

TECHNICAL MEMORANDUM

Results of Cyanobacteria and Microcystin Monitoring in the Vicinity of the Klamath Hydroelectric Project: June 22, 2009

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Introduction

This technical memorandum summarizes the latest results of monitoring during 2009 for cyanobacteria species and the associated toxin microcystin in Copco and Iron Gate reservoirs in PacifiCorp's Klamath Hydroelectric Project (Project) and in one monitoring station in the Klamath River below Iron Gate dam. This monitoring is particularly focused on *Microcystis aeruginosa* (MSAE), a cyanobacterium with a recent history of summertime blooms in Copco and Iron Gate reservoirs that is known to produce microcystin. This monitoring also estimates the presence of other potentially-toxigenic cyanobacteria, including *Anabaena spp.* and *Planktothrix (Oscillatoria) spp.* This monitoring is being conducted pursuant to Interim Measure 12, Water Quality Monitoring, contained in the Klamath Hydroelectric Project Agreement in Principle (AIP) executed between the United States Department of Interior, the States of California and Oregon, and PacifiCorp.

The results specifically addressed in this memorandum are for samples collected on June 22, 2009. Subsequent memoranda such as this will be prepared every two weeks to report the results of continued monitoring. PacifiCorp plans to prepare a final report of the results and interpretation of the complete set of collected data after the conclusion of the sampling effort in winter 2009.

Methods

PacifiCorp is conducting phytoplankton sampling for laboratory analysis of potentially-toxigenic cyanobacteria, notably MSAE, and microcystin at six sites in Copco and Iron Gate reservoirs and one site below Iron Gate dam as listed in Table 1, including:

- Two open-water reservoir sites in the lower ends of Iron Gate and Copco reservoirs (near the log booms). These sites are part of the basic water quality monitoring that is being performed under the 2009 AIP Measure 12 plan (in draft).
- Four shoreline sites in coves in Copco and Iron Gate reservoir (i.e., two cove sites in each reservoir).
- One Klamath River site below Iron Gate dam near the hatchery bridge.

Sampling will occur at the two open-water monitoring sites once per month in June through December. Samples will be taken at the shoreline locations in the reservoirs twice per month in June through October. Samples for the river site below Iron Gate dam will be collected twice per month in June, July and October and weekly in August and September.

Phytoplankton samples from the river sites are taken as grab samples offshore according to the standard operating procedure (SOP) developed by the Klamath Blue Green Algae Working Group (in draft). At the open-water reservoir sites public health samples will be collected according to the published SOP. Additional samples, including a grab sample at 0.5 m depth and an integrated sample over 8 m depth, will be collected as part of the baseline water quality monitoring.

Samples for phytoplankton speciation, density, and biovolume are preserved in Lugol's solution and sent to Aquatic Analysts in Milwaukie, Oregon for analysis. The laboratory analysis of phytoplankton speciation and density is done on prepared microscope slides of filtered samples using phase contrast microscopy. Species are counted as algal units of cell, filament, or colony depending on the natural growth form of the species. Algal forms are identified to species or otherwise to the lowest practicable taxonomic level. Biovolumes are estimated by multiplying the cell counts by the average geometric dimensions of the cells for a given phytoplankton taxa. 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 the 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. The quantitation limit is 0.16 µg/L or parts per billion (ppb). 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 all measurable microcystin variants.

Table 1. Sites of Cyanobacteria and Microcystin Public Health Monitoring in Copco and Iron Gate Reservoirs during 2009

Location	Approximate River Mile	Site ID
Copco reservoir at Mallard Cove ramp	201.5	CRMC
Copco reservoir at Copco Cove ramp	200.0	CRCC
Copco reservoir near dam at cable line	198.6	CR01
Iron Gate reservoir at Camp Creek ramp	192.8	IRCC
Iron Gate reservoir at Williams campground	192.4	IRJW
Iron Gate reservoir near dam at log boom	190.2	IR01
Klamath R. at Iron Gate Hatchery bridge	189.7	KRBI

Results

Samples of June 22, 2009

Five samples were collected for public health purposes on June 22, 2009. Samples were collected from Mallard Cove and Copco Cove in Copco reservoir, from Jay Williams campground and Camp Creek campground in Iron Gate reservoir, and from the Klamath River below Iron Gate dam near the Iron Gate hatchery bridge. Samples were sent to the EPA Region 9 laboratory for analysis for microcystin, and to Aquatic Analysts for cyanobacteria species identification and enumeration. Results for microcystin analysis for June 22 samples are not yet available.

The results of cyanobacteria species identification and enumeration are summarized in Table 2; cumulative data are included in Appendix 1. Two cyanobacteria species were present in the samples collected on June 22, 2009; *Anabaena flos-aquae*, and *Aphanizomenon flos-aquae*. Both species have been reported to produce anatoxin, a potentially dangerous neurotoxin (Codd et al 2005), although *Aphanizomenon* does not appear to produce toxins in Upper Klamath Lake or the Klamath River. Both

species were observed at all sites sampled except for Mallard Cove on Copco reservoir where *Anabaena* was absent. The concentration of *Anabaena flos-aquae* at Camp Creek in Iron Gate reservoir could present a low risk of adverse health effects to individuals engaging in water contact recreation.¹ The abundance of *Anabaena flos-aquae* at Camp Creek in Iron Gate reservoir and *Aphanizomenon flos-aquae* at Copco Cove in Copco Reservoir approached or exceeded the WHO recommended guidelines. The abundance of cyanobacteria at other sites was relatively low. Laboratory data sheets are included as Appendix 2.

Table 2. Summary of cyanobacteria and microcystin public health monitoring results in Copco and Iron Gate Reservoirs on June 22, 2009.

Date	Sample	Location ¹	Species	Biovolume, $\mu\text{m}^3/\text{mL}$	Rank ²	Cells/mL
6/22/09	KR9064	CRMC	<i>Aphanizomenon flos-aquae</i>	826,007	1	13,111
6/22/09	KR9065	CRCC	<i>Anabaena flos-aquae</i>	61,364	4	916
			<i>Aphanizomenon flos-aquae</i>	1,262,193	1	20,035
6/22/09	KR9066	IRJW	<i>Anabaena flos-aquae</i> cells/mL	22,136	12	330
			<i>Aphanizomenon flos-aquae</i>	272,567	3	4,326
6/22/09	KR9067	IRCC	<i>Anabaena flos-aquae</i>	1,303,884	1	19,461
			<i>Aphanizomenon flos-aquae</i>	406,734	2	6,456
6/22/09	KR9068	KRBI	<i>Aphanizomenon flos-aquae</i>	83,305	2	1,322
			<i>Anabaena flos-aquae</i>	14,238	10	213

¹CRMC = Copco reservoir at Mallard Cove ramp, CRCC = Copco reservoir at Copco Cove ramp, IRCC = Iron Gate reservoir at Camp Creek ramp, IRJW = Iron Gate reservoir at Williams campground, KRBI = Klamath R. at Iron Gate Hatchery bridge
²Rank = The rank of the species in the sample based on the count of algal units.

References

Codd, G. A., J. Lindsay, F. M. Young, L. F. Morrison, and J. S. Metcalf. 2005. Harmful cyanobacteria: from mass mortalities to management measures. In *Harmful Cyanobacteria*, J. Juisman, H. C. P. Matthijs, and P. M. Visser eds. Springer 2005.

¹The World Health Organization (WHO) has recommended guidelines for safe recreational water environments based on a low, moderate, or high probability of adverse health effects from exposure to concentrations of cyanobacterial cells and microcystin toxins in recreational waters (WHO 2003). The WHO guideline values for low and moderate probability of adverse health in recreational waters are 20,000 and 100,000 cyanobacterial cells/mL, respectively. WHO equates these cell count values to microcystin toxin concentrations of 4 $\mu\text{g/L}$ and 20 $\mu\text{g/L}$, respectively (WHO 2003). The WHO guideline for high probability of adverse health effects is a narrative; i.e., "Cyanobacterial scum formation in areas where whole-body contact and/or risk of ingestion/aspiration occur". No specific cyanobacterial cell or microcystin concentrations are provided by WHO for high probability of adverse health effects. The WHO (2003) guidance values were derived from calculations based on a 20 kg child that would swim for up to two hours (in a day) and would accidentally ingest 0.05 L of water per hour.

The California State Water Resources Control Board (SWRCB 2007) and Oregon Department of Health Services (ODHS 2005) provide guidelines for posting advisories in recreation waters. These guidelines were developed using information provided in WHO (2003). Both SWRCB (2007) and ODHS (2005) recommend posting advisories in recreation waters under three circumstances: (1) if "scum is present associated with toxigenic species"; (2) if scum is not present, but the density of *Microcystis* or *Planktothrix* is 40,000 cells/ml or greater; and (3) if scum is not present, but the density of all potentially toxigenic BGA is 100,000 cells/ml or greater. Based on WHO (2003) information, SWRCB (2007) and ODHS (2005) indicate that cell counts of 40,000 cells/mL and 100,000 cells/mL equate to microcystin toxin concentrations of 8 $\mu\text{g/L}$ and 20 $\mu\text{g/L}$, respectively.

ODHS. 2005. Public Health Advisory Guidance for Toxigenic Cyanobacteria in Recreational Waters. Oregon Department of Human Services, Environmental Toxicology Program.

PacifiCorp. 2008. Agreement in Principle to address issues pertaining to the resolution of certain litigation and other controversies in the Klamath Basin, including a path forward for possible Facilities removal. U.S. Secretary of the Interior, November 18, 2008.

SWRCB. 2007. Cyanobacteria in California Recreational Water Bodies: Providing Voluntary Guidance about Harmful Algal Blooms, Their Monitoring, and Public Notification. June 2007. Document provided as part of Blue-green Algae Work Group of State Water Resources Control Board (SWRCB) and Office of Environmental Health and Hazard Assessment (OEHHA).

World Health Organization (WHO). 2003. Guidelines for safe recreational waters, Volume 1 – Coastal and fresh waters, Chapter 8: Algae and cyanobacteria in fresh water. WHO Publishing, Geneva, pp. 136-158.

Appendix 1

Cumulative Data for 2009 Public Health Samples.

Date	Sample	Location ¹	Species	Biovolume, $\mu\text{m}^3/\text{mL}$	Rank ²	Cells/mL
6/8/09	KR9059	CRMC	<i>Anabaena flos-aquae</i>	271,627,386	1	4,054,140
6/8/09	KR9060	CRCC	<i>Anabaena flos-aquae</i>	1,019,824	2	15,221
			<i>Aphanizomenon flos-aquae</i>	9,471	26	150
6/8/09	KR9061	IRJW	<i>Anabaena flos-aquae</i>	18,829,827	1	281,042
6/8/09	KR9062	IRCC	<i>Anabaena flos-aquae</i>	83,936	2	1,253
6/8/09	KR9063	KRBI	<i>Aphanizomenon flos-aquae</i>	12,353	26	196
			<i>Anabaena flos-aquae</i>	9,306	27	139
6/22/09	KR9064	CRMC	<i>Aphanizomenon flos-aquae</i>	826,007	1	13,111
6/22/09	KR9065	CRCC	<i>Anabaena flos-aquae</i>	61,364	4	916
			<i>Aphanizomenon flos-aquae</i>	1,262,193	1	20,035
6/22/09	KR9066	IRJW	<i>Anabaena flos-aquae</i>	22,136	12	330
			<i>Aphanizomenon flos-aquae</i>	272,567	3	4,326
6/22/09	KR9067	IRCC	<i>Anabaena flos-aquae</i>	1,303,884	1	19,461
			<i>Aphanizomenon flos-aquae</i>	406,734	2	6,456
6/22/09	KR9068	KRBI	<i>Aphanizomenon flos-aquae</i>	83,305	2	1,322
			<i>Anabaena flos-aquae</i>	14,238	10	213

¹CRMC = Copco reservoir at Mallard Cove ramp, CRCC = Copco reservoir at Copco Cove ramp, IRCC = Iron Gate reservoir at Camp Creek ramp, IRJW = Iron Gate reservoir at Williams campground, KRBI = Klamath R. at Iron Gate Hatchery bridge

²Rank = The rank of the species in the sample based on the count of algal units.

Appendix 2

Laboratory Data Sheets for June 22, 2009 Public Health Samples.

Phytoplankton Sample Analysis

Sample: Klamath Basin
Sample Site: KR 9064
Sample Depth:
Sample Date: 22-Jun-09

Total Density (#/mL): 1,756
Total Biovolume (um³/mL): 2,050,729
Trophic State Index: 55.0

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Aphanizomenon flos-aquae	596	33.9	826,007	40.3
2 Rhodomonas minuta	467	26.6	9,342	0.5
3 Melosira granulata	322	18.3	1,027,636	50.1
4 Chlamydomonas sp.	97	5.5	31,409	1.5
5 Cryptomonas erosa	32	1.8	16,751	0.8
6 Cocconeis placentula	32	1.8	14,819	0.7
7 Stephanodiscus hantzschii	32	1.8	3,866	0.2
8 Nitzschia palea	16	0.9	2,899	0.1
9 Rhoicosphenia curvata	16	0.9	1,885	0.1
10 Chromulina sp.	16	0.9	322	0.0
11 Stephanodiscus astraea minutula	16	0.9	5,638	0.3
12 Fragilaria construens	16	0.9	72,160	3.5
13 Schroderia sp.	16	0.9	725	0.0
14 Amphora ovalis	16	0.9	9,310	0.5
15 Melosira varians	16	0.9	20,939	1.0
16 Asterionella formosa	16	0.9	3,544	0.2
17 Nitzschia frustulum	16	0.9	1,933	0.1
18 Nitzschia amphibia	16	0.9	1,546	0.1

Aphanizomenon flos-aquae cells/mL = 13,111
Aphanizomenon flos-aquae heterocysts/mL = 177

Aquatic Analysts

Sample ID: ML23

Phytoplankton Sample Analysis

Sample: Klamath Basin
Sample Site: KR 9065
Sample Depth:
Sample Date: 22-Jun-09

Total Density (#/mL): 2,043
Total Biovolume (um³/mL): 1,815,813
Trophic State Index: 54.1

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Aphanizomenon flos-aquae	1,336	65.4	1,262,193	69.5
2 Melosira granulata	191	9.3	367,305	20.2
3 Rhodomonas minuta	87	4.2	1,735	0.1
4 Anabaena flos-aquae	83	4.1	61,364	3.4
5 Fragilaria vaucheriae	69	3.4	23,979	1.3
6 Cocconeis placentula	52	2.5	23,938	1.3
7 Rhoicosphenia curvata	52	2.5	6,089	0.3
8 Stephanodiscus hantzschii	35	1.7	4,163	0.2
9 Melosira varians	17	0.8	11,275	0.6
10 Gomphonema subclavatum	17	0.8	10,408	0.6
11 Ankistrodesmus falcatius	17	0.8	434	0.0
12 Trachelomonas volvocina	17	0.8	32,698	1.8
13 Chromulina sp.	17	0.8	347	0.0
14 Nitzschia frustulum	17	0.8	2,082	0.1
15 Navicula pupula	17	0.8	4,683	0.3
16 Nitzschia palea	17	0.8	3,122	0.2

Aphanizomenon flos-aquae cells/mL = 20,035
Aphanizomenon flos-aquae heterocysts/mL = 208

Anabaena flos-aquae cells/mL = 916
Anabaena flos-aquae heterocysts/mL = 503
Anabaena flos-aquae akinetes/mL = 42

Aquatic Analysts

Sample ID: ML24

Phytoplankton Sample Analysis

Sample: Klamath Basin
Sample Site: KR 9066
Sample Depth:
Sample Date: 22-Jun-09

Total Density (#/mL): 1,539
Total Biovolume (um³/mL): 2,068,875
Trophic State Index: 55.1

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Melosira granulata	577	37.5	1,269,093	61.3
2 Fragilaria construens	262	17.0	381,777	18.5
3 Aphanizomenon flos-aquae	144	9.4	272,567	13.2
4 Fragilaria vaucheriae	131	8.5	37,758	1.8
5 Fragilaria construens venter	118	7.7	18,690	0.9
6 Cocconeis placentula	52	3.4	24,123	1.2
7 Nitzschia frustulum	52	3.4	6,293	0.3
8 Rhoicosphenia curvata	39	2.6	5,982	0.3
9 Stephanodiscus hantzschii	39	2.6	4,720	0.2
10 Nitzschia amphibia	39	2.6	3,776	0.2
11 Sphaerocystis Schroeteri	26	1.7	9,177	0.4
12 Anabaena flos-aquae	18	1.2	22,136	1.1
13 Ankistrodesmus falcatus	13	0.9	328	0.0
14 Stephanodiscus astraea minutula	13	0.9	4,589	0.2
15 Gomphonema subclavatum	13	0.9	7,866	0.4

Aphanizomenon flos-aquae cells/mL = 4,326
Aphanizomenon flos-aquae heterocysts/mL = 79

Anabaena flos-aquae cells/mL = 330
Anabaena flos-aquae heterocysts/mL = 16

Aquatic Analysts

Sample ID: ML25

Phytoplankton Sample Analysis

Sample: Klamath Basin
Sample Site: KR 9067
Sample Depth:
Sample Date: 22-Jun-09

Total Density (#/mL): 1,637
Total Biovolume (um³/mL): 2,377,851
Trophic State Index: 56.1

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Anabaena flos-aquae	649	39.6	1,303,884	54.8
2 Aphanizomenon flos-aquae	340	20.8	406,734	17.1
3 Melosira granulata	139	8.5	397,560	16.7
4 Chlamydomonas sp.	108	6.6	35,138	1.5
5 Gomphonema subclavatum	62	3.8	37,068	1.6
6 Rhodomonas minuta	62	3.8	1,236	0.1
7 Fragilaria construens	62	3.8	48,436	2.0
8 Cocconeis placentula	46	2.8	21,314	0.9
9 Nitzschia palea	31	1.9	5,560	0.2
10 Rhoicosphenia curvata	15	0.9	1,807	0.1
11 Fragilaria vaucheriae	15	0.9	4,448	0.2
12 Nitzschia amphibia	15	0.9	1,483	0.1
13 Sphaerocystis schroeteri	15	0.9	17,299	0.7
14 Trachelomonas volvocina	15	0.9	29,114	1.2
15 Nitzschia paleacea	15	0.9	1,514	0.1
16 Stephanodiscus hantzschii	15	0.9	1,853	0.1
17 Ankistrodesmus falcatus	15	0.9	386	0.0
18 Fragilaria capucina mesolepta	15	0.9	63,016	2.7

Aphanizomenon flos-aquae cells/mL = 6,456
 Aphanizomenon flos-aquae heterocysts/mL = 31

Anabaena flos-aquae cells/mL = 19,461
 Anabaena flos-aquae heterocysts/mL = 942
 Anabaena flos-aquae akinetes/mL = 93

Aquatic Analysts

Sample ID: ML26

Phytoplankton Sample Analysis

Sample: Klamath Basin
Sample Site: KR 9068
Sample Depth:
Sample Date: 22-Jun-09

Total Density (#/mL): 434
Total Biovolume (um³/mL): 500,364
Trophic State Index: 44.9

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Melosira granulata	170	39.2	345,971	69.1
2 Aphanizomenon flos-aquae	66	15.3	83,305	16.6
3 Cocconeis placentula	47	10.9	21,724	4.3
4 Ankistrodesmus falcatus	28	6.5	708	0.1
5 Nitzschia frustulum	19	4.4	2,267	0.5
6 Cryptomonas erosa	14	3.3	7,367	1.5
7 Achnanthes lanceolata	9	2.2	1,700	0.3
8 Rhodomonas minuta	9	2.2	189	0.0
9 Chlamydomonas sp.	9	2.2	3,070	0.6
10 Anabaena flos-aquae	9	2.0	14,238	2.8
11 Synedra delicatissima	5	1.1	3,117	0.6
12 Cocconeis klamathensis	5	1.1	1,322	0.3
13 Gloeocystis ampla	5	1.1	2,418	0.5
14 Melosira varians	5	1.1	3,070	0.6
15 Gomphonema angustatum	5	1.1	850	0.2
16 Gomphonema subclavatum	5	1.1	2,834	0.6
17 Synedra radians	5	1.1	1,700	0.3
18 Stephanodiscus astraea minutula	5	1.1	1,653	0.3
19 Nitzschia dissipata	5	1.1	1,270	0.3
20 Asterionella formosa	5	1.1	1,039	0.2
21 Rhoicosphenia curvata	5	1.1	553	0.1

Aphanizomenon flos-aquae cells/mL = 1,322
Aphanizomenon flos-aquae heterocysts/mL = 7

Anabaena flos-aquae cells/mL = 213
Anabaena flos-aquae heterocysts/mL = 8

Aquatic Analysts

Sample ID: ML27