

TECHNICAL MEMORANDUM

Results of Cyanobacteria and Microcystin Monitoring in the Vicinity of the Klamath Hydroelectric Project

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Introduction

This technical memorandum summarizes the results for the 2016 public health monitoring for cyanobacteria species and an associated toxin, microcystin, within PacifiCorp's Klamath Hydroelectric Project (Project) from Upper Klamath Lake to the Klamath River below Iron Gate Dam. Microcystin results from 2016 baseline monitoring are also included in the results summaries below. This monitoring is particularly focused on *Microcystis aeruginosa* (MSAE), which is known to produce microcystin. This monitoring also assesses the presence of other potentially-toxigenic cyanobacteria, including *Dolichospermum* sp., and others. Monitoring is being conducted pursuant to Interim Measure 15, Water Quality Monitoring Activities, contained in the Klamath Hydroelectric Settlement Agreement (KHSA) executed between the United States Department of Interior, the states of California and Oregon, PacifiCorp, and other parties.

Results from the baseline and public health sampling are used in coordination with the appropriate public health authority to determine if public health advisories are warranted^{1,2}. In addition to PacifiCorp's website (www.pacificorp.com/es/hydro/hl/kr.html#), these memos are also posted on the Klamath Basin Monitoring Program's (KBMP) website (www.kbmp.net) and inform the Blue Green Algae tracker on the KBMP website.

The data in Appendix 1 and Appendix 2 summarize results from all of the 2016 public health sampling events to date and microcystin results from the 2016 baseline sampling events.

¹ The California State Water Resources Control Board (SWRCB) provides guidelines for posting advisories in recreation water (California SWRCB 2016) for Project waters in California. SWRCB recommends posting advisories in recreation waters at three levels based on laboratory testing for microcystin. The posting levels are Caution, Warning, and Danger at microcystin concentrations of 0.8, 6, and 20 µg/L respectively. Toxin producing cells at concentrations of over 4,000 cells/ml or blooms, scums, or mats would result in posting at the Caution level.

² Postings of Project waters in Oregon are coordinated with the Oregon Health Authority (OHA; 2016). The health advisory guideline in Oregon waters is microcystin concentrations of 10 µg/L or more, over 100,000 cells/mL of all toxigenic species combined, or over 40,000 cells/mL of *Microcystis* spp. or *Planktothrix* spp.

Methods

PacifiCorp and the Oregon Department of Environmental Quality (ODEQ) are conducting public health sampling at ten sites (Table 1). Samples are collected and sent for laboratory analysis of potentially toxigenic cyanobacteria, notably MSAE and microcystin, from sites at:

- Three shoreline sites in Upper Klamath Lake, Oregon
- One shoreline site in Keno Reservoir, Oregon
- One shoreline site in J.C. Boyle Reservoir, Oregon
- Four shoreline sites in coves in Copco and Iron Gate reservoirs (i.e., two cove sites in each reservoir), California
- One Klamath River site below Iron Gate Dam near the hatchery bridge, California

Table 1. Sites of cyanobacteria and microcystin public health monitoring in Upper Klamath Lake, Keno Reservoir, J.C Boyle Reservoir, Copco Reservoir, Iron Gate Reservoir, and the Klamath River during 2016.			
Location	Approximate River Mile	Sampling Entity	Site ID
Upper Klamath Lake at Eagle Ridge County Park	N/A	ODEQ	UKEP
Upper Klamath Lake at Howard's Bay Park	N/A	ODEQ	UKHP
Upper Klamath Lake at Moore Park	N/A	ODEQ	UKMP
Keno Reservoir at Keno Park	234.0	ODEQ	KEKP
J.C. Boyle Reservoir at Topsy Campground	225.0	ODEQ	BRTC
Copco Reservoir at Mallard Cove	201.5	PacifiCorp	CRMC
Copco Reservoir at Copco Cove	200.0	PacifiCorp	CRCC
Iron Gate Reservoir at Camp Creek	192.8	PacifiCorp	IRCC
Iron Gate Reservoir at John Williams Campground	192.4	PacifiCorp	IRJW
Klamath River below Iron Gate dam near Hatchery Bridge	189.7	PacifiCorp	KRBI

Samples are planned to be taken at shoreline locations in the reservoirs once in May and twice per month in June, July, August, September, October, and November. Samples to be collected from the river site below Iron Gate Dam are scheduled to be collected according to the discretion of the sampling entity (PacifiCorp) based on river conditions.

In addition to public health sampling, monthly and bi-monthly baseline sampling for microcystin is conducted by PacifiCorp and the U.S. Bureau of Reclamation (BOR) from May through October at 14 locations extending from Link Dam to below Iron Gate Reservoir (Table 2).

Site Description	Approximate River Mile	Depth (m)	Sampling Entity	Site ID
Link Dam	254.4	0.5	BOR	KR254.4
Keno Reservoir at Miller Island	246.0	0.5	BOR	KR246.0
Klamath River below Keno Dam near a USGS Gage	231.8	0.5	BOR	KBK
Klamath River above JC Boyle Reservoir	228.2	0.5	PacifiCorp	KR22822
JC Boyle Reservoir at Log Boom (surface)	224.8	0.5	PacifiCorp	KR22478
Klamath River below JC Boyle Reservoir	224.6	0.5	PacifiCorp	KR22460
Klamath River at USGS Gage	219.5	0.5	PacifiCorp	KR21950
Klamath River above Shovel Creek	206.4	0.5	PacifiCorp	KR20642
Copco Reservoir at Buoy Line (surface)	198.7	0.5	PacifiCorp	KR19874
Copco Reservoir at Buoy Line (integrated)	198.7	0-8	PacifiCorp	KR19874
Klamath River below Copco 2 Reservoir	196.5	0.5	PacifiCorp	KR19645
Iron Gate Reservoir at Log Boom (surface)	190.2	0.5	PacifiCorp	KR19019
Iron Gate Reservoir at Log Boom (integrated)	190.2	0-8	PacifiCorp	KR19019
Klamath River below Hatchery Bridge	189.7	0.5	PacifiCorp	KR18973

Public health samples are taken as grab samples offshore according to the standard operating procedure (SOP) developed by the Klamath Blue Green Algae Working Group (www.kbmp.net/collaboration/klamath-hydroelectric-settlement-agreement-monitoring). Samples collected for potentially toxic phytoplankton are preserved in Lugol's solution and sent to Aquatic Analysts in Friday Harbor, Washington for analysis. The samples are labeled "Rush" for timely analysis and only potentially toxic cyanobacteria are identified and enumerated. However, once a reservoir or river reach is posted with health advisories signs, the samples are collected but not rushed until it visually appears that the algae bloom conditions have waned. Results for cyanobacteria species are reported as individual cells per milliliter.

Samples for determination of microcystin toxin are placed in a cooler on ice and shipped to the U.S. Environmental Protection Agency (EPA) Region 9 Laboratory in Richmond, California. The samples are analyzed using the competitive Enzyme-Linked ImmunoSorbent Assay (ELISA) method based on the EnviroLogix QuantiPlate Kit for microcystins through June 22, 2106 and the Abraxis Kit thereafter. For samples analyzed through June 22, 2016 the detection limit for microcystin using this method was 0.15 µg/L or parts per billion (ppb) while the quantitation limit was 0.18 µg/L or ppb. For samples analyzed after June 22, 2016, the detection limit was to 0.10 µg/L and the quantification limit was 0.15 µg/L. This test method does not distinguish between the specific microcystin congeners, but detects their presence to differing degrees. That is, ELISA test results yield one value as the sum of measurable microcystin variants.

Results

Public health samples (Table 3) were collected as planned, except for sample KR16847 because low water conditions at the IRCC site. Baseline microcystin samples were collected as planned (Tables 4

and 5), except for samples KR16183 and KR16184 because low water conditions restricting access to site KR19019. Appendix 3 includes the raw phytoplankton results for the samples reported in Table 3.

Table 3. Summary of available public health laboratory algal identification and enumeration and microcystin results from sampling September through October, 2016.

Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth	MSAE ⁽¹⁾	AFA ⁽²⁾	DKFA ⁽³⁾	Other ^{(4),(5), (6), (7), (8), (9), (10), or (11)}	Microcystin (µg/L)
09/26/16	16:45	CRMC	201.5	PacifiCorp	KR16840	SG	737,532	145,595	0	0	250
09/26/16	17:25	CRCC	200.0	PacifiCorp	KR16841	SG	415,467	102,500	44,417	0	220
09/26/16	17:50	IRCC	192.8	PacifiCorp	KR16842	SG	15,201,921	644,286	0	0	490
09/26/16	18:10	IRJW	192.4	PacifiCorp	KR16843	SG	1,713,800	1,488,300	0	0	850
09/26/16	18:30	KRBI	189.7	PacifiCorp	KR16844	SG	0	186	0	0	0.25
09/27/16	12:37	UKEP	N/A	ODEQ	UKEP16008	SG	2,092	490	0	0	2.0 ^{AT}
09/27/16	12:57	UKHP	N/A	ODEQ	UKHP16008	SG	1,077,630	25,044	0	0	470 ^{AT}
09/27/16	13:17	UKMP	N/A	ODEQ	UKMP16008	SG	0	3,398	0	0	3.0 ^{AT}
09/27/16	11:47	KEKP	234.0	ODEQ	KEKP16008	SG	904	0	0	0	0.46 ^{AT}
09/27/16	11:28	BRTC	225.0	ODEQ	BRTC16008	SG	0	0	0	0	0.21 ^{AT}
10/11/16	14:30	CRMC	201.5	PacifiCorp	KR16845	SG	*	*	*	*	15
10/11/16	12:30	CRCC	200.0	PacifiCorp	KR16846	SG	*	*	*	*	11000
10/11/16	NS	IRCC	192.8	PacifiCorp	KR16847	SG	*	*	*	*	NS
10/11/16	11:15	IRJW	192.4	PacifiCorp	KR16848	SG	*	*	*	*	15
10/11/16	10:40	KRBI	189.7	PacifiCorp	KR16849	SG	*	*	*	*	2.9
10/11/16	12:22	UKEP	N/A	ODEQ	UKEP16009	SG	*	*	*	*	0.17
10/11/16	12:42	UKHP	N/A	ODEQ	UKHP16009	SG	*	*	*	*	5.0
10/11/16	13:02	UKMP	N/A	ODEQ	UKMP16009	SG	*	*	*	*	0.15
10/11/16	11:35	KEKP	234.0	ODEQ	KEKP16009	SG	*	*	*	*	0.25
10/11/16	11:17	BRTC	225.0	ODEQ	BRTC16009	SG	*	*	*	*	0.17
10/25/16	10:52	UKEP	N/A	ODEQ	UKEP16010	SG	0	2,255	0	0	*
10/25/16	11:22	UKMP	N/A	ODEQ	UKMP16010	SG	0	85	0	0	*
10/25/16	10:00	BRTC	225.0	ODEQ	BRTC16010	SG	0	0	0	0	*

¹MSAE = *Microcystis aeruginosa* (cells/mL)

²AFA = *Aphanizomenon flos-aquae* (cells/mL)

³DKFA = *Dolichospermum flos-aquae*

Other = Cells/mL of either ⁴*Planktothrix (Oscillatoria) sp.*, ⁵*Gloeotrichia echinulata*, ⁶*Dolichospermum sp.*, ⁷*Lyngbya sp.*, ⁸*Dolichospermum circinalis*, ⁹*Dolichospermum planctonica*, ¹⁰*Planktothrix (Oscillatoria) limosa*, or ¹¹*Pseudanabaena spp.*

"NS" value indicates not sampled

"0" value indicates non-detect by analytical laboratory

"**" value indicates no result available

"AT" indicates the sample was received above the recommended temperature range

Table 4. Summary of September and October 2016 baseline laboratory microcystin results for samples collected in Oregon.

Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth (m)	Microcystin (µg/L)
09/26/16	14:45	KR22478	224.8	PacifiCorp	KR16155	0.5	0.16
09/27/16	9:00	KR254.4	254.4	BOR	2016KHSA-68	0.5	0.20
10/10/16	10:50	KR22822	228.2	PacifiCorp	KR16176	0.5	ND
10/10/16	13:45	KR22478	224.8	PacifiCorp	KR16178	0.5	ND
10/10/16	13:00	KR22460	224.6	PacifiCorp	KR16175	0.5	0.14 ¹
10/10/16	13:20	KR22460	224.6	PacifiCorp	KR16180	0.5	ND
10/10/16	13:30	KR22460	224.6	PacifiCorp	KR16181	0.5	1
10/10/16	12:30	KR21950	219.5	PacifiCorp	KR16177	0.5	ND
10/11/16	8:30	KR254.4	254.4	BOR	2016KHSA-73	0.5	0.18
10/11/16	7:50	KR246.0	246.0	BOR	2016KHSA-76	0.5	ND
10/11/16	10:00	KBK	231.8	BOR	2016KHSA-77	0.5	ND

¹The reported result for this analyte should be considered an estimated value because although the result was above the laboratory detection limit (0.1 µg/L) it was below the laboratory quantitation limit (0.15 µg/L).

"ND" value indicates a result less than the laboratory analytical detection limit (0.1 µg/L)

Table 5. Summary of September and October 2016 baseline laboratory microcystin results for samples collected in California.

Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth (m)	Microcystin (µg/L)
09/26/16	18:20	KR18973	189.7	PacifiCorp	KR16174	0.5	0.23
10/11/16	15:00	KR20642	206.4	PacifiCorp	KR16192	0.5	ND
10/11/16	13:10	KR19874	198.7	PacifiCorp	KR16188	0.5	1.1
10/11/16	13:20	KR19874	198.7	PacifiCorp	KR16189	0-8	3.3
10/11/16	12:00	KR19645	196.5	PacifiCorp	KR16187	0.5	0.6
10/11/16	NS	KR19019	190.2	PacifiCorp	KR16183	0.5	NS
10/11/16	NS	KR19019	190.2	PacifiCorp	KR16184	0-8	NS
10/11/16	10:00	KR18973	189.7	PacifiCorp	KR16182	0.5	2.6
10/11/16	10:30	KR18973	189.7	PacifiCorp	KR16195	0.5	2.8

"ND" value indicates a result less than the laboratory analytical detection limit (0.1 µg/L)

"NS" value indicates not sampled

References

California SWRCB 2016. Draft Statewide Voluntary Guidance on CyanoHABs in Recreational Waters. Available online at:

http://www.mywaterquality.ca.gov/monitoring_council/cyanohab_network/docs/triggers.pdf

Oregon Health Authority. 2016. Oregon Harmful Algal Bloom Surveillance (HABS) Program – Public Health Advisory Guidelines, Harmful Algae Blooms in Freshwater Bodies. 27 pp.

https://public.health.oregon.gov/HealthyEnvironments/Recreation/HarmfulAlgaeBlooms/Pages/resources_for_samplers.aspx

Appendix 1

Cyanobacteria Species and Microcystin Data for 2016 Public Health Samples

Table A1. Summary of 2016 public health laboratory algal identification and enumeration microcystin results.											
Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth	MSAE ⁽¹⁾	AFA ⁽²⁾	DKFA ⁽³⁾	Other ^{(4),(5), (6), (7), (8), (9), (10), or (11)}	Microcystin (µg/L)
05/23/16	14:05	CRMC	201.5	PacifiCorp	KR16800	SG	0	0	0	0	ND
05/23/16	13:15	CRCC	200.0	PacifiCorp	KR16801	SG	0	0	0	0	ND
05/23/16	12:45	IRCC	192.8	PacifiCorp	KR16802	SG	0	0	0	0	ND
05/23/16	12:25	IRJW	192.4	PacifiCorp	KR16803	SG	0	0	0	0	ND
05/23/16	11:55	KRBI	189.7	PacifiCorp	KR16804	SG	0	0	0	0	ND
06/14/16	11:47	UKEP	N/A	ODEQ	UKEP16001	SG	0	349,320	0	0	0.76
06/14/16	11:24	UKHP	N/A	ODEQ	UKHP16001	SG	100,686	296,927	0	0	14
06/14/16	11:10	UKMP	N/A	ODEQ	UKMP16001	SG	0	302,081	0	55,817 ⁽⁵⁾	0.56
06/14/16	10:38	KEKP	234.0	ODEQ	KEKP16001	SG	0	0	46,979	587 ⁽⁶⁾	0.23
06/14/16	10:09	BRTC	225.0	ODEQ	BRTC16001	SG	0	0	0	0	ND
06/08/16	16:15	CRMC	201.5	PacifiCorp	KR16805	SG	0	0	0	0	ND
06/08/16	13:10	CRCC	200.0	PacifiCorp	KR16806	SG	0	0	503	0	3.7
06/08/16	11:40	IRCC	192.8	PacifiCorp	KR16807	SG	0	0	0	0	ND
06/08/16	11:20	IRJW	192.4	PacifiCorp	KR16808	SG	0	0	0	0	ND
06/08/16	17:00	KRBI	189.7	PacifiCorp	KR16809	SG	0	0	0	0	ND
06/28/16	11:17	UKEP	N/A	ODEQ	UKEP16002	SG	163,293	10,103,761	0	0	56
06/28/16	11:34	UKHP	N/A	ODEQ	UKHP16002	SG	*	*	*	*	130
06/28/16	11:50	UKMP	N/A	ODEQ	UKMP16002	SG	1,485,481	3,157,000	0	0	32
06/28/16	10:35	KEKP	234.0	ODEQ	KEKP16002	SG	18,090	279,025	0	0	3.2
06/28/16	10:07	BRTC	225.0	ODEQ	BRTC16002	SG	490	456,392	0	0	0.53
06/20/16	16:40	CRMC	201.5	PacifiCorp	KR16810	SG	68,407	0	807	0	25
06/20/16	15:20	CRCC	200.0	PacifiCorp	KR16811	SG	496,424	0	17,034	0	61
06/20/16	14:40	IRCC	192.8	PacifiCorp	KR16812	SG	12,272	0	0	0	14
06/20/16	14:25	IRJW	192.4	PacifiCorp	KR16813	SG	4,940	0	859	658 ⁽⁶⁾ , 403 ⁽⁹⁾	1
06/20/16	13:50	KRBI	189.7	PacifiCorp	KR16814	SG	0	0	16	0	ND
07/12/16	11:58	UKEP	N/A	ODEQ	UKEP16003	SG	*	*	*	*	0.51
07/12/16	12:32	UKHP	N/A	ODEQ	UKHP16003	SG	*	*	*	*	79
07/12/16	12:46	UKMP	N/A	ODEQ	UKMP16003	SG	*	*	*	*	3.4
07/12/16	10:59	KEKP	234.0	ODEQ	KEKP16003	SG	0	20,528	0	78 ⁽⁶⁾	0.55
07/12/16	10:42	BRTC	225.0	ODEQ	BRTC16003	SG	0	775	0	0	0.31
07/12/16	16:55	CRMC	201.5	PacifiCorp	KR16815	SG	*	*	*	*	9.1
07/12/16	15:00	CRCC	200.0	PacifiCorp	KR16816	SG	*	*	*	*	21
07/12/16	12:40	IRCC	192.8	PacifiCorp	KR16817	SG	*	*	*	*	6.4
07/12/16	12:30	IRJW	192.4	PacifiCorp	KR16818	SG	*	*	*	*	2.5
07/12/16	18:00	KRBI	189.7	PacifiCorp	KR16819	SG	0	0	0	0	0.15
07/26/16	12:34	UKEP	N/A	ODEQ	UKEP16004	SG	*	*	*	*	1.9
07/26/16	12:08	UKHP	N/A	ODEQ	UKHP16004	SG	*	*	*	*	37
07/26/16	13:14	UKMP	N/A	ODEQ	UKMP16004	SG	*	*	*	*	0.54
07/26/16	11:37	KEKP	234.0	ODEQ	KEKP16004	SG	0	30,067	0	0	0.29
07/26/16	11:17	BRTC	225.0	ODEQ	BRTC16004	SG	0	0	0	0	0.20
07/26/16	11:15	CRMC	201.5	PacifiCorp	KR16820	SG	*	*	*	*	870

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Table A1 (cont.)

Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth	MSAE ⁽¹⁾	AFA ⁽²⁾	DKFA ⁽³⁾	Other ^{(4),(5), (6), (7), (8), (9), (10), or (11)}	Microcystin (µg/L)
07/26/16	12:15	CRCC	200.0	PacifiCorp	KR16821	SG	*	*	*	*	34000
07/26/16	12:45	IRCC	192.8	PacifiCorp	KR16822	SG	*	*	*	*	73
07/26/16	13:10	IRJW	192.4	PacifiCorp	KR16823	SG	*	*	*	*	380
07/26/16	13:40	KRBI	189.7	PacifiCorp	KR16824	SG	241	0	0	62 ⁽⁵⁾	0.38
08/08/16	11:15	UKEP	N/A	ODEQ	UKEP16005	SG	0	168,251	0	0	4.9
08/08/16	11:38	UKHP	N/A	ODEQ	UKHP16005	SG	*	*	*	*	170
08/08/16	11:56	UKMP	N/A	ODEQ	UKMP16005	SG	0	277,381	0	0	3.4
08/08/16	10:22	KEKP	234.0	ODEQ	KEKP16005	SG	0	16,955	0	0	0.28
08/08/16	10:03	BRTC	225.0	ODEQ	BRTC16005	SG	0	1,115	0	0	0.21
08/10/16	16:20	CRMC	201.5	PacifiCorp	KR16825	SG	*	*	*	*	5000
08/11/16	9:00	CRCC	200.0	PacifiCorp	KR16826	SG	*	*	*	*	3400
08/10/16	13:10	IRCC	192.8	PacifiCorp	KR16827	SG	*	*	*	*	790
08/10/16	12:45	IRJW	192.4	PacifiCorp	KR16828	SG	*	*	*	*	2500
08/10/16	17:00	KRBI	189.7	PacifiCorp	KR16829	SG	6,792	0	0	0	ND
08/22/16	8:00	CRMC	201.5	PacifiCorp	KR16830	SG	*	*	*	*	430
08/22/16	9:00	CRCC	200.0	PacifiCorp	KR16831	SG	*	*	*	*	7600
08/22/16	9:40	IRCC	192.8	PacifiCorp	KR16832	SG	*	*	*	*	30
08/22/16	10:00	IRJW	192.4	PacifiCorp	KR16833	SG	*	*	*	*	72
08/22/16	10:15	KRBI	189.7	PacifiCorp	KR16834	SG	*	*	*	*	0.38
08/30/16	12:13	UKEP	N/A	ODEQ	UKEP16006	SG	0	0	0	0	0.33
08/30/16	12:33	UKHP	N/A	ODEQ	UKHP16006	SG	*	*	*	*	1.2
08/30/16	12:52	UKMP	N/A	ODEQ	UKMP16006	SG	0	0	0	0	0.17
08/30/16	11:28	KEKP	234.0	ODEQ	KEKP16006	SG	64,845	2,708	0	0	10
08/30/16	11:07	BRTC	225.0	ODEQ	BRTC16006	SG	3,391	0	0	0	2.9
09/06/16	19:50	CRMC	201.5	PacifiCorp	KR16835	SG	*	*	*	*	86
09/06/16	19:20	CRCC	200.0	PacifiCorp	KR16836	SG	*	*	*	*	5.6
09/06/16	18:35	IRCC	192.8	PacifiCorp	KR16837	SG	*	*	*	*	780
09/06/16	18:00	IRJW	192.4	PacifiCorp	KR16838	SG	*	*	*	*	420
09/07/16	12:10	KRBI	189.7	PacifiCorp	KR16839	SG	*	*	*	*	4.9
09/13/16	11:45	UKEP	N/A	ODEQ	UKEP16007	SG	976	976	0	0	0.67
09/13/16	11:58	UKHP	N/A	ODEQ	UKHP16007	SG	*	*	*	*	1.4
09/13/16	12:20	UKMP	N/A	ODEQ	UKMP16007	SG	430	0	0	0	0.31
09/13/16	10:56	KEKP	234.0	ODEQ	KEKP16007	SG	1,203	0	0	0	5.8
09/13/16	10:38	BRTC	225.0	ODEQ	BRTC16007	SG	573	0	0	107 ⁴	0.92
09/26/16	16:45	CRMC	201.5	PacifiCorp	KR16840	SG	737,532	145,595	0	0	250
09/26/16	17:25	CRCC	200.0	PacifiCorp	KR16841	SG	415,467	102,500	44,417	0	220
09/26/16	17:50	IRCC	192.8	PacifiCorp	KR16842	SG	15,201,921	644,286	0	0	490
09/26/16	18:10	IRJW	192.4	PacifiCorp	KR16843	SG	1,713,800	1,488,300	0	0	850
09/26/16	18:30	KRBI	189.7	PacifiCorp	KR16844	SG	0	186	0	0	0.25
09/27/16	12:37	UKEP	N/A	ODEQ	UKEP16008	SG	2,092	490	0	0	2.0 ^{AT}
09/27/16	12:57	UKHP	N/A	ODEQ	UKHP16008	SG	1,077,630	25,044	0	0	470 ^{AT}
09/27/16	13:17	UKMP	N/A	ODEQ	UKMP16008	SG	0	3,398	0	0	3.0 ^{AT}
09/27/16	11:47	KEKP	234.0	ODEQ	KEKP16008	SG	904	0	0	0	0.46 ^{AT}
09/27/16	11:28	BRTC	225.0	ODEQ	BRTC16008	SG	0	0	0	0	0.21 ^{AT}
10/11/16	14:30	CRMC	201.5	PacifiCorp	KR16845	SG	*	*	*	*	15
10/11/16	12:30	CRCC	200.0	PacifiCorp	KR16846	SG	*	*	*	*	11000
10/11/16	NS	IRCC	192.8	PacifiCorp	KR16847	SG	*	*	*	*	NS

Table A1 (cont.)

Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth	MSAE ⁽¹⁾	AFA ⁽²⁾	DKFA ⁽³⁾	Other ^{(4),(5), (6), (7), (8), (9), (10), or (11)}	Microcystin (µg/L)
10/11/16	11:15	IRJW	192.4	PacifiCorp	KR16848	SG	*	*	*	*	15
10/11/16	10:40	KRBI	189.7	PacifiCorp	KR16849	SG	*	*	*	*	2.9
10/11/16	12:22	UKEP	N/A	ODEQ	UKEP16009	SG	*	*	*	*	0.17
10/11/16	12:42	UKHP	N/A	ODEQ	UKHP16009	SG	*	*	*	*	5.0
10/11/16	13:02	UKMP	N/A	ODEQ	UKMP16009	SG	*	*	*	*	0.15
10/11/16	11:35	KEKP	234.0	ODEQ	KEKP16009	SG	*	*	*	*	0.25
10/11/16	11:17	BRTC	225.0	ODEQ	BRTC16009	SG	*	*	*	*	0.17
10/25/16	10:52	UKEP	N/A	ODEQ	UKEP16010	SG	0	2,255	0	0	*
10/25/16	11:22	UKMP	N/A	ODEQ	UKMP16010	SG	0	85	0	0	*
10/25/16	10:00	BRTC	225.0	ODEQ	BRTC16010	SG	0	0	0	0	*

¹MSAE = *Microcystis aeruginosa* (cells/mL)

²AFA = *Aphanizomenon flos-aquae* (cells/mL)

³DKFA = *Dolichospermum flos-aquae*

Other = Cells/mL of either ⁴*Planktothrix (Oscillatoria) sp.*, ⁵*Gloeotrichia echinulata*, ⁶*Dolichospermum sp.*, ⁷*Lyngbya sp.*,

⁸*Dolichospermum circinalis*, ⁹*Dolichospermum planctonica*, ¹⁰*Planktothrix (Oscillatoria) limosa*, or ¹¹*Pseudanabaena spp.*

“ND” value indicates a result less than the laboratory analytical detection limit, which was originally 0.15 µg/L and was changed to 0.1 µg/L as of June 23, 2016

“0” value indicates non-detect by analytical laboratory

“*” value indicates no result available

“NS” value indicates not sampled

“AT” indicates the sample was received above the recommended temperature range

Appendix 2

Microcystin Data for 2016 Baseline Samples

Table A2-1. Summary of 2016 baseline laboratory microcystin results for samples collected in Oregon.							
Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth (m)	Microcystin (µg/L)
05/10/16	10:00	KR246.0	246.0	BOR	2016-KHSA-22	0.5	0.15
05/10/16	7:45	KBK	231.8	BOR	2016-KHSA-23	0.5	0.19
05/10/16	9:50	KR22822	228.2	PacifiCorp	KR16062	0.5	0.16 ¹
05/10/16	12:35	KR22478	224.8	PacifiCorp	KR16064	0.5	ND
05/10/16	13:15	KR22460	224.6	PacifiCorp	KR16061	0.5	0.16 ¹
05/10/16	11:20	KR21950	219.5	PacifiCorp	KR16063	0.5	0.16 ¹
06/07/16	10:15	KR246.0	246.0	BOR	2016KHSA-32	0.5	ND
06/07/16	8:00	KBK	231.8	BOR	2016KHSA-33	0.5	ND
06/07/16	11:00	KR22822	228.2	PacifiCorp	KR16084	0.5	0.15 ¹
06/07/16	14:10	KR22478	224.8	PacifiCorp	KR16086	0.5	ND
06/07/16	14:30	KR22460	224.6	PacifiCorp	KR16083	0.5	0.15 ¹
06/07/16	15:00	KR22460	224.6	PacifiCorp	KR16089	0.5	ND
06/07/16	13:10	KR21950	219.5	PacifiCorp	KR16085	0.5	ND
07/12/16	8:30	KR254.4	254.4	BOR	2016KHSA-40	0.5	0.74
07/12/16	10:30	KR246.0	246.0	BOR	2016KHSA-43	0.5	0.13
07/12/16	7:40	KBK	231.8	BOR	2016KHSA-44	0.5	SL
07/11/16	9:40	KR22822	228.2	PacifiCorp	KR16107	0.5	0.2
07/11/16	12:35	KR22478	224.8	PacifiCorp	KR16109	0.5	0.12
07/11/16	11:50	KR22460	224.6	PacifiCorp	KR16106	0.5	0.13
07/11/16	12:00	KR22460	224.6	PacifiCorp	KR16112	0.5	0.1
07/11/16	11:10	KR21950	219.5	PacifiCorp	KR16108	0.5	ND
07/26/16	9:00	KR254.4	254.4	BOR	2016KHSA-46	0.5	0.34
08/09/16	8:00	KR254.4	254.4	BOR	2016KHSA-51	0.5	0.38
08/09/16	9:40	KR246.0	246.0	BOR	2016KHSA-54	0.5	0.19
08/09/16	7:15	KBK	231.8	BOR	2016KHSA-55	0.5	0.15
08/09/16	10:40	KR22822	228.2	PacifiCorp	KR16130	0.5	0.11 ¹
08/09/16	13:20	KR22478	224.8	PacifiCorp	KR16132	0.5	0.1 ¹
08/09/16	12:55	KR22460	224.6	PacifiCorp	KR16129	0.5	0.14 ¹
08/09/16	12:50	KR22460	224.6	PacifiCorp	KR16135	0.5	0.11 ¹
08/09/16	12:00	KR21950	219.5	PacifiCorp	KR16131	0.5	ND
08/23/16	8:30	KR254.4	254.4	BOR	2016KHSA-57	0.5	0.10
09/05/16	11:00	KR22822	228.2	PacifiCorp	KR16153	0.5	1.1
09/05/16	13:00	KR22460	224.6	PacifiCorp	KR16152	0.5	0.56
09/05/16	13:20	KR22460	224.6	PacifiCorp	KR16158	0.5	0.71
09/05/16	12:30	KR21950	219.5	PacifiCorp	KR16154	0.5	0.43

Table A2-1. (Cont.)							
Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth (m)	Microcystin (µg/L)
09/13/16	8:30	KR254.4	254.4	BOR	2016KHSA-62	0.5	0.14
09/13/16	9:45	KR246.0	246.0	BOR	2016KHSA-65	0.5	0.22
09/13/16	7:45	KBK	231.8	BOR	2016KHSA-66	0.5	0.40
09/21/16	15:45	KR22478	224.8	PacifiCorp	KR16155	0.5	*
09/26/16	14:45	KR22478	224.8	PacifiCorp	KR16155	0.5	0.16
09/27/16	9:00	KR254.4	254.4	BOR	2016KHSA-68	0.5	0.20
10/10/16	10:50	KR22822	228.2	PacifiCorp	KR16176	0.5	ND
10/10/16	13:45	KR22478	224.8	PacifiCorp	KR16178	0.5	ND
10/10/16	13:00	KR22460	224.6	PacifiCorp	KR16175	0.5	0.14 ¹
10/10/16	13:20	KR22460	224.6	PacifiCorp	KR16180	0.5	ND
10/10/16	13:30	KR22460	224.6	PacifiCorp	KR16181	0.5	1
10/10/16	12:30	KR21950	219.5	PacifiCorp	KR16177	0.5	ND
10/11/16	8:30	KR254.4	254.4	BOR	2016KHSA-73	0.5	0.18
10/11/16	7:50	KR246.0	246.0	BOR	2016KHSA-76	0.5	ND
10/11/16	10:00	KBK	231.8	BOR	2016KHSA-77	0.5	ND

¹The reported result for this analyte should be considered an estimated value because although the result was above the laboratory detection limit it was below the laboratory quantitation limit. The laboratory detection limit was originally 0.15 µg/L and was changed to 0.1 µg/L as of June 23, 2016. The laboratory quantitation limit for was originally 0.18 µg/L and was changed to 0.15 µg/L as of June 23, 2016.

"ND" value indicates a result less than the laboratory analytical detection limit, which was originally 0.15 µg/L and was changed to 0.1 µg/L as of June 23, 2016

"SL" indicates sample loss

"*" value indicates no result available

Table A2-2. Summary of 2016 baseline laboratory microcystin results for samples collected in California.

Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth (m)	Microcystin (µg/L)
05/11/16	15:10	KR20642	206.4	PacifiCorp	KR16078	0.5	ND
05/11/16	12:50	KR19874	198.7	PacifiCorp	KR16074	0.5	0.15 ¹
05/11/16	13:00	KR19874	198.7	PacifiCorp	KR16075	0-8	ND
05/11/16	12:05	KR19645	196.5	PacifiCorp	KR16073	0.5	0.17 ¹
05/11/16	9:45	KR19019	190.2	PacifiCorp	KR16069	0.5	ND
05/11/16	9:55	KR19019	190.2	PacifiCorp	KR16070	0-8	ND
05/11/16	16:35	KR18973	189.7	PacifiCorp	KR16068	0.5	ND
05/23/16	11:50	KR18973	189.7	PacifiCorp	KR16082	0.5	ND
06/08/16	15:25	KR20642	206.4	PacifiCorp	KR16100	0.5	ND
06/08/16	13:30	KR19874	198.7	PacifiCorp	KR16096	0.5	ND
06/08/16	13:40	KR19874	198.7	PacifiCorp	KR16097	0-8	ND
06/08/16	12:20	KR19645	196.5	PacifiCorp	KR16095	0.5	ND
06/08/16	9:10	KR19019	190.2	PacifiCorp	KR16091	0.5	ND
06/08/16	9:20	KR19019	190.2	PacifiCorp	KR16092	0-8	ND
06/08/16	16:50	KR18973	189.7	PacifiCorp	KR16090	0.5	ND
06/08/16	17:20	KR18973	189.7	PacifiCorp	KR16103	0.5	ND
06/20/16	13:40	KR18973	189.7	PacifiCorp	KR16105	0.5	ND
07/12/16	16:40	KR20642	206.4	PacifiCorp	KR16123	0.5	0.1
07/12/16	14:20	KR19874	198.7	PacifiCorp	KR16119	0.5	6.2
07/12/16	14:30	KR19874	198.7	PacifiCorp	KR16120	0-8	3.2
07/12/16	13:40	KR19645	196.5	PacifiCorp	KR16118	0.5	0.89
07/12/16	10:30	KR19019	190.2	PacifiCorp	KR16114	0.5	0.2
07/12/16	10:50	KR19019	190.2	PacifiCorp	KR16115	0-8	0.36
07/12/16	17:20	KR18973	189.7	PacifiCorp	KR16113	0.5	0.13
07/12/16	17:40	KR18973	189.7	PacifiCorp	KR16126	0.5	0.18
07/12/16	13:30	KR18973	189.7	PacifiCorp	KR16128	0.5	0.3
08/10/16	15:50	KR20642	206.4	PacifiCorp	KR16146	0.5	ND
08/11/16	9:30	KR19874	198.7	PacifiCorp	KR16142	0.5	22
08/11/16	9:50	KR19874	198.7	PacifiCorp	KR16143	0-8	3.6
08/10/16	14:30	KR19645	196.5	PacifiCorp	KR16141	0.5	3.6
08/10/16	10:30	KR19019	190.2	PacifiCorp	KR16137	0.5	15
08/10/16	10:40	KR19019	190.2	PacifiCorp	KR16138	0-8	3.7
08/10/16	16:55	KR18973	189.7	PacifiCorp	KR16136	0.5	2.3
08/10/16	17:20	KR18973	189.7	PacifiCorp	KR16149	0.5	1.4
08/22/16	10:10	KR18973	189.7	PacifiCorp	KR16151	0.5	0.42
09/06/16	20:05	KR20642	206.4	PacifiCorp	KR16169	0.5	0.53
09/07/16	10:00	KR19874	198.7	PacifiCorp	KR16165	0.5	0.99
09/07/16	10:10	KR19874	198.7	PacifiCorp	KR16166	0-8	0.44

Table A2-2. (Cont.)							
Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth (m)	Microcystin (µg/L)
09/06/16	19:00	KR19645	196.5	PacifiCorp	KR16164	0.5	0.44
09/06/16	12:20	KR19019	190.2	PacifiCorp	KR16160	0.5	6.4
09/06/16	12:30	KR19019	190.2	PacifiCorp	KR16161	0-8	3
09/07/16	12:00	KR18973	189.7	PacifiCorp	KR16159	0.5	2.7
09/07/16	12:25	KR18973	189.7	PacifiCorp	KR16172	0.5	2.1
09/26/16	18:20	KR18973	189.7	PacifiCorp	KR16174	0.5	0.23
10/11/16	15:00	KR20642	206.4	PacifiCorp	KR16192	0.5	ND
10/11/16	13:10	KR19874	198.7	PacifiCorp	KR16188	0.5	1.1
10/11/16	13:20	KR19874	198.7	PacifiCorp	KR16189	0-8	3.3
10/11/16	12:00	KR19645	196.5	PacifiCorp	KR16187	0.5	0.6
10/11/16	NS	KR19019	190.2	PacifiCorp	KR16183	0.5	NS
10/11/16	NS	KR19019	190.2	PacifiCorp	KR16184	0-8	NS
10/11/16	10:00	KR18973	189.7	PacifiCorp	KR16182	0.5	2.6
10/11/16	10:30	KR18973	189.7	PacifiCorp	KR16195	0.5	2.8

¹ The reported result for this analyte should be considered an estimated value because although the result was above the laboratory detection limit it was below the laboratory quantitation limit. The laboratory detection limit was originally 0.15 µg/L and was changed to 0.1 µg/L as of June 23, 2016. The laboratory quantitation limit was originally 0.18 µg/L and was changed to 0.15 µg/L as of June 23, 2016.

“ND” value indicates a result less than the laboratory analytical detection limit, which was originally 0.15 µg/L and was changed to 0.1 µg/L as of June 23, 2016

“NS” value indicates not sampled

Appendix 3 Laboratory Phytoplankton Results

Note: To reflect current taxonomic decisions, the genus for *Anabaena* was changed to *Dolichospermum* in the summary data presented in the body of this memo but not in the actual lab results presented in this appendix.

Phytoplankton Sample Analysis

Klamath
Sample: Basin
Sample ID: KR16840
Sample Depth:
Sample Date: 26-Sep-16 1645

Total Density (#/mL): 19,118
Total Biovolume (um³/mL): 15,072,714
Trophic State Index: 69.4

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Microcystis aeruginosa	12,501	65.4	5,900,257	39.1
2 Aphanizomenon flos-aquae	6,618	34.6	9,172,458	60.9

Microcystis aeruginosa cells/mL = 737,532
 Aphanizomenon flos-aquae cells/mL = 145,595

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
Sample ID: KR16841
Sample Depth:
Sample Date: 26-Sep-16 1725

Total Density (#/mL): 30,408
Total Biovolume (um³/mL): 12,757,150
Trophic State Index: 68.2

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Microcystis aeruginosa	25,967	85.4	3,323,733	26.1
2 Aphanizomenon flos-aquae	4,100	13.5	6,457,500	50.6
3 Dolichospermum flos-aquae	342	1.1	2,975,917	23.3

Microcystis aeruginosa cells/mL = 415,467
 Aphanizomenon flos-aquae cells/mL = 102,500
 Dolichospermum flos-aquae cells/mL = 44,417

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
 Sample ID: KR16842
 Sample Depth:
 Sample Date: 26-Sep-16 1750

Total Density (#/mL): 492,879
 Total Biovolume (um³/mL): 162,205,371
 Trophic State Index: 86.6

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Microcystis aeruginosa	460,664	93.5	121,615,371	75.0
2 Aphanizomenon flos-aquae	32,214	6.5	40,590,000	25.0

Microcystis aeruginosa cells/mL = 15,201,921
 Aphanizomenon flos-aquae cells/mL = 644,286

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Klamath
Sample: Basin
Sample ID: KR16843
Sample Depth:
Sample Date: 26-Sep-16 1810

Total Density (#/mL): 161,071
Total Biovolume (um³/mL): 107,473,300
Trophic State Index: 83.6

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Microcystis aeruginosa	90,200	56.0	13,710,400	12.8
2 Aphanizomenon flos-aquae	70,871	44.0	93,762,900	87.2

Microcystis aeruginosa cells/mL = 1,713,800
 Aphanizomenon flos-aquae cells/mL = 1,488,300

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Klamath
Sample: Basin
Sample ID: KR16844
Sample Depth:
Sample Date: 26-Sep-16 1830

Total Density (#/mL): 9
Total Biovolume (um³/mL): 11,693
Trophic State Index: 18.3

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Aphanizomenon flos-aquae	9	100.0	11,693	100.0

Aphanizomenon flos-aquae cells/mL = 186

Phytoplankton Sample Analysis

Sample: Klamath Basin
Sample Site: BRTC
Sample Depth:
Sample Date: 27-Sep-16 1128

Total Density (#/mL): <3
Total Biovolume (um³/mL):
Trophic State Index:

Species	Density #/mL	Density Percent	Biovolume um³/mL	Biovolume Percent
1 No Toxic Algae Present	<3			

Note: Toxic Algae Only

Phytoplankton Sample

Analysis

Sample: Klamath Basin
Sample Site: KEKP
Sample Depth:
Sample Date: 27-Sep-16 1147 (corrected)

Total Density (#/mL): 43
Total Biovolume (um³/mL): 7,235
Trophic State Index: 15.2

Species	Density #/mL	Density Percent	Biovolume um³/mL	Biovolume Percent
1 Microcystis aeruginosa	43	100.0	7,235	100.0

Microcystis aeruginosa cells/mL = 904

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
Sample Site: UKMP
Sample Depth:
Sample Date: 27-Sep-16 1317

Total Density (#/mL): 154
Total Biovolume (um³/mL): 214,071
Trophic State Index: 38.8

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Aphanizomenon flos-aquae	154	100.0	214,071	100.0

Aphanizomenon flos-aquae cells/mL = 3,398

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
 Sample Site: UKEP
 Sample Depth:
 Sample Date: 27-Sep-16 1237

Total Density (#/mL): 98
 Total Biovolume (um³/mL): 47,616
 Trophic State Index: 28.0

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Microcystis aeruginosa	65	66.7	16,733	35.1
2 Aphanizomenon flos-aquae	33	33.3	30,884	64.9

Aphanizomenon flos-aquae cells/mL = 490

Microcystis aeruginosa cells/mL = 2,092

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
 Sample Site: UKHP
 Sample Depth:
 Sample Date: 27-Sep-16 1257

Total Density (#/mL): 16,587
 Total Biovolume (um³/mL): 10,198,780
 Trophic State Index: 66.6

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Microcystis aeruginosa	15,395	92.8	8,621,038	84.5
2 Aphanizomenon flos-aquae	1,193	7.2	1,577,741	15.5

Microcystis aeruginosa cells/mL = 1,077,630
 Aphanizomenon flos-aquae cells/mL = 25,044

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
Sample Site: BRTC
Sample Depth:
Sample Date: 25-Oct-16 1000

Total Density (#/mL): <3
Total Biovolume (um³/mL):
Trophic State Index:

Species	Density #/mL	Density Percent	Biovolume um³/mL	Biovolume Percent
-	-	-	-	-
1 No Toxic Algae Present	<3			

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
 Sample Site: UKMP
 Sample Depth:
 Sample Date: 25-Oct-16 1122

Total Density (#/mL): 5
 Total Biovolume ($\mu\text{m}^3/\text{mL}$): 5,381
 Trophic State Index: 13.4

Species	Density #/mL	Density Percent	Biovolume $\mu\text{m}^3/\text{mL}$	Biovolume Percent
1 Aphanizomenon flos-aquae	5	100.0	5,381	100.0

Aphanizomenon flos-aquae cells/mL = 85

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
 Sample Site: UKEP
 Sample Depth:
 Sample Date: 25-Oct-16 1052

Total Density (#/mL): 125
 Total Biovolume (um³/mL): 142,065
 Trophic State Index: 35.8

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Aphanizomenon flos-aquae	125	100.0	142,065	100.0

Aphanizomenon flos-aquae cells/mL = 2,255

Note: Toxic Algae Only