical budgets for water quality improvements were determined. Clayton recommended that as part of Activity 4, the team should take a look at the Stillwater et al. report to look at how the oxygenation of Keno reservoir fits in with all the other options that are being actively evaluated for water quality improvements. If the oxygenation project ends up being a large infrastructure project in order to achieve the goals of the project, then the TAC should take into consideration how other water quality improvements in the Klamath Basin upstream of Keno reservoir may affect the size and scope of the required system.

Ken Carlson noted that there is a recognition that the solution to Keno reservoir is going to be multifaceted in order to get to a 6.5 mg/l DO level and that oxygenation will not be a standalone technology. Ken asked Clayton if he had any suggestions as to how the scope of the Activity 4 study analysis might be altered or changed by understanding the other technologies and water quality improvement projects envisioned in the Stillwater et al. report.

Clayton Creager responded that he did not have recommendations for how the oxygenation analysis should change. However, the working team will need to have an understanding of the proposed improvement projects as they may impact the design, location, or sequence of the oxygenation project.

Maia Singer commented that at a conceptual level, one thing that may be useful to consider that wouldn't change the criteria of DO modeling is the lifetime of an oxygenation system. As these other water quality improvements come online and conditions improve, the system may not be needed indefinitely. So, there would not be a change of criterion for modeling, but we should take into consideration the phasing of the system.

David Austin noted that one thing that is seen in the industry is a substantial decrease in the required oxygenation over time. There tends to be an accumulated oxygen debt and as oxygen is injected the debt is paid back, requiring less oxygen over time. If the project is large enough to require a large oxygen plant and then the oxygen demand decreases within a short timeframe, it is embarrassing to have constructed such a large plant that then needs to be reduced.

Mike Deas commented that future reductions in the transport of oxygen demanding materials into the reach would certainly result in a drop in the oxygen demand that the system would be addressing.

Ken Carlson noted that as we write up our findings, the context discussed above will be valuable. A timeline for implementation of the technology will need to be considered. The assumed project lifetime will need to be examined to make sure it makes sense given the other water quality improvements planned to occur in the Klamath Basin.

b. Analysis activities and schedule

Ken Carlson noted that the intent moving forward is to have the initial modeling analysis completed prior to the next TAC meeting (conference call), so that the results of the initial analysis could be presented and discussed during the next TAC meeting.

11. Activity 7: Conceptual Assessment of Algae Removal at Link River Dam

a. Review "Key Questions and Status of Responses"

Ken Carlson provided information to the TAC listing the key questions and status of answers based on information from the previous August 20 TAC meeting. The goal for today is to complete an assessment of the Priority 1 questions which are key drivers of feasibility.

b. Discuss and develop responses to Priority 1 Key Questions

Question 1: What quantity of algae biomatter would need to be removed to significantly reduce loading and enhance water quality in the Klamath River downstream of Link River Dam?

Ken Carlson commented that algae harvesting at the Link River Dam is one of many solutions that we'd be looking to implement to provide water quality enhancement. In the previous August 20 TAC meeting, Mike Deas indicated that previous model simulations found that organic matter reductions in the 5-8 percent range didn't demonstrably improve water quality. Organic matter reduction in the 15-25 percent range did produce a notable effect downstream. Ken asked if there is there a tonnage of algae removal that can be identified, as a more firm removal range needs to be developed. Mike Deas noted that we need to decide on a metric and how success will be measured. If dissolved oxygen is used, the fish passage or regulatory criteria could apply to produce something meaningful.

Eli Asarian mentioned that the TAC might want to consider several different end points for the nutrient and organic matter reduction at the outlet of Keno dam. The Sullivan et al. report has tables in the appendices that talk about the nutrients. This would result in a range of outcomes rather than a set number. In the end, we're going to come back to doing as much as is feasible. A good outcome would be removal of 50% of the organic matter. A lot of the nutrients are in dissolved form, so even substantial removal of algae may not result in significant nutrient reductions.

Ken Carlson asked if the goal should be to remove as much algae biomass (organic material) as possible at the Link River Dam, or a specific goal for an amount to be removed that would help to achieve downstream regulatory compliance or greater fish habitat suitability. If so, we would need to define what we consider such a specific amount to be. A specific goal would be best for determining algae biomass removal system requirements and feasibility.

Mike Deas noted that most folks understand that there isn't a single activity that will remedy water quality issues in the Klamath Basin. Eli's concept of an assessment to cover a range of conditions is useful if we keep in mind that it will take a suite of activities to achieve the desired outcome. Maybe there is an approach of quantifying the application of different activities and adding a caveat about inclusion of an oxygenation system. We could consider whether the two activities (i.e., Keno oxygenation and Link River dam algae biomass removal) complement each other or cancel each other out. Implementation of one activity may make another activity ineffective.

John Rueter commented that there may be a scale of an activity that is more feasible than another. For example, regarding algae biomass removal, the size of the operation could become infeasible at some point with regards to disposal and moving the material.

Demian Ebert reiterated that the purpose of this activity is to determine how much algae we're trying to remove.

Ken Carlson noted that the Priority 1 questions are drivers of feasibility. It seems it would be best to have a goal for enhancement (e.g., reduction in nutrients or improvement in DO) that equates to a certain amount of algae biomass removal. This would allow us to determine how large of a system would be required to remove that amount. Removing as much as possible is another way to look at the issue, but in that case would be driven only by engineering and cost constraints, rather than a specific targeted water quality outcome. At the end of the day, we will still need to understand what kind of water quality improvement the algae biomass reduction equates to. The Sullivan et al. work would help us get a sense of the effects downstream of certain percentages of organic matter removal.

Mike Deas commented that the existing simulation results could be used to calculate removal of tons per day and then a little bit of work would need to be done to come up with an intermediate point (if that is desired).

Eli Asarian commented that the existing nutrient quantities are cited in reports completed by Mike Deas and USGS. We will need to determine the average daily load of organic matter present. Then, based on percentages of that load that is assumed to be removed, the equivalent amount of algae biomatter can be calculated. Presumably, the resulting DO change could also be estimated. Eli believes the information is available to calculate these, and perhaps it just needs to be done and summarized.

Tammy Wood added that one additional question that should be asked is: if you were to do algae removal upstream in Upper Klamath Lake instead of at Link River dam, what kind of benefit is seen by moving algae removal locations? Tammy commented that consideration should perhaps be given to how the proposed location compares to other upstream locations. Tammy suggested that the Klamath Lake TMDL model could be used to determine if the proposed amount of algae removal would have an impact in Upper Klamath Lake. The model is simple, so it wouldn't be hard to answer the question at a conceptual level.

Mary Grainey mentioned that she thought dispersed wetlands were being considered for Upper Klamath Lake, and that these wetlands may be a more well-suited technology for the lake.

Eli Asarian commented that Jake Kann, Maia Singer and Eli Asarian ran calculations on algae removal from Upper Klamath Lake. It seemed clear that lake is so large and algal growth is exponential, that it was impossible to remove enough algae from the lake in order to make a dent in the improvement. Jake Kann noted that when the calculations were completed, they focused instead on watershed restoration to reduce algae in the Lake.

Ken Carlson noted that algae removal at the Link River dam seems the logical and best algae removal point for affecting the Klamath River downstream. However, the extent to which we can effect Upper Klamath Lake processes long-term is certainly beneficial. As we move forward, we may need to consider various locations. Also, some technology is going to be better suited for certain locations over others and protections for ESA-listed sucker species may be quite different depending on location as well.

Question 2: Are technologies or types of systems available to remove algae biomatter at the scale required?

Ken Carlson commented that in the previous August 20 TAC meeting, Doug Jackson shared information about an algal removal system that was being operated on the A Canal in the 1990s. An impressive amount of algae was being removed for commercial purposes. This indicates that there is technology available to remove algal biomatter at Link River dam (or other alternative locations in the area).

Jerry Anderson noted that he and Doug have over 30 years of algae harvesting experience and have seen the technology develop over that time. Jerry is confident that algae can be removed, but it is dependent upon the quantity. Removal of 20 percent of the algae may be doable, however 50 percent may not (it's more of a question of economics). The benefit of the completing algae removal at the Link River is the narrow channel that allows easier removal of the algae material. Jerry and Doug are interested in a commercial practice that removes millions of pounds of algae per year that would be sold as a health supplement. Jerry and Doug have recently developed a new proprietary screening technology (patent pending) and could look at adapting that technology to a stationary site such as at Link River dam. There would be a dewatering process required. In terms of disposal, much of the year the species of algae that is used commercially can be removed from the water. However, there are other times of the year where there may be other types of algae present and disposal would need to be considered.

Question 3: What would be the disposition or disposal needs of the removed algae biomatter? Is release to the A Canal an acceptable approach? Are there other options (e.g., land application) to dispose of the removed algae biomatter?

Ken Carlson proposed further discussion on algae removal to occur in a sub-group to discuss with Jerry and Doug about their past experiences with algae removal technology. John Hamilton, Klamath Falls Fish and Wildlife Service (FWS) folks, Eli Asarian, Clayton Creager, Mike Deas, Mike Hiatt, Mary Grainey, and Maia Singer all would like to participate. The goal of the subgroup is to determine what the options are locally for disposal of algae and other material that goes beyond what is needed for commercial purposes.

Jerry Anderson noted that if algal toxins are present, the handling and disposal of the removed material is more challenging.

Question 4: What is the potential for take of Endangered Species Act- (ESA) listed species associated with algae removal? Can incidental take authorization be obtained and what would be the likely mitigation requirements?

As an action item from the previous August 20 TAC meeting, Demian Ebert, Eli Asarian, and Ken Carlson has an informational discussion with Dan Blake of the U.S. Fish and Wildlife Service (USFWS) about potential ESA considerations with regards to algae removal. Ken noted that a detailed description of the information obtained from Dan is contained in the "IM11 Activity 7 Key Questions Status" document (handout for this meeting). Based on the information obtained, Ken indicated that ESA considerations are likely not a "fatal flaw" that would prevent an algae harvesting project at Link River dam, but will be important considerations to continue to discuss with USFWS going forward. The type of algae removal system and its location will be important related to ESA considerations. ESA-related incidental take authorization for an algae harvesting project would be possible if it can be shown that improvements would either have

no effect or a beneficial effect on ESA species. Regarding timeline, incidental take authorization would likely take at least a couple of years to obtain. The most straightforward process would be the ESA Section 7 process, which would require a federal nexus (e.g., involvement by a federal agency or federal funding). Otherwise, the ESA Section 10 process is available, which would involve preparation of a habitat conservation plan (HCP), which would likely take longer (e.g., 3-4 years).

Eli Asarian commented that he thought it was a good sign that Dan Blake was receptive to balancing potential negative and positive effects on the listed sucker species, as long as net benefits on the fish could be demonstrated. However, at the moment, there are tools available to show the effect of algal removal on water quality, but there aren't tools to help us understand how algae removal would affect the suckers.

Ken Carlson noted that the fate of larvae downstream is unknown. As suckers move downstream, they are considered lost to the reproducing population.

Darrick Weissenfluh commented that it is important to realize that 5 miles of Link River is considered critical sucker habitat. It is too early for USFWS to make effective assessment of impacts to the sucker. However, Darrick reemphasized that USFWS wants to be involved through the whole process. Darrick mentioned a tool that could be used. Darrick will send Ken a link to the tool.

Ken Carlson asked if there are other aspects that we need to address regarding regulatory or legal aspects, such as water rights, land ownership, funding, etc. Due to the regulatory aspects of algae removal, it is important to identify who could drive the process; for example, a non-federal entity, federal entity, or public-private partnership. What are the important approval steps that we need to consider as we complete the evaluation?

Eli Asarian noted that there is a potential need for a state water right and land-based activities may require a permit from the City. From a water rights perspective, Mary Grainey added that at least a limited license for pilot project would probably be needed, which is easier to get than a regular water rights permit. At the point where water is being taken, it would be beneficial to get an agreement from the Bureau of Reclamation that it's not injurious to them. This might be harder at a location on Upper Klamath Lake. For a full scale project, Mary indicated that the more the potential project is non-consumptive, the better. There is a high-level of interest in seeing the water quality improvement, so that should carry weight in terms of needed regulatory approvals.

Clayton Creager noted that loss of wetlands can be mitigated. A compliance schedule can be developed for a restoration project that has short-term water quality impacts. In California, there is criteria to evaluate long-term benefits if a compliance schedule is developed with USFWS. Clayton also suggested that a question be added regarding the commercial use for benefit of the local economy. Nancy Simon has conducted some preliminary studies regarding the use of algae for feed stock.

Ken Carlson asked if the fish agencies have specific requirements for entrainment of water that would likely be required as a part of the algae harvesting screening process. Darrick Weissenfluh noted that the State has requirements for fish that would come into effect. A follow-up with ODFW is suggested. The State will want to see screening for other native fish.

Ken Carlson commented that as we think big picture, we need to think about the footprint of the facility and the requirements regarding land purchase, etc. Jerry Anderson noted that in the system he is thinking about, the footprint on shore would be a couple of container trucks so they could be removed during the winter. He also has an idea of a spot where this might be feasible.

12. Follow-up Action Items & Adjourn

The next TAC meeting is tentatively scheduled from October 29, 2015. Brittany will send out a meeting invitation. Brittany is also looking into third party meeting software to be used on future calls.

Ken Carlson will follow-up with Ted Wise regarding the most opportune time to oxygenate Keno Reservoir as a part of adult upstream migration and downstream juvenile movements.

Subgroup follow-up discussion with Jerry Anderson to be held. This discussion will include John Hamilton, Klamath Falls FWS, Eli Asarian, Clayton Creager, Mike Deas, Mike Hiatt, Mary Grainey, and Maia Singer.

Darrick Weissenfluh will send Ken link to a tool and follow-up with ODFW on screening requirements for fish.

Ken Carlson to touch base with Nancy Simon to get status on research on beneficial uses of algae.

Interim Measure 11 of the Klamath Hydroelectric Settlement Agreement
Activities 4 and 7

Technical Advisory Committee Meeting #3

MEETING DATE: February 11, 2016

MEETING TIME: 2:00 PM – 4:00 PM

LOCATION: Teleconference; Conference Call In: 1-866-203-7023;
Conference ID: 815-997-4011

ATTENDEES (checked box indicates attendance):

☒ Brittany Hughes/CH2M	☒ Jake Kann/AES	☒ Micah Gibson/Yurok Tribe
☐ Chauncey Anderson/USGS	☐ Jerry Anderson/New Earth	☒ Mike Deas/Watercourse
☐ Chris Stine/ODEQ	☐ Jim Carpenter/Carpenter Design	☒ Mike Hiatt/ODEQ
☐ Clayton Creager/CA RWQCB	☐ Joe Eilers/MaxDepth Aquatics	☐ Parker Thaler/CA RWQCB
☐ Dan Blake/USFWS	☐ John Hamilton/USFWS	☒ Rick Carlson/USBR
☒ Darrick Weissenfluh/USFWS	☐ John Rueter/PSU	☒ Susan Corum/Karuk Tribe
☒ David Austin/CH2M	☒ Ken Carlson/CH2M	☐ Tammy Wood/USGS
☒ Demian Ebert/PacifiCorp	☐ Kyle Gorman/OWRD	☐ Ted Wise/ODFW
☒ Doug Jackson/New Earth	☐ Larry Dunsmoor/Klamath Tribes	☒ Tim Hemstreet/PacifiCorp
☒ Eli Asarian/Riverbend	☐ Maia Singer/Stillwater Sciences	
☒ Elyse Will/CA RWQCB	☒ Mary Grainey/OWRD	

Meeting Notes

13. Introductions and Agenda Review

Ken Carlson opened the meeting by reviewing the agenda for the meeting. The call is a continuation of the conversations from past calls to discuss Activities 4 and 7 of the 2015 Interim Measure (IM) 11 Study Plan of the Klamath Hydroelectric Settlement Agreement (KHSA). This third TAC meeting is an opportunity to status where we are at with responses to the key questions for Activity 7 and determine the level of completeness or whether additional information is needed to fill in the gaps. The discussion today will focus solely on Activity 7.

14. Review of Activity 7 Key Questions – Priority 1

The purpose of Activity 7 is to assess potential algae harvesting and removal techniques at Link River Dam as a possible method for enhancing water quality in the Klamath River downstream. The Priority 1 Questions are questions that are drivers of feasibility. These questions have been designated as priority 1 questions as they could pose fatal flaws and will provide context for what and how algae harvesting and removal is accomplished.

Eli Asarian shared with the TAC that there is a potential funding source available for small water quality projects (algal biomass) that are proposed to be conducted in the upper basin. Grant applications are due to EPA in September and will fund projects up to $100,000. The funding does require a $40,000 match.

Review Status of Responses

1. What quantity of algae biomatter would need to be removed to significantly reduce loading and enhance water quality?

Ken Carlson reviewed the current responses included in the IM 11 Activity 7 Key Questions document. He noted that the summary of the answers do not specifically state what the targeted level of algae removal should be, but the Sullivan et al. (2013) report[1] and Watercourse Engineering (2015) report[2] indicates that around at least the 20 to 25-percent range of biomass (as dry weight) removal will likely be required to make a demonstrable change to water quality downstream.

Eli Asarian suggested the answer should include summary information about the Watercourse Engineering (2015) hydrodynamic stormwater separator report. It should include model scenarios and results between 0- and 25- percent removal. Also, the appendices of the Sullivan et al. (2013) report have graphs showing the spatial effects on the reservoir that would be helpful to include, as the report showed improvements would be greater in certain sections of the reservoir than others.

Mike Deas discussed the Watercourse Engineering (2015) hydrodynamic stormwater separator report results. Watercourse ran 20-, 30-, and 40-percent reductions and the results are temporally and spatially presented in the report. Spatially, the positive impacts on the reservoir are in the same ballpark of the Sullivan at al. (2013) report, but the Watercourse Engineering (2015) report presents some different spatial and temporal information.

2. Are technologies or types of systems available to remove algae biomatter at the scale required?

Ken Carlson reviewed the current responses included in the IM 11 Activity 7 Key Questions document. Ken asked what technologies are available if an approximate 20-percent range of removal is assumed.

Doug Jackson indicated that he is not aware of a system that is available or has been used that might remove loads at 20 to 25-percent range of the algae biomatter load (as dry weight) that is in the discharge from Upper Klamath Lake Doug noted that the A Canal harvesting system (that Doug described in the previous TAC meeting) is that largest system he is aware of, harvesting at a rate of about 200,000 pounds per day of wet algae biomass. Doug noted that the mix of algae would depend on the time of year, and there is a potential for toxins to be involved.

Ken Carlson noted that and the technological means are probably available to build a system to remove 20 percent if money were no object. As such, feasibility probably comes down to cost rather than available technological capability. Doug and Jerry are willing to share information with the TAC, but need TAC members to understand there is some information that New Earth can't share in order to protect their intellectual property.

[1] Sullivan, A.B., Sogutlugil, I.E., Rounds, S.A., and Deas, M.L. 2013. Modeling the water-quality effects of changes to the Klamath River upstream of Keno Dam, Oregon: U.S. Geological Survey Scientific Investigations Report 2013–5135, 60 p.

[2] Watercourse Engineering. 2015. Technical Report. Conceptual Design Evaluation for Full-Scale Particulate Organic Matter Removal from Klamath River Source Water Using Stormwater Treatment Technology. Prepared for PacifiCorp, Portland, Oregon. Prepared by Watercourse Engineering, Inc., Davis, California. March 2015. 54 p.

Mary Grainey asked Doug what he knew about the schedule for commercialization of New Earth's technology. Doug Jackson noted that everything has been submitted for a patent and should be finalized in the next 6 to 8 months. He said much of the information he's provided is based on work that was completed in the 90s and that nothing has changed on this particular subject matter.

Eli Asarian commented that with useful information from New Earth on algae removal, it would be useful to provide a removal effectiveness table similar to that presented in Sullivan et al. (2013) to get a sense on removal effort. If same A-Canal-type algae removal system was functioning at Link Dam today, what percentage of algae would we be able to remove?

Jake Kann asked TAC members how we move forward with this aspect of the project in terms of a pilot project, as a next step is not clear.

Ken Carlson noted that before we launch into a pilot study, we wanted to use this activity to answer some basic questions to make sure pilot is worth doing and to determine what kind of pilot test to do and what data gaps exist to help inform the next step in the process.

Tim Hemstreet commented that the next step is to lay out what would be required for a pilot and to understand how you assess whether a pilot project would be useful.

Ken Carlson noted that there is more to a pilot and removal strategy than just the removal piece. Processing, transportation, and disposal are all crucial items. We know that 20 to 25-percent removal may be feasible, but 50-percent is likely not. We need to understand what a system would look like and require (including for transport, disposal, permitting, etc.) to achieve 20 to 25-percent algae removal.

Mary Grainey asked if the TAC had considered whether the algae could be used as a biofuel.

Ken Carlson noted that based on discussions, there are some potential commercial uses (soil amendment) for algae, but the lipid content isn't at a sufficient level to qualify it for use as a liquid biofuel.

Rick Carlson said an idea for a power plant had been discussed, but didn't happen. Nancy Simon said the algae has a high amount of protein and might be a good feed product.

Mary Grainey noted that hauling adds a significant expense, so the TAC might want to keep burning the algae on the table as an option.

3. What would be the disposition or disposal needs of the removed algae biomatter? Is release to the A Canal an acceptable approach? Are there other options (e.g., land application) to dispose of the removed algae biomatter?

Ken Carlson noted that previous TAC discussion indicated that the A Canal may not be an acceptable location for release of the algae removal waste stream. Therefore, are there other options such as land application to dispose of biomatter? Mike Hiatt noted that there is another possible outlet for the material - a composting facility is being proposed just north of the state-line along the highway. It would be a large facility. Mike has spoken with the individual who is putting the facility together. It would be a little bit of a drive for transportation (17 miles). The composting facility has people who want the material to amend their soil and they are currently putting together a list of what the facility would accept.

Ken Carlson asked if the facility is facility being set-up to take algal material.

Mike Hiatt said the facility is being proposed with a large lagoon system and a compost pile that is composed of manure and other materials received throughout the area. Lagoon materials would be used to apply to the compost pile to help with the degradation process. Mike said he

believes toxins would be broken down through the composting process. The end user is the agricultural community.

4. What is the potential for take of Endangered Species Act (ESA)-listed species associated with algae removal? Can incidental take authorization be obtained and what would be the likely mitigation requirements?

Ken Carlson reviewed the current responses included in the IM 11 Activity 7 Key Questions document.

A special conference call was held with the U.S. Fish and Wildlife Service about the potential and likelihood for incidental take to occur (primarily juvenile suckers) due to screening and algal removal process. This doesn't mean the level of take isn't approvable or a fatal flaw, but careful evaluation of negative benefits and positive benefits that could occur will require careful consultation with agencies and evaluation of the take. This would require a 6-month to 2-year process to get through permitting and needs to be factored into the project going forward, including a pilot project.

Derrick Weissenfluh noted that a pilot study would be the best way to start the effort to get a handle on the impacts of a large scale project. All of the Link River and downstream to Keno Dam is critical habitat for suckers. There is a tool, which is currently being updated, for estimating entrainment. It will be helpful in evaluating and Derrick will send out the tool once it has been updated. The A Canal as pilot study or full effort would be an optimal location, but we need to understand whether impacts for water quality could be achieved by working at the A Canal location.

5. What are the approval steps (e.g., legal, regulatory, financing) that would be needed, and what are the potential constraints that could be imposed from these approvals?

Ken Carlson reviewed the current responses included in the IM 11 Activity 7 Key Questions document.

Mary Grainey didn't have any additional updates at this time regarding water diversion or water rights requirements.

Ken Carlson noted that nothing the TAC has looked at from a regulatory and permitting perspective has seemed to pose a fatal flaw. However, answers to questions do reveal that may be at the margins in terms of the feasibility of algae removal at the scale to substantially improve water quality. It can certainly be done, but could be costly. Feasibility is a question at the margins. ESA will take a significant effort to get through.

Rick Carlson suggested the following report be added as a citation into the questions document: Simon, N.S., Ali, A.A., Samperton, K.M., Korson, C.S., Fischer, Kris, and Hughes, M.L., 2013, Characterization of cyanophyte biomass in a Bureau of Reclamation reservoir, U.S. Geological Survey Open-File Report 2013–1156, 59 p., http://dx.doi.org/10.3133/ofr20131156. The report notes the high protein content of the algae.

Derrick Weissenfluh said he'd had a call with Ted Wise and John Hamilton to discuss fish screening requirements. Derrick said USFWS has screening requirements to prevent entrainment of fish that would prescribe screen mesh size of no greater that 3/32nds of an inch and approach velocities of no more than 0.33 feet per second. This would impact amount of incidental take.

Eli Asarian asked if anyone had talked to any of the wastewater treatment plants about TMDL compliance to see they might want to be partners and a part of the discussion. Mike Hiatt indicated that the wastewater treatment plants are still waiting on the finalized TMDL. Once updated, it will be put in permit queue. 2017 is earliest their permits would be renewed.

15. **Review of Activity 7 Key Questions – Priority 2 & 3**

Ken Carlson noted that the priority 2 questions are drivers of scope, size, and type of system needed. The priority 3 questions then drill down into the process-related steps. These questions begin to determine the level of detail needed to lay out an algae removal system. They will either result in the decision to do a pilot or determine that an additional evaluation step is needed in order to answer information that is still lacking.

Discuss whether responses to these questions are still needed at this point

1. What system component or steps would be required to remove the desired amount of algae biomatter (e.g., screening, filtration, centrifugal, sedimentation, flotation, flocculation, dewatering, drying, transport, disposal)

Ken Carlson noted that this is very much a question for New Earth. The steps would require engineering and thoughts in terms of mapping out major system components, but not to the level of specific details in terms of identifying pumps, pipes, etc.

2. What quantity of algae biomatter would available or alternative systems potentially remove (i.e. at Link River dam)?

Ken Carlson reiterated that if there are alternative systems, they need to be identified.

3. How might the approach to algae biomatter removal at Link River dam be affected by (or integrated with) other efforts in the basin to reduce nutrient and algae loads in Upper Klamath Lake and the Klamath River?

Ken Carlson noted that this question goes back to the presumption that this would not be the only tool in the tool box for water quality improvements and strengthens the argument that just a portion of removal is acceptable.

4. What are the potential commercial uses and quantities of the harvested algae biomatter?

Ken Carlson reiterated that depending on uses and material, the TAC need to consider what is going to need to be disposed of in some other fashion.

5. Could algae biomatter removal quantities (as estimated above) be sufficient to affect oxygen depletion at the sediment/water interface? If so, is information available to estimate this effect?

Ken Carlson noted that over time, as you remove organic matter material, the sediment oxygen demand may gradually lessen. If so, Keno reservoir water quality may improve not only by reducing organic matter in the water column, but also by reducing sediment oxygen demand.

6. If release of additional algal loads to the A Canal is an acceptable approach, what potential effect would that have on Lost River water quality?

As discussed previously, Ken Carlson noted that release to the A Canal may not be acceptable or would need to be carefully examined regarding effect on the Lost River System.

7. If other disposal is required, where would that occur?

Ken Carlson noted the TAC needs to consider not just where the disposal would occur, but also how it would occur.

Ken Carlson commented that the Priority 3 questions are process-related and provide more detail on the kind of overarching process of algae removal.

1. What are the specific process steps and methods needed to dewater or dry the harvested algae biomatter?

Ken Carlson noted that based on previous discussions, dewatering and drying can be fairly demanding and an expensive step in the process.

2. Would the operational requirements be for a batch or continuous mode harvesting system?

Ken Carlson noted that we are all aware that this system will only operate for part of the year during the peak algae growth period. This question relates to whether the system is going to be operating continuously or in batches. This is important from the standpoint of energy consumption and how much material is processed on a daily basis.

3. What specific process steps are needed to detoxify algae biomatter?

Ken Carlson noted that cyanobacteria may need to be dealt with. If required, this is a developing technical area, and may present an ongoing challenge as there may not be solid answers at this point in time.

4. What specific process steps are needed to transport or dispose of harvested algae biomatter?

Ken Carlson noted that truck transport has been discussed. We will need to determine how many and how often, which are important questions from an economics standpoint.

5. What are the estimated energy consumption demands, and/or costs or cost ranges of the above (Priority 3 Questions 1-4)?

Ken Carlson noted that cost could be the driver of feasibility, but in order to come up with accurate costs, it will require more system details. Watercourse did this with the organic matter removal study. This helps grasp how easy or hard it would be to fund something.

6. Based on the answers to the above, what are some example conceptual layouts for an algal biomass harvesting system?

Ken Carlson noted that this question gets at potential conceptual layouts for a harvesting system and would be a springboard for more detailed engineering assessment and design.

Ken Carlson asked the TAC what direction that TAC wants to move in now. We have solid answers to the priority 1 questions. Are we ready to move onto priority 2 and 3 questions, and get into those details, or are there additional overarching questions to answer or decisions to make first before moving forward.

Tim Hemstreet commented that there are some questions where we could gather an answer with the use of New Earth's expertise with regards to dewatering and detoxification. We could gather answers (non-proprietary) to understand dewatering, transport, etc. to help everyone understand. Tim suggested interviewing Doug Jackson offline to provide information to answer questions.

Doug Jackson said he likes idea of offline interview and is happy to answer questions and help determine what needs further research or discussion.

Doug Jackson commented that related to priority 2, question 1, the initial harvest part of getting algae out of the water depends on the screen. After screening, you end up with a product that is 1 percent solids. This product is easy to pump to shore or a land-based facility or other apparatus with any kind of pump. The next step in the process is dewatering. Dewatering will take the product from 1 percent solids to possibly as high as 6 or 7 percent solids. This product is a very thick paste that is hard to pump. It takes a long time to fill a tanker truck to haul it off. The water removed during this process has to go somewhere and it is green in color, containing broken algae cells. Once paste is in tanker truck and driven to the disposal site, it takes a long time to drain out of the truck. At 6 to 7 percent solids it is hard and slow to pump and it is still 94 percent water. It would be hard to burn it as a potential fuel at that point without going through

a drying step. New Earth would batch freeze the 6 to 7 percent sludge and then dry it. When dried, the algae has a high protein content and lipids are as high as they will get.

Demian Ebert asked Doug how much material he was referring to in his description.

Doug Jackson said a semi-tractor trailer with a gross vehicle weight is 40,000 lbs.

Doug Jackson said to answer priority 2 question 2, TAC would need to look for other sources for ideas outside of New Earth's screening technology.

Ken Carlson asked Doug to talk about how fish screening has been dealt with in the past.

Doug Jackson said one screening method has a very similar look to what most small irrigation districts have used for screening fish out of their intake with drum-type rotation. Fish would get rotated and can swim out of way. By blocking off the mouth of A Canal, you could minimize impingement of fish. Screening should be reviewed and with the approach evaluated during the design phase. Doug expected this to be low impact.

Ken Carlson asked Doug what New Earth's process is now for the water after algae is filtered out.

Doug Jackson noted that New Earth currently returns the water back to the lake. They do not make any additions to the water after screening.

Mike Hiatt commented that he thinks these activities are covered under Department of Agriculture.

Doug Jackson noted that New Earth does not have a permit that is specific for return of the water to the Lake. They have their boats licensed and permits for docks. Other than screening out the algae, they don't take any additional water out of the lake.

Mike Hiatt noted that from a DEQ standpoint, its cleaner water being discharged to the Lake than what was originally taken out. There has been a similar process with algae ventures for testing – no NPDES permits were needed. Taking water out and putting it in a different water body would require additional research on requirements.

Doug Jackson said the facility on the A Canal in 1990s had discharge permits through DEQ. Monitoring occurred at inspection stations (vaults). The Oregon Department of Agriculture was a regulator for the lake process because it was a food-based product.

Ken Carlson noted that CH2M will follow up with Doug Jackson offline on the rest of the questions to get as much information filled in on second and third set of questions as they related to the process itself. This will allow us to identify gaps and consider what follow-up assessment work may be needed.

Eli Asarian noted that the intent of a pilot was to understand the quantity of algae that could be removed. Secondarily, it allows us to test out every step of the process to determining permits, work on end uses, etc. New Earth would not be ready to sign up for a pilot project tomorrow due to patenting. One significant gap is the fate of algal toxins – how long do they last for? Toxins may degrade over time, but maybe we should do some pilots or do a literature review. For human health, a pure stream would be required. With dirty streams, how do we get toxins out and get into animal food stream? Is there anywhere in the world where algae is being used for animal feed and have toxins been addressed?

Demian Ebert commented that on one hand we can figure out how to remove algae from the system, but then what do you do with it? Is there a way to post-process it so you can use it to recover some costs? Need to determine if there is any way you can make it more economically sound.

Mary Grainey noted that a system at A Canal may need to be a large system; for example, to screen 1000 cfs. A system at Link River Dam may have to be a much smaller system. TAC should consider if there is room for a fish and algae screen at Link River Dam. Determine space requirements.

Tim Hemstreet noted that the stormwater separator work with Watercourse revealed that for 200-300 cfs, there is not a large screen or space requirement. System could pump water or use the eastside forebay space - a footprint of 200 feet long and 30 to 40 feet wide just downstream of Link River Dam.

Doug Jackson said he would look forward to having a conversation about that area and what it could be used for. Knowing it is an option for use would be helpful in a planning stage. The patent process was promised as 2 to 2.5 years. New Earth is 2 years in and haven't heard anything to make them believe that they wouldn't receive their patent within the next 6 months. Doug also noted that there is currently no methodology of removing toxins from biomass, they just don't harvest when it is present.

16. **Follow-up Action Items & Adjourn**

Ken Carlson suggested a series of action items going forward:

- CH2M to conduct a follow-up interview with Doug Jackson and Jerry Anderson to flush out as much as possible on second and third sets of questions. Bring additional information to bear and identify gaps.
- CH2M to update key questions document based on interview and additional information offered today.
- TAC members to forward additional comments, input to CH2M and will incorporate into document.
- Hold fourth call of the TAC to discuss updated question document and use call to identify tasks and gaps of information going forward and use to identify potential elements for follow-up work. Plan to hold the fourth call of the TAC 4 to 8 weeks from now.

Eli Asarian noted he would be interested in Ken Carlson or Mike Hiatt doing some more outreach to proposed compost facility and finding a farm person to talk more about animal feed.

Mike Hiatt said he would check in with composting facility and get some further information and details on how this material looks to them and if they might be interested in a pilot study on toxin degradation. Mike will also check on permitting with Cell Tech on A Canal.

Ken Carlson noted that the TAC need to continue to think about permitting of a pilot and start to focus on a location. If we wanted to do something in summer of 2017, and it is some type of screen or filtration base, we need to stay ahead of permitting requirements.

Ken Carlson noted that he appreciated everyone's input. This is the kind of project that can go in a lot of different directions, but we've managed to maintain a focused discussion.

Interim Measure 11 Activities 4 and 7 Technical Advisory Committee (TAC)

IM 11 Activity 7 Priority 2 and 3 Questions Follow-up with New Earth Technologists

MEETING DATE: March 2, 2016

MEETING TIME: 2:00 PM – 3:00 PM

LOCATION: Teleconference; Conference Call In: 1-855-559-2426; Conference ID: 370-4351

ATTENDEES (checked box indicates attendance):

☒ Brittany Hughes/CH2M	☐ Jake Kann/AES	☐ Micah Gibson/Yurok Tribe
☐ Chauncey Anderson/USGS	☒ Jerry Anderson/New Earth	☐ Mike Deas/Watercourse
☐ Chris Stine/ODEQ	☐ Jim Carpenter/Carpenter Design	☐ Mike Hiatt/ODEQ
☒ Clayton Creager/CA RWQCB	☐ Joe Eilers/MaxDepth Aquatics	☐ Parker Thaler/CA RWQCB
☐ Dan Blake/USFWS	☐ John Hamilton/USFWS	☐ Rick Carlson/USBR
☐ Darrick Weissenfluh/USFWS	☐ John Rueter/PSU	☐ Susan Corum/Karuk Tribe
☐ David Austin/CH2M	☒ Ken Carlson/CH2M	☐ Tammy Wood/USGS
☐ Demian Ebert/PacifiCorp	☐ Kyle Gorman/OWRD	☐ Ted Wise/ODFW
☒ Doug Jackson/New Earth	☐ Larry Dunsmoor/Klamath Tribes	☒ Tim Hemstreet/PacifiCorp
☒ Eli Asarian/Riverbend	☒ Maia Singer/Stillwater Sciences	
☒ Elyse Will/CA RWQCB	☒ Mary Grainey/OWRD	

Meeting Notes

17. Introductions and Agenda Review

Ken Carlson opened the meeting by reminding the call participants that the call being held today with Doug Jackson and Jerry Anderson from New Earth was an action item from our previous TAC call for Interim Measure (IM) 11 Activity 7 pertaining to algal harvest at Link River Dam. The TAC has been working through a number of questions aimed at the feasibility of applying algal harvesting technology and expectations around what may be gained from the use of the technology. The call today with New Earth will focus on the more detailed Priority 2 and 3 questions to gather additional details regarding scope, size and type of system, and important process related steps. New Earth will discuss what they can without jeopardizing their proprietary intellectual property.

18. Additional Input for Key Questions (Priority 2 and 3)

1. What system component or steps would be required to remove the desired amount of algae biomatter (e.g., screening, filtration, centrifugal, sedimentation, flotation, flocculation, dewatering, drying, transport, disposal)

Doug Jackson and Jerry Anderson of New Earth explained that steps would include: (1) a primary in-water harvest screening that would result in algal mass material of 1 percent solids: (2) a

secondary on-shore de-watering step to concentrate the algal material to about 6 percent solids (with the extra water returned to the river); and (3) loading of the 6 percent concentrated product into tanker trucks (or other transport approach). New Earth noted that the dewatering step results in a paste that is approximately 6 percent solids, can be difficult to pump, and it is hard to find effective ways to move it other than by tanker truck. Based on the other ideas listed (filtration, centrifuges, flocculation), screening out the material is the most preferential from an ease and expense of process standpoint. Once the 6 percent solids material is loaded into a tanker truck, it is then transported to its end use.

Ken Carlson asked if there are any steps once it leaves the site and before it reaches its end use, such as additional dewatering or drying. New Earth noted that additional steps are completely dependent upon the end use.

New Earth also asked that a correction be made to the previous set of notes from the TAC call. The notes stated that "much of the year the species of algae that is removed from the water could be used commercially". This is not necessarily the case, as the process is very much subject to the whims of Mother Nature.

2. What quantity of algae biomatter would available or alternative systems potentially remove (i.e. at Link River dam)?

New Earth noted that their experience relates to screening flow with a certain type of system, which may or may not be the right system for the situation at Link Dam envisioned by the TAC. In the 1990s, New Earth was able to screen out approximately 200,000 wet pounds per day (estimated at about 12,000 dry pounds per day of biomatter) using their harvesting system on the A Canal, which filtered a large portion of the water passing through that location. New Earth noted that a pilot study would help determine the type and size of the system required before a large scale system is designed and constructed. The pilot study could also be used to test for: (1) the amount/rate of biomass removal, (2) potential fish entrainment effects; and (3) speciation, toxins, and weights of the algae biomass. Location of the system could be a determining factor in the selection of the methods used for algal removal.

Doug Jackson indicated that the table from Sullivan et al. (2013) report[3] included as a part of the response to question 1 is derived from Keno Reservoir, which doesn't necessarily represent the material moving through the Link River, unless we can correlate one to the other. Clarification is needed on whether these can be correlated. Scenarios in the table in the Sullivan et al. (2013) report represent a decrease in algal concentration from the Link River into Keno reservoir. The reductions listed are modeled average reductions in Keno Reservoir. The intent of the modeling was to look at the effects of reduction.

New Earth has a lot of experience in engineering, a lot of which could be transferrable to a pilot project. One of the goals of a pilot project is to look at the amount of biomass removal. Doug Jackson noted that the East Side and West Side forebays and penstocks at Link Dam might lend some advantages on how an algal removal system could be engineered. A pilot should also look at a system to be placed in the Link River upstream of the dam.

Mary Grainey asked how much instrumentation is needed when algae is being removed from the water. Is algae being weighed and tested? New Earth noted that a lot of testing is completed on the biomass including speciation, toxin presence, weight, etc.

Tim Hemstreet commented that the use of the East Side and West Side forebays and canals may be possible in terms of space, depth of water, etc. It is also private access, and there is no public

[3] Sullivan, A.B., Sogutlugil, I.E., Rounds, S.A., and Deas, M.L. 2013. Modeling the water-quality effects of changes to the Klamath River upstream of Keno Dam, Oregon: U.S. Geological Survey Scientific Investigations Report 2013–5135, 60 p.

nature trails where people would be walking by the operation. The East Side forebay is larger than West Side. PacifiCorp could potentially allow use in that area.

3. How might the approach to algae biomatter removal at Link River dam be affected by (or integrated with) other efforts in the basin to reduce nutrient and algae loads in Upper Klamath Lake and the Klamath River?

Clayton Creager noted that the Stillwater et al. 2013 report[4] did not include algal biomass removal among the water quality improvement techniques examined for the Upper Klamath Basin. Rather, the Stillwater et al. 2013 report focused on a range of other approaches for dissolved oxygen improvement in Keno reservoir and at treatments to reduce nutrient loads coming into Upper Klamath Lake from the basin above. Clayton likes the idea of modeling the entire basin. Current TAC discussions have been focusing on the Link-Keno segment of the basin rather than the basin as a whole. A Soil & Water Assessment Tool (SWAT) model of the watershed is currently being developed and should help quantify the impact of land management practices in the basin. Clayton doesn't think that the current approach addresses how to apportion improvements across the projects.

Maia Singer questioned whether algal biomass removal at Link Dam would have a significant impact on algae downstream. This is not something that has been examined. Algae biomatter discharged to Link River is no doubt contributing to the dissolved oxygen issue. However, removing algae biomatter at Link Dam doesn't mean that the algae won't grow in the reservoirs downstream.

Clayton Creager noted that monitoring results for chlorophyll-a have shown a distinct decline downstream from Upper Klamath Lake for a certain distance (to Copco Dam), but then the levels jumps back up again downstream of Copco dam. In-lake manipulations are complex and the thinking is that the most direct way to affect algal populations moving downstream is to correct phosphorus input into the Lake. This thinking resulted in a push to consider use of treatment wetlands upstream of the lake.

Clayton Creager also noted that Rosemary Records (a PhD graduate student at Colorado State University) is creating a SWAT model that looks at all the inputs from the upper watershed. However, the model may have been limited to the Sprague River basin instead of the whole Upper Klamath basin. Documentation related to a presentation of her model can be found at http://www.kbmp.net.

4. What are the potential commercial uses and quantities of the harvested algae biomatter?

Ken Carlson described potential uses that had been mentioned in previous TAC calls, including for pharmaceuticals, health supplements, biofuel, and feedstock. Algae harvested material from Upper Klamath Lake may not have appropriate amount of lipid content for use as a biofuel.

Jerry Anderson noted that when there is no toxin in the biomass, there are uses available for it. However, when toxins are present, that is when it is difficult to find uses. Another key question to answer is what to do with the material when toxins are present. The presence of toxins varies from year to year.

Doug Jackson commented that most everybody refers to the material in a dry powder sense. The cost to get algae to that point can be very expensive. There might not be enough money in the dry powder product to justify drying the collected algae biomatter to that state.

[4] Stillwater Sciences, Jones & Trimiew Design, Atkins, Tetra Tech, Riverbend Sciences, Aquatic Ecosystem Sciences, and NSI/Biohabitats. 2013. Water Quality Improvement Techniques for the Upper Klamath Basin: A Technical Workshop and Project Conceptual Designs. Prepared for California State Coastal Conservancy, Oakland, California.

5. Could algae biomatter removal quantities (as estimated above) be sufficient to affect oxygen depletion at the sediment/water interface? If so, is information available to estimate this effect?

Clayton Creager noted that he raised this question initially, and his question pertained more to potential algal biomass removal in Upper Klamath Lake itself and removal of phosphorus from sediments. With focus on Keno reservoir (based on removal at Link Dam), the question may not be as relevant now. Clayton suggests that further work on this question perhaps be deferred to the USGS/Watercourse model of Keno reservoir.

6. If release of additional algal loads to the A Canal is an acceptable approach, what potential effect would that have on Lost River water quality?

Ken Carlson noted that we originally thought the A Canal may be a way to dispose of material, but discussion in previous TAC calls indicates that disposal to A Canal may not be acceptable. Clayton Creager commented that it is apparent that the Lost River System is already inundated with organic matter and nutrients. There is mobilization in the sediments from the canals that causes dissolved oxygen conditions to go to zero. Conditions are already critical in the Lost River system. It would be difficult to get regulatory approvals to push more to Lost River.

7. If other disposal is required, where would that occur?

Ken Carlson asked: for algae biomass that is collected and can't be used, where would disposal of that biomatter occur? Mike Hiatt talked about a composting facility on a previous TAC call. Doug Jackson noted that he didn't have anything else to add. He commented that he would encourage the group to find a way to dispose of the material and not count on finding a commercial use for the product.

Eli Asarian noted that he had talked with Jake Kann after the last TAC call regarding the use of algae as animal feed. The Oregon Health Authority (OHA) or some other entity has an allowable concentration of microcystin which is similar to human consumption. Eli also left a message with the Oregon Institute of Technology (OIT) agriculture extension office.

8. What are the specific process steps and methods needed to dewater or dry the harvested algae biomatter?

Ken Carlson noted that this questions assumes that there may be a need to dewater or dry a good portion of the biomatter (such as for certain commercial uses). If so, how would that would be accomplished? What does it depend on? Are there optional approaches?

Jerry Anderson noted that there are different ways of dewatering. New Earth has a method they use that works well for them with no additives. The process removes a little more of water (not intracellular) that is present in algae slurry (river/lake water) so there is no disposal issue for that water. If talking about commercial-use material, this dewatering would take place on the side of the river. Drying is a whole other topic that would depend entirely on specific end use. In any event, drying would not take place on the side of the river. Rather, the material would have to be trucked to an offsite location for drying.

Ken asked if the material has a commercial use as a dried powder product, would the entity that is doing harvesting offer to sell or transport slurry to whoever wants the product and they would do the drying. Or would drying have to occur prior to make the product commercially attractive?

Doug Jackson noted that an end use needs to be identified. If the end use has to have good nutrients and profile of the algae to have value, it's like harvesting milk. You have to be able to process the material in a short amount of time in order to maintain its nutrient value. The material may not have enough value if it is dried in a cheap way. Low temperature drying is expensive. Drying requires specialized process/equipment that can deliver the right temperatures for drying.

Jerry Anderson noted that end uses such as animal feed or soil amendments don't sell for a lot of money. Drying is one of the more expensive parts of the process.

Ken Carlson asked if dewatering is an expensive part of the process as compared to screening. Doug Jackson noted that it depends on the approach and the equipment chosen for the step. May require personnel to monitor and process. Other equipment may cost a little more, but require less manpower to operate. Dewatering is not cheap, but it is not as expensive of initial removal from lake itself. Jerry Anderson noted that if you can dewater on-site in a manner that doubles your solids content, you have a lot less drying that you have to do subsequently.

9. Would the operational requirements be for a batch or continuous mode harvesting system?

Doug Jackson noted that New Earth's operation on the A canal in the 1990s went 24 hours a day, 7 days a week from July 4th to Oct 15th when the canal shut down. The process can easily be a continuous process. New Earth doesn't operate those hours out on the lake (daylight hours only). The process is a constant through-put process until loading into tankers is completed. Think of it as a batch process for the loading piece. Screening and algae removal process would still be continuous.

10. What specific process steps are needed to detoxify algae biomatter?

Doug Jackson noted that New Earth avoids toxins up-front. Jerry Anderson added that New Earth does testing ahead of time to avoid toxins and do not harvest when it is present.

Clayton Creager noted that Nancy Simon was looking at an enzyme treatment to reduce toxicity of microcystin. If you can address the toxicity issue, might be able to use algae as a feed source.

Eli Asarian noted that there is a fine line between reuse and disposal. Eli finds it hard to believe that composting is not going to destroy the algal toxin; rather, it will be a condition of the time scale of how long it takes for toxins to break down. This is a critical question we need to figure out – exploring degradation of toxins in a variety of field conditions.

Ken Carlson and Jerry Anderson commented that they had heard that exposure of collected biomatter to sunlight (such as in a land-based drying step) breaks down microcystin toxins, so this may be worth looking into.

11. What specific process steps are needed to transport or dispose of harvested algae biomatter?

Ken Carlson asked whether transport via tanker truck (used by New Earth) is still a logical process considering large quantities of material.

Doug Jackson noted that for commercial use, tankers would have to be the approach. For non-commercial uses, pumping to a certain location is another possible approach.

Jerry Anderson noted that based on current location (due to proximity of homes), a tanker truck may be the only option for transport or disposal of algae.

12. What are the estimated energy consumption demands, and/or costs or cost ranges of the above (Priority 3 Questions 1-4)?

Ken Carlson noted that, in concept, it is possible to engineer pretty much anything, but ultimately costs will become so high as to be limiting or unfeasible. Because funds will be limited, we would need cost effective approaches to get this done.

Doug Jackson commented that drying costs are by far the largest. If taking the product to a dry form is needed, drying costs would be the driver.

Jerry Anderson noted that there would be significant electrical costs associated with the screening process.

13. Based on the answers to the above, what are some example conceptual layouts for an algal biomass harvesting system?

Jerry Anderson asked if it makes sense to have another call to dive deeper into conceptual layouts. The group is aware of the major steps involved as discussed today and on previous TAC calls. Conceptual layout will have two potential paths depending on whether the collected algae biomatter will be a usable product or is material to be disposed.

Mary Grainey suggested we might try to get an estimate on square footage of screens needed for 100 cfs. What screen size do you need for the first step?

Doug Jackson noted that in another meeting to develop project size, those answers will come to light. If you scale too small, there is a lot more room for error and misunderstanding impacts that are positive and negative at the same time. Need to understand where everyone would feel comfortable on the size of the pilot project.

Clayton Creager noted that he is unsure whether it is worth moving this study further into the pilot phase or whether we use the available IM 11 study funds to other methods that have a bigger "bang-for-buck" on water quality. Clayton is thinking about this particular algae harvesting approach in relationship to other potential approaches – known benefits of some of the other approaches may be more worthwhile pursuing.

Eli Asarian noted that we need to understand the cost per unit removal. Ken Carlson noted that coming up with reliable costs at this point would be a big challenge given that any such cost estimates would be very broad until certain key decisions can be made with regard to key elements of the system. For example, how big of a system is needed, what size, how and where to dispose, commercial uses? The specific answers on these elements will factor heavily into cost estimates. Might be the basis of next round of work.

Appendix B: IMIC Comments and Responses on Draft Report

PacifiCorp Responses to IMIC Comments on the Draft Technical Report for Activity 7 – Assessment of Potential Algae Harvesting and Removal Techniques at Link River Dam			
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SWRCB/Thaler - 1		State Water Board staff has reviewed the Technical Memorandum for IM-11, Activity 7- *Assessment of Potential Algae Harvesting Removal Techniques at Link River Dam* and has no comments.	Comment noted.
USFWS/ Hamilton - 1		Section 3.1.4: Please revise this section to clarify that the portions of the Link River and the Klamath River located upstream of Keno Dam are specified as designated critical habitat for both Lost River sucker and shortnose sucker.	The report has been modified to include this information.
USFWS/ Hamilton - 2		Section 3.2.1: Please revise this section to clarify that the A Canal is already screened and is a location to consider implementation of a pilot study, if pursued.	The report has been modified to include this information.
ODEQ/ Stine-1		The Department has reviewed the Technical Memorandum for IM-11, Activity 7, Assessment of Potential Algae Harvesting Removal Techniques at Link River Dam and recommends that further information be provided on both the cost of the project and a potential outlet for the biomass. The Department believes that a fairly substantial footprint would be needed to a) install the equipment needed to harvest the algal material; b) install a fish screen large enough to facilitate the amount of water needed to make a true impact on water quality; and c) install a facility to collect and transport the biomass for disposal. The Department would also recommend that the IMIC revisit the method of disposition, as the A Canal will not be a suitable location due to constraints from the TMDL. The Department would also suggest a different approach such as an Ozone injection system to destroy the biomass and toxins from the water providing a fresher cleaner water source to be added to the Keno Reservoir.	PacifiCorp agrees that if this project is pursued, additional information about algae reuse or disposal options is necessary to determine project feasibility.
Karuk/Yurok - 1	p. 3	p. 3: "However, at times of severe anoxia the reservoir has limited primary production, apparently as a result of the lack of available oxygen to meet algal respiratory demands (Deas 2008)." - This sentence may not be correct. This same sentence also appears on page 3 of the draft report on Activity 4: Conceptual Feasibility Study of Oxygenation Systems at Keno Reservoir. Please refer to our comment above on that report.	The sentence has been deleted from the final report.
Karuk/Yurok – 2	p. 4	p. 4: "Jake Kann, Applied Ecosystem Sciences (AES)" - Should be "Jake Kann *Aquatic* Ecosystem Sciences (AES)"	The report has been corrected to reflect the proper name.

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Karuk/Yurok – 3	p. 7	p. 7: "Removing 50 percent or more of the material would likely require an extensive facility capable of handling this increased volume. For planning purposes it may be worth considering just the 25 percent removal rate since the 50 percent facility would occupy a large area that is not immediately available." - We recommend citing question 3.1.2 here, which provides information to justify this statement. As currently written, there is no rationale presented to support the statement.	The report has been modified to cite question 3.1.2 as suggested in the comment.
Karuk/Yurok – 4	p. 8	p. 8: Regarding screen sizes "Removal of the zooplankton *Daphnia*, which is a food source for fish, may also need to be examined." - We recommend revising this for clarity: "Removal of the zooplankton *Daphnia*, which is a food source for fish, will likely be unavoidable and the effects may also need to be examined."	The report has been modified as suggested in this comment.
Karuk/Yurok - 5	p. 7	p. 8: "Doug said that the A Canal harvesting system was the largest system he is aware of, harvesting at a rate of about 200,000 pounds per day of wet algae biomass, which is estimated to be equivalent to about 12,000 pounds dry weight, by processing 1,000 cfs." - We recommend also presenting the 200,000 pounds in approximate volumetric units such as number of cubic meters and/or tanker trucks? If this wet weight to volume ratio is not already known, please ask New Earth because they should know the answer. This would be very helpful in understanding the requirements for how much on-site storage will be needed and how many truck trips would be needed per day for transporting the material.	The report has been modified to clarify that this is "roughly equivalent to about 2 to 4 tanker trucks per day (assuming tanker trucks with typical capacities ranging from 5,500 to 11,600 gallons)".
Karuk/Yurok - 6	p. 10	p. 10: "Darrick Weissenfluh (USFWS) commented that it is important to realize that 5 miles of Link River is considered critical sucker habitat." - Darrick noted in a sub-sequent call that this was a misquote. Link River is much shorter than 5 miles, and the critical habitat designation extends through the entirety of Link River (as well as Upper Klamath Lake and Keno Reservoir). Here is an excerpt of the federal register notice (https://www.gpo.gov/fdsys/pkg/FR-2012-12-11/html/2012-29332.htm): "We are designating two units as critical habitat for Lost River sucker and two units as critical habitat for shortnose sucker. The critical habitat areas described	The report has been updated to reflect this comment.

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		below constitute our best assessment at this time of areas that meet the definition of critical habitat. For Lost River sucker, those two units, which were occupied at the time of listing and are still occupied, are: (1) Upper Klamath Lake Unit, including Upper Klamath Lake and tributaries as well as the Link River and Keno Reservoir, and (2) Lost River Basin Unit, including Clear Lake Reservoir and tributaries. For shortnose sucker, those two units, which were occupied at the time of listing and are still occupied, are: (1) Upper Klamath Lake Unit, including Upper Klamath Lake and tributaries as well as the Link River and Keno Reservoir, and (2) Lost River Basin Unit, including Clear Lake Reservoir and tributaries, and Gerber Reservoir and tributaries."	
Karuk/Yurok - 7	p. 14	p. 14: "Answer: The answer to this question is unclear at this time. The TAC exhibited some reluctance to extrapolate from the theoretical construct of algae removal at Link River dam to Upper Klamath Lake conditions and other watershed management actions. Given the large nutrient loads in Upper Klamath Lake, it seems unlikely that in-lake conditions would improve over the life-span of an algae removal facility. Meanwhile removal of adequate material could improve water quality downstream of the facility." - This is likely an overly pessimistic view of the ability for the lake to respond. If restoration actions and improvement management leads to substantial reductions in phosphorus inflow to the lake, the lake should begin to respond rapidly but it would take approximately 20 years to reach a new lower equilibrium (Wherry et al. 2015). Therefore, we recommend changing "…it seems unlikely that in-lake conditions would improve over the life-span of an algae removal facility." to "…it seems unlikely that in-lake conditions would improve so substantially over the life-span of an algae removal facility that the facility would no longer be needed."	The report has been modified in response to this comment to reflect that "it seems unlikely that in-lake conditions would improve so substantially over the life-span of an algae removal facility that the facility would no longer be needed. Meanwhile removal of adequate material could improve water quality downstream of the facility."
Karuk/Yurok - 8		p. 14: "However, the algae material from Upper Klamath Lake likely does not have an adequate amount of lipid content for use as a biofuel." - Please cite Simon et al. (2013) here. The document, which is already included in the references section, quantifies this issue.	The citation to Simon et al. (2013) has been added to the report.

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Karuk/Yurok - 9		p. 15: "Rick Carlson (USBR) suggested the report by Simon et al. (2013) be added as a citation in answering these questions (included in section 4 below). The Simon et al. (2013) report notes the high protein content of the algae." - We suggest this be revised to "…notes the high protein *and low lipid* content of the algae"	The report has been modified as suggested in the comment.
Karuk/Yurok - 10		p. 16: "3.3.3 What specific process steps are needed to detoxify algae biomatter?" - To help answer this question, we conducted a brief literature review and we request that you paste/include it in section 3.3.3: "Degradation rates for cyanotoxins are highly dependent on conditions. Mechanisms for removal include photochemical degradation by ultraviolet radiation (e.g. sunlight), adsorption onto sediments or suspected particles, and biodegradation by micro-organisms (Corbel et al. 2014b). Microcystin added to surface sediment samples from Taihu Lake and incubated at 20°C degraded rapidly due to favorable conditions for bio-degrading bacteria, reducing by more than 90% loss in 4 days and reaching levels at or near zero within 7 days (Chen et al. 2008). Conversely, crusts of dried *Microcystis aeruginosa* collected on the shore of an Australian lake that were 5-6 months old still contained high levels of microcystins (Jones et al. 2005). If applied to land and not degraded, microcystins have the potential to contaminate groundwater and can be uptaken by terrestrial plants including agricultural crops (Chen et al. 2012; Corbel 2014a, 2014b, 2016).	The additional suggested text has been added to the report.