FINAL REPORT

# Intake Barrier Curtain Summary Report


PacifiCorp
825 N.E. Multnomah, Suite 1800
Portland, OR 97232

May 2021

# CONTENTS

Page



**Appendices**

Page

**Tables**

Page

Page

Page



**Figures**

Page

Page

Page

Page

Page

Page

# Acronyms and Abbreviations

| | |
|---|---|
| °C | degree(s) Celsius |
| µg/L | microgram(s) per liter |
| ADCP | Acoustic Doppler Current Profiler |
| *Aphanizomenon* | *Aphanizomenon flos-aquae* |
| BGA | blue-green algae (cyanobacteria) |
| BOB | Basic Observation Buoy |
| cm/s | centimeter(s) per second |
| ELISA | enzyme-linked immunosorbent assay |
| EPA | U.S. Environmental Protection Agency |
| h | depth of the mixed layer (m) |
| IM | interim measure |
| $kg/m^3$ | kilogram(s) per cubic meter |
| KHSA | Klamath Hydroelectric Settlement Agreement |
| L | fetch represented by the reservoir open water length in the direction of the wind (meter) |
| m | meter(s) |
| mL | milliliter |
| m/s | meter(s) per second |
| $m/s^2$ | meter(s) per second squared |
| mg/L | milligram(s) per liter |
| *Microcystis* | *Microcystis aeruginosa* |
| N/A | not applicable |
| $\rho_A$ | density of air ($kg/m^3$) |
| $\rho_w$ | density of water ($kg/m^3$) |
| qPCR | quantitative polymerase chain reaction |
| RFU | relative fluorescence unit |
| vs. | versus |
| *Wn* | Wedderburn number |

# Terminology

**Downstream of the curtain:** Basic Observation Buoy within Iron Gate Reservoir approximately 10 m downstream of the intake barrier curtain and 60 m upstream of the Iron Gate Powerhouse intake tower.

**Epilimnetic stratification:** The existence of vertically distinct zones of different densities resulting from unequal distribution of water temperatures through the epilimnion. Epilimnetic stratification is often intermittent and changes rapidly (i.e., within hours or days) depending on thermal loading and wind, as opposed to the more stable and gradually changing seasonal stratification, which often deepens through the season with the addition of heat to the system.

**Epilimnetic thermocline(s):** The layer(s) within a stratified epilimnion that encompasses the most rapid transition of water temperatures and density differences through the epilimnion. More than one epilimnetic thermocline may exist within the epilimnion.

**Epilimnion:** The upper, warmest, least dense layer of a stratified lake.

**Hypolimnion:** The bottom, coldest, and most dense layer of a stratified lake.

**Iron Gate log boom (log boom):** Log boom within Iron Gate Reservoir, approximately 500 m upstream of the Iron Gate Dam.

**Klamath River downstream of Iron Gate Dam:** Klamath River sampling location at the boat ramp below Iron Gate Dam, approximately 90 m downstream of Lakeview Road bridge.

**Metalimnion (thermocline):** The middle layer of a stratified lake that represents the transition between the warmer surface layer (epilimnion) and the colder bottom layer (hypolimnion).

**Mixed layer:** The surface layer that is well-mixed and includes the zone from the water surface down to the epilimnetic thermocline. Depth of the mixed layer (h) is used in the *Wn* calculation.

**Project area:** Area that spans from the Iron Gate Reservoir log boom to the grab sampling location in the Klamath River downstream of Iron Gate Dam.

**Seasonal stratification:** The existence of vertically distinct zones of different densities resulting from unequal distribution of water temperatures through the water column.

**Seasonal thermocline:** The metalimnion, or middle layer of a stratified lake that encompasses the most rapid transition of water temperatures and density differences through the water column.

**Upstream of the curtain:** Basic Observation Buoy within Iron Gate Reservoir approximately upstream 30 m of the intake barrier curtain.

**Wedderburn number (*Wn*):** A dimensionless parameter that relates the stability of stratification (density, depth) to mixing energy (wind velocity) and represents short-term mixing patterns in the epilimnion.

# Executive Summary

One element of improving water quality in the Klamath River downstream of Iron Gate Dam involves managing cyanobacteria (also known as blue-green algae or BGA) transported to the river from Iron Gate Reservoir. Use of an intake barrier curtain is one strategy PacifiCorp is employing to limit cyanobacteria releases from Iron Gate Reservoir into the Klamath River. Seasonal cyanobacteria blooms in the reservoir typically occur in near-surface waters of the photic zone where light and nutrients are available. The penstock intake for Iron Gate Powerhouse has an invert elevation that is approximately 10.7 meters (m) below normal water surface elevation. Because the intake tower is open from the reservoir bottom to the surface of the reservoir, it entrains water from the full depth of the water column. This includes water from the photic zone, which in turn can result in releases of cyanobacteria to the Klamath River downstream.

The purpose of the curtain is to improve releases to downstream river reaches by retaining near-surface waters with greater levels of cyanobacteria in the reservoir. Retaining near-surface waters in the reservoir takes advantage of several naturally occurring conditions. First, density differences associated with seasonal temperature stratification in the reservoir provide an opportunity to use an intake barrier curtain to isolate warmer, less dense near-surface waters. Second, these near-surface waters include the photic zone where light and nutrients are available. Finally, the buoyancy compensating capability of cyanobacteria generally keep them in the photic zone and near-surface waters. Thus, while a notable fraction of the cyanobacteria is retained in the reservoir, cooler, denser, and deeper waters are withdrawn from the reservoir for downstream Klamath River releases.

The effectiveness of a curtain is dependent on the presence of stratified conditions in the reservoir that allow a curtain to isolate warmer, less dense surface waters. Such stratification can range from weak, intermittent conditions to more robust, persistent conditions. This concept was originally tested with a 3-m-deep curtain deployed at the log boom (Deas and Miao 2010), then a solid cover on the intake tower itself (Miao and Deas 2014), followed by the installation of the existing curtain in 2015.

This intake barrier curtain assessment uses findings and data collected from 2015 through 2018 (Deas and Miao 2010; Watercourse 2013a, 2013b; Miao and Deas 2014; Watercourse 2016; PacifiCorp 2017) to address physical attributes of stratification, mixing, localized flow changes caused from deploying a barrier curtain in Iron Gate Reservoir, and curtain efficacy in reducing cyanobacteria downstream. The reader is referred to Watercourse (2016) and PacifiCorp (2017) for specifics regarding the previous activities and analyses.

This assessment builds on the previous efforts by assessing 4 years of sonde and grab sample data from the reservoir, and provides additional analysis of stratification (i.e., short-term fluctuations in epilimnetic stratification). The assessment includes an analysis of stratification strength and depth [based on Wedderburn number (*Wn*) calculations] through the season, curtain depths, and resulting curtain effectiveness. The assessment then compares upstream of the curtain and downstream of the curtain grab sample data [i.e., chlorophyll-*a* (surrogate for cyanobacteria biomass), *Microcystis* sp., microcystin, and cyanobacteria] and upstream of the curtain and downstream of the curtain profiling sonde data (i.e., water temperature, total algae as chlorophyll, and cyanobacteria as phycocyanin) to assess curtain effectiveness. The dam and associated infrastructure (i.e., intake tower, hatchery outlets, and spillway) are expected to reduce cyanobacteria concentrations released to the Klamath River. Because of this expected reduced concentration, chlorophyll-*a* data from grab samples collected from Iron Gate Reservoir at the log boom and in the Klamath River downstream of Iron Gate Dam are also compared to explore “dam only” and “dam with curtain” effects on cyanobacteria concentrations downstream of the dam. Finally, this assessment builds on the previous flow assessment (Watercourse

2016) by reviewing vertical velocities near the curtain that could potentially affect the size and shape of the flow envelope, and discusses 2017 and 2018 stratification and meteorological conditions.

Collectively this analysis indicates that if the curtain is deployed to its design depth of 10.7 m or below the depth of the epilimnetic thermocline, it is effective at significantly reducing release of cyanobacteria downstream of Iron Gate Dam. This is supported by *Wn* calculations that indicate the surface waters of Iron Gate Reservoir are more strongly stratified in July and August than September and October. This in turn improves curtain effectiveness in July and August. When the curtain can only be deployed to shallower depths, it is less effective. Deployment to these shallower depths is often driven by the need to ensure certain levels of dissolved oxygen remain in the Klamath River downstream of Iron Gate Dam. Analysis indicates that the presence of Iron Gate Dam itself may provide some reduction of chlorophyll-*a* concentrations in the river as compared to those in Iron Gate Reservoir and that there is an even larger reduction in chlorophyll-*a* when the effect of the curtain is combined with that of Iron Gate Dam itself. Additional sample pairs, especially during curtain deployment periods with greater cyanobacterial concentration, may provide further insight.

# 1. Introduction

The Klamath Hydroelectric Settlement Agreement (KHSA; as amended on November 30, 2016) includes Interim Measure (IM) 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. Activity 5 of PacifiCorp's 2015 IM 11 Study Plan is "Continued Evaluation of Intake Barrier Systems for Water Quality Improvement from Iron Gate Powerhouse Releases." The purpose of Activity 5 was to evaluate the intake barrier curtain (henceforth referred to as the "curtain") in Iron Gate Reservoir to improve the quality of water that the Iron Gate Powerhouse releases to the Klamath River. Testing of this water quality improvement measure has been ongoing for the past 4 years and is focused on the use of the curtain to retain biomass from blooms of cyanobacteria and potential associated algal toxins (i.e., microcystin) in the reservoir, thereby reducing releases of such matter to the river.

This report summarizes previous Iron Gate Reservoir studies assessing passive algae reduction efforts (Deas and Miao 2010; Watercourse 2013a, 2013b; Miao and Deas 2014; Watercourse 2016; PacifiCorp 2017) and synthesizes 4 years of water quality data to assess the performance of the curtain. Water quality data collected prior to the curtain placement in Iron Gate Reservoir are examined to assess chlorophyll-*a* reductions attributable to the dam versus those attributable to the curtain.

Tasks to address performance of the intake barrier curtain include:

a. Review of previous Iron Gate Reservoir curtain work.

b. Review and discussion of 2017 and 2018 conditions (with additional data presented in Appendix A).

c. Assessment of stratification strength and curtain efficacy through four summer field seasons (2015-2018).

d. Analysis of 2004-2018 chlorophyll-*a*, microcystin, total *Microcystis aeruginosa* (simply *Microcystis* hereafter), and total cyanobacteria data in the reservoir upstream of the curtain and downstream of the curtain with (2015-2018) and without (2015-2018) the curtain deployed to assess curtain effects on cyanobacteria reduction.

e. Analysis of 2004-2018 chlorophyll-*a* data in the reservoir at the Iron Gate Reservoir log boom (log boom) and in the Klamath River downstream Iron Gate Dam with (2015-2018) and without (2004-2018) the curtain deployed to assess potential dam versus dam-plus-curtain effects on cyanobacteria reduction.

f. Review of the 2015 Acoustic Doppler Current Profiler (ADCP) data to refine the initial assessment of curtain effects on local velocities.

PacifiCorp presented preliminary analysis to the Interim Measures Implementation Committee (IMIC) multiple times as the analysis was being developed. Following the April 2020 IMIC meeting, the Yurok Tribe submitted written comments and suggestions to PacifiCorp. PacifiCorp appreciates these constructive comments and incorporated several of them into this report. A detailed response to the Yurok comments is in Appendix B.

# 2. Background

Iron Gate Reservoir experiences seasonal vertical stratification and cyanobacteria blooms. In an effort to reduce release of cyanobacteria and associated toxins to downstream Klamath River, PacifiCorp installed a curtain in the reservoir to retain surface waters, which often contain high concentrations of cyanobacteria. Factors that are important to the efficacy of the curtain include reservoir stratification, cyanobacteria distributions, and mixing processes. These topics, as well as previous work performed to assess and manage the downstream movement of cyanobacteria in Iron Gate Reservoir, are discussed in this section.

## 2.1 Seasonal Stratification and Cyanobacteria Blooms

Seasonal thermal stratification (seasonal stratification) occurs in Iron Gate Reservoir. The reservoir experiences isothermal winter conditions (uniform temperatures top to bottom), followed by the onset of seasonal stratification in spring, persistence of seasonal stratification through summer and into fall, and subsequent seasonal stratification breakdown and return to isothermal conditions in late fall or early winter. Seasonal stratification occurs because thermal loading increases as day length and solar altitude increase through spring into summer, leading to warmer, less dense water overlying cooler, denser water. This unequal distribution of water temperature results in stratification defined by three vertically distinct zones of different densities (Figure 2-1):

- Epilimnion: the upper, warmest, least dense layer of a stratified lake.
- Metalimnion (thermocline): the middle layer of a stratified lake that represents the transition between the warmer surface layer (epilimnion) and the colder bottom layer (hypolimnion).
- Hypolimnion: the bottom, coldest, and most dense layer of a stratified lake.

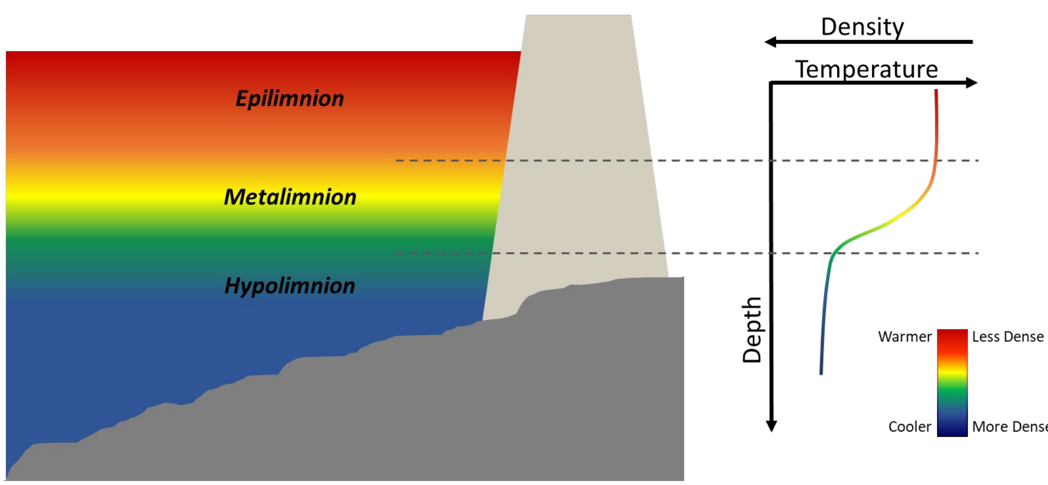



**Figure 2-1. Conceptual schematic of reservoir stratification showing the different layers of water temperature and density.**

Persistent summer seasonal stratification coincides with a period of relatively high cyanobacteria abundance. Blooms of cyanobacteria create a water quality concern because certain cyanobacteria can produce toxins. Strains of *Microcystis* that have been found in the Klamath River from Upper Klamath Lake to the estuary, including Iron Gate Reservoir, can produce microcystin (Otten et al. 2015; Otten et al. 2012). Microcystin is a hepatotoxin (liver toxin) that can lead to health advisories if levels exceed public health standards (SWRCB 2016). Other species that occur in the reservoir, such as *Dolichospermum sp.*, are also capable of producing toxins (Dreher et al. 2019).

Blooms of cyanobacteria in Iron Gate Reservoir are usually concentrated in surface waters where favorable light conditions in the photic zone promote their growth. Certain cyanobacteria have the ability to control their buoyancy, and thus their vertical position in the water column to maintain favorable conditions (e.g., light). Previous studies at Copco and Iron Gate reservoirs have demonstrated that *Microcystis* is more prevalent in near-surface waters than at deeper depth (Figure 2-2; Moisander 2008).

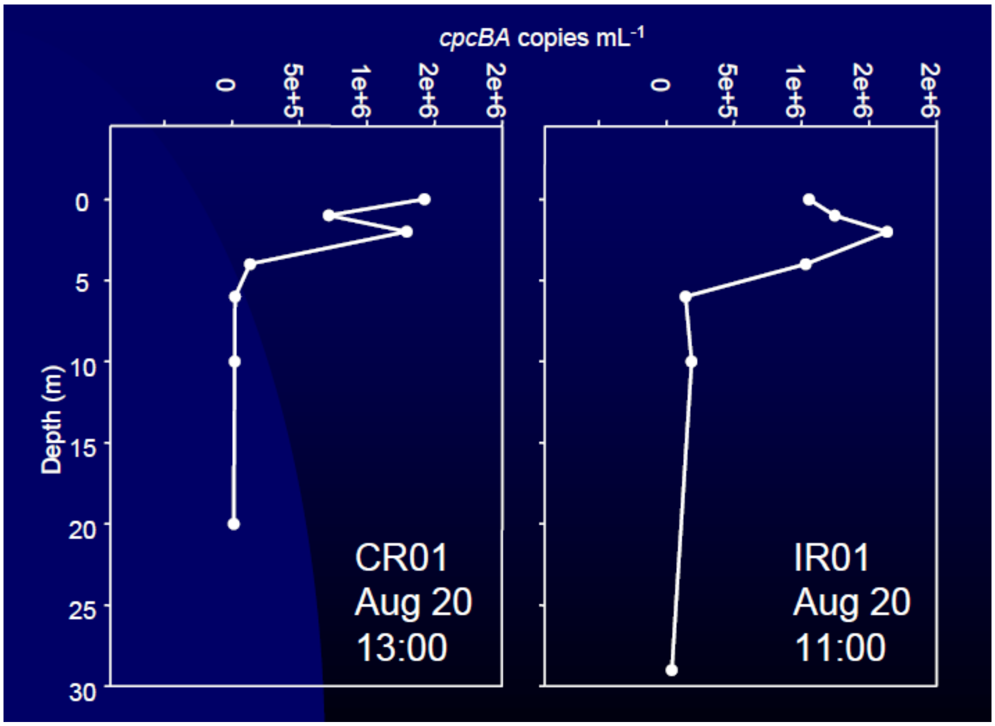



**Figure 2-2.** ***Microcystis aeruginosa*** **vertical distribution in August 2008. (Moisander 2008.)**

Beyond potentially impacting water quality conditions in Iron Gate Reservoir, these near-surface waters can also be discharged to the downstream Klamath River. The Iron Gate Powerhouse intake tower has a vertically-oriented opening that draws water from the reservoir bed to the water surface (up to approximately 11 meters (m), depending on reservoir elevation). Thus, waters from the photic zone that may contain cyanobacteria are entrained into the powerhouse intake and released to the Klamath River (Figure 2-3).

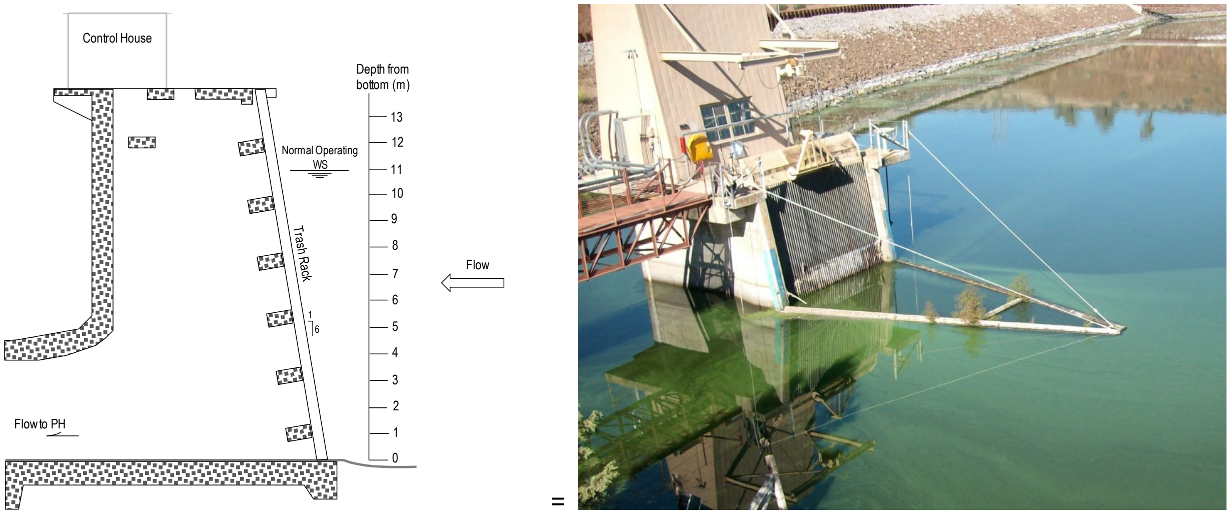



**Figure 2-3. Elevation profile schematic of the Iron Gate Powerhouse intake tower illustrating reservoir operating water surface elevations and vertical extent of trash rack (left) and photograph of intake tower showing open trash rack at reservoir surface (right).**

## 2.2 Iron Gate Intake Barrier Curtain

The curtain is located across the southwest corner of Iron Gate Reservoir just to the northeast of the existing powerhouse intake tower (Figure 2-4). The curtain consists of impermeable coated nylon fabric that spans a horizontal length of about 245 m and consists of panels cut to fit the reservoir profile to a maximum depth of 10.7 m. The top edge of the curtain is strengthened to allow clamping to a surface float system and the lower edge is weighted by a chain. Additional details of the curtain construction and installation are described in Watercourse (2016). Previous work leading up to the installment of the existing curtain is described in Watercourse (2016) and PacifiCorp (2017), and is briefly covered in Section 2.4.

**Figure 2-4. Photograph of barrier curtain surface float (black pipe in center of image), anchor-line floats (white balls on either side of surface float), and intake tower at the southwest corner of Iron Gate Reservoir (taken on May 24, 2018, from the sampling platform upstream of the curtain).**

## 2.3 Intake Barrier Function in Relation to Epilimnetic Stratification, Cyanobacteria Distribution, and Mixing in Iron Gate Reservoir

The curtain is intended to take advantage of thermal stratification and associated vertical density differences to retain near-surface waters, which often contain high concentrations of cyanobacteria, in the reservoir while withdrawing deeper waters with less cyanobacteria. Density differences not only segregate warmer surface waters from cooler, deeper waters, but also tend to resist vertical mixing (e.g., wind mixing). Vertical stratification in Iron Gate Reservoir at the log boom (approximately 500 m upstream of the dam) is displayed for different periods through 2016 (Figure 2-5). In June, the top of the persistent, seasonal thermocline in Iron Gate Reservoir is at a depth of approximately 5 m and the seasonal thermocline extends to approximately 25 m.[1] By September, the top of the seasonal thermocline (see Figure 2-6 for explanation of terms) is at a depth of approximately 15 m and extends to

[1] Depths herein are a function of storage in Iron Gate Reservoir and are approximate with respect to typical operating range of 708.4 m to 709.6 m.

approximately 25 m to 30 m. This is consistent with other years (i.e., vertical profiles examined for 2015, 2017, and 2018).

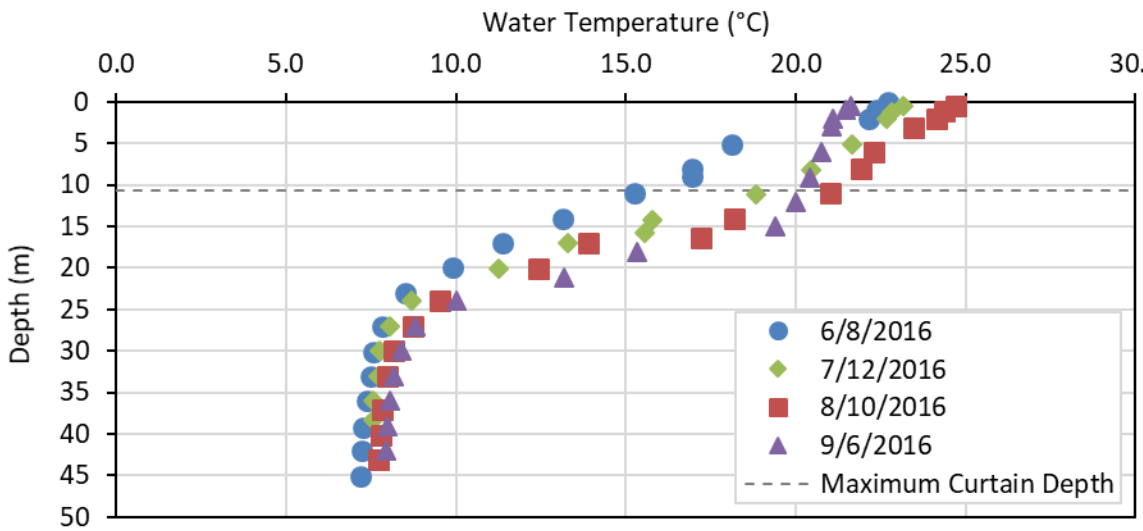



**Figure 2-5. Average daily temperature profiles at the Iron Gate Reservoir log boom from 0 to 45 m for June 8, July 12, August 10, and September 6, 2016. Maximum curtain depth is shown as dashed line for reference.**

Reservoir depth at the center of the curtain is approximately 25.6 m and approximately 10.7 m at the intake tower about 65 m downstream of the curtain. The bottom of the curtain, completely furled, sits at a depth of approximately 1.5 m, can be lowered to depths ranging from approximately 3 m to over 10 m (in 1.5-m increments), and was designed for a deployed depth of 10.7 m. Thus, waters in the vicinity of the curtain during June through August may include both epilimnion and upper portions of the metalimnion, while in September these waters typically comprise largely epilimnetic waters.

Throughout the late-spring, summer, and early fall, waters within the epilimnion may exhibit weak intermittent stratification, forming temporary epilimnetic thermoclines (Figure 2-6). Like the seasonal thermocline, epilimnetic thermoclines are a result of energy (i.e., heat) input to the reservoir surface resulting in a density difference between vertical layers. Stratified layers resist mixing unless additional energy is input to overcome the stratification (e.g., sufficient wind). Additional heating of the surface usually strengthens epilimnetic stratification. Winds can deepen or break up epilimnetic stratification. Therefore, the strength and depth of this intermittent epilimnetic stratification depends on energy fluxes and environmental conditions. In Iron Gate Reservoir, epilimnetic thermoclines usually develop between 0.1 m and 8 m, and vary in depth and strength depending on energy inputs (i.e., meteorological conditions) and mixing energy (e.g., wind).

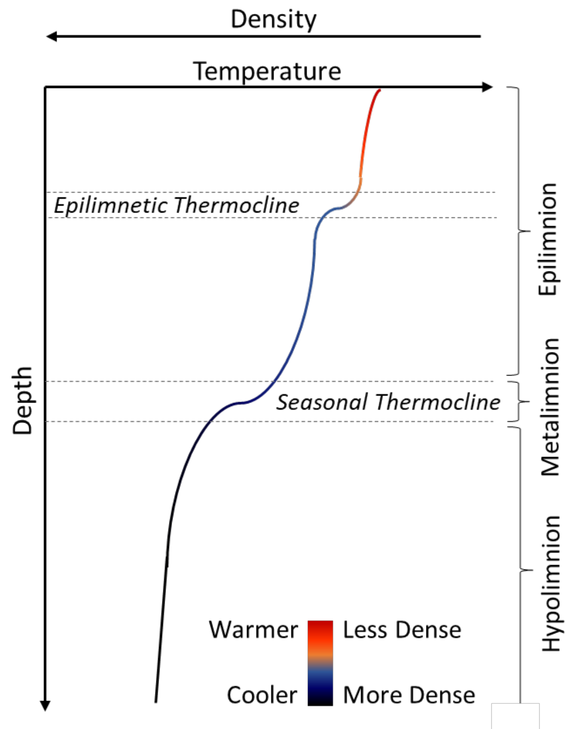



**Figure 2-6. Epilimnetic and seasonal stratification with epilimnetic and seasonal thermoclines.**

### 2.3.1 Epilimnetic Stratification: the Wedderburn Number

While small temperature differences can result in stratification that will inhibit vertical mixing (Henry et al. 1997), such stratification can be readily broken down by external forces. Stability of epilimnetic stratification can be represented by the Wedderburn number (*Wn*), a dimensionless parameter that relates the stability of stratification (density, depth) to mixing energy (wind velocity) (Kalff 2002; Horne and Goldman 1994; Fischer et al. 1979) and represents short-term mixing patterns in the epilimnion. The *Wn* accounts for depth of the mixed layer (the water surface down to the epilimnetic thermocline), change in density between layers, shear stress acting on the water surface (i.e., wind), and fetch. The *Wn* is calculated as:

$$Wn = \frac{g'h^2}{(u^*)^2 L} \qquad \text{(Equation 1)}$$

Where:

| | | |
|---|---|---|
| *Wn* | = | Wedderburn number |
| g' | = | Reduced gravitational acceleration due to the density difference across the epilimnetic thermocline (meters per second squared; $m/s^2$) |
| h | = | Depth of the mixed layer (m) |
| u* | = | Characteristic shear velocity (meters per second; m/s) |
| L | = | Fetch represented by the reservoir open water length in the direction of the wind (m) |

Characteristic shear velocity, u* (m/s), is calculated as $u^* = ((C_D)(\rho_A/\rho_W)(U^2))^{0.5}$, where U is wind speed (m/s) at 10 m, $\rho_A$ is density of air [kilograms per cubic meter ($kg/m^3$)], $\rho_w$ is density of water ($kg/m^3$), and $C_D$ is the wind on water drag coefficient (Fischer et al. 1979). Reduced gravitational acceleration, g' ($m/s^2$), is a function of density differences across the zone of interest, the epilimnetic thermocline in our case, and is calculated as $g' = g\,(\rho_{\text{bottom layer}} - \rho_{\text{mixed layer}})/\rho_{\text{average}}$.

A small *Wn* (*Wn* < 1.0) indicates unstable conditions that translate to an isothermal or near isothermal state in the epilimnion, whereas a large *Wn* (*Wn* > 1.0) indicates stability in the epilimnion that represents stratification. Epilimnetic stratification often changes over relatively short time scales (i.e., hours to days) compared to seasonal stratification.

The mixed layer is characterized by waters that frequently mix and have unstable *Wn* (*Wn* < 1.0). The epilimnetic thermocline occurs below the mixed layer where there is a notable vertical change in temperatures and thus densities within the epilimnion; *Wn* transitions from less than 1 to greater than 1 within the epilimnetic thermocline. The epilimnetic thermocline can fluctuate in thickness and vertical position over short time scales (i.e., hourly or daily) depending on changes to water temperature and wind energy. The layer at the bottom of the epilimnion is resistant to mixing with the mixed layer (upper layer of epilimnion) because of the density gradient in the epilimnetic thermocline (Figure 2-7). The layer at the bottom of the epilimnion is characterized by stable *Wn* (*Wn* > 1.0) during periods of epilimnetic stratification.

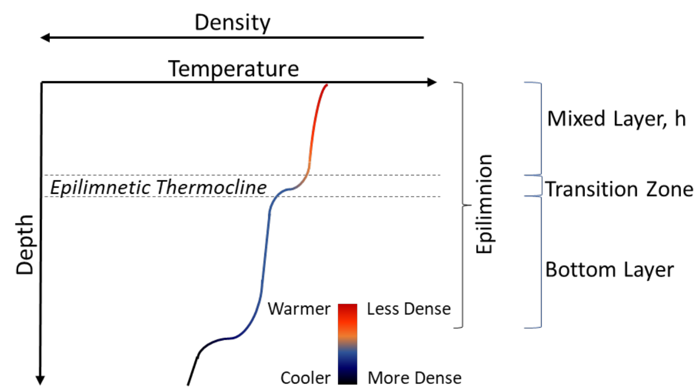



**Figure 2-7. Epilimnetic stratification within the epilimnetic thermocline. Epilimnetic stratification includes a mixed layer (*h*), a transition zone, and an unmixed stable zone at the bottom of the epilimnion.**

### 2.3.1 Iron Gate Reservoir Algae Distribution

Planktonic algae concentrate in the photic zone where they take advantage of light for photosynthesis. Buoyancy compensating cyanobacteria, such as *Microcystis, Dolichospermum sp. (Dolichospermum),* and *Aphanizomenon flos-aquae* (*Aphanizomenon*), have the distinct advantage of controlling their position in the water column which enables them to seek water depths with conditions (e.g., light, nutrients) optimal for growth (Walsby et al. 1997; Reynolds et al. 2010). Moisander (2008), Moisander et al. (2009), and Watercourse (2013b) found that *Microcystis* distribution exhibited vertical variability over a diel period in Iron Gate Reservoir.

Reviews of previous reports and available data indicate that during summer, cyanobacteria in Iron Gate Reservoir generally occupy the top 3 meters[2] of the water column where light conditions are optimal for photosynthesis, but may distribute over a greater depths due to a) convective cooling[3] and passive motion of the algae through this vertical convection to deeper waters; b) active sinking of buoyancy

[2] The photic zone can be approximated using Secchi depth (depth that a black and white disk can be seen when lowered into a lake), where the photic zone is two to three times the Secchi depth. Secchi depths in Iron Gate Reservoir typically range from approximately 1.0 to 4.0 m during summer periods (PacifiCorp 2017, see Section 5).

[3] Convective cooling occurs when cooling at the surface creates water parcels that are colder and thus denser than deeper waters. This colder, denser parcel sinks until it reaches water of a similar temperature (density). Both convection (vertical displacement of water), coupled with turbulence associated with this process results in mixing.

compensating species; or c) wind mixing (Serra et al. 2007; Eslinger and Iverson 2001; Huisman et al. 2004; Walsby et al. 1997). Buoyancy compensating cyanobacteria are at a competitive advantage in these intermittently stratified environments within the epilimnion because they actively move vertically to retain a position in the photic zone.

Curtain depth can be managed to a level at or below intermittent epilimnetic stratification to retain cyanobacteria in upstream of the curtain near-surface waters and reduce releases to the Klamath River. However, the curtain is often unfurled to a depth shallower than the design depth (10.7 m) or epilimnetic stratification because constraints on dissolved oxygen levels that often occur late in the season (i.e., late August through September) downstream of Iron Gate Dam. When the curtain is deployed to a depth shallower than epilimnetic stratification, or when epilimnetic stratification is absent, the curtain may still act as a barrier to some surface cyanobacteria and thus provide some benefit.

### 2.3.2 Iron Gate Reservoir Mixing Processes

Thermal stratification in reservoirs results in vertical density differences that impede mixing. In the case of seasonal stratification, the density differences are sufficient that seasonal stratification persists throughout the summer and into fall. Factors impacting the degree of seasonal stratification include meteorological conditions, reservoir morphology, flow and operations, and withdrawal point (Fischer et al. 1979; Imboden and Wüst 1995; Fantin-Cruz et al. 2015). While many factors determine the degree of seasonal stratification, the thermal structure within the epilimnion is largely governed by energy exchange at the air-water interface (e.g., solar radiation and wind mixing), or lack thereof. During summer, high seasonal thermal loading rates can introduce weak, but persistent epilimnetic stratification; however, windy conditions can break down this epilimnetic stratification. As the summer progresses into fall, day lengths are shorter and nights are longer. During these longer nights, convective cooling begins to play a larger role in epilimnetic mixing. A key aspect of the curtain assessment is to ascertain if these mixing mechanisms are sufficient in Iron Gate Reservoir to break down epilimnetic stratification to the extent that near-surface waters could be entrained to depths sufficient to pass under the curtain.

Wind mixing is explicitly included in the *Wn* equation and convective cooling is implicitly addressed via the density difference with depth. The greater the *Wn*, the greater the wind speed needed to overcome stability and induce mixing. In addition to wind, convective cooling reduces vertical density gradients, minimizes gravitational acceleration ($g'$ in equation 1), and reduces *Wn* (Fischer et al. 1979).

Mixing of the epilimnion is a function of thermal loading, vertical temperature (density) differences, wind velocity, and depth of the mixed layer (*h* in equation 1, Figure 2-7). For example, *Wn* calculations for July and August, summer months with high thermal loading rates, often indicate notable epilimnetic stratification with the development of a mixed layer (*h*) of 4 m that is up to 4 degrees Celsius (°C) warmer than deeper epilimnetic waters. This stratification is sufficiently strong to persist under wind speeds of up to 7 m/s. For similar conditions with *h* 6 m deep, stratification would persist for wind speeds of up to of 11 m/s. Alternatively, in September, shorter day length (longer nights) leads to reduced thermal loading rates resulting in extended periods of convective cooling that effectively reduce the vertical density difference in the epilimnion. *Wn* calculations indicate that wind speeds as low as 3 m/s can mix near-surface waters and break down the epilimnetic thermocline when the temperature difference is only 1°C between the mixed layer and deeper epilimnetic waters and when *h* is 4 m deep.

This assessment calculated *Wn* to illuminate the specific depth[4] at which unstable *Wn* transitioned to stable *Wn*. This allowed a determination of curtain effectiveness (based on depth of stable *Wn* and curtain depth) throughout curtain deployment periods.

Another mechanism that can lead to mixing associated with wind is internal seiching and thermocline tilt (Fischer et al. 1979), which can be assessed with the Richardson number. PacifiCorp (2017) calculated Richardson numbers and concluded that thermocline tilt was insufficient to cause destratification and adversely impact curtain performance under planned operations, even under extreme winds (15.3 m/s). Thermocline tilt is not assessed further in this document.

Finally, increased water velocities potentially created by the presence of the curtain were investigated to understand potential disruption of reservoir stratification from the bottom edge of the curtain upwards towards the surface (PacifiCorp 2017). PacifiCorp (2017) found that horizontal velocities were not sufficiently large to cause destratification in the vicinity of the curtain. This study revisits ADCP data collected in 2015 and examines vertical water velocities in the vicinity of curtain, and potential impacts on stratification (Section 5.2).

## 2.4 Previous Work

The intake barrier curtain system, installed in 2015 and employed each summer up through 2018, builds on several previous studies that investigated different approaches to isolate near-surface waters of Iron Gate Reservoir. In 2009, PacifiCorp installed a floating curtain across the entire width of Iron Gate Reservoir at the log boom location (approximate 335 m in length), approximately 500 m upstream of the dam, to assess the potential efficacy of reducing cyanobacteria entrainment (Deas and Miao 2010). This curtain extended to a depth of 3 m and was attached to the log boom. Upstream and downstream velocity measurements taken with an ADCP indicated that the curtain lacked sufficient depth and that surface waters, particularly under windy conditions, readily passed under the curtain. Overall, the 2009 study indicated that the curtain was of insufficient depth and its location was too distant from the intake tower to affect surface entrainment of cyanobacteria into the intake tower. However, these findings, including additional velocity measurements in the vicinity of the intake tower, led to the concept of installing a cover on the upper portion of the intake tower to reduce the amount of entrained surface water (and associated greater algal concentrations) drawn into the tower and powerhouse.

In 2011, an intake cover was constructed and installed on the Iron Gate intake tower trash rack to largely seal off the top of the intake tower to a depth of approximately 3.7 m (Watercourse 2013a). Water quality conditions were characterized prior to and after the cover was deployed (i.e., lowered into place on the intake tower trash rack) by monitoring water quality parameters upstream of the intake tower and in the Klamath River downstream of Iron Gate Dam, and collecting ADCP velocity measurements upstream of the intake tower. The ADCP measurements taken during the study period indicated an increase in velocity near the penstock intake depth, suggesting the withdrawal profile (or "envelope") was altered by placement of the cover. When the intake cover was lowered to the test depths, *Microcystis* cell counts were less downstream compared to cell counts when the cover was not present.

Despite initial reductions in *Microcystis* concentrations downstream of Iron Gate Dam, subsequent ADCP velocity measurements over the next 24 hours indicated that velocity profiles in the vicinity of the intake tower had not stabilized. Thus, the Intake Cover Study was repeated in 2012 (Watercourse 2013b), with deployment and monitoring occurring over several days. Field observations identified high velocities near the bottom edge of the intake cover, which developed over the course of a day or more, brought

[4] Limited by depths with available thermograph data including: 0.1, 0.5, 1, 1.5, 2, 3, 4, 5, 6, 8, 10, 15, and 20 m.

about by the reduced outlet area with the cover in place. The cover reduced the surface area of the intake by approximately 30 percent at the 3.7 m deployment depth. These increased velocities, over time, resulted in vertical mixing and entrainment of near-surface waters (and associated cyanobacteria). Thus, the cover provided only a temporary change in the origin of withdrawal waters from Iron Gate Reservoir. Key findings of the 2012 study included:

- Placing a cover directly on the intake tower increased velocities into the intake tower, increasing mixing at the bottom edge of the cover and, after a relatively short duration (24 to 28 hours), re-entraining near-surface waters, essentially offsetting the effect of the cover.
- The depth of the cover appeared to be insufficient to impede mixing because the density differential in the top 3.7 m was insufficient to prevent mixing at these increased velocities.
- A need for more detailed bathymetry in the downstream reservoir region (approximately from the log boom to the dam/intake tower) was identified.

In sum, a more effective barrier would require placement farther away from the intake tower to prevent increased velocities at the intake tower and also extend deeper into the reservoir to accommodate vertical stratification and limit mixing under the barrier.

The next phase of the study, conducted in 2013 (Miao and Deas 2014), focused on performing a bathymetric survey of the reservoir in the vicinity of the dam to better understand the bottom contours and flow dynamics that occur in the reservoir around the curtain location. Data from a series of ADCP velocity transects generated comprehensive and detailed velocity profiles between the A-frame log structure at the intake tower and the log boom (approximately 500 m upstream of the dam). In a separate 2013-14 study, a barrier curtain was placed in Long Gulch Cove (in Iron Gate Reservoir) to assess isolating the cove for seasonal algaecide application (Watercourse 2015). At the end of the 2014 season (October), the curtain was redeployed near the intake tower as a proof-of-concept exercise. Lessons learned in both the installation of the curtain at Long Gulch Cove and its redeployment near the dam facilitated the design of the intake barrier curtain that was installed in 2015. Concurrent with this work was computational fluid dynamics modeling in the region between the log boom and Iron Gate Dam. Bathymetry survey information and ADCP measurements at the log boom (Miao and Deas 2014; Deas and Miao 2010) were used to develop the model and analyze potential curtain configurations. These findings were instrumental in final design of a prototype curtain.

In 2015, the existing intake barrier curtain was installed and tested (Watercourse 2016). The presence of the curtain resulted in the withdrawal of deeper waters from Iron Gate Reservoir. Data from ADCP velocity measurements upstream of the curtain indicated that shallow, near-surface waters had little or no velocity while deeper waters near the bottom of the curtain had notable downstream velocities. Multiple transects upstream of the curtain indicated largely quiescent shallow waters and a well-defined horizontal flow zone or envelope at and below the curtain bottom in which water was moving downstream towards the curtain. In addition, water quality samples, physical measurements, and field observations of conditions in the project area consistently identified that waters of the photic zone, where the majority of cyanobacteria occur, were largely isolated to the upstream side of the curtain. Waters that ultimately passed under the curtain were drawn from deeper, cooler depths in Iron Gate Reservoir upstream of the curtain (Figure 2-8). The 2015 study indicated that the curtain was effective at isolating near-surface waters of Iron Gate Reservoir upstream of the curtain (Watercourse 2016).

The 2016 assessment of curtain effectiveness characterized the physical attributes of stratification, mixing, and the localized flow changes caused from deploying the curtain (PacifiCorp 2017). The dimensionless *Wn* and Richardson numbers were used to assess the strength of stratification and the effects of wind mixing and increased local velocities associated with curtain placement (e.g., larger velocities under the curtain than would occur without the curtain). Mixing in the epilimnion was predicted to have minimal effects on curtain performance. Overall, the 2016 field studies indicated that the curtain functioned as an effective water quality management tool that isolated near-surface waters in Iron Gate Reservoir and reduced the entrainment and downstream release of cyanobacteria in the near-surface waters of Iron Gate Reservoir. As a secondary benefit, the curtain also functioned as a passive selective withdrawal device that isolated warmer surface waters and drew deeper cooler waters for release to the Klamath River.

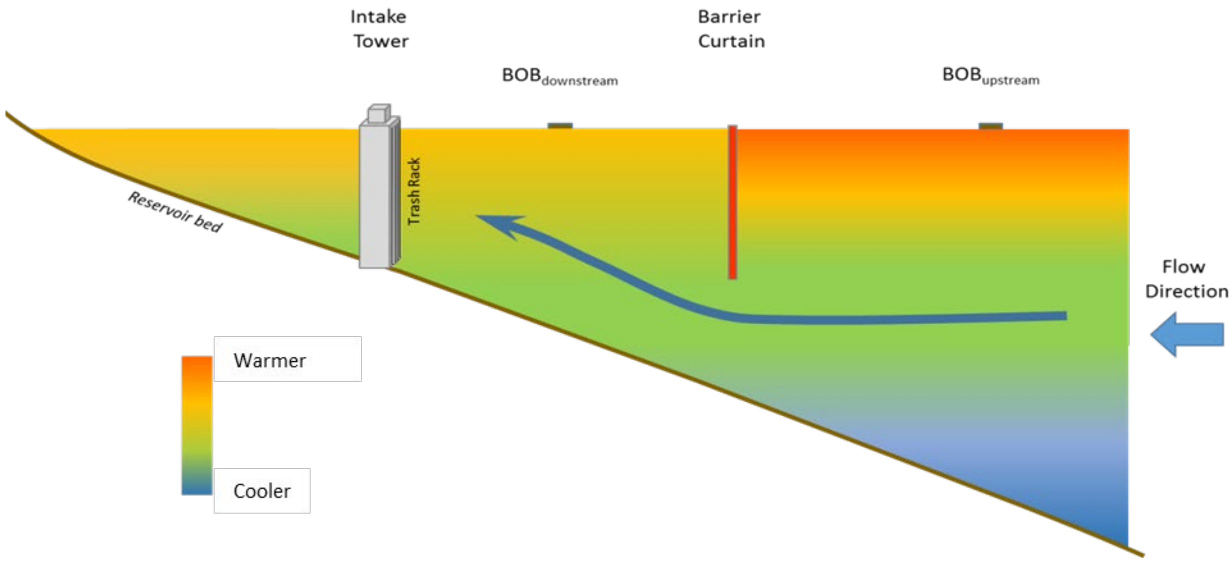



**Figure 2-8. Conceptual profile view of thermal conditions in Iron Gate Reservoir showing the location of the barrier curtain, upstream of the curtain and downstream of the curtain Basic Observation Buoys (BOBs), and intake tower.**

# 3. Hypotheses

The premise for placement of an intake barrier curtain in Iron Gate Reservoir to take advantage of seasonal thermal stratification and associated vertical density differences in the water column, retain cyanobacteria in the near-surface waters within the reservoir, and reduce releases of cyanobacteria and associated toxins to the downstream Klamath River was based on an understanding that:

- The majority of cyanobacteria exist in or near surface waters (photic zone).
- Epilimnetic stratification minimizes mixing of surface waters with deeper epilimnetic waters.

Three hypotheses were developed to frame the analysis and characterize the effect of using a curtain to reduce cyanobacteria concentrations. Input from the IMIC led to the inclusion of an evaluation of the effect of just Iron Gate Dam on reducing cyanobacteria concentrations (i.e., in the absence of a curtain or curtain not deployed).

## 3.1 Hypothesis 1: Reductions in Downstream Loading Attributable to Curtain

Using available field data collected prior to and during curtain deployment periods and considering that epilimnetic stratification presence and persistence can vary throughout curtain deployment periods, as can curtain depths, the effects of curtain deployment on water quality were assessed through the development of hypothesis 1 (H1):

- **H1**: The curtain is effective at reducing cyanobacteria loads in downstream waters by reducing the downstream movement of surface waters, which often contain high concentrations of cyanobacteria, from Iron Gate Reservoir into the Klamath River.

Hypothesis 1 was assessed for three conditions (see Section 4.3.1) to capture the range of system responses that can occur in Iron Gate Reservoir under curtain deployment conditions.

## 3.2 Hypothesis 2: Reductions in Downstream Loading Attributable to Iron Gate Dam Only

The presence of Iron Gate Dam and associated outlet facilities, collectively referred to as Iron Gate Dam, can act to reduce cyanobacteria released from the reservoir to downstream Klamath River reaches. The intake tower design and operation lead to preferential withdrawals from deeper waters associated with the depth of the penstock intake (invert approximately 11 m deep) (Deas and Miao 2014). Therefore, in the absence of a curtain, downstream Klamath River conditions should reflect reduced cyanobacteria concentrations when compared to upstream concentrations in an integrated sample that spans similar depths as the intake tower, leading to hypothesis 2 (H2):

- **H2**: Iron Gate Dam, without a curtain present, provides some downstream reduction in cyanobacteria loads by reducing the downstream movement of surface waters, which often contain high concentrations of cyanobacteria, from Iron Gate Reservoir into the Klamath River.

Hypothesis 2 was assessed for four curtain not deployed conditions (see Section 4.3.2) to capture differences in response between periods with no curtain installed versus a curtain installed but not deployed, and differences in system response when all data are included versus only data collected during the productive season.

## 3.3 Hypothesis 3: Reductions in Downstream Loading Attributable to Iron Gate Dam plus Curtain

The presence of a curtain in combination with Iron Gate Dam can act to further reduce surface cyanobacteria released into the downstream Klamath River reaches. Using available field data collected prior to and during curtain deployment periods and considering epilimnetic stratification and curtain depths, the effects of the curtain deployment and the dam were assessed through the development of hypothesis 3 (H3):

- **H3**: The curtain in combination with Iron Gate Dam is effective at reducing cyanobacteria loads in downstream waters by reducing the downstream movement of surface waters, which often contain high concentrations of cyanobacteria, from Iron Gate Reservoir into the Klamath River.

Hypothesis 3 was assessed for three conditions (see Section 4.3.1) to capture the range of system responses that can occur in Iron Gate Reservoir under curtain deployment conditions.

# 4. Methods

Assessment of curtain performance in Iron Gate Reservoir utilized a range of data, including sondes, thermograph arrays, grab samples (including use of autosamplers), and meteorological data. Outlined herein are the available data and data analysis methods. These methods were developed to assess the effects of the curtain on seasonally retaining waters with high concentrations of cyanobacteria in the reservoir.

## 4.1 Available Data

A range of data from studies specifically associated with the curtain assessment, as well as other monitoring programs that collected information in the project area (from Iron Gate Reservoir log boom to the grab sampling site the Klamath River downstream of Iron Gate Dam) were used in this analysis (Figure 4-1). The curtain-specific field studies from 2015 to 2018 were designed to span from upstream of the curtain to downstream of Iron Gate Dam. Other monitoring programs that collected information in or around the project area include information as far upstream as the log boom in Iron Gate Reservoir and downstream about 870 m from the Iron Gate Powerhouse to the U.S. Geological Survey gage (gage no. 11516530) on the Klamath River (Figure 4-1). Outlined in this section are field data collection associated with the 2015-2018 barrier studies, including:

- 2015 – 2018: Continuously sampling data sondes
- 2016 – 2018: Thermograph arrays
- 2015 – 2018: Curtain observation buoy vertical profile grab sampling
- 2015 – 2017: Diel autosampler studies
- 2004 – 2018: KHSA IM-15 monitoring and previous water quality studies
- 2015 – 2018: Meteorological data

Information for many of the aforementioned data can be found at https://www.pacificorp.com/energy/hydro/klamath-river.html. Data collected in 2015 and 2016 are summarized in previous reports (Watercourse 2016, PacifiCorp 2017). Data collected in 2017 and 2018 are summarized herein.

### 4.1.1 Continuous Sampling with Data Sondes

Data sondes (YSI, EXO2™ units[5]) were used to measure temperature, dissolved oxygen, pH, specific conductivity, total algae as chlorophyll (chlorophyll), cyanobacteria as phycocyanin[6] (phycocyanin), and depth for 2015, 2016, 2017, and 2018. These sondes were used to characterize vertical conditions both upstream and downstream of the curtain from near the surface to deeper waters below the photic zone, including depths where water flows under the curtain. In all years, sondes were suspended from floating

[5] Sonde manufacturer specifications for all parameters is adapted from the user manual (Xylem 2017).

| Parameter | Range | Accuracy |
|---|---|---|
| Water Temperature | -5 to 35°C; 35 to 50°C | ±0.01°C; ±0.05°C |
| Dissolved Oxygen | 0 to 50 mg/L; 0 to 500% air saturation | * |
| Total Algae as Chlorophyll | 0 to 44 µg/L Chl; 0 to 100 RFU | * |
| Cyanobacteria as Phycocyanin | 0 to 100 µg/L; 0 to 100 RFU | R2 >0.999 for serial dilution of Rhodamine WT solution from 0 to 100 µg/mL BGA-PC equivalents* |
| Depth | 0 to 10 m (0 to 33 ft) | ±0.04% FS (±0.004 m or ±0.013 ft) |

* Accuracy in RFU or µg/L for these sensors is not available.

[6] Phycocyanin is a pigment specific to cyanobacteria and the phycocyanin probe measures the fluorescence of phycocyanin in the water to provide a relative measure of cyanobacteria standing crop.

platforms in the reservoir located upstream and downstream of the curtain (Figure 4-1). The sondes communicated remotely with PacifiCorp facilities at Iron Gate Dam, allowing local operators (as well as PacifiCorp employees in Portland) to track operation of the sondes and conditions in the reservoir.

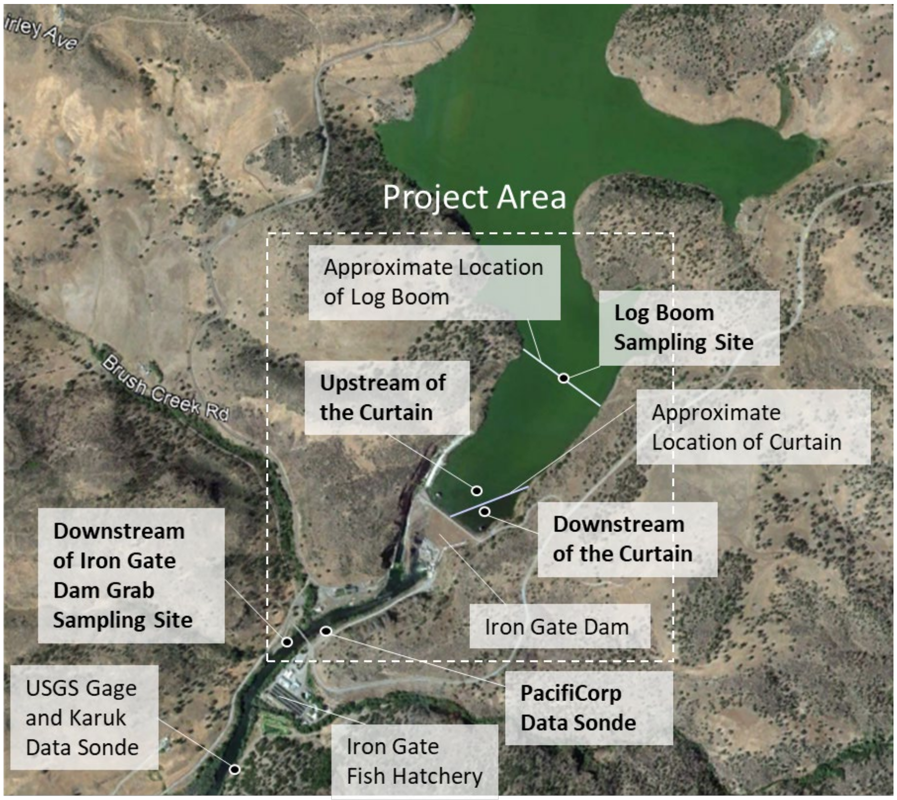



**Figure 4-1. Map with project area (dashed line), sampling locations (bold), and surrounding landmarks.**

In 2015, a single data sonde was attached to a cable and winch system that moved the sonde vertically through the water column continuously at regular intervals (i.e., completing approximately 8 vertical profiles per day and spanning depths from approximately 0.5 m to 12 m). The sonde moved in approximate 1-m intervals and collected data at 15-minute intervals, taking approximately 3 hours to complete a vertical profile. Challenges encountered with this method were most often caused by algae build-up and fouling on the winch, cable, or associated pulleys. To avoid this in 2016, three data sondes were deployed on each side of the curtain at fixed depths (0.5 m, 5 m, and 10 m) to characterize water quality near the surface, mid-water column, and near the maximum depth of the curtain. While this provided useful information, a vertical profiling system to capture details, particularly in the near-surface waters (surface to 5 m) was desired. Thus, in 2017 and 2018, the winch system with a single data sonde at each of the platforms was put back into use, but with a reduced profiling frequency to minimize fouling. Sondes were programmed to complete one vertical profile per week in 2017. This frequency was increased to three vertical profiles per week in 2018. Challenges caused by algae build-up continued in 2017 and 2018, but were more manageable than in 2015.

Sondes were cleaned, calibrated, and accumulated data downloaded at regular intervals of every 3 to 6 weeks in 2015 and 2016. The service interval was reduced to 3 weeks from 2017 to present to ensure units were properly functioning, clean, and data retrieved. Data collected during service intervals were removed from the data set by reviewing the time, depth, and cable power values and field service data sheets. Occasionally outliers were identified in these data sets during data processing. These were instances where a single probe would spike and then return to prespike levels within the next two or three readings. These were flagged and removed from the data set.[7] Data were reviewed for drift associated with biofouling. Once reviewed, data from each sonde location were compiled into a single file.

### 4.1.2 Thermograph Arrays

Thermograph arrays consisted of Onset U-22 Pro v2 temperature loggers[8] suspended vertically in the reservoir from each platform. Such arrays were deployed seasonally in 2016, 2017, and 2018, and provided a continuous, detailed record of vertical water temperature profiles upstream and downstream of the curtain. These temperature data augmented data from the sondes, but at a more refined vertical spatial resolution.

Thermograph arrays included 12 or 13 temperature loggers recording water temperatures at 15-minute intervals. The arrays were deployed in May or June and retrieved in November. Data loggers were attached to a weighted line or chain at depths of: 0.1, 0.5, 1, 1.5, 2, 3, 4, 5, 6, 8, 10, 15, and 20 m. At the downstream of the curtain site, the bottom depth was approximately 15 m, so a 20-m depth was not monitored.

A thermograph array was installed on the log boom in 2016, 2017, and 2018. This array consisted of 12 to 16 Onset U22-001 data loggers recording water temperatures at no less than 30-minute intervals. This array was typically deployed by June and retrieved in the November to January period, depending on available resources. In 2016, data loggers were attached to a cable at depths of 0.5, 1, 1.5, 3, 6, 9, 12, 15, 21, 24, 27, and 30 m. In 2017 and 2018, data loggers were attached to a cable at intervals of 0.5, 1, 1.5, and 3 m from 3 m through 39 m.[9]

After retrieval, the data loggers were downloaded and data from before installation and after retrieval were removed from each record. The final data sets were combined into a single file for the upstream of the curtain and downstream of the curtain and log boom sites.

### 4.1.3 Detailed Vertical Profiles

Detailed vertical profiles were collected upstream and downstream of the curtain within Iron Gate Reservoir during site visits in 2015, 2016, 2017, and 2018. The goal of this study element was to assess microcystin, *Microcystis*, chlorophyll-*a*, and cyanobacteria concentrations with depth at two locations. Concentrations were compared across the curtain to determine whether the curtain effectively isolated the reservoir near-surface waters upstream of the curtain. Cyanobacteria assemblages were compared using genetic analysis (quantitative polymerase chain reaction [qPCR]) for all samples. Genetic analysis allowed for a more rapid processing of samples and greater accuracy in identifying cyanobacteria species composition than traditional visual cell count methodology using microscopy. Analysis of samples was conducted by one of three laboratories depending on the constituent being analyzed and the year (Table 4-1).

Profile sampling occurred at both locations upstream and downstream of the curtain at depths of 0.5, 1.5, 3, 6, 9, 12, and 15 m.[10] The sampling depth of 0.5 m was selected to represent conditions in the top

---

[7] Spikes in total algae and total cyanobacteria sonde data not removed.

[8] Temperature manufacturer specifications for water temperature are available at https://www.onsetcomp.com/products/data-loggers/u22-001. U22 Pro v2 loggers have an operating range of -40°C to 50°C in water, with an accuracy of ±0.21°C from 0°C to 50°C, and a resolution of 0.02°C at 25°C.

[9] The log boom thermograph array did not include data at 30 m in 2017.

[10] In 2018, samples were collected at each of these depths but only samples from depths of 0.5 m, 6 m, and 12 m were analyzed with qPCR and ELISA. At times, the sampler hit the bottom or drew sediment at the 15-m depth downstream of the curtain depth and was therefore not collected. In 2018, a 15-m sample was no longer collected downstream of the curtain.

1 m of water. When profiles were conducted, a corresponding water sample from the Klamath River downstream of Iron Gate Dam was also collected from a depth of 0.5 m. Vertical profile and river samples were collected before and after curtain deployment.

Water samples were analyzed for total and filtered microcystin (using enzyme-linked immunosorbent assay [ELISA]), total cyanobacteria (using qPCR), total *Microcystis* (using qPCR), and total chlorophyll-*a*[11] (using fluorescence detection). The total *Microcystis* analysis targeted a specific region of the phycocyanin gene to detect all species of *Microcystis*, and includes both toxigenic and nontoxic strains. The combined total of other cyanobacteria species (e.g., *Aphanizomenon sp., Anabaena sp., Gloeotrichia sp.*) can be estimated by the difference between total cyanobacteria and total *Microcystis.*

Physical data were collected using a handheld YSI 6600 data sonde or a handheld YSI Professional Plus data sonde[12] at the time of water sample collection. Physical data collected included water temperature, dissolved oxygen, and pH. The sonde was calibrated before each sampling event. Secchi disk readings were also taken during water sample collections.[13]

**Table 4-1. Summary of laboratories processing total microcystin, total *Microcystis*, total cyanobacteria, and total chlorophyll-*a* from 2015-2018 (detection limits in parenthesis, unless noted).**

| Laboratory | Total Microcystin | Total *Microcystis* | Total Cyanobacteria | Total Chlorophyll-*a* |
|---|---|---|---|---|
| EPA Region 9 Laboratory [a] | EPA 546 - ELISA (0.15 µg/L) | N/A | N/A | N/A |
| Bend Genetics [b] | EPA 546 ELISA (0.15 µg/L)[c] | qPCR (100 genes/mL)[d] | qPCR (100 genes/mL)[d] | N/A |
| Chesapeake Biological Laboratory | N/A | N/A | N/A | EPA 445.0, SM10200H.3[e] |

[a] U.S. Environmental Protection Agency (EPA) Region 9 laboratory was used in 2015.

[b] Bend Genetics was used from 2016 to 2019.

[c] Bend Genetics processed both filtered (not cell-bound) and unfiltered (total) microcystin samples.

[d] The qPCR method is a DNA-based analysis, allowing for rapid processing of samples and accurate identification of cyanobacteria species composition. All qPCR results are presented in units of genes per milliliter (mL) and are not directly comparable to cell counts.

[e] Method detection limits varied by year: 0.21 microgram per liter (µg/L), 0.21 µg/L, 0.89 µg/L, and 0.68 µg/L for 2015, 2016, 2017, and 2018, respectively.

Note: N/A = not applicable

### 4.1.4 Diel Autosampler Study

Additional data available for this analysis were derived from the 2017 diel study using autosamplers. Autosamplers were deployed from July 24 to July 27, 2017, upstream and downstream of the curtain to assess near-surface conditions across the curtain. Autosamplers were programmed to take coincident samples at 4-hour intervals from a depth of 0.5 m over a 72-hour period. Water samples were analyzed for total microcystin (using ELISA), cyanobacteria species including total cyanobacteria and total *Microcystis* (using qPCR), and total chlorophyll-*a* (using fluorescence detection).

---

11 Total chlorophyll-*a* is presented in this report, as opposed to the value corrected for phaeophytin.

12 Sonde manufacturer specifications for water temperature, dissolved oxygen, and pH data are ±0.15°C, ±0.1 milligrams per liter (mg/L) or 1 percent, whichever is greater, and ±0.2 units, respectively.

13 Secchi depth readings were only available for one sample collection date in 2018.

### 4.1.5 Other Monitoring and Previous Water Quality Studies

Data from the KHSA Interim Measure 15 (IM-15) monitoring program and previous water quality studies spanning the period 2004 – 2018 were used. Total chlorophyll-*a* results from sampling locations at the log boom and the Klamath River downstream of Iron Gate Dam were of interest, specifically total chlorophyll-*a* from the integrated 0- to 8-m samples at the log boom and total chlorophyll-*a* from 0.5-m depth downstream of Iron Gate Dam.

### 4.1.6 Meteorological Data

Meteorological data were collected at PacifiCorp's meteorological station located on Iron Gate Dam. Data included air temperature, barometric pressure, relative humidity, precipitation, solar radiation, and wind speed (peak gusts, instantaneous, and average). Wind speed was the principal parameter used in this analysis.

Review of the data from the meteorological station indicated that there were several instances where the station was offline or where the system had automatically flagged data as being of "bad quality." There were also extended blocks of wind speed data reported as 999.8 or 999.9 miles per hour, denoting an invalid reading. These data were removed from the data set before analysis.

## 4.2 Review of 2015 Acoustic Doppler Current Profiler Data

Acoustic Doppler Current Profiler data from 2015 were previously analyzed (Watercourse 2016) to assess velocity and flow patterns upstream of the intake tower along both sides of the curtain. These field measurements included measurements of velocity magnitude and direction in the horizontal (x-y) and vertical (z) directions. Previously, only the x-y velocity data were assessed. There data were revisited and included the vertical directional data to determine if additional information could be gleaned from this highly detailed data set with regards to the curtain's efficacy at retaining near-surface waters in the reservoir and limiting their movement under the curtain.

Horizontal and vertical velocities were categorized based on the direction of flow of the horizontal component. Flow that was within a 90° envelope of perpendicular to the curtain was considered tending clearly towards either the reservoir (upstream) or the intake tower (downstream) and was analyzed in this assessment. Of these flows moving strongly towards the reservoir or intake tower, the vertical velocity components were categorized as either positive (flowing upward, toward the ADCP) or negative (flowing downward, away from the ADCP). For each transect, velocity x and y data were aggregated into 17 bins (vertical columns running the depth of the curtain from dam to shore) approximately 13.7 m wide. Of these 17 bins, the center 8 bins were selected for further analysis because maximum depth was approximately equal to or exceeded 10 m, the approximate depth of the curtain.

## 4.3 Data Analysis Methods

While considerable data are available, the spatial and temporal representation, at times, varied among the studies. As a result, available data sets were assessed to develop information that could be compared at similar times and at similar locations to address specific conditions, including the aforementioned hypotheses:

- **H1**: The curtain is effective at reducing cyanobacteria loads in downstream waters by reducing the downstream movement of surface waters, which often contain high concentrations of cyanobacteria, from Iron Gate Reservoir into the Klamath River.
- **H2**: Iron Gate Dam, without a curtain present, provides some downstream reduction in cyanobacteria loads by reducing the downstream movement of surface waters, which often contain high concentrations of cyanobacteria, from Iron Gate Reservoir into the Klamath River.

- **H3**: The curtain in combination with Iron Gate Dam is effective at reducing cyanobacteria loads in downstream waters by reducing the downstream movement of surface waters, which often contain high concentrations of cyanobacteria, from Iron Gate Reservoir into the Klamath River.

Methods and assumptions associated with data analyses are detailed below.

### 4.3.1 H1: Reductions in Downstream Loading Attributable to Curtain

Hypothesis 1 was assessed by first considering epilimnetic stratification and wind conditions (*Wn* calculations). Curtain effectiveness was tested for three curtain deployed conditions by comparing upstream of the curtain and downstream of the curtain sample concentrations (2015-2018 sonde data and vertical profile data). Paired data for similar sample depths for total microcystin, total *Microcystis*, total cyanobacteria, and total chlorophyll-*a* were employed. Paired sonde data for similar sample depths for water temperature, dissolved oxygen, chlorophyll, and phycocyanin were also reviewed. The curtain deployed conditions represented a range of intermittent stratification settings in relation to deployed curtain depth (Figure 4-2):

- Curtain Deployed Condition 1: Epilimnetic thermocline is shallower than the curtain depth
- Curtain Deployed Condition 2: Epilimnetic thermocline is at curtain depth
- Curtain Deployed Condition 3: Epilimnetic thermocline is deeper than curtain depth or stratification was nonexistent or weak.

***Curtain Deployed Condition 1***: Epilimnetic thermocline is shallower than the curtain depth ($Z_{T1} < Z_{T2} < Z_1$, where $Z_{T1}$ and $Z_{T2}$ represents the depth at the top and bottom of the epilimnetic thermocline, respectively and $Z_{1,\ 2,\ \text{or}\ 3}$ is the curtain depth):

a. Upstream of the curtain waters at depths within the upper mixed layer are effectively retained upstream (“high” effectiveness)
b. Upstream of the curtain waters at depths from the transition between the upper mixed layer and lower layer and above the bottom of the curtain may be retained (“medium to low” effectiveness)
c. Upstream of the curtain waters at depths below the curtain depth are not retained, but simply pass under the curtain (“ineffective”).

***Curtain Deployed Condition 2***: Epilimnetic thermocline is at curtain depth ($Z_{T1} < Z_2 < Z_{T2}$):

a. Upstream of the curtain water at depths within the upper mixed layer are effectively retained upstream (“high” effectiveness)
b. Upstream of the curtain waters at depths from the transition between the upper mixed layer and lower mixed layer and above the bottom of the curtain may be retained (“medium to low” effectiveness)
c. Upstream of the curtain waters at depths below the curtain depth are not retained, but simply pass under the curtain (“ineffective”).

***Curtain Deployed Condition 3***: Epilimnetic thermocline is deeper than curtain depth ($Z_3 < Z_{T1} < Z_{T2}$) or stratification was nonexistent or weak:

a. Upstream of the curtain water in the mixed layer may be retained upstream of the curtain at shallower depths (e.g., at $z_3$), but deeper depths are not effectively retained. Because all depths may be entrained, all depths in the mixed layer under these conditions are assigned a “medium to low” effectiveness.

b. Upstream of the curtain waters at depths below the curtain depth are not retained, but simply pass under the curtain ("ineffective").

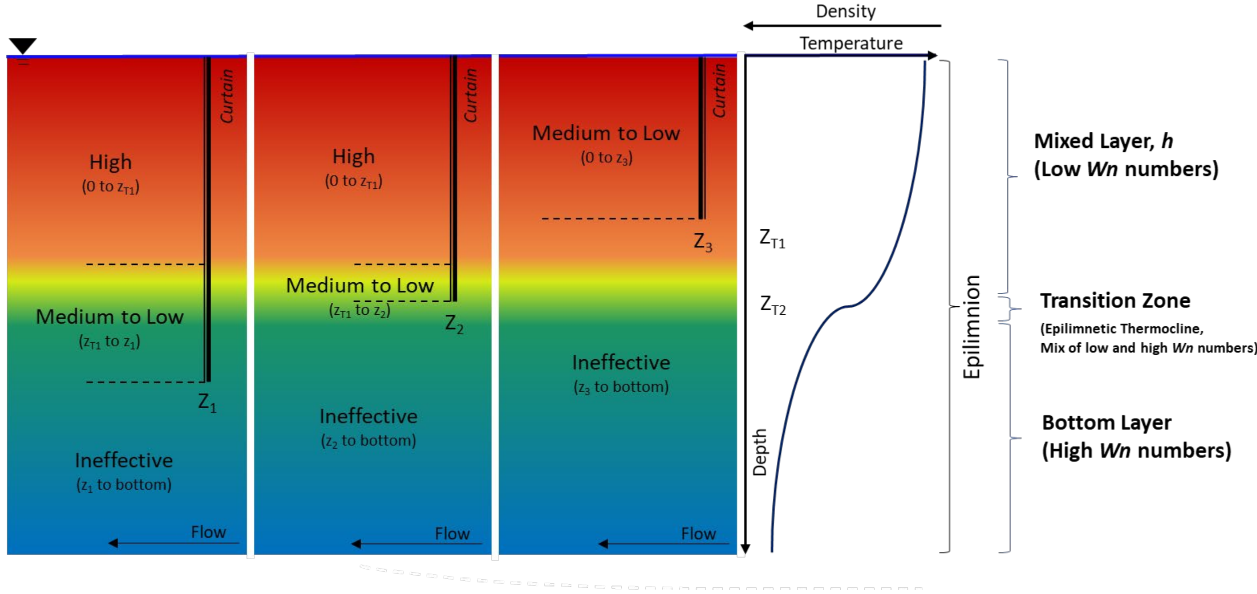



**Figure 4-2. Curtain deployed conditions and potential curtain effectiveness (Condition 1 – left panel, Condition 2 – middle panel, Condition 3 – Right panel).**

In general, a deeper curtain deployment depth is more effective than a shallower deployment depth at retaining surface water upstream of the curtain. However, at certain times of the season there are concerns with lower dissolved oxygen concentration in deeper waters being released into the Klamath River downstream of Iron Gate Dam. A balance between maximizing the benefits of the curtain (i.e., deploying the curtain to a certain depth based on the location of the epilimnetic thermocline) and achieving the desired dissolved oxygen concentration in releases from Iron Gate Dam to the downstream Klamath River is needed. Identifying curtain effectiveness as a function of depth is desirable from an operations perspective (i.e., lower the curtain only to the depth needed to be effective and no deeper), but other constraints (e.g., dissolved oxygen) may require shallower deployment depths even though shallower depths reduce curtain effectiveness.

#### 4.3.1.1 Wedderburn Number Calculations

Hypothesis 1 was tested under curtain not deployed conditions and the three curtain deployed conditions identified above. Wedderburn numbers were calculated to estimate the depth at which unstable *Wn* (low *Wn*) transitioned to stable *Wn* (high *Wn*). Wedderburn numbers were calculated at each depth for which measured water temperatures were available (0.1 m, 0.5 m, 1 m, 2 m, 3 m, 4 m, 5 m, 6 m, 8 m, 10 m, 15 m, and 20 m for 2016 through 2018).[14] Wedderburn numbers were calculated at hourly intervals to evaluate short-term (i.e., hourly and daily) changes in stratification strength with depth. The fetch length for Iron Gate Reservoir was estimated to be approximately 3,000 m, extending from near the dam upstream along the main axis of the reservoir. This value is different than the 2,200-m fetch (PacifiCorp 2017) and represents a more conservative *Wn* calculation (resulting in smaller *Wn*) because wind-driven mixing is more effective.

[14] *Wn* calculations were performed by using water temperature data at the surface (average of 0.5-m and 0.1-m waters) for the mixed layer term versus water temperature at each depth that water temperature data were available for the bottom layer term. This resulted in a series of *Wn* by depth in order to identify the depth of epilimnetic stratification (*Wn* > 1).

**METHODS**

Water temperature data were compiled from the continuously profiling upstream curtain sonde or observations from a handheld probe in 2015, and from upstream of the curtain thermograph strings in 2016, 2017, and 2018. Wind speed and air temperature data were compiled from the meteorological station on Iron Gate Dam for 2015 through 2018. Water temperature and meteorological data were reviewed visually and outliers[15] and poor-quality data were removed. The 15-minute average wind speeds, 15-minute air temperatures, and 15-minute thermograph data were filtered to hourly data for use in *Wn* calculations. The use of hourly data as opposed to time-weighted daily averages provided subdaily stratification patterns that allowed for more representative categorization of grab sample data based on the grab sample time.

Hourly *Wn* were calculated for June through October in 2015[16], 2016, 2017, and 2018 at the upstream of the curtain location by comparing surface waters (average of 0.1- and 0.5-m depths[17]) to each depth. These are reported as the primary *Wn* for each depth.

Hourly *Wn* were calculated using a secondary method by comparing each sequential depth down to 20 m, and are reported as the depth versus (vs.) depth *Wn*.[18] This depth vs. depth *Wn* provided additional insight when surface waters (average of 0.1-m and 0.5-m waters) were not representative of the mixed layer. When stability was indicated by the primary *Wn* and instability was indicated by the depth vs. depth *Wn*, there was often a gradual change in temperatures with depth, the depth of epilimnetic stratification was not obvious (e.g., multiple epilimnetic thermoclines), and/or heating was observed near the surface with near-isothermal conditions below. This secondary method provided additional insight into the determination of curtain effectiveness when conditions were between high and low curtain effectiveness (e.g., "medium effectiveness").

#### 4.3.1.2 Sample Comparisons: Paired Data

Sample comparisons were carried out using paired data. Curtain not deployed and curtain deployed June through October 2015-2018 sample data from barrier curtain observation buoys (sonde data[19] total microcystin, total *Microcystis*, total cyanobacteria, and total chlorophyll-*a*) were paired based on sample date and sample depth[20] to assess H1. Similarly, curtain not present or not deployed total

---

[15] Outliers were identified visually in graphical data as infrequent events that deviated notably from background or typical conditions.

[16] In 2015, hourly water temperature data did not exist at each depth of interest—instead, available sonde data or handheld probe data were used to calculate hourly *Wn* when data existed. Sondes in 2015 profiled continuously (15-minute intervals), parking and sampling at depths ranging from approximately 0.2 m to 12.0 m (approximate 1-m intervals); each vertical profile took approximately 3 hours to complete, with seven or eight profiles collected daily. Water temperature data from each 3-hour profile were assumed stable for the duration of the profile and were used to calculate density differences across depths. The sonde did not always park on the same depth intervals as provided by the thermograph arrays (i.e., 0.1 m, 0.5 m, 1.5 m, 2.0 m, 3.0 m, 4.0 m, 5.0 m, 6.0 m, 8.0 m, 10.0 m, 15.0 m, 20.0 m). Likewise, data collected with a handheld probe did not always match the intervals provided by the thermograph arrays. Therefore, 2015 water temperature data were interpolated to provide data at those depths for use in calculations.

[17] In 2016, because of an equipment failure, there were no thermograph data at 0.1 m; 0.5-m data were used to represent surface waters in the *Wn* calculations.

[18] Depth vs. depth *Wn* calculations were performed by using water temperature data at sequential depths (e.g., average of 0.5-m and 0.1-m waters for the mixed layer term versus water temperature at each 1 m, then water temperature at 1 m for the mixed layer term versus water temperature at 2 m, and so on), which provided a series of depth vs. depth *Wn* by depth in order to identify the depth of epilimnetic stratification (*Wn* > 1).

[19] Sonde data were filtered to include data available across all 4 years. Data consistent across years included data spanning the entire day at sonde depth of approximately 0.5 m and data spanning the period from 8:00 AM to 11:30 AM (late morning) at sonde depths of approximately 5 m and 10 m. Sonde daily averages were calculated for 0.5 m and sonde late morning averages were calculated for 5-m and 10-m depths. Averages were filtered to only include sample pairs (i.e., upstream curtain and downstream curtain data) for the same date.

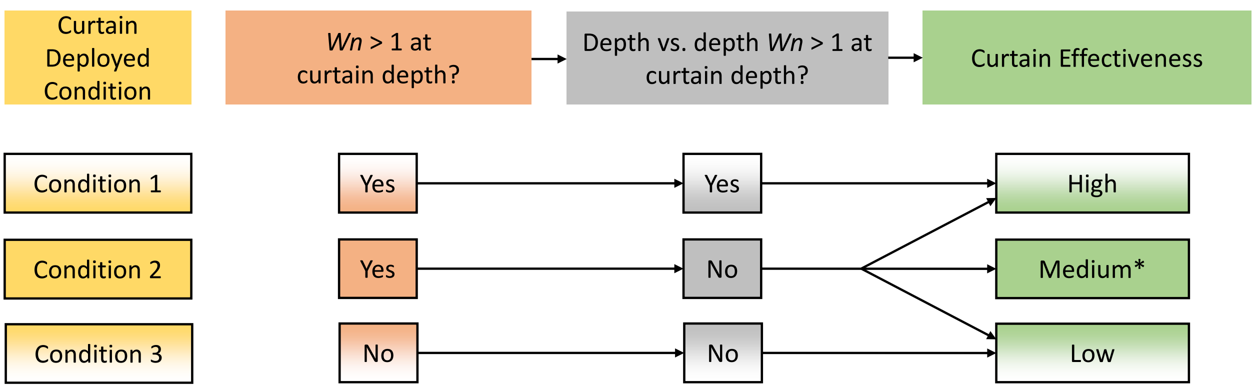
[20] Barrier curtain sample pairs were collected on the same date and included: 1) sonde data collected at various depth ranges: 0.101 m – 0.999 m for "0.5 m" and averaged over the period from 0:00 AM to 11:45 PM, 4.501 m to 5.499 m for "5 m" samples averaged over the period from 8:00 AM to 11:30 AM (late morning), and 9.001 m to 10.999 m for "10 m" samples averaged over the late morning; 2) total microcystin, total *Microcystis*, total cyanobacteria, and total chlorophyll-*a* grab samples collected at various discrete depths (collected 1 to 2 hours apart), and 3)

chlorophyll-*a* data for 2004-2018 from the log boom (integrated 0- to 8-m sample[21]) and the Klamath River downstream of Iron Gate (0.5-m sample) were paired based on sample date to assess H2; and curtain deployed total chlorophyll-*a* data for 2015-2018 from the log boom (integrated 0- to 8-m sample) and the Klamath River downstream of Iron Gate (0.5-m sample) were paired based on sample date to assess H3.

Sample pairs during curtain not deployed and post-curtain deployed periods were assessed. Curtain effectiveness for curtain deployed sample pairs below the depth of the curtain was assumed ineffective (Figure 4-2) and not assessed further. Curtain effectiveness for sample pairs at or above the depth of the deployed curtain was determined based on:

- Curtain depth
- Depth of epilimnetic stratification (conditions 1, 2, or 3, above, based on *Wn* calculations)
- *Wn* number (i.e., stability) at curtain depth
- Depth vs. depth *Wn* at curtain depth[22]

The process employed to identify conditions 1, 2, or 3 and curtain effectiveness during curtain deployed periods involved first evaluating the *Wn*, then the depth vs. depth *Wn*, which combined to indicate curtain effectiveness. Next, the depth of the sample in relation to the depth of the curtain and the depth of the stratification was evaluated to determine curtain effectiveness at the specific sample depth (Figure 4-3). Although the curtain may have been categorized as highly effective for a specific date and time, the curtain would not necessarily restrict the downstream movement of waters for all depths. Water below the mixed layer (i.e., below the epilimnetic thermocline) but above the deployed depth of the curtain might pass under the curtain, depending on the strength of the density gradient within this bottom layer of the epilimnion.




*Condition 2 generally results in medium curtain effectiveness although grab samples were reviewed on a case-by-case basis and on two days, Condition 2 resulted in a high curtain effectiveness categorization. Medium and Low categories occurring at or above the depth of the deployed curtain were combined during analyses of grab sample and sonde sample pairs.

**Figure 4-3. Flowchart for determining curtain effectiveness (likelihood of curtain to retain surface waters upstream).**

total microcystin, total *Microcystis*, total cyanobacteria, and total chlorophyll-*a* grab autosampler samples collected at 0.5 m (collected at the same time).

[21] The 0- to 8-m integrated log boom sample was chosen for comparison because these depths are more representative of water depths entrained at the intake tower than the 0.5-m log boom sample.

[22] For grab sample pair comparisons, *Wn* calculations were inspected based on the downstream sample collection time. For sonde data, *Wn* calculations were averaged and inspected for the entire day (0.5-m pairs) or averaged and inspected for the late morning period when the sondes profiled (5-m and 10-m pairs).

**METHODS**

The curtain effectiveness categories are perhaps best illustrated in an example. Assume that there is a mixed layer depth of 3.0 m, the transition zone (epilimnetic thermocline) is between 3.0 and 5.0 m, and the curtain is deployed to a depth of 6.1 m:

- The curtain would restrict waters within the mixed layer from moving downstream (0.0 to 3.0 m) and therefore be considered highly effective.
- The curtain may restrict the movement of waters below the depth of the mixed layer but above the curtain depth (3.1 m to 6.1 m) and therefore would be considered to have only medium to low levels of effectiveness.
- The curtain would not restrict the movement of waters at 6.1 m or deeper and would therefore be ineffective at these depths.

In summary, if the deployed curtain depth was below the mixed layer depth, the curtain should retain waters within the mixed layer and be highly effective. For deployed depths between the mixed layer depth and the depth of the curtain, the curtain would have a medium to low level of effectiveness. If the deployed curtain depth was not below the mixed layer depth, the curtain would not retain waters within the mixed layer and have low effectiveness. The curtain cannot retain waters below the deployed depth of the curtain and was considered ineffective at these depths.

Assignment of “high” or “low” curtain effectiveness, were readily identified through this analysis, with more than 80 percent of curtain deployed grab samples at or above the deployed curtain depth falling within one of these two curtain effectiveness ratings (Table 4-2). However, when the epilimnetic thermocline was in the proximity of the curtain depth (condition 2, initial effectiveness determination of “medium”), additional information was considered. This was done for approximately 15 percent of curtain deployed sample pairs analyzed (Table 4-2). Any sample pairs from the “medium” effectiveness rating that remained after additional considerations (secondary effectiveness determination) were combined with “low” sample pairs for analysis.

**Table 4-2. Distribution of curtain deployed grab sample pairs by curtain effectiveness rating.**

| | | Initial Effectiveness Determination | | | Secondary Effectiveness Determination | | |
|---|---|---|---|---|---|---|---|
| **Constituent** | **Total Number of Curtain Deployed Sample Pairs** | **Percent High (No. Pairs)** | **Percent Low (No. Pairs)** | **Percent Medium (No. Pairs)** | **Percent High (No. Pairs)** | **Percent Low (No. Pairs)**** | **Percent Medium (No. Pairs)**** |
| Total Chlorophyll-*a* | 49* | 57% (28) | 27% (13) | 14% (7) | 63% (31) | 27% (13) | 12% (6) |
| Total Microcystin | 45* | 62% (28) | 22% (10) | 13% (6) | 67% (30) | 22% (10) | 13% (6) |
| Total *Microcystis* | 33 | 61% (20) | 24% (8) | 15% (5) | 67% (22) | 24% (8) | 9% (3) |
| Total Cyanobacteria | 33 | 61% (20) | 24% (8) | 15% (5) | 67% (22) | 24% (8) | 9% (3) |

* Not enough information was available to determine curtain effectiveness for one pair (no meteorological and/or water temperature data to perform *Wn* calculations).

** Low and medium pairs were combined into one category prior to analysis.

For sonde data, approximately 80 percent of curtain deployed sample pairs fell within “high” or “low” curtain effectiveness ratings (Table 4-3). Sample pairs that fell within “medium” effectiveness ratings were combined with sample pairs that fell within “low” effectiveness ratings. These pairs were combined for analysis without using the secondary effectiveness process outlined below for the grab samples because there was no consistent way to evaluate the effectiveness rating of the “medium” effective sonde pairs.

**Table 4-3. Distribution of curtain deployed sonde sample pairs by curtain effectiveness rating.**

| Constituent | Total Number of Curtain Deployed Sample Pairs | Percent High (No. Pairs) | Low (No. Pairs)* | Percent Medium (No. Pairs)* |
|---|---|---|---|---|
| Water Temperature (0.5 m, 5 m, and 10 m) | 371 | 44% (164) | 36% (134) | 20% (73) |
| Chlorophyll (0.5 m, 5 m, and 10 m) | 324 | 42% (136) | 36% (116) | 22% (72) |
| Phycocyanin (0.5 m, 5 m, and 10 m) | 337 | 42% (143) | 36% (121) | 22% (73) |

* Low and medium pairs were combined into one category prior to analysis.

For the four instances where condition 2 existed for grab sample data, the *Wn* was greater than 1.0, but depth vs. depth *Wn* was less than 1.0. In these cases, local wind speed and thermal profile data were reviewed on a case-by-case basis using the following rules:

- If wind speeds that generated an unstable *Wn* only persisted for less than 1 hour prior to downstream curtain sampling and/or if thermograph thermal profiles indicated stratification was maintained shallower than the deployed curtain depth, curtain effectiveness was assigned “high.”
- If thermograph profiles indicated mixing occurred down to the approximate deployed depth of the curtain, curtain effectiveness was assigned “medium.”
- If thermograph profiles indicated mixing to depths greater than the deployed curtain depth, curtain effectiveness was assigned “low.”
- If a determination could not be made based on these rules, curtain effectiveness was maintained as “medium.”

Using these rules, the curtain effectiveness was changed from medium to high in two cases and in two cases curtain effectiveness remained medium (Table 4-4).

**Table 4-4. Additional consideration for grab sample paired sample dates, curtain depth, and initial and final curtain effectiveness assignment.**

| Date | Curtain Depth (m) | Initial Assignment | Final Assignment |
|---|---|---|---|
| August 11, 2015 | 7.6 | Medium | Medium |
| August 29, 2016 | 4.6 | Medium | Medium |
| July 25, 2017 | 7.6 | Medium | High |
| July 26, 2018 | 4.6 | Medium | High |

#### 4.3.1.3 Statistical Analysis

Water quality data were often skewed left (and differences between paired data were also often skewed left), concentrations changed significantly through the season, and logical pairing existed within each sample group (i.e., sample date); therefore, a nonparametric sign test and nonparametric Wilcoxon signed-rank test for related samples was used (Helsel and Hirch 2002) to test differences between Iron Gate Reservoir upstream of the curtain and downstream of the curtain, and between Iron Gate Reservoir at the log boom and the Klamath River downstream of Iron Gate Dam. Statistical tests were performed for each condition (i.e., curtain not deployed, curtain deployed high effectiveness, and curtain deployed medium to low effectiveness).

The sign test does not analyze the magnitude of differences between samples in a pair, but instead counts the number of positive and the number of negative differences between pairs,[23] then determines whether there is a consistent difference between pairs of observations. For data pairs ($x_i$, $y_i$ where $i$ = 1,...,$n$), the sign test determines whether $x$ is generally different than $y$. The Wilcoxon signed-rank test assesses whether $x$ is generally different than $y$ by comparing their median values. The sign test and the Wilcoxon signed-rank test may be used regardless of the distribution of the paired data sets or their differences. For both tests, the one-tailed p-value was used because the direction of the difference was hypothesized for each trial. The direction of the difference was hypothesized based on the proportion of negative versus positive differences (sign test) or the magnitude of the sum of negative ranks versus the sum of positive ranks (Wilcoxon signed-rank test). For example, if there were more negative differences than positive differences, indicating reduction in concentration in the downstream direction occurred more often within a set of sample pairs, then the hypothesis for the sign test was that upstream curtain concentrations (either upstream of the curtain or at the log boom) were greater than downstream curtain concentrations (either downstream of the curtain or of Iron Gate Dam).

Similarly, if the Wilcoxon signed-rank test indicated that the sum of the negative ranks was greater than the sum of the positive ranks, then the hypothesis for this test was that the upstream concentrations were greater than downstream concentrations. Differences were considered significant when the p-value was less than or equal to 0.05 (i.e., 95 percent confidence interval). Bias between each pair was calculated as the downstream value minus the upstream value and the mean bias was reported for each parameter and curtain effectiveness category.

#### 4.3.1.4 Uncertainty Factors

**Background**

Uncertainty factors were incorporated into the analysis to address system heterogeneity (cyanobacteria distributions are naturally patchy), sonde accuracy, and laboratory analysis uncertainty. While it may not have been explicitly stated, PacifiCorp's goal in installing and operating the curtain in Iron Gate Reservoir is to keep enough cyanobacteria and related toxins in Iron Gate Reservoir that public health postings are not necessary on the Klamath River downstream of the dam; this is an absolute goal that sets a target microcystin level of less than 0.08 µg/L in samples collected in the river downstream of the dam regardless of the concentrations in the reservoir.

An underlying assumption in the analysis associated with the effectiveness of the curtain is that the data collected at the two observation buoys are representative of conditions on either side of the curtain. Comments by the IMIC on the 2015 report (Watercourse 2016) raised the concern that the sampling design did not accurately capture the spatial variability in the reservoir as related to the patchiness of cyanobacteria in the reservoir. To address the IMIC comment and better understand how representative of conditions upstream of the curtain the sampling location was, PacifiCorp conducted a heterogeneity study in 2016 field season (PacifiCorp 2017). Others have noted that the sampling location had an important influence on the resulting data (Rode and Suhr 2007). While the Rode and Suhr (2007) analysis focused on suspended sediment and related materials, cyanobacteria and phytoplankton are probably even less evenly distributed than particulate matter (because of individual species mobility) and are not equally distributed throughout the water column or along the face of the curtain in Iron Gate Reservoir.

---

[23] If there are pairs with no difference, the number of pairs (n) is reduced by the number of pairs with no difference.

As expected, the heterogeneity study indicated that the water quality in Iron Gate Reservoir upstream of the curtain was not homogenous. While conditions were different at locations surrounding the upstream buoy, the study showed that sampling at the upstream buoy location generated data that were representative of conditions at the other locations. In a natural system that is affected by wind, solar radiation, flow patterns, buoyancy of the cyanobacteria, and other factors, this variability was not unexpected.

Not only are conditions heterogenous on the upstream side of the curtain, similar conditions can be found on the downstream side of the curtain. Water moves under the curtain, rises to the surface in large, uneven eddies, and unevenly mixes with the water on the downstream side of the curtain before being entrained into the powerhouse intake.

**Definitions**

To facilitate understanding of how the uncertainty analysis is applied in this report, it is necessary to understand specifically what is meant by the term. For this report, uncertainty is meant to represent random statistical variation that is present within the data sets being used in the analysis. Sources of uncertainty include, but are not limited to, sample collection, sample preservation/storage, and lab analysis, and some consideration should be given to data processing and management (Harmel et al. 2006).

**Approach**

A variety of methods could be applied to address uncertainty and in turn to analyze the data. The following list is by no means intended to be complete, but rather provides a range of potential methods for determining uncertainty in a given data set. Some of the methods for determining uncertainty include:

- In some cases, measurement performance parameters like method detection limits create a defined target that can be used as a measure of uncertainty (Silva 2013).
- Laboratory proficiency tests are another approach (Silva 2013) but since these are instituted by independent third parties, this approach is not applicable to this project.
- Defined uncertainty targets are applicable in some cases where, for example, a regulation sets performance criteria (Silva 2013). While PacifiCorp operates the curtain to prevent the need to post the river, this is not a defined uncertainty target.
- Silva (2013) discussed the use of defined measurement performance parameters such as method detection limits and limits of quantification, range of values from duplicate samples, coefficients of variance, or mean error statistics. Although not duplicate samples, the range of values from the heterogeneity study is applicable as measurement performance parameters.
- Stanley et al. (2019) evaluated the relative uncertainty and expressed the resulting value as a percentage of the difference between median values; however, this approach required an extremely large database (100,000s of datapoints) that could be randomly subsampled to create the necessary median values from the same data set. This approach is not possible with the relatively small data set available for this project.
- Harmel et al. (2006) used a root mean square method of uncertainty propagation to compare uncertainty introduced at each procedural level (e.g., sample collection, preservation/storage, and lab analysis). This approach is valid because uncertainty at each step is bidirectional (both positive and negative) and nonadditive (meaning it is not appropriate to simply add the uncertainty from one step to that from the next step). To use this approach requires an evaluation of the uncertainty at each step in the overall process. While there are some literature values available, there do not appear to be any readily available for the type of variables of

interest in this study. To apply this to the intake curtain analysis would require a host of assumptions about the uncertainty at each step in the process for each data point, and those assumptions are not readily available.

- Bayesian Analysis – Bayesian analysis may be an approach to explore uncertainty to the analysis data using a probability-based statistical approach. A parameter is summarized by a distribution of values instead of one fixed value, termed a prior distribution. This prior distribution and a likelihood model are used to produce a posterior distribution based on observed data. Output can include point estimates of posterior distribution means, medians, percentiles, and other information, as well as model parameters expressed as probability statements (Hoff 2010). To apply a Bayesian model to the curtain data would require several assumptions that have not been assessed at this time.

Harmel et al. (2006: 694) recommend the use of "… uncertainty estimates that correspond to specific data sets, if that information is available." The decision to use the differences present in the heterogeneity study as uncertainty factors certainly meets this recommendation. At this time, this is the most appropriate choice given the limited data sets for analysis. Assuming studies on the curtain continue, at some point a more statistically robust analysis may be feasible.

If the measurement values cause a high level of uncertainty, then the ability to definitively state that the curtain is performing as intended is reduced. The approach taken in the uncertainty analysis in this report is simply the most conservative approach possible. By taking the largest differences from the heterogeneity study and applying them to both data points from a sample pair, when the statistics indicate that a significant difference remains between the upstream and downstream sides of the curtain after this addition is made, the results inspire an extremely high level of confidence.

### Methods

Uncertainty factors for sonde data (Table 4-5) were determined based on the largest difference encountered between heterogeneity sites during the 2016 heterogeneity study (PacifiCorp 2017)[24] and sonde probe accuracy.[25] For paired sonde data where a significant difference was identified, the uncertainty factor was subtracted from the data set with larger data values and added to the data set with smaller data values, and the sign and Wilcoxon signed-rank tests were performed a second time. If the second test indicated no significant difference, or if the result opposed the original result (e.g., downstream of the curtain was greater than upstream of the curtain whereas the original result indicated that upstream of the curtain was greater than downstream of the curtain), then the two sets of sample pairs were assumed to be no different from each other.

Ninety-five percent confidence intervals were available from laboratory replicates analyzed at Bend Genetics (2016-2018 qPCR and ELISA data), but were not available for 2015 data analyzed at the EPA Region 9 Laboratory. A conservative value of 25 percent of the result, or the constituent's reporting limit

---

[24] In the heterogeneity study, total uncertainty was calculated as the difference between the sonde results from two different heterogeneity sites, and an average uncertainty for any one sonde as total uncertainty divided by two (PacifiCorp 2017). This single sonde uncertainty was applied to the barrier study sonde data.

[25] There is no manufacturer (YSI 2017) accuracy provided for chlorophyll or phycocyanin probes. Therefore, accuracy was estimated using variability in the RFU data during the calibration process using readings from the chlorophyll and phycocyanin probes in deionized water, as well as inspecting data for a visual threshold, below which values appeared to bear no relationship between upstream and downstream of the curtain sites.

(whichever is greater) was used as the uncertainty factor for all grab sample data (Table 4-6).[26] This approach is consistent with the quality assurance criteria used in the long-term KHSA IM-15 program.

Grab sample data sets comprise all the sample pairs collected under similar curtain effectiveness conditions for each constituent of interest. For grab sample data where a significant difference was identified, this uncertainty factor of 25 percent of the result or the constituent's reporting limit (whichever is greater), was subtracted from the data set with greater concentrations (generally the upstream of the curtain data set) and added to data set with smaller concentrations (generally the downstream of the curtain data set), and the sign and Wilcoxon signed-rank tests were performed a second time. If the second test indicated no significant difference, or if the result opposed the original result (e.g., downstream of the curtain was greater than upstream of the curtain whereas the original result indicated that upstream of the curtain was greater than downstream of the curtain), then the two sets of sample pairs were assumed to be no different from each other.

**Table 4-5. Sonde uncertainty factors.**

| Parameter | Uncertainty Factor |
|---|---|
| Temperature (°C) | 0.10 |
| Dissolved Oxygen (mg/L) | 0.35 |
| Total algae as chlorophyll (RFU) | 0.6 |
| Cyanobacteria as phycocyanin (RFU) | 0.4 |

Note: RFU = relative fluorescence unit

**Table 4-6. Grab sample uncertainty factors.**

| Parameter | Uncertainty Factor |
|---|---|
| Total microcystin (µg/L) | 25% of result or RL, whichever is greater |
| Total cyanobacteria (genes/mL) | 25% of result or RL, whichever is greater |
| Total *Microcystis* (genes/mL) | 25% of result or RL, whichever is greater |
| Total chlorophyll-*a* (µg/L) | 25% of result or RL, whichever is greater |

#### 4.3.1.5 Percent Time of Mixing to Each Depth

Low curtain effectiveness (*Wn* < 1) for a particular depth represents the potential for mixing of surface waters down to that depth. The total amount of time that *Wn* was less than 1 (based on thermograph and meteorological data) at each depth of interest (3 m, 4 m, 5 m, 6 m, 8 m, and 10 m) was calculated to show the percent time of potential mixing to each depth for bimonthly and monthly periods.

### 4.3.2 H2: Reduction in Downstream Loading Attributable to Iron Gate Dam

The presence of the dam and associated outlet facilities can act to reduce cyanobacteria concentrations released from the reservoir to downstream Klamath River reaches. The intake tower withdrawal incorporates waters from the surface of the reservoir to approximately 11 m in depth, entraining both surface and deeper waters. As a result, the releases from the dam include near-surface waters with relatively high concentrations of cyanobacteria and deeper waters with lower concentrations of

[26] Ninety-five percent confidence interval values adjusted to account for additional heterogeneity (95 percent confidence interval values doubled), and averaged over all 2016-2018 data for each constituent, were similar to values provided by calculating 25 percent of the result, and consistent with differences noted between heterogeneity sites.

cyanobacteria, effectively diluting the near-surface concentrations when measured downstream of the dam (Figure 4-4). Therefore, a comparison of conditions in the Klamath River downstream of Iron Gate Dam to conditions in the reservoir should reflect reduced concentrations when compared to surface conditions in Iron Gate Reservoir, but higher concentrations when compared to deeper waters in Iron Gate Reservoir.

Total chlorophyll-*a* concentrations were used to assess the reduction associated with Iron Gate Dam on its own (i.e., without a curtain). Specifically, the analysis used grab sample total chlorophyll-*a* data at the log boom (the integrated 0- to 8-m sample) and from the Klamath River downstream of Iron Gate Dam (0.5-m depth). These data were filtered to include only sample pairs that existed on the same date[27]. Chlorophyll-*a* was used instead of *Microcystis* or microcystin because substantially more data were available for chlorophyll-*a* as compared to *Microcystis* or microcystin and chlorophyll-*a* is a reasonable surrogate for *Microcystis*. Sample pairs from curtain not deployed periods were analyzed for the 2004-2018 period, which included sample pairs from periods when the curtain was not present (2004-2014) or was completely furled (2015-2018, curtain depth approximately 1.5 m). These two data sets were also analyzed separately to determine if there was a difference in chlorophyll-*a* concentrations when the curtain was not present, and when it was installed but completely furled to a depth of 1.5 m. Percent reduction from the log boom to the river was calculated (Section 4.3.1.2) for all available curtain not deployed data (i.e., January through December) and separately for curtain not deployed data collected during the productive season (i.e., July through October).

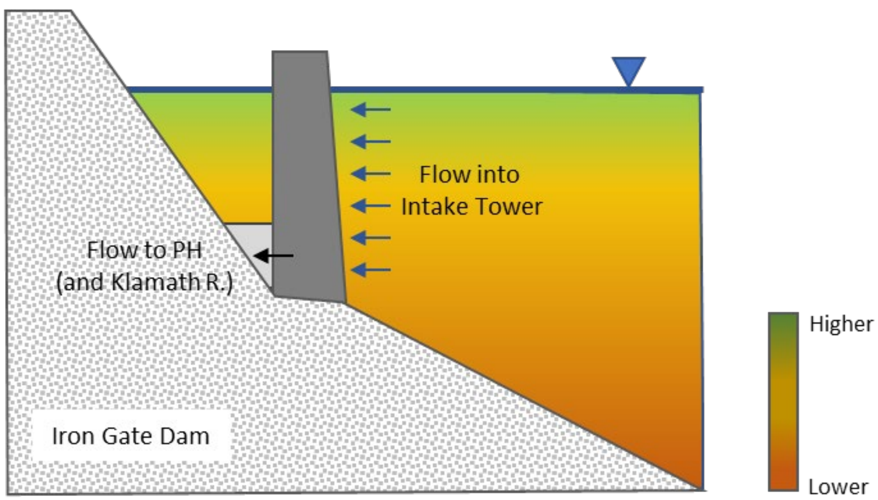



**Figure 4-4. Conceptual diagram of vertical cyanobacteria distribution showing Iron Gate Dam intake tower region with flow entering from full depth (no curtain): summertime.**

### 4.3.3 H3: Reduction in Downstream Loading Attributable to Iron Gate Dam in Combination with a Barrier Curtain

Hypotheses 1 and 2 focus on the independent effects that the curtain and Iron Gate Dam have on cyanobacteria concentrations downstream of the curtain and dam, respectively. The third hypothesis builds on those previous hypotheses to assess the combined effects of the curtain in combination with the dam on cyanobacteria concentrations released from the reservoir to downstream Klamath River

[27] Twelve out of 90 curtain not deployed sample pairs were collected on consecutive dates rather than the same date. All curtain deployed sample pairs were collected on the same date. When multiple samples were collected on the same date, the results were averaged and compared for that date.

reaches. A comparison of downstream Klamath River conditions should reflect reduced concentrations when compared to upstream cyanobacteria concentrations.

To assess reduction associated with the curtain in combination with Iron Gate Dam, total chlorophyll-*a* concentrations were the primary data employed. Specifically, grab sample total chlorophyll-*a* data at the log boom in Iron Gate Reservoir (the integrated 0- to 8-m sample) and data in the Klamath River downstream of Iron Gate Dam (0.5-m depth) were employed; this is consistent with the Hypothesis 2 analysis. These data were filtered to include only pairs that existed on the same date[28] during curtain deployed periods in 2015-2018. Percent reduction from the log boom to the river was calculated (Section 4.3.1.2) for all available curtain deployed data, which occurred during the productive season (i.e., July through October).

[28] All 13 of 13 post-curtain sample pairs were collected on the same date. When multiple samples were collected on the same date, the results were averaged and compared for that date.

# 5. Results

Seasonal monitoring efforts have occurred each year since the installation of the barrier in 2015. Results from the 2015 and 2016 efforts are summarized in annual reports (Watercourse 2016; PacifiCorp 2017), and are not presented herein. Rather, this report focuses on monitoring results for those topics and years that have not been documented. Specifically:

- Summary of 2015-2018 curtain deployment patterns
- Summary of seasonal monitoring efforts for 2017 and 2018

The information included herein, coupled with that of the 2015 and 2016 reports, form the basis for analysis included in Section 6, which discusses the role the curtain and dam play individually and cumulatively in reduction of cyanobacteria loads downstream of the curtain and downstream of the dam.

## 5.1 Curtain Deployment Patterns

The physical location of the curtain in Iron Gate Reservoir is approximately static, but the deployed depth of the curtain can be changed in response to water quality conditions in the reservoir or downstream of Iron Gate Dam. The curtain was designed for a maximum deployment depth of 10.7 m, but downstream operational constraints sometimes required that the curtain deployment depth be shallower than this maximum to meet required downstream dissolved oxygen requirements.

PacifiCorp staff made adjustments to the curtain depth (lowering/raising) throughout each deployment season from 2015 to 2018. Adjustments were typically done in 1.5-m increments to minimize loading stress on the curtain.

In 2015, the installation of the curtain was completed on June 26 and the curtain remained fully furled (1.5 m) until July 10. The curtain was lowered incrementally over a period of 7 weeks starting on July 10, and reached its maximum depth of 10.7 m on August 27 (Figure 5-1, Table 5-1). The curtain remained at this depth until November 13 when it was fully furled to 1.5 m.

In 2016, the curtain was gradually lowered from late June through mid-July to its maximum depth of depth of 10.7 m. The curtain remained at this depth until August 22 and 23 when it was raised to 7.6 and 6.1 m, respectively, where it remained until September 29 when it was raised to 3.0 m (Figure 5-1, Table 5-1). The curtain was fully furled on November 9.

In 2017, the curtain remained fully furled until July 25, when is lowered to 7.6 m. The curtain was raised gradually between early and mid-August, to the fully furled depth of 1.5 m on August 11. The curtain was lowered to 3 m on August 28 and remained at this depth until it was fully furled on September 21 (Figure 5-1, Table 5-1). The curtain was raised to the 1.5-m depth during the month of August because of reduced dissolved oxygen concentrations in the epilimnion and in the river downstream of Iron Gate Dam.

In 2018, the curtain was lowered to 4.6 m and 6.1 m in late July and early August, respectively. The curtain was raised to 4.6 m in mid-August and remained at this depth until it was lowered to 6.1 m in late September (Figure 5-1, Table 5-1). The curtain was fully furled after November 6 (the precise date is unclear). As with 2017, the curtain was raised to the 1.5-m depth during the month of August because of reduced dissolved oxygen concentrations in the epilimnion and in the river downstream of Iron Gate Dam.

Water quality sampling through the 4 years of curtain deployment depths represents a broad range of conditions to assess curtain performance.

**RESULTS**

**Table 5-1. 2015-2018 Deployment dates and depths in meters (m) for the intake barrier curtain in Iron Gate Reservoir.**

| 2015 | | 2016 | | 2017 | | 2018 | |
|---|---|---|---|---|---|---|---|
| **Date** | **Depth (m)** | **Date** | **Depth (m)** | **Date** | **Depth (m)** | **Date** | **Depth (m)** |
| July 10 | 3.0 | June 28 | 4.6 | July 25 | 7.6 | July 24 | 4.6 |
| July 16 | 4.6 | June 30 | 7.6 | August 4 | 4.6 | August 7 | 6.1 |
| July 27 | 6.1 | July 12 | 9.1 | August 10 | 3.0 | August 16 | 4.6 |
| July 31 | 7.6 | July 19 | 10.7 | August 11 | 1.5 | September 27 | 6.1 |
| August 17 | 9.1 | August 22 | 7.6 | August 28 | 3.0 | November 7* | 1.5 |
| August 27 | 10.7 | August 23 | 6.1 | September 21 | 1.5 | | |
| November 13 | 1.5 | September 29 | 3.0 | | | | |
| | | November 9 | 1.5 | | | | |

Note:

* The precise date the curtain was completely furled in 2018 is unclear, but it was after November 6 when data collection stopped.

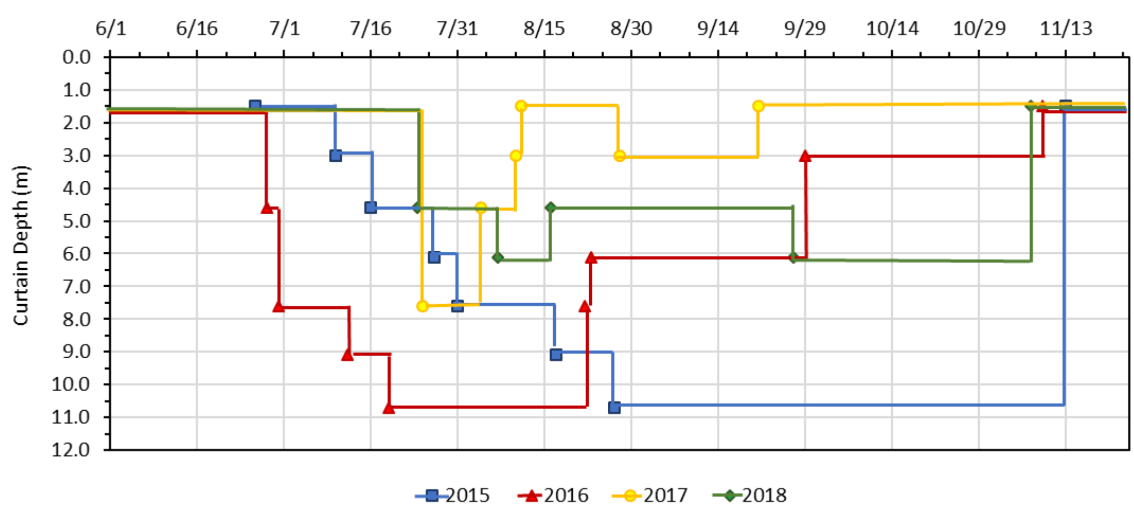



**Figure 5-1. 2015-2018 Deployment depths in meters (m) for the Intake Barrier Curtain in Iron Gate Reservoir.**

## 5.2 Review of 2015 Acoustic Doppler Current Profiler Data

In 2015, an ADCP was used to measure velocities upstream and downstream of the curtain. Data from ADCP velocity measurements upstream of the curtain indicated that shallow, near-surface waters had little or no velocity, while deeper waters near the bottom of the curtain had notable downstream velocities. Multiple transects upstream of the curtain indicated largely quiescent shallow waters and a well-defined horizontal flow zone or envelope at and below the curtain bottom (Watercourse 2016). Horizontal velocities flowed under the curtain ranged from 5 centimeters per second (cm/s) to 14 cm/s in the direction of the intake tower (Watercourse 2016).

In addition to the horizontal velocity component, the ADCP also measures vertical velocities, which were much smaller than the horizontal component. The vertical velocities generally ranged from -2.5 cm/s (downward) to 2.5 cm/s (upward) with most being between -1.0 cm/s and 1.0 cm/s (Figure 5-2b and c). Upstream of the curtain, most of the water velocities in each bin from the surface to the bottom of the curtain indicate a mix of both vertically upward and downward, both towards and away from the dam (Figure 5-2b). These results indicate that low velocities upstream of the curtain do not exhibit a consistent flow pattern or direction. Exceptions include bins #10 and #12. Bin #10 measurements indicate waters moving both vertically upward and downward towards the dam, with few toward reservoir velocities. Bin #12 results are largely downward throughout the depth of the curtain, but typically under 0.5 cm/s. At depths deeper than the curtain, velocities are generally upward and towards the dam (bins #8, 9, 10, 12, 13, 14), consistent with water flowing under the curtain and moving upwards, trending along the reservoir bed, toward the intake tower.

Downstream of the curtain flow conditions illustrate considerable complexity, most likely associated with mixing as water passes under the curtain and moved towards the intake tower. During on-reservoir sampling, gentle surface eddies and boils can be observed downstream of the curtain, indicating complicated hydrodynamic conditions on the downstream side of the curtain. These complex conditions represent vertically upward and downward velocities, both towards and away from the dam (Figure 5-2c).

Both upstream and downstream of the curtain, vertical flow was moving in both upward or downward throughout the water column. On average, most of the bins[29] tended to have more flow heading downward (negative average). Unlike the previous analysis of horizontal flow, the vertical flow component does not indicate larger velocities near the bottom of the curtain, nor does it appear to be heading in one direction over the other (down versus up or up versus down) near the bottom of the curtain. Additionally, the orientation of vertical velocities (i.e., upward or downward) do not appear to be consistently influenced by the longitudinal location of the bin or the water depth.

Analysis of the vertical velocity component did not display evidence of downward (or upward) moving waters near the bottom of the curtain, or at any location within the water column, that could affect stratification upstream of the curtain.

[29] The ADCP software divides the transect into multiple bins. The user specifies the number of ensembles (individual data records collected by the ADCP) to be averaged into each bin. The data presented herein collected upstream and downstream of the curtain were divided into 17 bins (each bin representing the average of 25 ensembles).

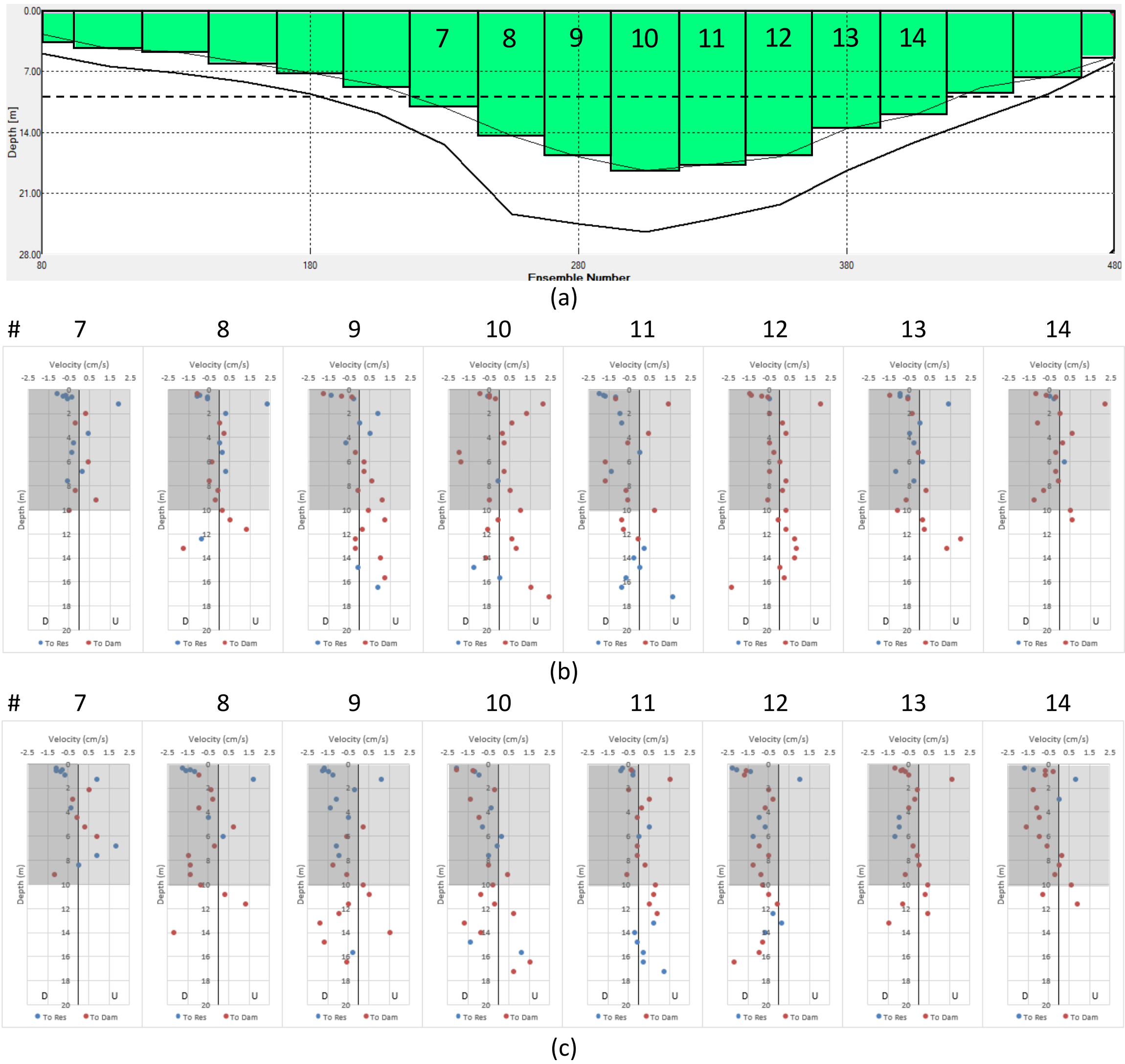



**Figure 5-2. (a) Location of ADCP data bin #7 through #14 (dashed line denotes 10 m, approximate depth of the curtain) looking from east to west (downstream towards Iron Gate Dam) and the vertical velocity component of velocity vectors heading generally toward the reservoir (To Res - blue) or generally toward the dam (To Dam - red) for (b) upstream and (c) downstream of the curtain. Negative values indicate flow in the downward direction; positive values indicate flows in the upward direction. Gray denotes deployed curtain depth, with darker and lighter gray depicting negative and positive vertical velocities, respectively.**

# 5.3 2017 Data Summary

The 2017 data considered in this assessment include sonde data collected upstream of the curtain and downstream of the curtain; thermograph data; vertical profile grab sample data collected upstream of the curtain and downstream of the curtain; grab sample data collected in the Klamath River downstream of Iron Gate Dam; autosampler grab sample data collected upstream of the curtain and downstream of the curtain; and meteorological data collected at Iron Gate Dam. Each data type is outlined below.

## 5.3.1 Sonde Data

As in previous years, data sondes were used to monitor water temperature, dissolved oxygen, pH, specific conductance, total algae as chlorophyll (chlorophyll), and cyanobacteria as phycocyanin (phycocyanin). The sondes were installed on June 26 and removed on November 6, 2017. They were serviced, cleaned, calibrated, and the data downloaded approximately every 3 to 4 weeks during the period of deployment. The sondes profiled one time per week during the morning hours of approximately 7:00 AM to 11:45 AM. At all other times, the sondes were positioned at approximately 0.5 m in depth.

To assess curtain performance, three depths were selected and average constituent values calculated: 0.5 m[30], 5 m, and 10 m.[31] Daily averages were calculated based on available data from 0:00 AM to 11:45 PM to represent surface conditions over the course of a 24-hour period. Because data sondes were at 0.5 m in depth except when actively profiling, this 24-hour average was used throughout the analysis for all sonde parameters for comparison of 0.5-m depths. Averages were calculated based on available data from 8:00 AM to 11:30 AM to represent conditions at depth in the late morning period. This late morning period was used throughout the analysis for all sonde parameters for comparison of 5-m and 10-m depths because for the 5-m and 10-m depths, sondes only profiled in the morning.

Water temperature, dissolved oxygen, chlorophyll, and phycocyanin results are presented below while pH and specific conductance results are presented in Appendix A.

#### 5.3.1.1 Water Temperature

Daily average water temperature from a depth of 0.5 m upstream and downstream of the curtain ranged from approximately 19°C to 29°C during the curtain deployment period. Temperatures were similar upstream and downstream of the curtain until the curtain was deployed on July 25 (Figure 5-3). After curtain deployment, the sonde downstream of the curtain indicated an approximately 4°C reduction in daily average water temperatures at 0.5 m in depth while water temperatures upstream of the curtain continued to increase over the next week at 0.5 m in depth. Daily average 0.5-m water temperatures upstream and downstream of the curtain began to converge when the curtain was raised to 4.6 m, 3.0 m, and then 1.5 m in early August. Water temperatures downstream of the curtain cooled slightly compared to those upstream of the curtain when the curtain was redeployed to a depth of 3.0 m in late August through early September. With seasonal reduction in solar radiation and water temperatures, and increased frequency of mixing events in September, daily average water temperature values at the upstream and downstream of the curtain sites converged prior to the curtain being fully furled in late September.

At the 5-m depth, average water temperatures upstream and downstream of the curtain ranged from approximately 19°C to 21°C during the curtain deployment period (Figure 5-3). Water temperatures were similar until the curtain was deployed, and after the curtain was furled. A gap in upstream of the curtain sonde data precludes comparisons at 5-m depths during curtain deployment, except on July 26 when water temperatures downstream of the curtain dropped by approximately 1°C in comparison to water temperatures upstream of the curtain, and on September 20 when water temperatures downstream of the curtain were approximately equal to water temperatures upstream of the curtain.

At the 10-m depth, average water temperatures upstream and downstream of the curtain were similar prior to curtain deployment and after the curtain was furled (Figure 5-3). A gap in upstream of the curtain sonde data precludes comparisons at 10-m depths during curtain deployment except on July 26 and September 20 when water temperatures downstream of the curtain were approximately equal to water temperatures upstream of the curtain.

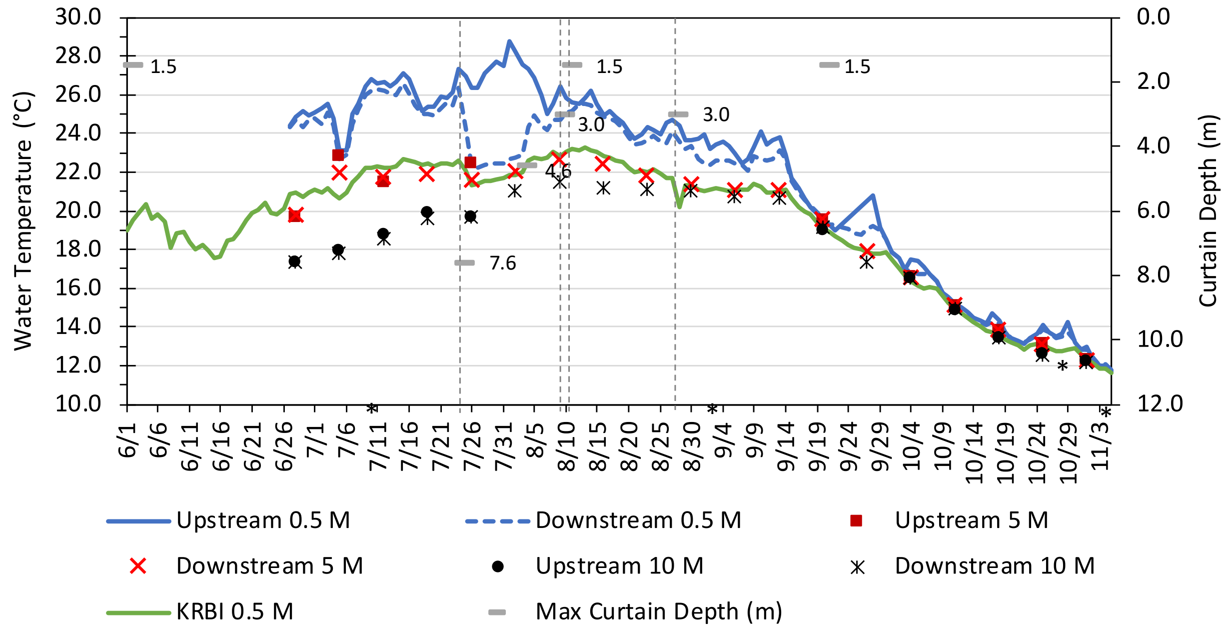
---

[30] Sondes were installed at approximately 0.5 m, and returned to approximately 0.5 m after servicing. The mechanical profiler did not always return the sonde to a depth of 0.5 m, but instead ranged from approximately 0.1 to 0.8 m. Waters at 0.5 m are assumed to represent surface water in the first meter, but due to limited data at exactly 0.5 m, all sonde data from the depths of 0.101 m to 0.999 m were analyzed and presented here as “0.5 m.”

[31] During profiles, sondes did not always stop at exactly 5 m or 10 m. Therefore, a range of depths were used to represent “5 m” and “10 m” (4.501 m to 5.499 m and 9.001 m to 10.999 m, respectively).

## RESULTS

In the Klamath River downstream of Iron Gate Dam, average water temperatures were similar to those at 5 m upstream and downstream of the curtain and ranged from approximately 19°C to 23°C during the deployment period. When the curtain was deployed to 7.6 m, temperatures downstream of the dam dropped by approximately 1°C.




*Due to limited sample sizes, 5-m and 10-m samples are displayed as markers.

**Figure 5-3. Average sonde water temperature (°C) at three depths (0.5 m, 5 m, and 10 m) upstream and downstream of the curtain and in the Klamath River downstream of Iron Gate Dam (KRBI) and curtain depth (m). Vertical dashed lines indicate curtain deployment on July 25, August 4, August 11 (furled), and August 28 (final furling of the curtain occurred on September 21, 2017).**

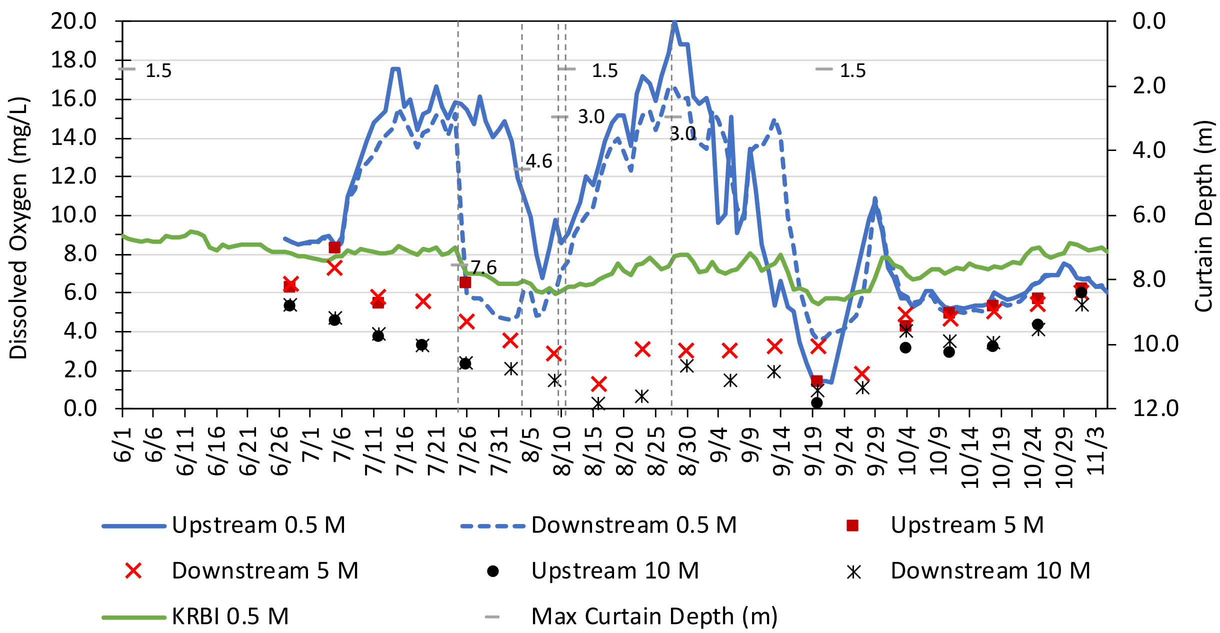
### 5.3.1.2 Dissolved Oxygen

Dissolved oxygen daily averages from 0.5 m in depth upstream and downstream of the curtain ranged from less than 5 mg/L to 20 mg/L (less than 60 to 240 percent saturation) during the curtain deployment period (Figure 5-4, Figure 5-5). Concentrations were similar or less (by 0.0 mg/L to 2 mg/L) downstream of the curtain until the curtain was deployed to 7.6 m on July 25. After initial deployment, daily average dissolved oxygen concentrations at the downstream sonde were reduced to approximately 5 mg/L for the next 7 to 10 days. During this same period, surface dissolved oxygen concentrations upstream of the curtain also were reduced to less than 7 mg/L. The curtain was subsequently raised up to 4.6 m, 3.0 m, and 1.5-m depths in August (Figure 5-4) in response to low dissolved oxygen concentrations.

At the 5-m depth, average dissolved oxygen upstream and downstream of the curtain ranged from approximately 1 mg/L to 6.5 mg/L (less than 20 to 75 percent saturation) during the curtain deployment period (Figure 5-4, Figure 5-5). Concentrations were similar at the 5-m depth until the curtain was deployed, and after the curtain was furled, except on July 5 where dissolved oxygen concentrations were 1 mg/L less downstream of the curtain than upstream of the curtain. A gap in upstream curtain sonde data precludes comparisons at the 5-m depth during curtain deployment except for on July 26 where average dissolved oxygen concentrations were less (by 2 mg/L) downstream of the curtain than upstream of the curtain and on September 20 where concentrations were greater (by 2 mg/L) downstream of the curtain than upstream of the curtain.

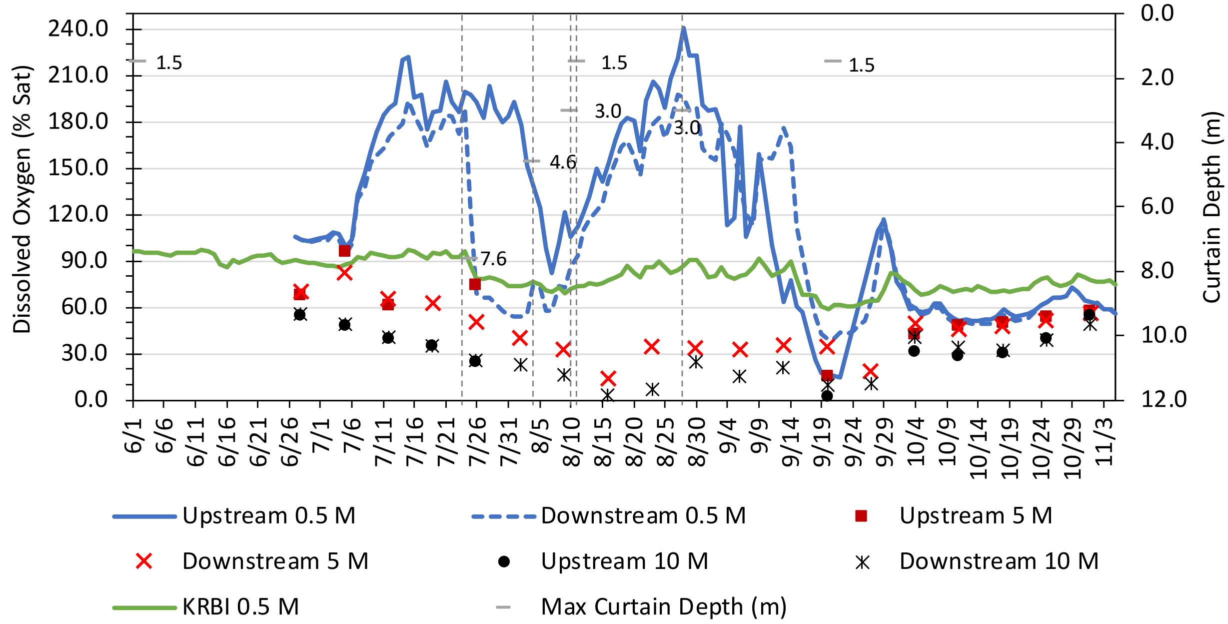
Similarly, a gap in upstream of the curtain sonde data precludes comparisons at 10-m depths during curtain deployment, except on July 26 where average dissolved oxygen concentrations were similar at upstream and downstream of the curtain sites and on September 20 when concentrations were slightly greater (by less than 0.5 mg/L) downstream of the curtain than upstream of the curtain.

In the Klamath River downstream of Iron Gate Dam, daily average dissolved oxygen concentrations were approximately 8 mg/L (90 percent saturation) prior to curtain deployment and ranged from 6 mg/L to 8 mg/L (60 to 90 percent saturation) during deployment (Figure 5-4, Figure 5-5). The curtain was raised from 7.6 m to 4.6 m, 3.0 m, and then 1.5 m in early August in response to low dissolved oxygen concentrations in the river. In late August the curtain was lowered to 3 m until the end of the season, and during this period, the daily average dissolved oxygen concentrations in the Klamath River downstream of Iron Gate Dam remained in the 7 mg/L to 8 mg/L (80 to 90 percent saturation) range until mid-September, when concentrations dropped below 6 mg/L (60 percent saturation) (Figure 5-5). The curtain was completely furled on September 21, but concentrations in the river downstream of the dam remained low through the end of the month. Average dissolved oxygen concentrations downstream of the dam were typically greater than those observed at the 5-m and 10-m depths both upstream and downstream of the curtain, but were often less than surface water dissolved oxygen concentrations upstream and downstream of the curtain during productive periods (July through mid-September).




*Due to limited sample sizes, 5-m and 10-m samples are displayed as markers.

**Figure 5-4. Average dissolved oxygen (mg/L) at three depths (0.5 m, 5 m, and 10 m) upstream and downstream of the curtain and in the Klamath River downstream of Iron Gate Dam (KRBI) and curtain depth (m). Vertical dashed lines indicate curtain deployment on July 25, August 4, August 11 (furled), and August 28 (final furling of the curtain occurred on September 21, 2017).**




*Due to limited sample sizes, 5-m and 10-m samples are displayed as markers.

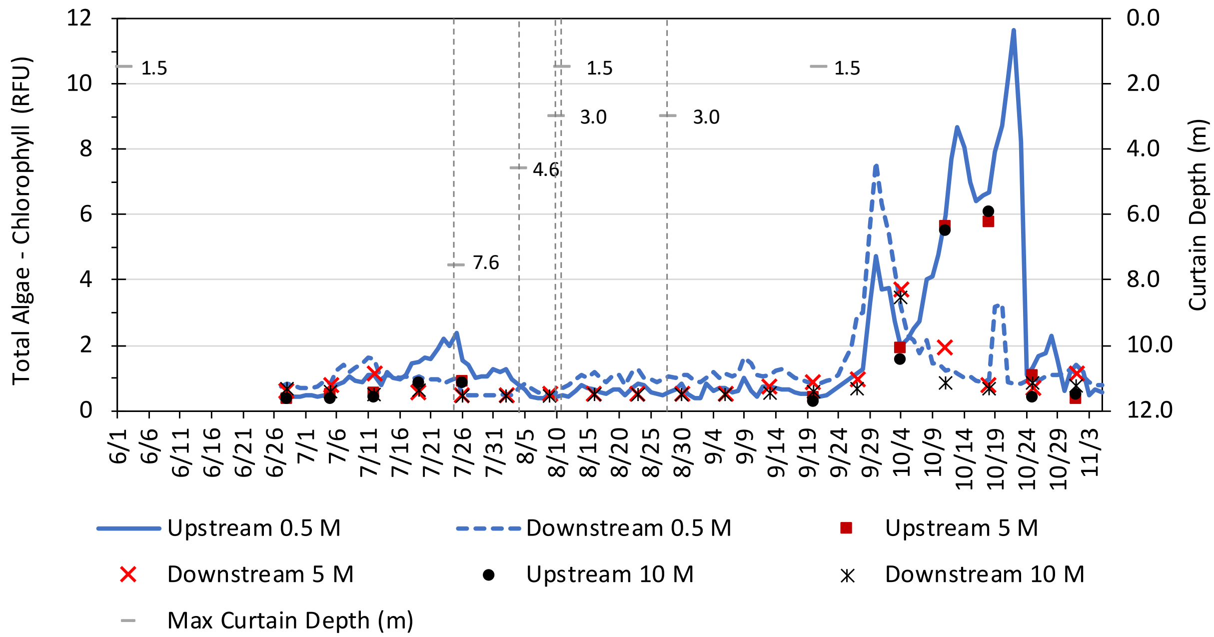
**Figure 5-5. Average dissolved oxygen (% saturation) at three depths (0.5 m, 5 m, and 10 m) upstream and downstream of the curtain and in the Klamath River downstream of Iron Gate Dam (KRBI) and curtain depth (m). Vertical dashed lines indicate curtain deployment on July 25, August 4, August 11 (furled), and August 28 (final furling of the curtain occurred on September 21, 2017).**

### 5.3.1.3 Total Algae as Chlorophyll

Daily average chlorophyll values from 0.5 m in depth both upstream and downstream of the curtain ranged from approximately 0.4 to 1.6 RFUs during the curtain deployment period. Chlorophyll values were initially less downstream of the curtain than upstream of the curtain after deployment of the curtain. Chlorophyll values downstream of the curtain increased and were greater than those from upstream of the curtain when the curtain was raised in early August (Figure 5-6). Data less than 0.6 RFU are not distinguishable from background conditions and are not reliable in assessing differences.

At 5 m in depth, average chlorophyll values from upstream and downstream of the curtain ranged from approximately 0.5 to 0.9 RFU during the curtain deployment period (Figure 5-6). A gap in the upstream curtain sonde data precludes comparisons at 5 m in depth during curtain deployment expect on July 26 and on September 20 when values were similar.

At 10 m in depth, average chlorophyll values upstream and downstream of the curtain ranged from approximately 0.4 to 0.8 RFU during the curtain deployment period (Figure 5-6). A gap in the upstream curtain sonde data precludes comparisons at 10 m in depth during curtain deployment except on July 26 and on September 20; however, differences between upstream and downstream of the curtain were within 0.6 RFU and not different from background conditions.




*Due to limited sample sizes, 5-m and 10-m samples are displayed as markers.

**Figure 5-6. Average chlorophyll (RFU) at three depths (0.5 m, 5 m, and 10 m) upstream and downstream of the curtain and curtain depth (m). Vertical dashed lines indicate curtain deployment on July 25, August 4, August 11 (furled), and August 28 (final furling of the curtain occurred on September 21, 2017).**

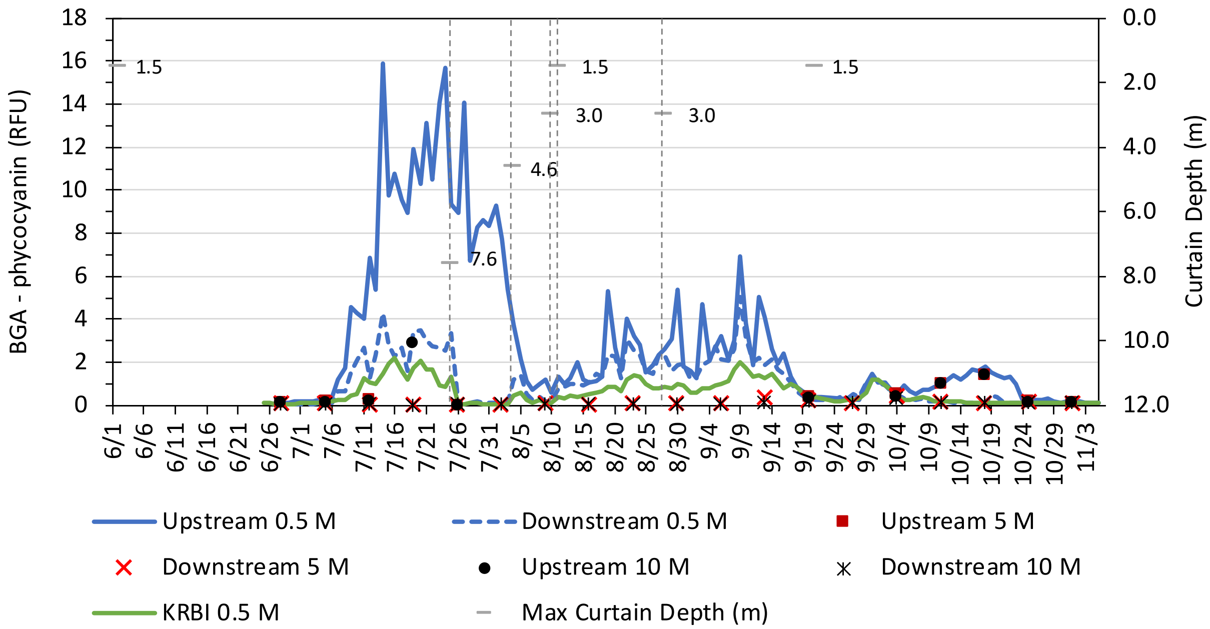
### 5.3.1.4 Cyanobacteria as Phycocyanin

Daily average phycocyanin values from 0.5 m in depth upstream and downstream of the curtain ranged from approximately 0.1 to 14.1 RFU during the curtain deployment period (Figure 5-7). Phycocyanin values were generally less downstream before, during, and after deployment of the curtain than upstream of the curtain (Figure 5-7). Data below 0.4 RFU are not distinguishable from background conditions and are not reliable in assessing differences.

At 5 m in depth, average phycocyanin values upstream and downstream of the curtain ranged from approximately 0 to 0.4 RFU during the curtain deployment period (Figure 5-7). A gap in the upstream curtain sonde data precludes comparisons at 5 m in depth during curtain deployment except on July 26, when phycocyanin values were similar upstream and downstream of the curtain (less than 0.1 RFU) and on September 20 when values were similar upstream and downstream of the curtain (approximately 0.3 RFU and approximately 0.2 RFU, respectively).

At 10 m in depth, average phycocyanin values upstream and downstream of the curtain ranged from approximately 0 to 0.3 RFU during the curtain deployment period (Figure 5-7). A gap in the upstream of the curtain sonde data precludes comparisons at 10 m in depth during curtain deployment expect on July 26, when phycocyanin values were similar upstream and downstream of the curtain (less than 0.1 RFU) and September 20, when values were similar upstream and downstream of the curtain (approximately 0.3 RFU and 0.2 RFU, respectively).

In the Klamath River downstream of Iron Gate Dam, daily average phycocyanin values ranged from less than 0.1 RFU to 2.0 RFU during the curtain deployment period (Figure 5-7). In general, phycocyanin values in the river showed a similar pattern to those observed downstream of the curtain at 0.5 m in depth, but with consistently smaller values during the deployment period and then similar values thereafter.




*Due to limited sample sizes, 5-m and 10-m samples are displayed as markers.

**Figure 5-7. Average phycocyanin (RFU) at three depths (0.5 m, 5 m, and 10 m) upstream and downstream of the curtain and in the Klamath River downstream of Iron Gate Dam (KRBI) and curtain depth (m). Vertical dashed lines indicate curtain deployment on July 25, August 4, August 11 (furled), and August 28 (final furling of the curtain occurred on September 21, 2017).**

## 5.3.2 Thermograph Data

At the log boom upstream of Iron Gate Dam, a thermograph array recorded water temperatures every 30 minutes from March 14, 2017, through to January 8, 2018. The log boom site was approximately 46 m (150 feet) deep and the thermographs ranged in depth from 0.5 m to 39 m. Daily average water temperatures at the log boom are presented for the period June 1, 2017, through November 7, 2017 (Figure 5-8). Daily average water temperatures in the Klamath River downstream of Iron Gate Dam (from the PacifiCorp data sonde) are included for comparison (Figure 5-8). Daily average temperatures in the river generally correspond to daily average temperatures between the 3-m to 6-m log boom thermographs prior to curtain deployment. After curtain deployment, river temperatures cool and generally correspond to daily average temperatures at the 6-m to 9-m log boom thermographs.

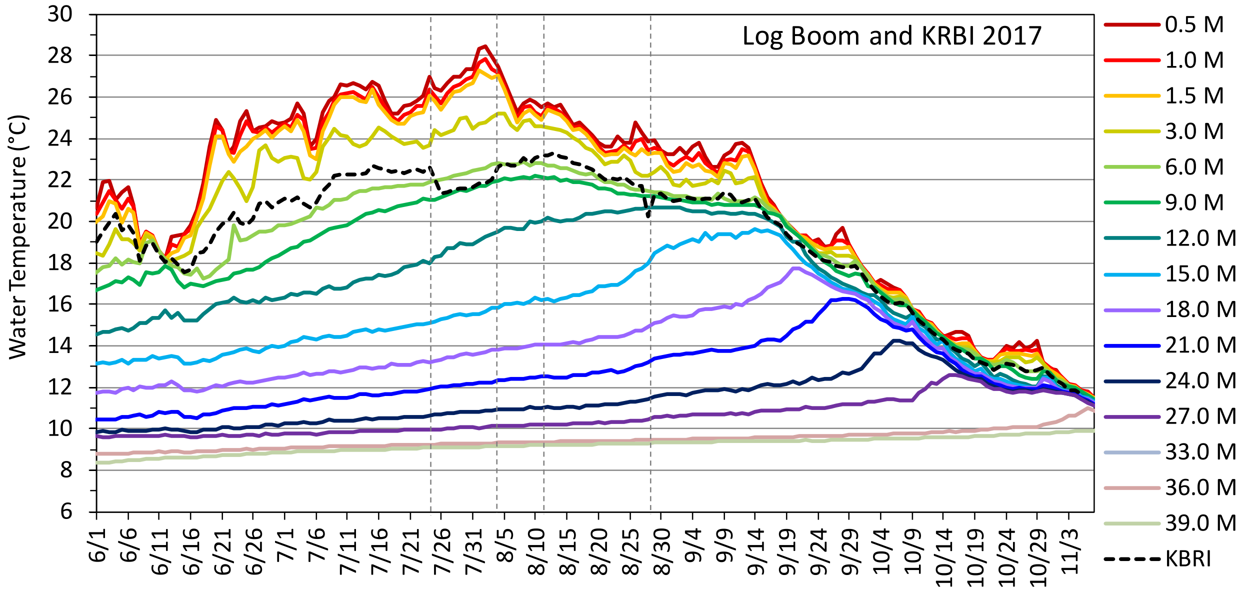



**Figure 5-8. Daily average water temperature from a thermograph array at log boom in Iron Gate Reservoir and the PacifiCorp sonde in the Klamath River downstream of Iron Gate Dam (KRBI): June 1, 2017, through November 7, 2017. Vertical dashed lines indicate curtain deployment on July 25, August 4, August 11 (furled up), and August 28 (final furling of the curtain occurred on September 21, 2017).**

At the upstream and downstream of the curtain monitoring sites, thermograph arrays recorded water temperatures every 15 minutes from June 5 through to November 6, 2017. The deepest thermograph at the upstream site was approximately 20 m deep. Because the reservoir bed slopes up towards the intake, the deepest thermograph from the downstream site was approximately 15 m deep. The 15-minute data were processed into daily average water temperatures. While the patterns are similar until July 25 between the upstream and downstream sides of the curtain, the range of temperatures is substantially less on the downstream side of the curtain after the curtain was deployed in late July (Figure 5-9, Figure 5-10). Daily average water temperatures at the PacifiCorp sonde in the Klamath River downstream of Iron Gate Dam are included for comparison. Daily average water temperatures in the river generally correspond to daily average temperatures at the 3-m to 5-m upstream of the curtain thermographs prior to curtain deployment, and then drop and generally correspond to daily average temperatures at the 5-m to 8-m upstream of the curtain thermographs during curtain deployment (Figure 5-9).

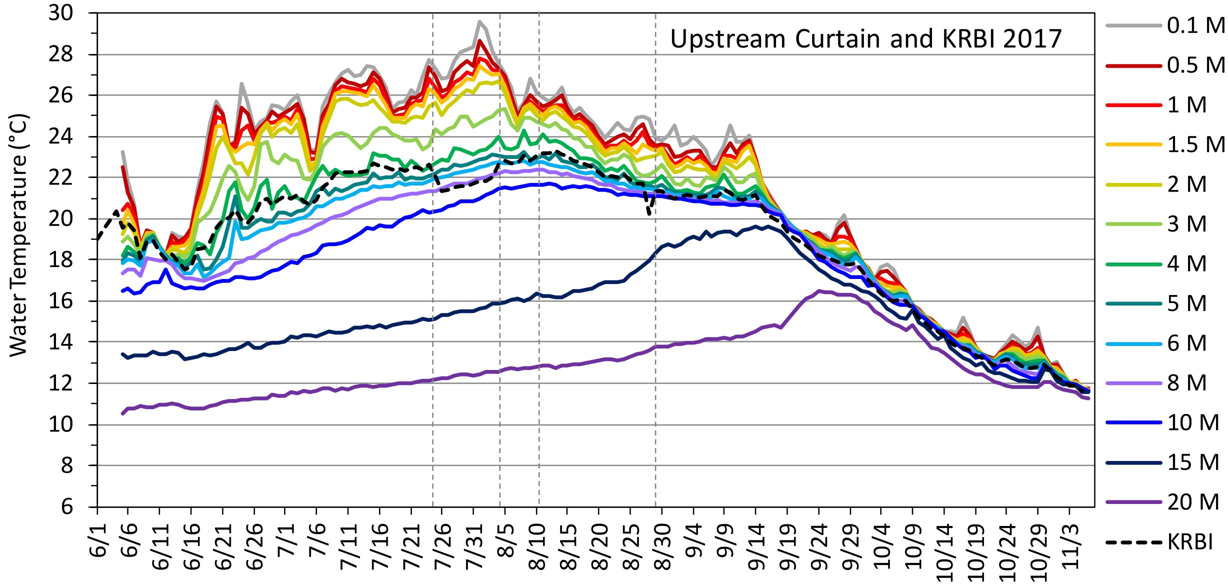



**Figure 5-9. Daily average water temperature from a thermograph array upstream of the curtain and the PacifiCorp sonde in the Klamath River downstream of Iron Gate Dam (KRBI): June 5, 2017, through November 6, 2017. Vertical dashed lines indicate curtain deployment on July 25, August 4, August 11 (furled up), and August 28 (final furling of the curtain occurred on September 21, 2017).**

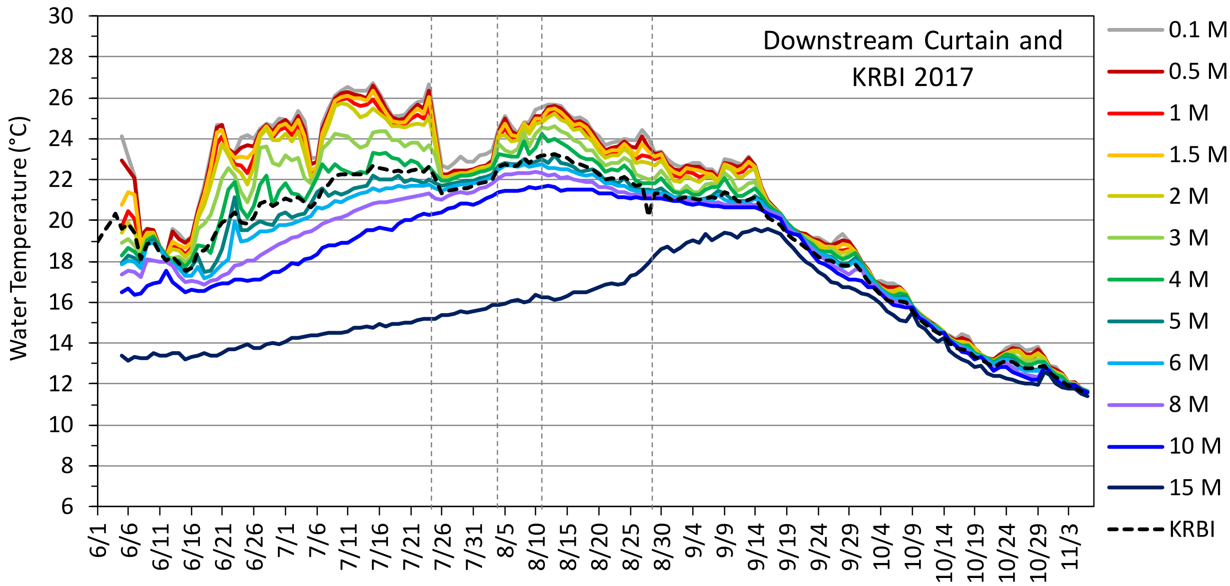



**Figure 5-10. Daily average water temperature from a thermograph array downstream of the curtain and the PacifiCorp sonde in the Klamath River downstream of Iron Gate Dam (KRBI): June 5, 2017, through November 6, 2017. Vertical dashed lines indicate curtain deployment on July 25, August 4, August 11 (furled up), and August 28 (final furling of the curtain occurred on September 21, 2017).**

### 5.3.3 Vertical Profiles

Vertical profile grab samples were collected in 2017 at the sites upstream of the curtain, downstream of the curtain, and in the Klamath River downstream of Iron Gate Dam. Samples were analyzed for total microcystin, filtered microcystin, total cyanobacteria, total *Microcystis*, and total chlorophyll-*a*.[32] The curtain was deployed to 7.6 m on July 25 and remained at 7.6 m during both post-curtain deployment grab sample collections on July 27 and August 3. The curtain was raised to 4.6 m on August 4 and to shallower depths after that. No additional grab samples were collected. Pre-curtain and post-curtain results are presented.

### 5.3.3.1 Total Microcystin

Concentrations of total microcystin (µg/L) in vertical profile grab samples collected during the post-curtain deployment period (July 27 and August 3) demonstrate reduction from upstream to downstream of the curtain within near-surface depths (0.5 m and 1.5 m on July 27, and 0.5 m, 1.5 m, and 3 m on August 3, b and c in Figure 5-11). In addition, total microcystin concentrations were reduced from upstream to downstream of the curtain at a depth of 0.5 m during the pre-curtain period (the curtain remains at about 1.5 m in depth when not deployed) (Figure 5-11a). Concentrations of microcystin in the Klamath River downstream of Iron Gate Dam samples were similar to concentrations in samples downstream of the curtain for all periods.

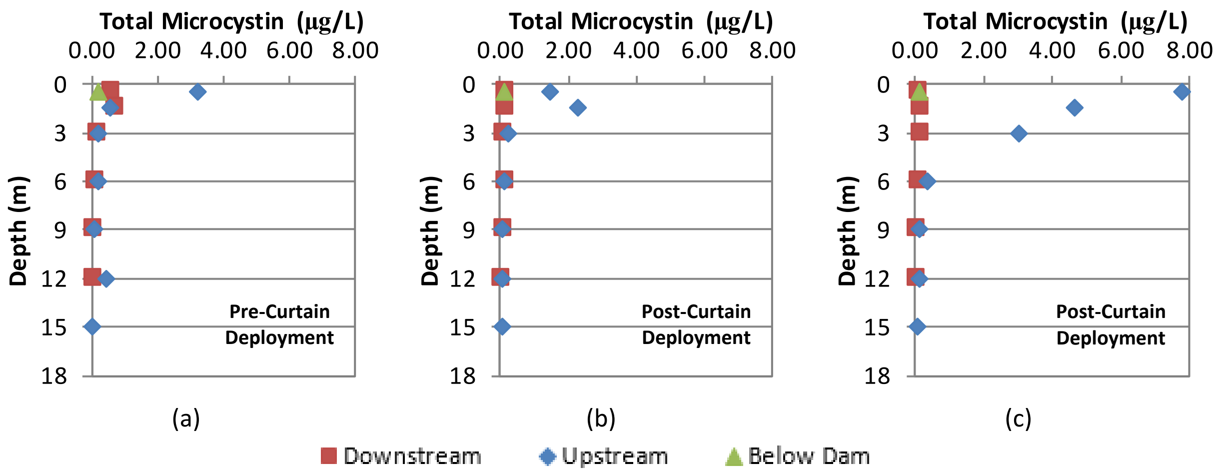



**Figure 5-11. Comparison of total microcystin in vertical profiles upstream and downstream of curtain and downstream of Iron Gate Dam on (a) July 24, (b) July 27, and (c) August 3, 2017 (quantification limit is 0.15 µg/L).**

### 5.3.3.2 Filtered Microcystin

The relationship between total and filtered (dissolved) microcystin concentrations (µg/L) was similar as in 2016 and 2018 (averaging approximately 20 to 30 percent of the total microcystin result when total microcystin values are greater than or equal to 0.50 µg/L). Concentrations of filtered microcystin in vertical profile grab samples collected during the pre-curtain (July 24) and post-curtain (July 27 and August 3) deployment periods demonstrate a similar trend as total microcystin concentrations. In general, filtered microcystin concentrations were reduced from upstream to downstream of the curtain within near-surface depths (0.5 m and 1.5 m on July 27, and 0.5 m, 1.5 m, and 3 m on August 3) when the curtain was deployed (Figure 5-12b and c). There was also some reduction in filtered microcystin concentrations from upstream to downstream of the curtain at a depth of 0.5 m during the pre-curtain period on July 24 (Figure 5-12a). Concentrations of filtered microcystin in the Klamath River downstream of Iron Gate Dam samples were similar to concentrations in samples downstream of the curtain for all periods (Figure 5-12).

32 Grab samples were analyzed for total chlorophyll-*a*, corrected chlorophyll-*a*, and pheophytin. Total chlorophyll-*a* results are presented.

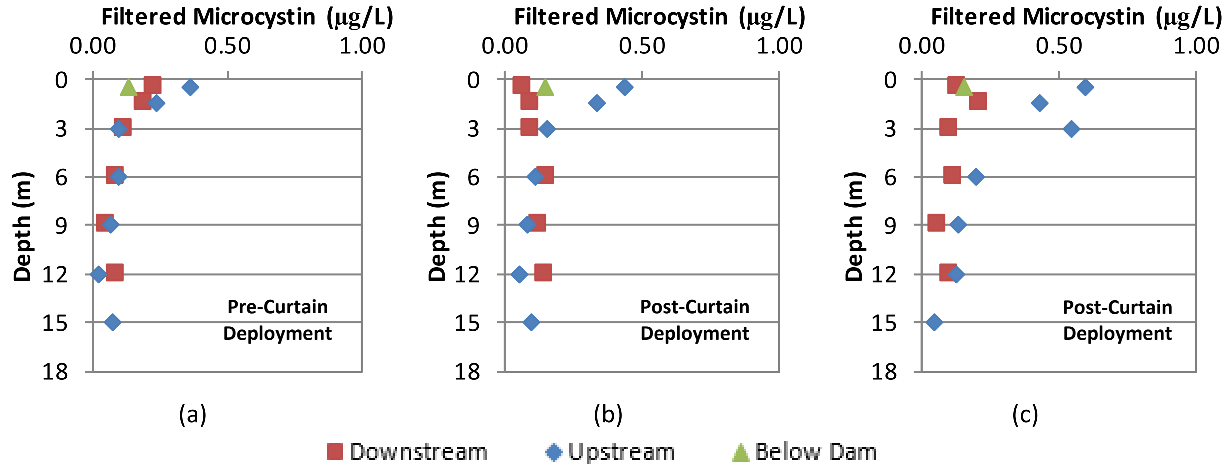



**Figure 5-12. Comparison of microcystin concentrations in filtered samples from vertical profiles upstream and downstream of curtain and downstream of Iron Gate Dam on (a) July 24, (b) July 27, and (c) August 3, 2017 (quantification limit is 0.15 µg/L).**

### 5.3.3.3 Total Cyanobacteria

Results of genetic analysis conducted via qPCR are in gene copies per milliliter (genes/mL). Total cyanobacteria concentrations (genes/mL) in vertical profile grab samples collected when the curtain was deployed demonstrate reduction in concentrations from upstream to downstream of the curtain within near-surface depths (0.5 m and 1.5 m on July 27, and 0.5 m, 1.5 m, and 3 m on August 3) and some deeper depths (6 m on August 3) (Figure 5-13b and c). Total cyanobacteria concentrations were also reduced from upstream to downstream of the curtain for the 1.5-m depth prior to curtain deployment (Figure 5-13a). Concentrations of total cyanobacteria in the Klamath River downstream of Iron Gate Dam samples were similar to concentrations found in samples downstream of the curtain for all periods (Figure 5-13).

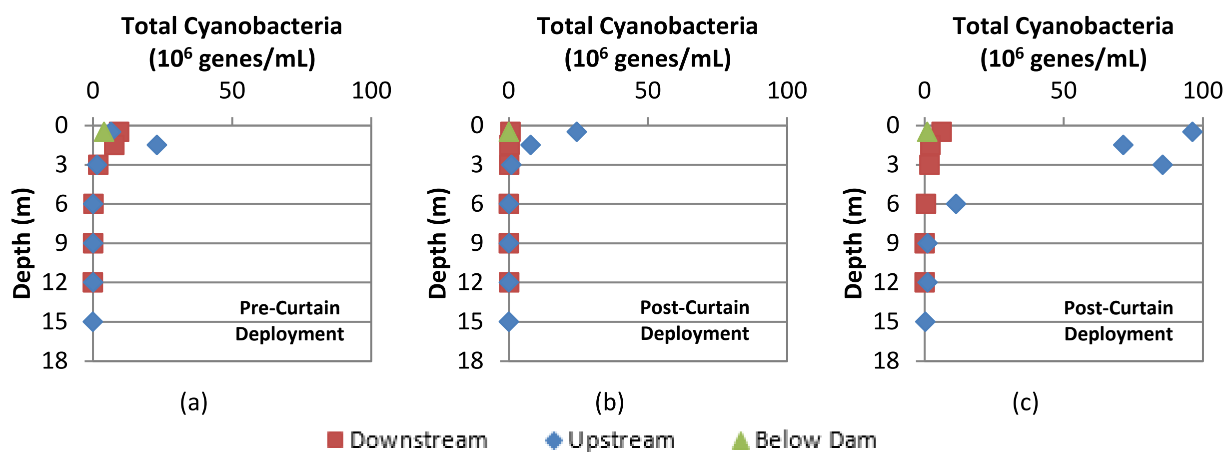



**Figure 5-13. Comparison of total cyanobacteria concentrations in water samples collected in vertical profiles upstream and downstream of the curtain and downstream of Iron Gate Dam on (a) July 24, (b) July 27, and (c) August 3, 2017 (quantification limit is 100 genes/mL).**

### 5.3.3.4 Total *Microcystis*

As with total cyanobacteria concentrations, total *Microcystis* concentrations were assessed via qPCR and are presented in gene copies per milliliter (genes/mL). Total *Microcystis* concentrations in vertical profile grab samples collected prior to curtain deployment (July 24) were similar upstream and downstream of the curtain (Figure 5-14a). Total *Microcystis* concentrations were reduced from upstream to downstream of the curtain within near-surface depths (0.5 m and 1.5 m on July 27, and 0.5 m, 1.5 m, and 3 m on August 3) when the curtain was deployed (Figure 5-14b and c). Concentrations of total *Microcystis* in the Klamath River downstream of Iron Gate Dam samples were similar to concentrations found in samples downstream of the curtain for all periods (Figure 5-14).

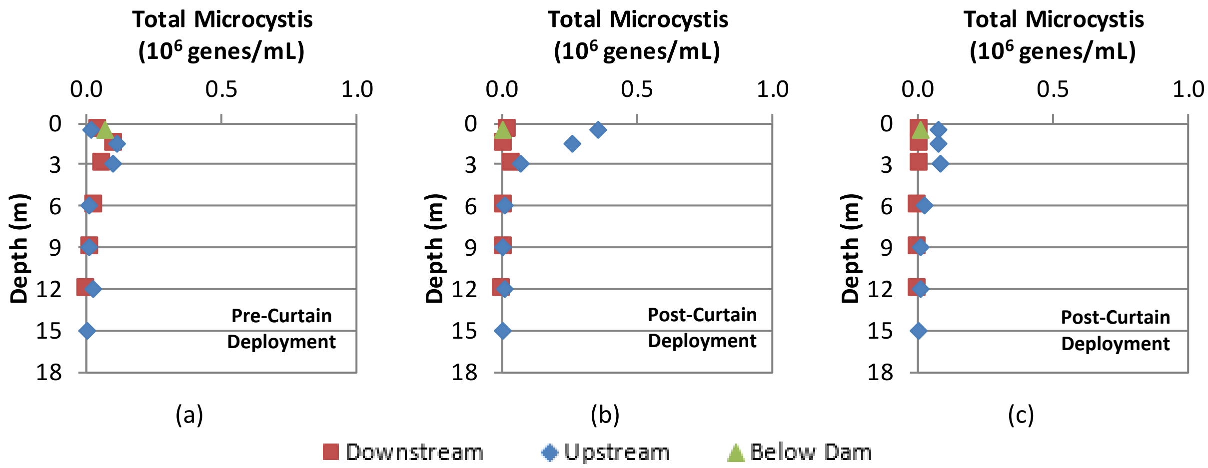



**Figure 5-14. Comparison of total *Microcystis* concentrations in water samples collected in vertical profiles upstream and downstream of the curtain and downstream of Iron Gate Dam on (a) July 24, (b) July 27, and (c) August 3, 2017 (quantification limit is 100 genes/mL).**

### 5.3.3.5 Total Chlorophyll-*a*

Total chlorophyll-*a* concentrations (µg/L) in vertical profile grab samples collected prior to curtain deployment (July 24) and after the curtain had been deployed (July 27 and August 3) demonstrate reduction from upstream to downstream of the curtain sites for surface samples (0.5 m and 1.5 m) during all periods; greater reductions in chlorophyll-*a* were observed after the curtain had been deployed (Figure 5-15). Concentrations of chlorophyll-*a* in the Klamath River downstream of Iron Gate Dam were less than concentrations found in surface waters downstream of the curtain prior to curtain deployment (July 24) and were similar to concentrations from downstream of the curtain when the curtain was deployed (July 27 and August 3) (Figure 5-15).

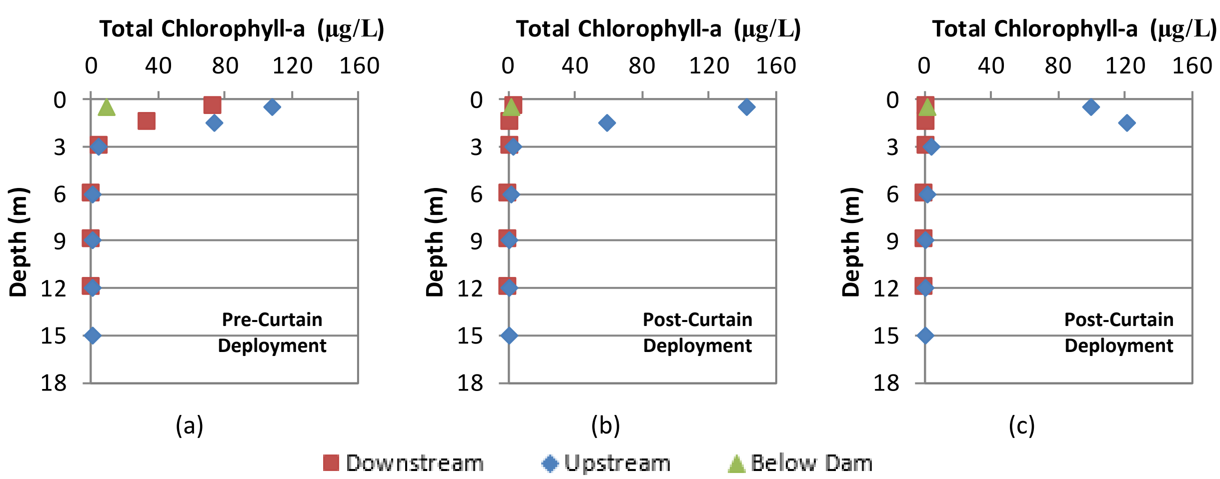



**Figure 5-15. Comparison of total chlorophyll-*a* concentrations in water samples collected in vertical profiles upstream and downstream of the curtain and downstream of Iron Gate Dam on (a) July 24, (b) July 27, and (c) August 3, 2017 (quantification limit is 0.89 µg/L).**

### 5.3.3.6 Water Temperature

Water temperatures (°C) observed during vertical profiles were similar at sites upstream and downstream of the curtain prior to curtain deployment (Figure 5-16a). After the curtain had been deployed to 7.6 m[33] on July 25, water temperatures were reduced from upstream to downstream of the curtain sites from the surface depth to approximately 3 m to 6 m in depth (Figure 5-16b-e). Water temperature reduction ranged from less than 1°C to approximately 6°C during these periods and depth ranges.

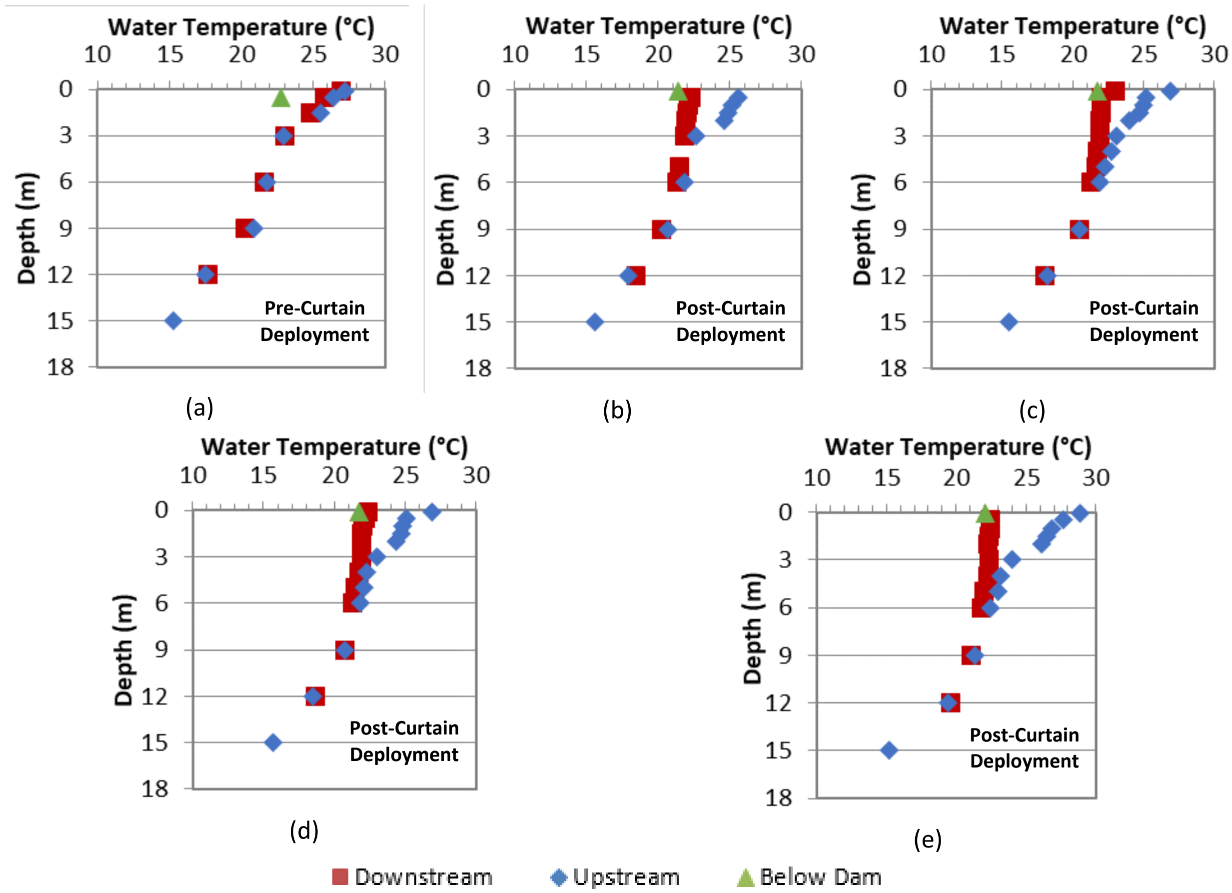



**Figure 5-16. Comparison of water temperature (°C) collected during vertical profiles upstream and downstream of the curtain and downstream of Iron Gate Dam on (a) July 24, (b) July 25, (c) July 26, (d) July 27, and (e) August 3, 2017.**

### 5.3.3.7 Dissolved Oxygen

Dissolved oxygen concentrations (mg/L) observed during vertical profiles were similar at sites upstream and downstream of the curtain prior to curtain deployment (Figure 5-17a). After the curtain had been deployed to 7.6 m on July 25, dissolved oxygen concentrations were reduced from upstream to downstream of the curtain sites from the surface depth to approximately 3 m to 6 m in depth (Figure 5-17b-e). Reduction in dissolved oxygen concentrations ranged from approximately 1 mg/L to 8 mg/L during these periods and depth ranges.

---

[33] Water temperature measurements were not collected between 6-m and 9-m depths.

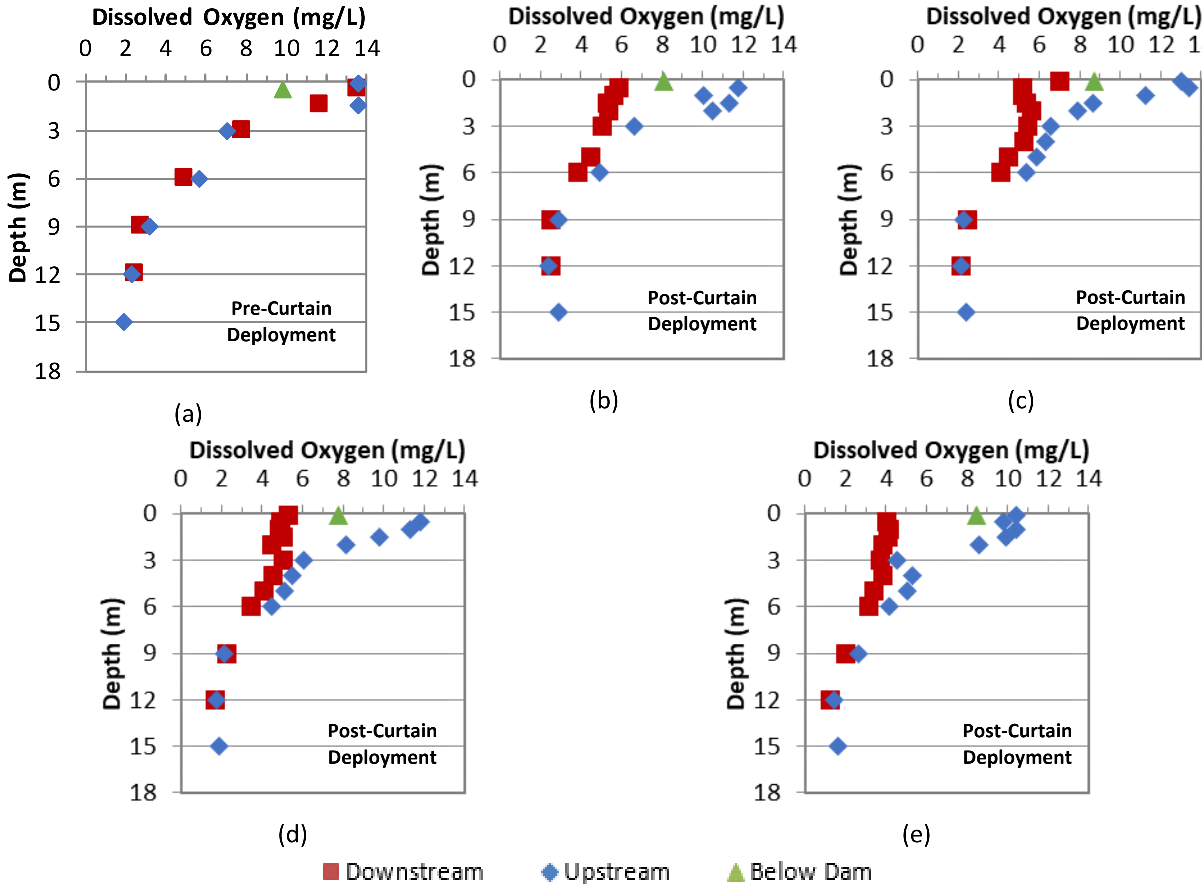



**Figure 5-17. Comparison of dissolved oxygen concentrations from data collected in vertical profiles upstream and downstream of the curtain and downstream of Iron Gate Dam on (a) July 24, (b) July 25, (c) July 26, (d) July 27, and (e) August 3, 2017.**

## 5.3.4 Autosamplers

Autosamplers were deployed in 2017 from the platforms upstream and downstream of the curtain to assess near-surface conditions and allow comparison of those conditions across the curtain. The autosamplers were programmed to take coincident samples at 4-hour intervals from a depth of 0.5 m over a 72-hour period (spanning July 24, 2017 10:00 AM through July 27, 2017 at 10:00 AM). Water samples were analyzed for total microcystin (using ELISA), cyanobacteria species including total cyanobacteria and total *Microcystis* (using qPCR), and total chlorophyll-*a* (using fluorescence detection).

In 2017, the curtain was lowered to 7.6 m on July 25. The process to lower the curtain began after the 10:00 AM sample was collected and was completed by 1:00 PM to avoid sample collection while the curtain was being actively deployed. The autosamplers were installed approximately 24 hours prior to curtain deployment and remained in place for approximately 44 hours after deployment was completed.

### 5.3.4.1 Total Microcystin

Total microcystin concentrations ranged from 0.2 to 5.3 µg/L upstream of the curtain and from 0.1 to 1.5 µg/L downstream of the curtain. Prior to the deployment of the curtain, the upstream and downstream microcystin concentrations were variable and neither site was consistently greater or less than the other. After curtain deployment to 7.6 m, the upstream total microcystin concentrations remained variable and were consistently greater than those observed in the surface water (0.5 m) downstream of the curtain (Figure 5-18).

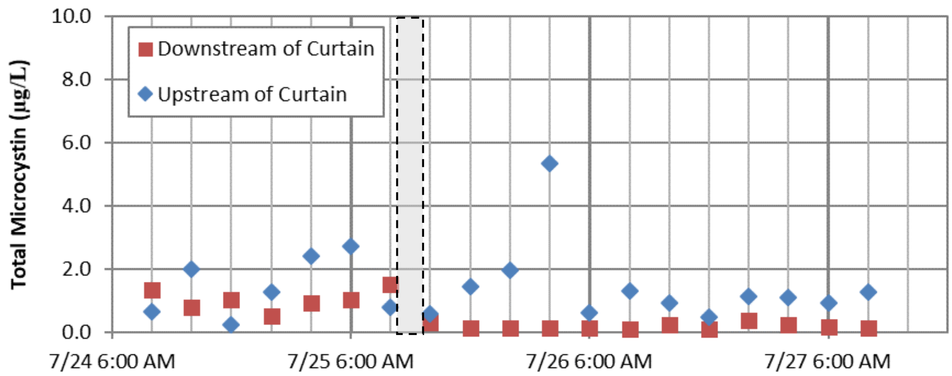



**Figure 5-18. Total microcystin concentrations from samples collected over a 72-hour sampling period using autosamplers upstream and downstream of the curtain for July 24 through July 27, 2017 (dashed grey box denotes the active curtain deployment period).**

### 5.3.4.2 Total Cyanobacteria

Total cyanobacteria concentrations ranged from 2.6 to 492.6 million genes/mL in surface (0.5 m) samples upstream of the curtain and from 0.2 to 57.5 million genes/mL in surface samples downstream of the curtain. Prior to the deployment of the curtain, concentrations of total cyanobacteria upstream and downstream of the curtain were similar and samples from neither site contained concentrations consistently greater or less than the other. After curtain deployment to a depth of 7.6 m, total cyanobacteria concentrations in surface samples upstream of the curtain were consistently greater than those observed in the surface samples downstream of the curtain (Figure 5-19).

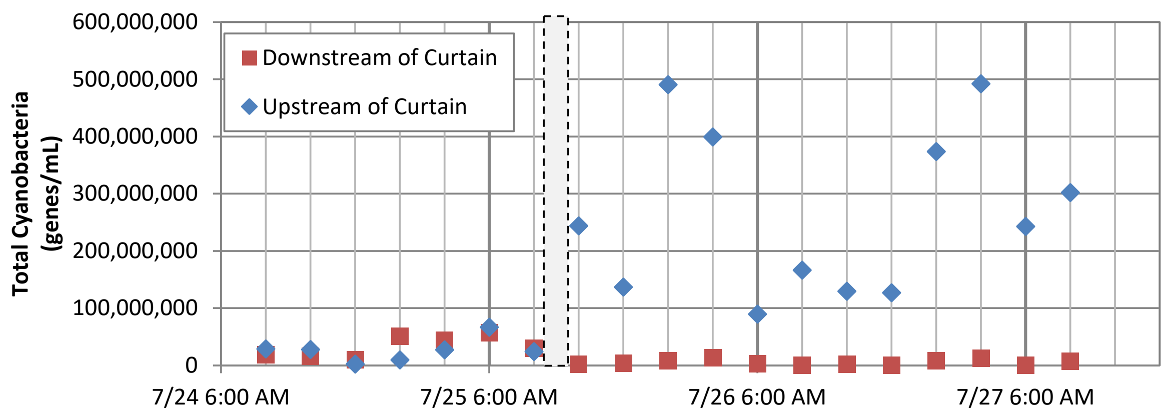



**Figure 5-19. Total cyanobacteria concentrations from samples collected over a 72-hour sampling period using autosamplers upstream and downstream of the curtain for July 24 through July 27, 2017 (dashed grey box denotes the active curtain deployment period).**

### 5.3.4.3 Total *Microcystis*

Total *Microcystis* concentrations ranged from less than 0.1 to 0.5 million genes/mL in surface (0.5 m) samples upstream of the curtain and from less than 0.1 to 0.3 million genes/mL in surface samples downstream of the curtain. Prior to the deployment of the curtain, concentrations of total *Microcystis* in samples upstream and downstream of the curtain were variable and samples from either side of the curtain did not contain concentrations consistently greater or less than the other (Figure 5-20). After curtain deployment to a depth of 7.6 m, concentrations in surface samples upstream of the curtain remained variable and were consistently greater than those observed in the surface samples downstream of the curtain (Figure 5-20).

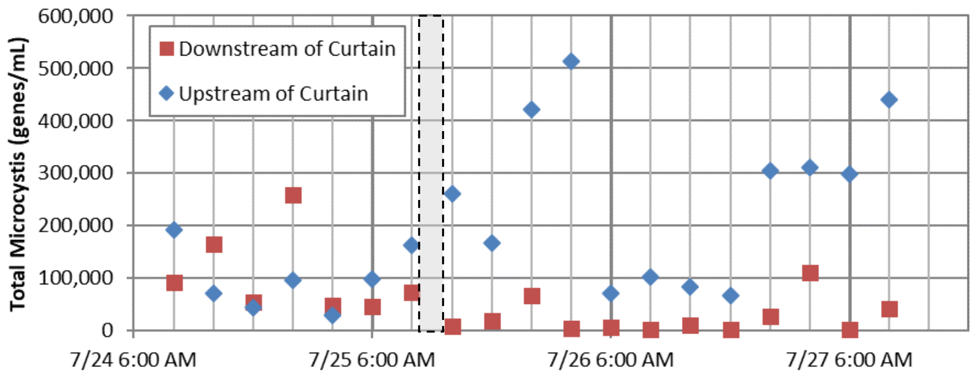



**Figure 5-20. Total *Microcystis* concentrations from samples collected over a 72-hour sampling period using autosamplers upstream and downstream of the curtain for July 24 through July 27, 2017 (grey dashed box denotes the active curtain deployment period).**

#### 5.3.4.4 Total Chlorophyll-*a*

Total chlorophyll-*a* concentrations ranged from 8 to 225 µg/L in surface (0.5 m) samples upstream of the curtain and from 1 to 210 µg/L in surface samples downstream of the curtain. Prior to the deployment of the curtain, concentrations of total chlorophyll-*a* upstream and downstream of the curtain were variable and samples from either side of the curtain did not contain concentrations consistently greater or less than the other (Figure 5-21). After curtain deployment to a depth of 7.6 m, concentrations in surface samples upstream of the curtain remained variable and were consistently greater than those of the surface water samples downstream of the curtain (Figure 5-21).

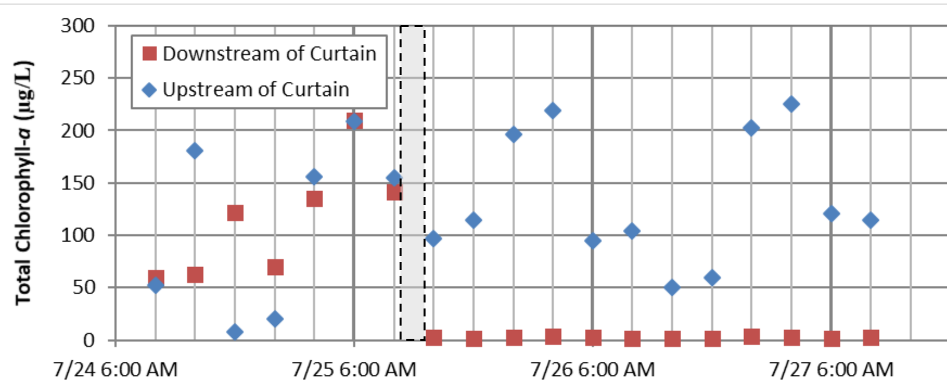



**Figure 5-21. Total chlorophyll-*a* concentrations from samples collected over a 72-hour sampling period using autosamplers upstream and downstream of the curtain for July 24 through July 27, 2017 (grey box denotes the active curtain deployment period).**

### 5.3.5 Meteorological Data

Meteorological data were collected at PacifiCorp's meteorological station located on the crest of Iron Gate Dam in 2017. These data include air temperature, barometric pressure, relative humidity, precipitation, solar radiation, and wind speed (peak gusts, instantaneous, and average). The following discussion focuses on wind speed and air temperature data.

#### 5.3.5.1 Wind Speed

Average 15-minute and daily average of the 15-minute average wind speeds (Figure 5-22 and Figure 5-23) and monthly average 15-minute average wind speeds (Figure 5-24) demonstrate variation between subdaily, daily, and monthly averages. Daily average wind speeds were slower in 2017 than in 2015 or 2016 during the month of July, and slower in 2017 than in 2015, 2016, and 2018 during the month of August (Figure 5-23, Figure 5-24). Monthly average wind speeds were slower in 2017 than in 2015 or 2016 during the months of July and September, and slower in 2017 than in 2015, 2016, and 2018 during the month of August (Figure 5-23, Figure 5-24).

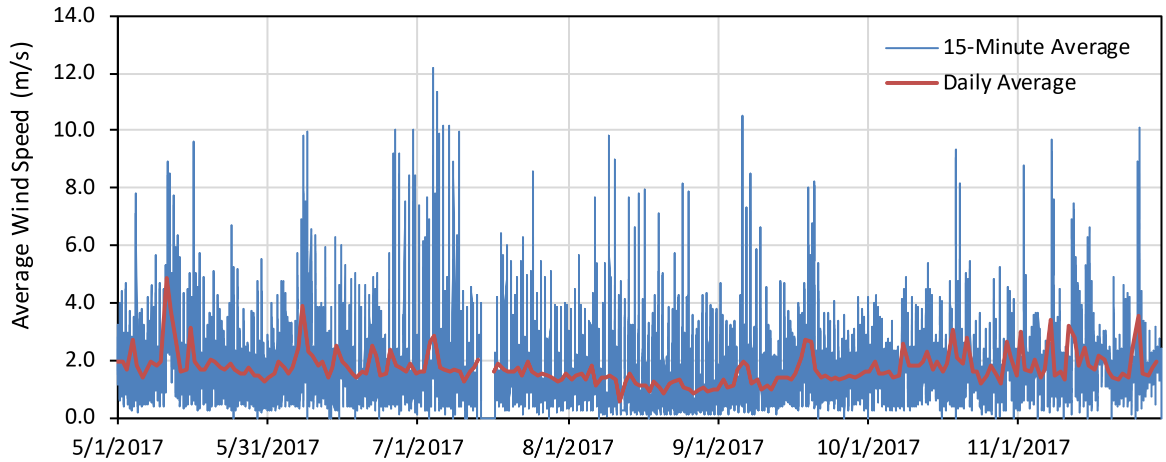



**Figure 5-22. 15-minute average and daily average of the 15-minute average wind speeds (m/s) at Iron Gate Dam from May 1 to November 30, 2017.**

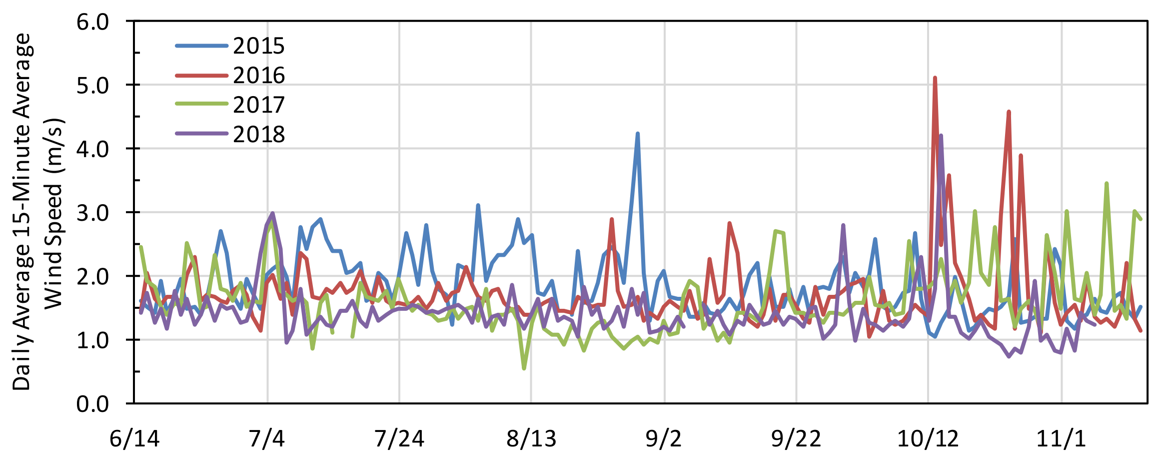



**Figure 5-23. Daily average of the 15-minute average wind speeds (m/s) at Iron Gate Dam mid-June through mid-November for 2015 through 2018.**

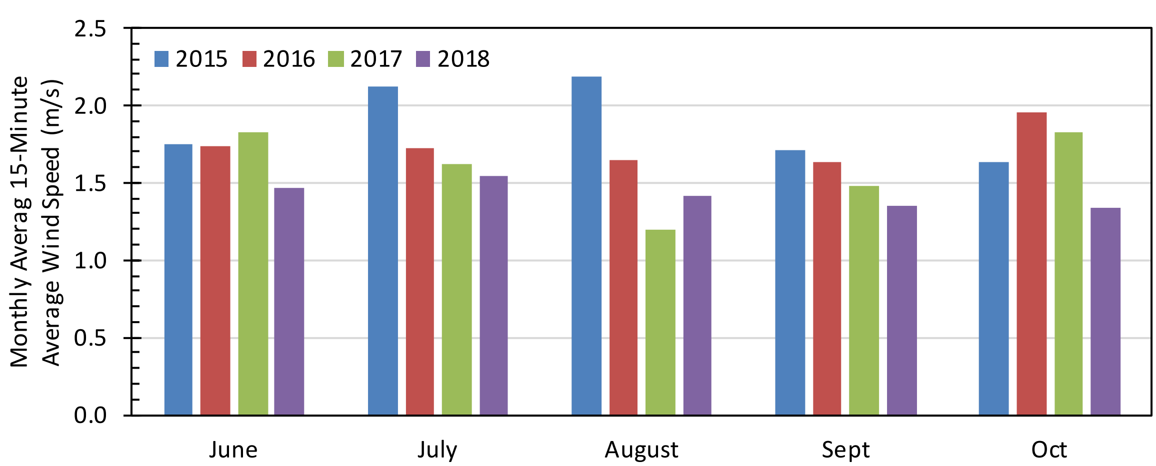



**Figure 5-24. Monthly average of 15-minute average wind speeds (m/s) at Iron Gate Dam June through October for 2015 through 2018.**

#### 5.3.5.2 Air Temperature

Air temperatures collected from the weather station at Iron Gate Dam represent short-term (subdaily to daily and multiple day) and long-term (monthly to seasonal) variations (Figure 5-25). Air temperatures increased gradually from mid to late June, peaking over 40°C in late July and early August before cooling gradually through the late summer and fall.

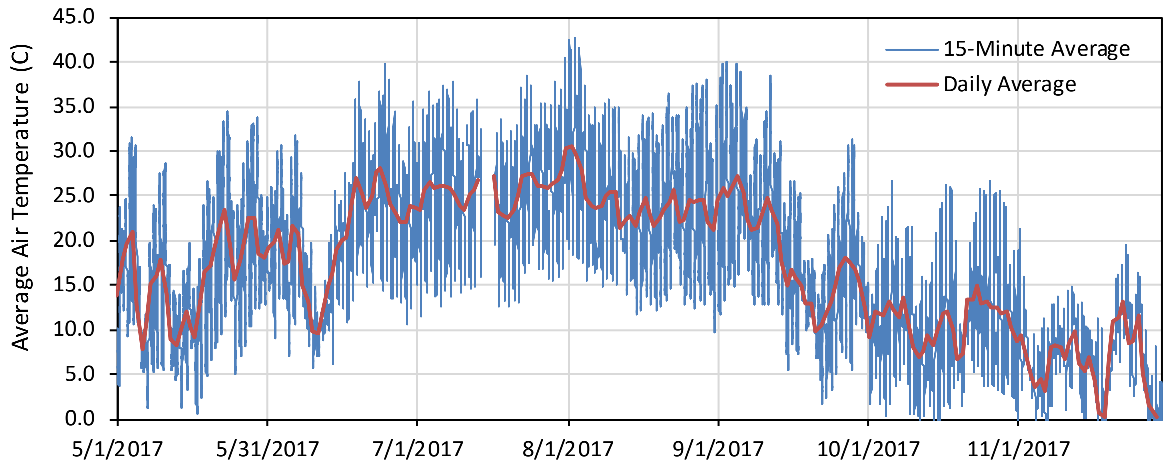



**Figure 5-25. 15-minute average and daily average of the 15-minute average air temperature (°C) at Iron Gate Dam from May 1 to November 30, 2017.**

## 5.4 2018 Data Summary

The 2018 data considered in this assessment include sonde data collected upstream of the curtain and downstream of the curtain; thermograph data; vertical profile grab sample data collected upstream of the curtain and downstream of the curtain; Secchi depth data observed upstream and downstream of the curtain during vertical profile sample collection; grab sample data collected in the Klamath River downstream of Iron Gate Dam; and meteorological data collected at Iron Gate Dam. Each data type is outlined below.

### 5.4.1 Sonde Data

As in previous years, data sondes were used to monitor water temperature, dissolved oxygen, pH, specific conductance, chlorophyll, and phycocyanin. The sondes were installed on May 3 and removed on November 6, 2018. They were serviced, cleaned, calibrated, and the data downloaded approximately every 3 to 4 weeks during the period of deployment. The sondes profiled three times per week during the morning hours of approximately 7:00 AM PDT to 11:45 AM PDT. At all other times, the sondes were positioned at approximately 0.5 m. To assess curtain performance and allow comparison between years, the 2018 data were processed in the same manner as the 2017 sonde data (Section 5.3.1). Water temperature, dissolved oxygen, chlorophyll, and phycocyanin are presented below while pH and specific conductance results are presented in Appendix A.

#### 5.4.1.1 Water Temperature

Daily average water temperature from a depth of 0.5 m upstream and downstream of the curtain ranged from approximately 13°C to 26°C during the curtain deployment period in 2018. Water temperatures were similar upstream and downstream of the curtain until the curtain was deployed on July 24 (Figure 5-26). After curtain deployment from a depth of 1.5 m to 4.6 m, the sonde downstream of the curtain at 0.5 m in depth recorded substantial (approximately 2°C) and rapid cooling in water temperatures while the sonde upstream of the curtain at 0.5 m in depth recorded stable water temperatures until a mixing event in early August. The curtain was deployed to a deeper depth of 6.1 m on August 7 and again the downstream sonde showed a substantial (approximately 3°C) and rapid cooling at 0.5 m in depth in comparison to water temperatures upstream of the curtain.

At 5 m and 10 m in depth, average water temperature upstream and downstream of the curtain were similar throughout the curtain deployment period (Figure 5-26). Average water temperatures at 5 m ranged from approximately 13°C to 22°C during the deployment period. Average water temperatures at 10 m ranged from approximately 12°C to 21°C during the deployment period.

In the Klamath River downstream of Iron Gate Dam, average water temperatures were similar to those at the 5-m depth upstream and downstream of the curtain and ranged from approximately 13°C to 22°C during the deployment period.

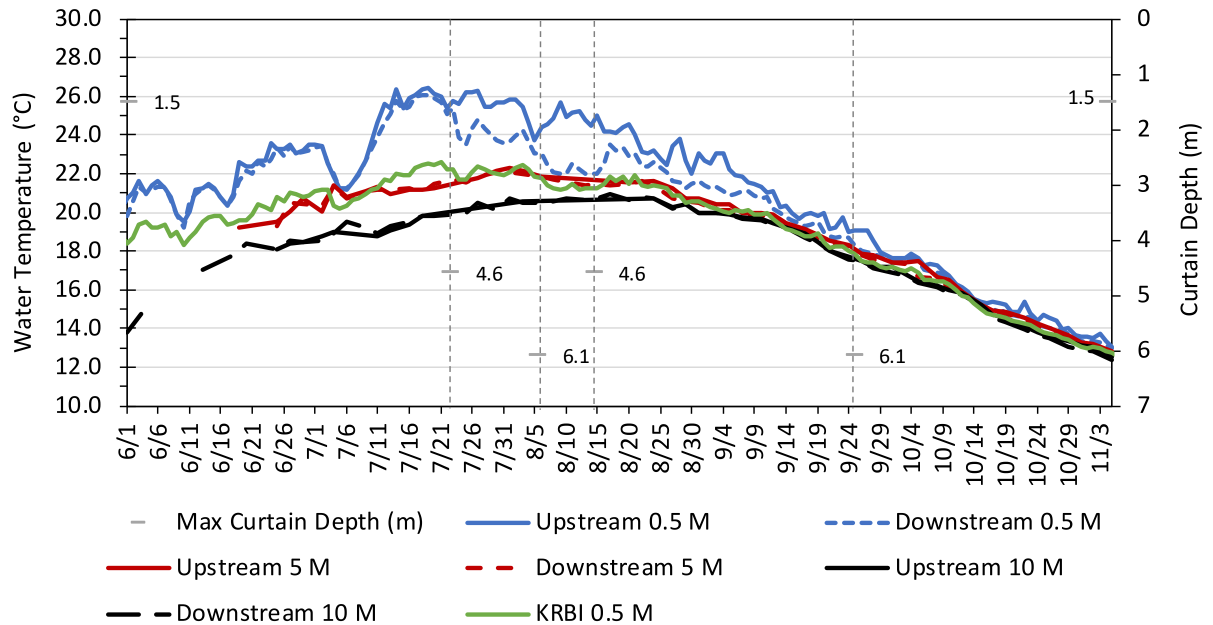



**Figure 5-26. Average sonde water temperature (°C) at three depths (0.5 m, 5 m, and 10 m) upstream and downstream of the curtain and in the Klamath River downstream of Iron Gate Dam (KRBI) and curtain depth (m). Vertical dashed lines indicate curtain deployment on July 24, August 7 and 16, and September 27, 2018 (final furling of the curtain occurred on November 7, 2018).**

### 5.4.1.2 Dissolved Oxygen

Daily average dissolved oxygen concentrations at 0.5 m in depth upstream and downstream of the curtain ranged from approximately 4 to 17 mg/L (50 to 210 percent saturation) during the curtain deployment period. Concentrations were similar until the curtain was deployed on July 24 (Figure 5-27 and Figure 5-28). After curtain deployment from 1.5 m to a depth of 4.6 m, the downstream sonde showed substantial (approximately 5 mg/L) and rapid reductions in concentrations at 0.5 m in depth while upstream of the curtain at 0.5 m in depth, dissolved oxygen concentrations remained elevated until a mixing event in early August. Daily average dissolved oxygen concentrations declined both upstream and downstream of the curtain when the curtain was deployed to a depth of 6.1 m on August 7. The curtain was subsequently raised to 4.6 m and concentrations increased both upstream and downstream of the curtain. In general, dissolved oxygen concentrations downstream of the curtain remained less than upstream of the curtain until late September. With seasonal reduction in solar radiation and water temperatures, and increased frequency of mixing events in late September through early November, daily average dissolved oxygen concentrations upstream and downstream of the curtain converged for the remainder of the deployment period, even with a deployed curtain depth of 6.1 m.

At 5 m in depth, average dissolved oxygen concentrations upstream and downstream of the curtain generally ranged from 2 to 7 mg/L (20 to 75 percent saturation) during the deployment period (Figure 5-27 and Figure 5-28). Concentrations during the deployment period were similar upstream and downstream of the curtain until late-August. After that, upstream of the curtain concentrations were typically greater than those downstream of the curtain through early October. By mid-October, the average upstream and downstream dissolved oxygen concentrations at 5 m in depth were similar through the remainder of the deployment period.

At 10 m in depth, average dissolved oxygen concentrations upstream and downstream of the curtain generally ranged from less than 1 to 5 mg/L (less than 10 to 30 percent saturation) during the deployment period (Figure 5-27 and Figure 5-28). Concentrations upstream and downstream of the curtain were similar until early September. After that, upstream of the curtain concentrations were similar or slightly greater than downstream of the curtain concentrations through the end of the curtain deployment period.

In the Klamath River downstream of Iron Gate -Dam, daily average dissolved oxygen concentrations ranged from approximately 6 to 9 mg/L (70 to 95 percent saturation) during the curtain deployment period (Figure 5-27 and Figure 5-28) and were more stable than those observed upstream and downstream of the curtain. Average dissolved oxygen concentrations downstream of the dam were typically greater than those observed at the 5-m and 10-m depths both upstream and downstream of the curtain, but often less than surface water dissolved oxygen concentrations upstream and downstream of the curtain during productive periods (July through September).

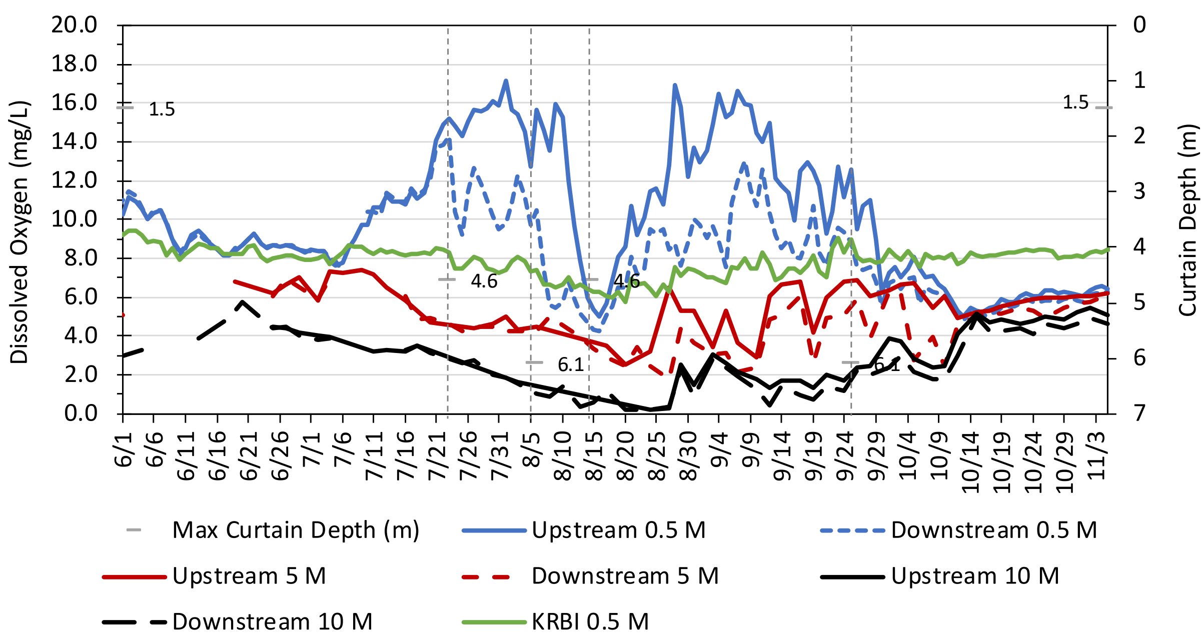



**Figure 5-27. Average sonde dissolved oxygen concentrations (mg/L) at three depths (0.5 m, 5 m, and 10 m) upstream and downstream of the curtain and in the Klamath River downstream of Iron Gate Dam (KRBI) and curtain depth (m). Vertical dashed lines indicate curtain deployment on July 24, August 7 and 16, and September 27, 2018 (final furling of the curtain occurred on November 7, 2018).**

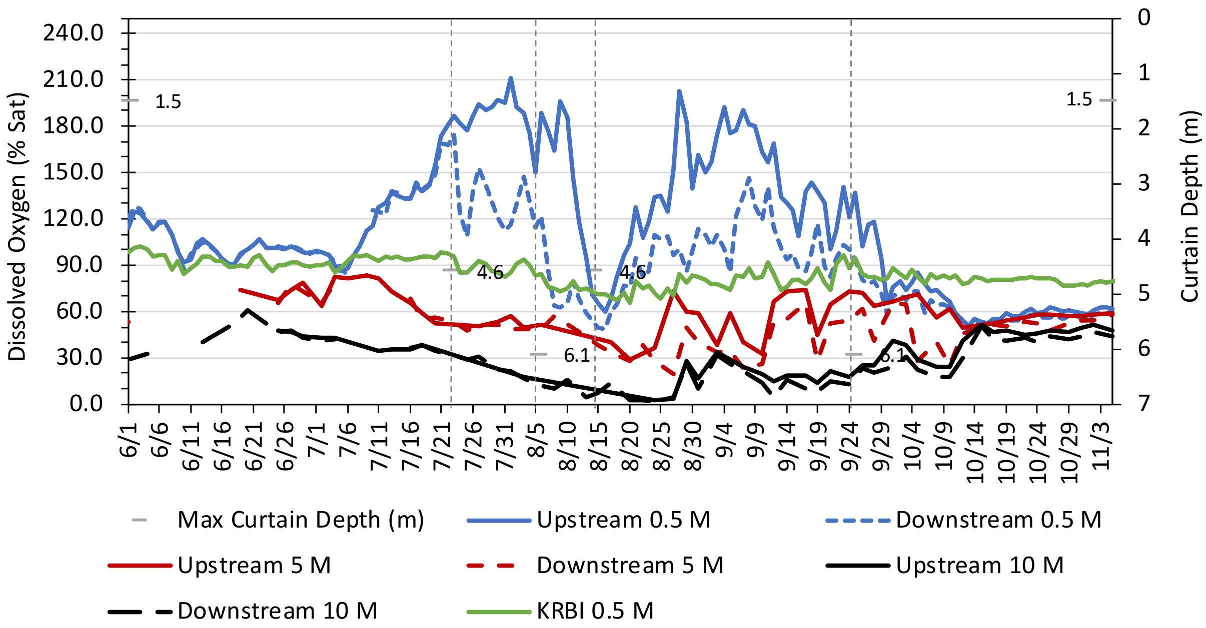



**Figure 5-28. Average sonde dissolved oxygen (% saturation) at three depths (0.5 m, 5 m, and 10 m) upstream and downstream of the curtain and in the Klamath River downstream of Iron Gate Dam (KRBI) and curtain depth (m). Vertical dashed lines indicate deployment on July 24, August 7 and 16, and September 27, 2018 (final furling of the curtain occurred on November 7, 2018).**

### 5.4.1.3 Total Algae as Chlorophyll

Daily average chlorophyll values from 0.5 m in depth upstream and downstream of the curtain ranged from 0.2 to 7.0 RFU during the curtain deployment period. Chlorophyll values were generally greater downstream of the curtain than upstream of the curtain regardless of the curtain status (by -0.7 RFU to 6.6 RFU, with an average of 0.3 RFU) (Figure 5-29). Data below 0.6 RFU are not distinguishable from background conditions and are not reliable in assessing differences.

At the 5-m depth, average chlorophyll upstream and downstream of the curtain ranged from 0.2 RFU to 1.0 RFU (Figure 5-29). Differences between upstream and downstream of the curtain were within background conditions; no difference is noted at the 5-m depth.

At the 10-m depth, average chlorophyll upstream and downstream of the curtain ranged from 0.2 RFU to 0.6 RFU throughout the deployment period (Figure 5-29). As with the 5-m depth, differences between upstream and downstream of the curtain were within background conditions; no difference is noted at the 10-m depth.

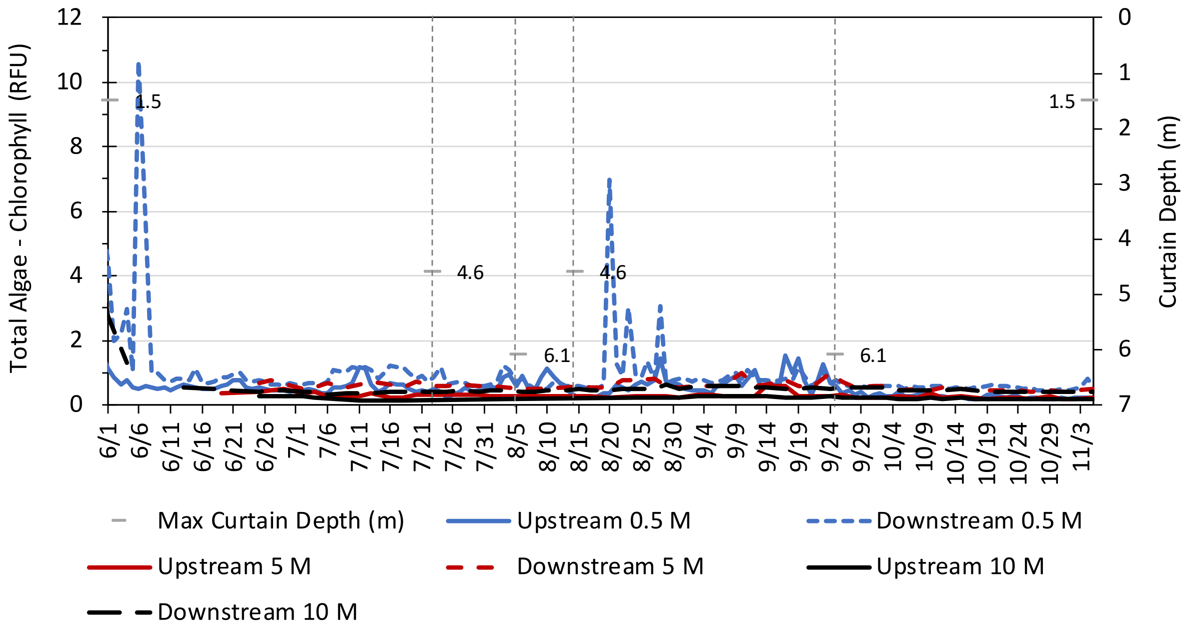



**Figure 5-29. Average sonde chlorophyll (RFU) at three depths (0.5 m, 5 m, and 10 m) upstream and downstream of the curtain and curtain depth (m). Vertical dashed lines indicate curtain deployment on July 24, August 7 and 16, and September 27, 2018 (final furling of the curtain occurred on November 7, 2018).**

### 5.4.1.4 Total Cyanobacteria as Phycocyanin

Daily average total cyanobacteria as phycocyanin (total cyanobacteria) values from 0.5 m in depth upstream and downstream of the curtain ranged from approximately 0.1 to 16.2 RFU during the curtain deployment period. Values were generally less downstream of the curtain than upstream of the curtain before, during, and after deployment of the curtain (Figure 5-30). Data below 0.4 RFU are within background conditions and are not reliable in assessing differences.

At the 5-m depth, average total cyanobacteria values upstream and downstream of the curtain ranged from approximately 0.1 to 2.5 RFU during the curtain deployment period (Figure 5-30). Differences between upstream and downstream of the curtain were within background conditions; no difference is noted at the 5-m depth.

At the 10-m depth, average total cyanobacteria values upstream and downstream of the curtain ranged from approximately 0 to 0.4 RFU during the curtain deployment period (Figure 5-30). As with the 5-m depth, differences between upstream and downstream of the curtain were within background conditions; no difference is noted at the 10-m depth.

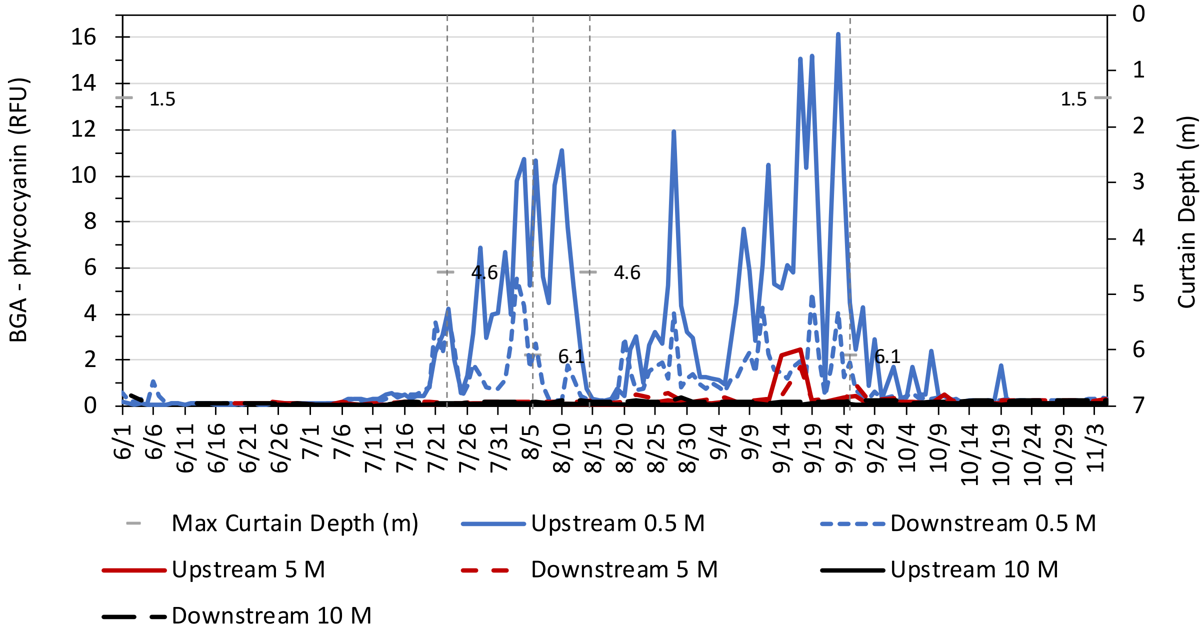



**Figure 5-30. Average sonde phycocyanin (RFU) at three depths (0.5 m, 5 m, and 10 m) and curtain depth (m) upstream and downstream of the curtain and in the Klamath River downstream of Iron Gate Dam (KRBI). Vertical dashed lines indicate curtain deployment on July 24, August 7 and 16, and September 27, 2018 (final furling of the curtain occurred on November 7, 2018).**

### 5.4.2 Thermograph Data

At the log boom upstream of Iron Gate Dam, a thermograph array recorded water temperatures every 30 minutes from May 12, 2018, through to January 11, 2019. Thermograph depths were the same as in 2017 (Section 5.3.2). Daily average water temperatures at the log boom are presented for the period June 1, 2018, through November 7, 2018 (Figure 5-31). Daily average water temperatures in the Klamath River downstream of Iron Gate Dam (PacifiCorp sonde) are included for comparisons (Figure 5-31). Daily average temperatures in the river generally correspond to daily average temperatures between the 3-m to 6-m log boom thermographs prior to curtain deployment. After curtain deployment, river temperatures cool and generally correspond to daily average temperatures at the 6-m to 9-m log boom thermographs.

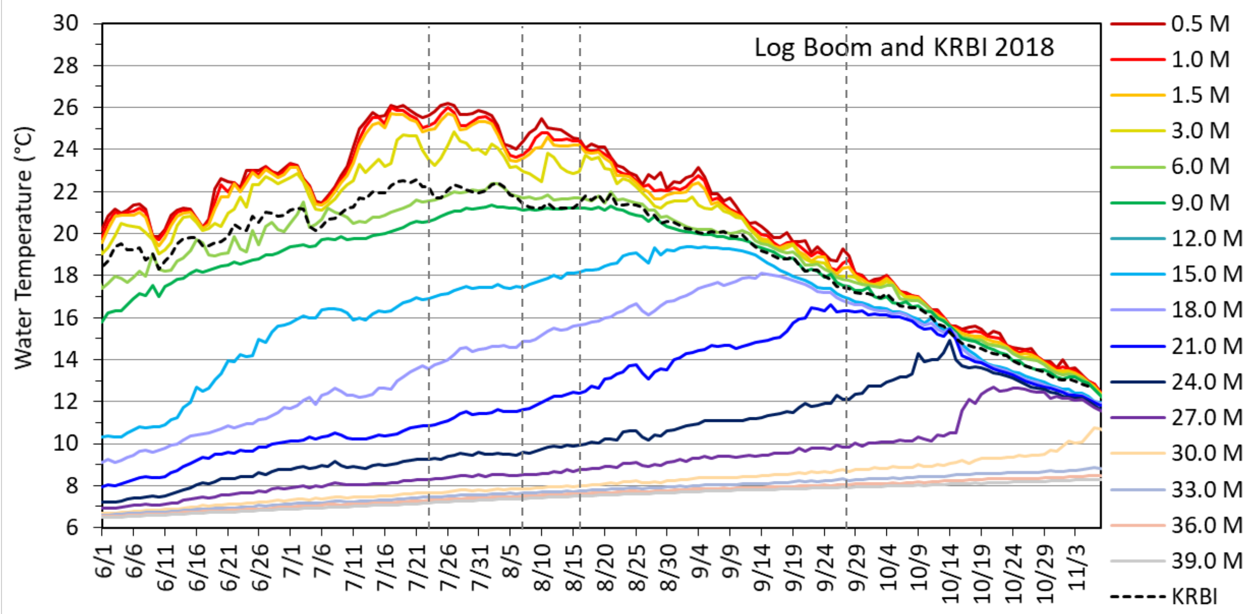



**Figure 5-31. Daily average water temperature from thermograph array at the log boom in Iron Gate Reservoir and from the PacifiCorp sonde in the Klamath River downstream of Iron Gate Dam (KRBI): 6/1/2018 through 11/5/2018. Vertical dashed lines indicate initial indicate curtain deployment on July 24, August 7 and 16, and September 27, 2018 (final furling of the curtain occurred on November 7, 2018).**

At upstream and downstream of the curtain monitoring sites, thermograph arrays recorded water temperatures every 15 minutes from May 4 through to November 5, 2018. Thermograph depths were the same as in 2017 (Section 5.3.2). The 15-minute data were processed into daily average water temperatures. Daily average water temperatures from thermograph arrays upstream and downstream of the curtain show similar patterns in the early spring and summer prior to curtain deployment (Figure 5-32 and Figure 5-33). Once the curtain was deployed on July 24, the water temperatures as recorded by the thermograph array downstream of the curtain showed substantially less warming and daily variation (Figure 5-32 and Figure 5-33). Daily average water temperatures at the PacifiCorp sonde in the Klamath River downstream of Iron Gate Dam are included for comparison. Daily average temperatures in the river generally correspond to daily average temperatures at the 4-m to 6-m upstream of the curtain thermographs prior to curtain deployment, and then drop and generally correspond to daily average temperatures at the 5-m to 8-m upstream of the curtain thermographs during curtain deployment (Figure 5-32).

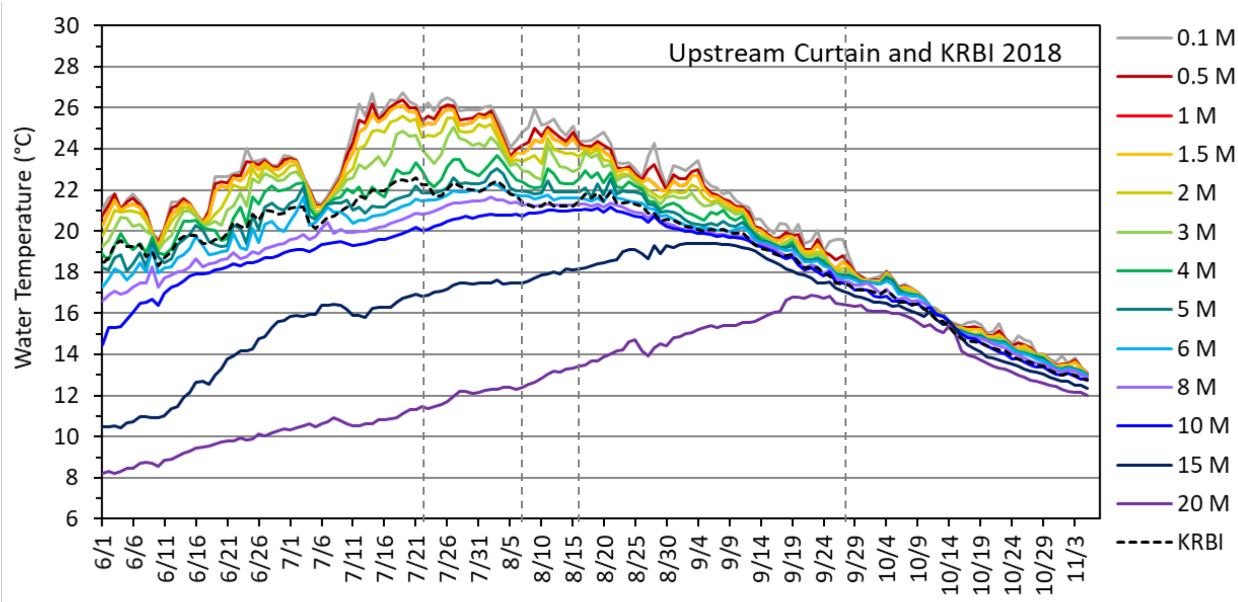



**Figure 5-32. Daily average water temperature from thermograph array on the upstream side of the curtain and in the Klamath River below Iron Gate (KRBI): 6/1/2018 through 11/5/2018. Vertical dashed lines indicate initial indicate curtain deployment on July 24, August 7 and 16, and September 27, 2018 (final furling of the curtain occurred on November 7, 2018).**

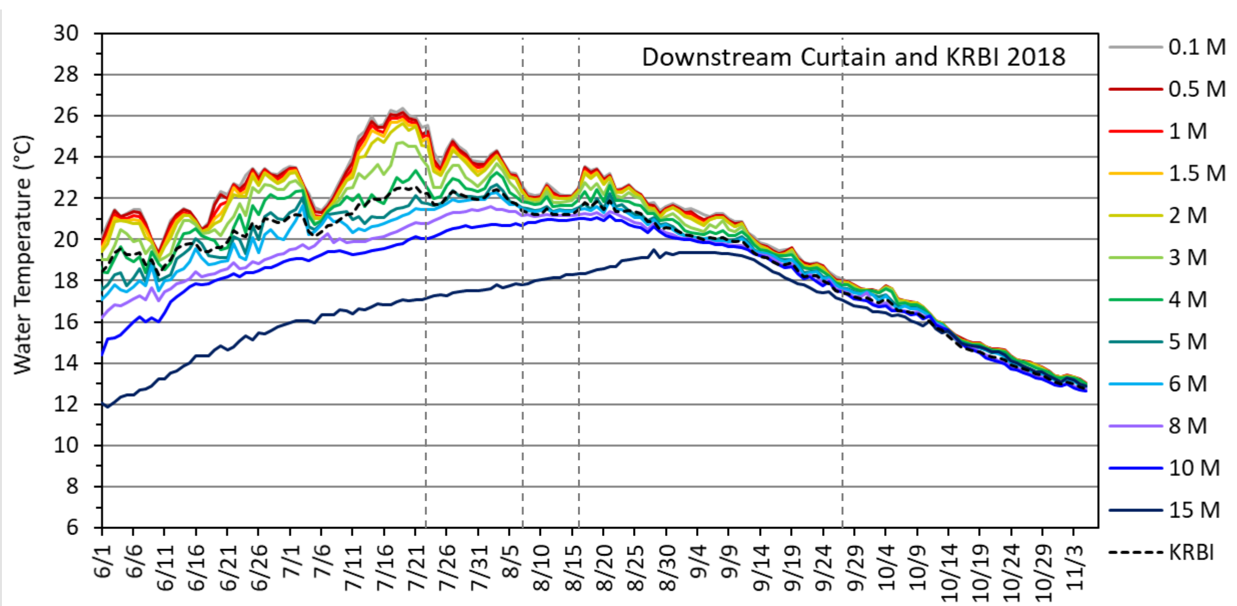



**Figure 5-33. Daily average water temperature from thermograph array on the downstream side of the curtain and in the Klamath River below Iron Gate (KRBI): 6/1/2018 through 11/5/2018. Vertical dashed lines indicate curtain deployment on July 24, August 7 and 16, and September 27, 2018 (final furling of the curtain occurred on November 7, 2018).**

### 5.4.3 Vertical Profiles

Vertical profile grab samples were collected in 2018 at the sites upstream of the curtain, downstream of the curtain, and in the Klamath River downstream of Iron Gate Dam. As in 2017, samples were analyzed for total microcystin, filtered microcystin, total cyanobacteria, total *Microcystis*, and total chlorophyll-*a*.[34] The curtain was deployed to 4.6 m on July 24 and remained at 4.6 m during both post-curtain deployment grab sample collections on July 26 and August 2, 2018. The curtain was lowered further to 6.1 m in early August. No additional grab sample collections were collected.

### 5.4.3.1 Total Microcystin

Concentrations of total microcystin (µg/L) in vertical profile grab samples showed variable levels of microcystin in the samples from 0.5 m in depth regardless of sample date and curtain deployment depth (Figure 5-34). Total microcystin concentrations were not consistently reduced from upstream to downstream curtain sites following curtain deployment (July 26 and August 2), even in surface (0.5-m) samples (Figure 5-34c and d). Total microcystin concentrations in samples from the Klamath River downstream of Iron Gate Dam were similar to concentrations in samples downstream of the curtain (Figure 5-34).

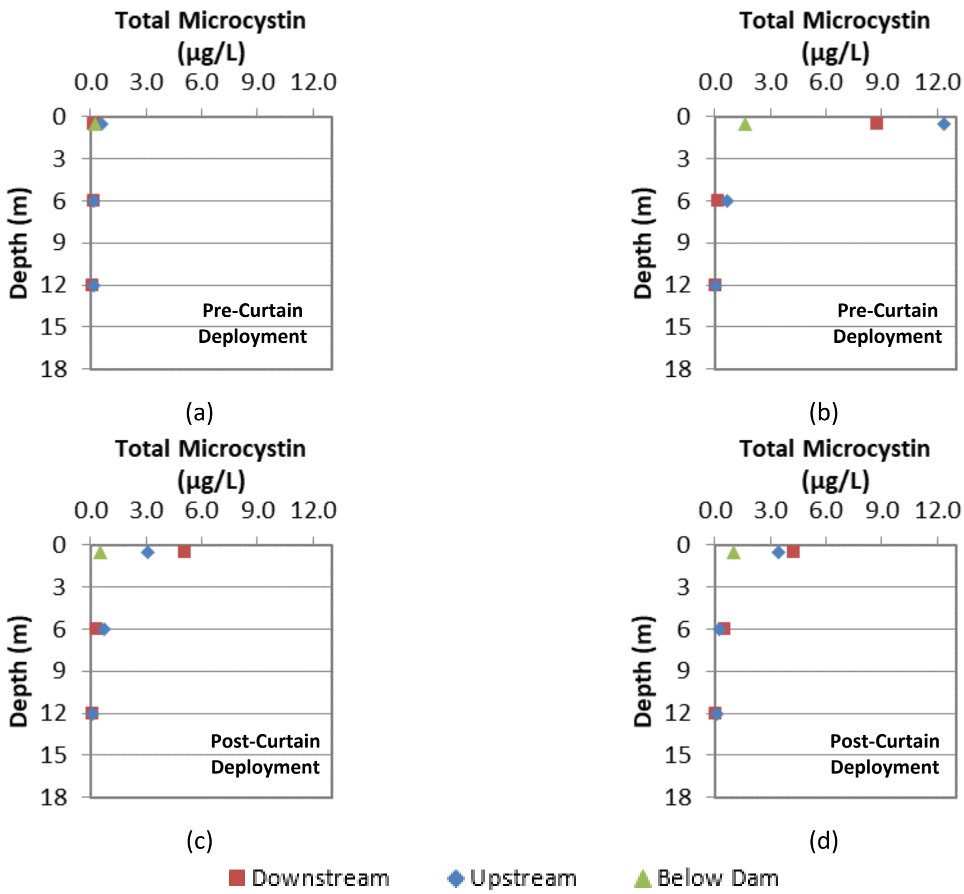



**Figure 5-34. Comparison of total microcystin vertical profiles upstream and downstream of curtain and below Iron Gate Dam on (a) July 5, (b) July 23, (c) July 26, and (d) August 2, 2018; (quantification limit is 0.15 µg/L).**

### 5.4.3.2 Filtered Microcystin

The relationship between total and filtered microcystin was similar to that observed in 2016 and 2017 and averaged approximately 20 to 30 percent of total microcystin concentrations when total microcystin concentrations were greater than or equal to 0.50 µg/L. Filtered microcystin concentrations (µg/L) were reduced from upstream to downstream of the curtain at 0.5-m depths for one pre-curtain date (July 23)

[34] Grab samples were analyzed for total chlorophyll-*a*, corrected chlorophyll-*a*, and pheophytin. Total chlorophyll-*a* results are presented.

and both dates following curtain deployment (July 26 and August 2) (Figure 5-35b-d). Concentrations between upstream of the curtain and downstream of the curtain water samples from other depths (6 m and 12 m) were similar for all collection dates (Figure 5-35). Concentrations of filtered microcystin in samples from the Klamath River downstream of Iron Gate Dam were similar to concentrations found in samples downstream of the curtain except on July 23 (prior to curtain deployment) when concentrations downstream of the dam are reduced compared to concentrations found at a depth of 0.5 m downstream of the curtain (Figure 5-35b).

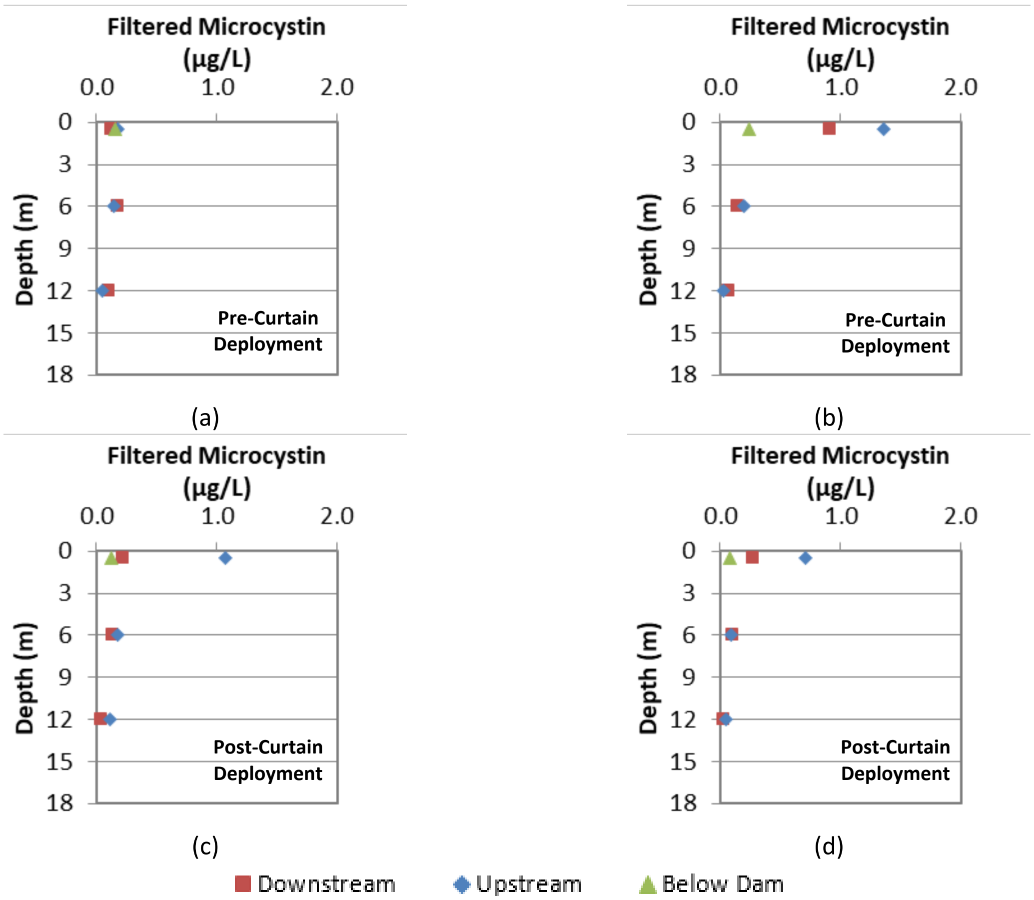



**Figure 5-35. Comparison of filtered microcystin vertical profiles upstream and downstream of curtain and below Iron Gate Dam on (a) July 5, (b) July 23, (c) July 26, and (d) August 2, 2018 (quantification limit is 0.15 µg/L).**

### 5.4.3.3 Total Cyanobacteria

Total cyanobacteria concentrations (genes/mL) in vertical profile grab samples collected prior to curtain deployment (July 5 and July 23) were similar between upstream and downstream of the curtain sites, except at the surface depth (0.5 m) on July 23 when concentrations were reduced downstream of the curtain (Figure 5-36). Total cyanobacteria concentrations in samples collected after curtain deployment (July 26 and August 2) were also reduced from upstream to downstream of the curtain at the surface depth (0.5 m) (Figure 5-36c and d). Concentrations between upstream of the curtain and downstream of the curtain samples from other depths (6 m and 12 m) were similar for all vertical profile collection dates. Total cyanobacteria concentrations in samples from the Klamath River downstream of Iron Gate Dam were similar to concentrations in samples collected downstream of the curtain (Figure 5-36).

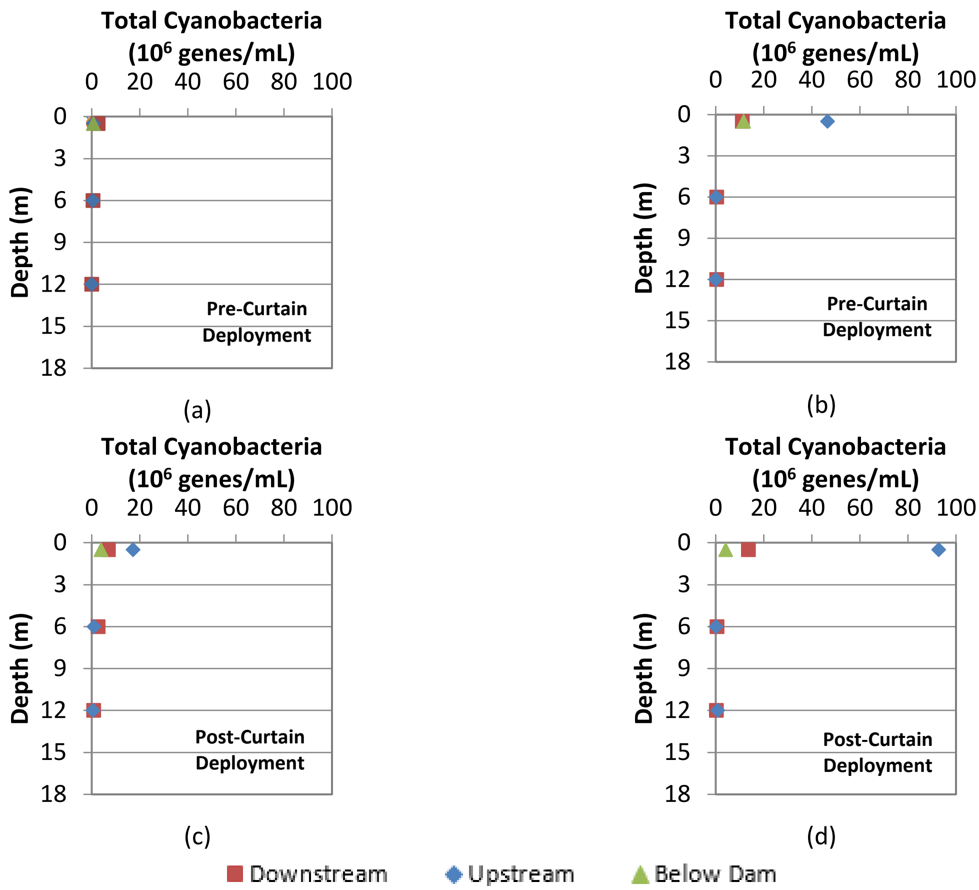



**Figure 5-36. Comparison of total cyanobacteria vertical profiles upstream and downstream of curtain and below Iron Gate Dam on (a) July 5, (b) July 23, (c) July 26, and (d) August 2, 2018 (quantification limit is 100 genes/mL).**

### 5.4.3.4 Total *Microcystis*

Total *Microcystis* concentrations (genes/mL) in vertical profile grab samples collected prior to curtain deployment (July 5 and July 23) were similar upstream and downstream of the curtain (Figure 5-37a and b). Total *Microcystis* concentrations in samples were not consistently reduced from upstream to downstream of the curtain sites after curtain deployment (July 26 and August 2), even in surface (0.5 m) samples (Figure 5-37c and d). Total *Microcystis* concentrations in samples from the Klamath River downstream of Iron Gate Dam were similar to concentrations in samples collected downstream of the curtain (Figure 5-37).

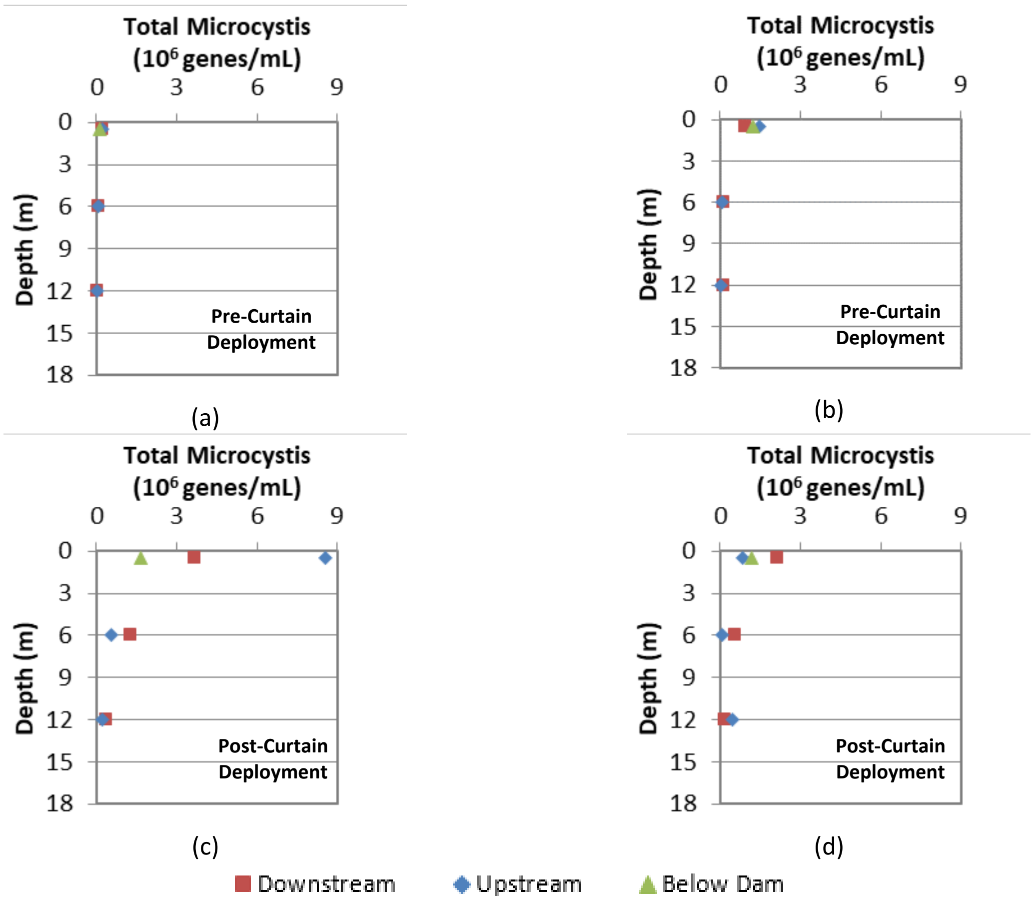



**Figure 5-37. Comparison of total *Microcystis* vertical profiles upstream and downstream of curtain and below Iron Gate Dam on (a) July 5, (b) July 23, (c) July 26, and (d) August 2, 2018 (quantification limit is 100 genes/mL).**

### 5.4.3.5 Total Chlorophyll-*a*

Total chlorophyll-*a* concentrations (µg/L) in vertical profile grab samples were similar between upstream to downstream of curtain sites prior to curtain deployment (July 5 and July 23), except at the surface depth (0.5 m) on July 23 where concentrations were reduced at the downstream of curtain site (Figure 5-38a and b). Total chlorophyll-*a* concentrations in samples were often but not always reduced from upstream to downstream curtain sites at near-surface depths (0.5 m, 1.5 m, and 3 m) during curtain deployment (July 26 and August 2) (Figure 5-38c and d). Total chlorophyll-*a* concentrations in samples from the Klamath River downstream of Iron Gate Dam are similar to concentrations in samples collected downstream of the curtain (Figure 5-38).

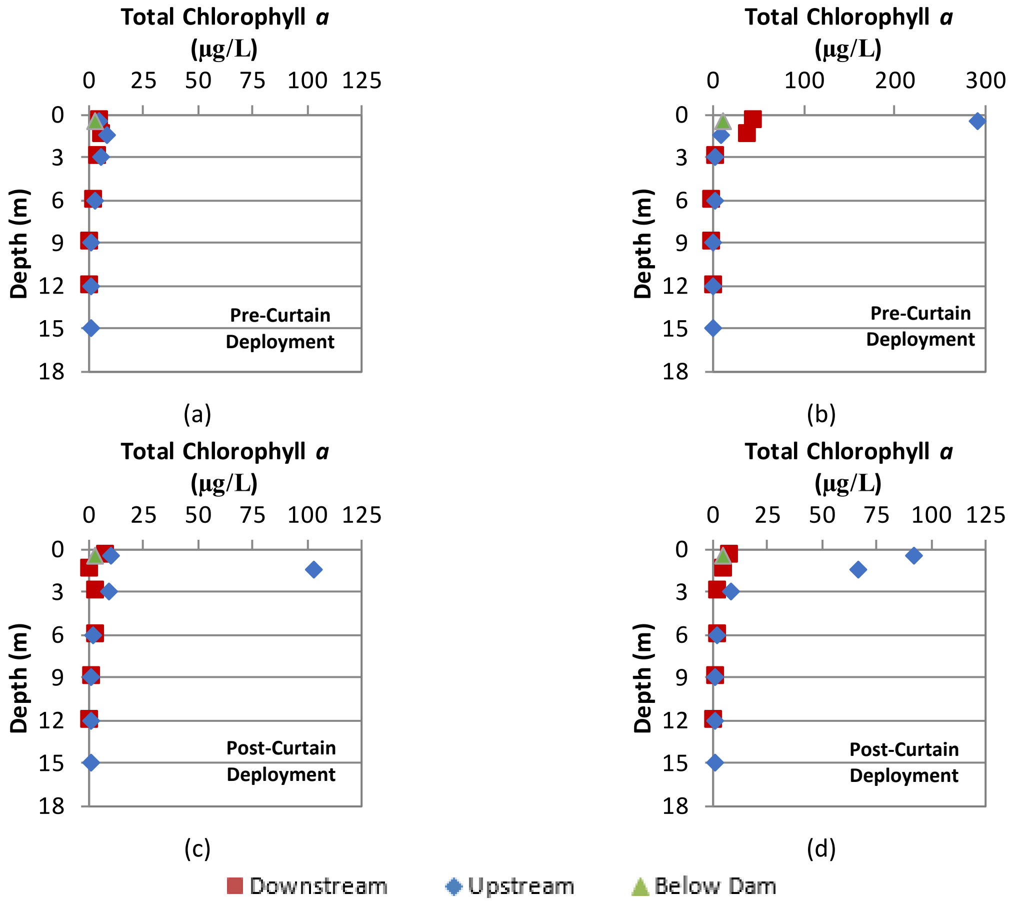



**Figure 5-38. Comparison of total chlorophyll-*a* vertical profiles upstream and downstream of curtain and below Iron Gate Dam on (a) July 5, (b) July 23 (Note the scale is different than in other total chlorophyll-*a* figures) (c) July 26, and (d) August 2, 2018 (quantification limit is 0.68 µg/L).**

### 5.4.3.6 Water Temperature

Water temperatures (°C) observed during vertical profiles were similar at sites upstream and downstream of the curtain prior to curtain deployment (Figure 5-39a and b). After the curtain had been deployed to 4.6 m on July 24, water temperatures were reduced from upstream to downstream of the curtain sites from the surfaced depth to approximately 3 m in depth (Figure 5-39c and d). Water temperature reduction ranged from approximately 1°C to 2°C during these periods and depth ranges. Water temperatures in the Klamath River downstream of Iron Gate Dam were approximately 22°C for the latter three dates (similar to water temperatures at the 4-m depth at the downstream of curtain site for July 23, July 26, and August 2).[35]

[35] The Klamathon fire started on July 5, 2018, in the nearby town of Hornbrook and forced the rapid evacuation of the field crew, which is why there were no data collected downstream of Iron Gate Dam on July 5, 2018.

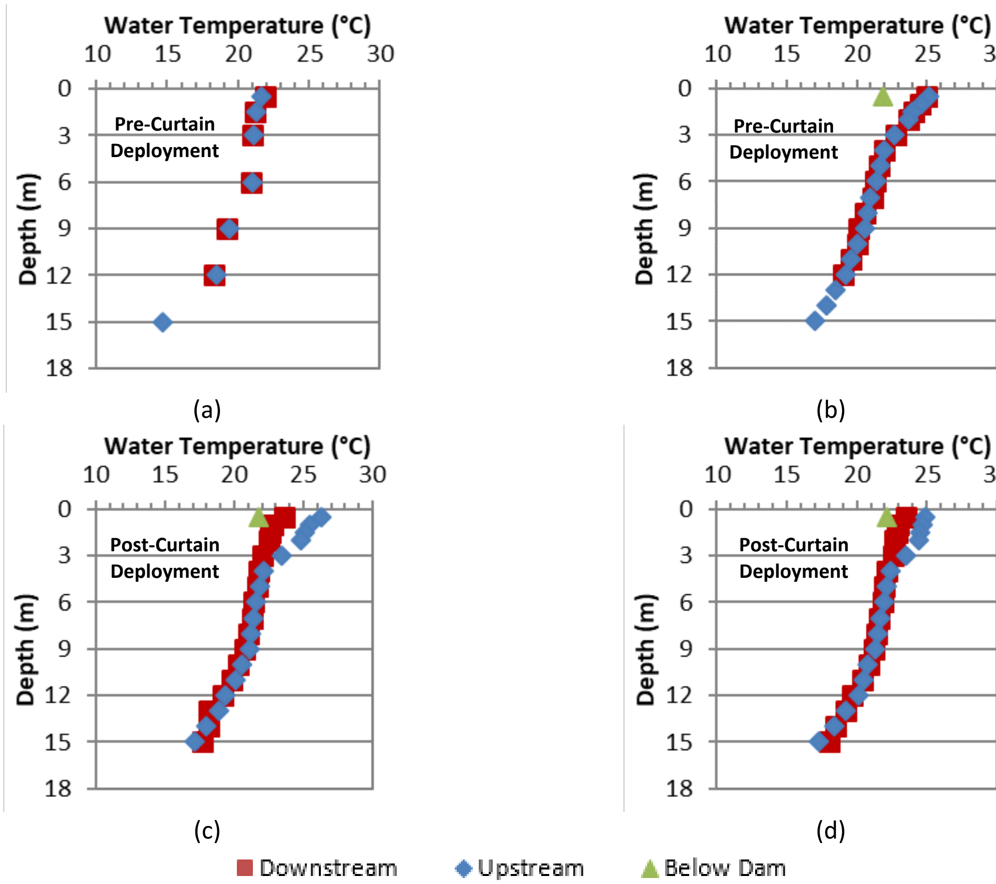



**Figure 5-39. Comparison of water temperature vertical profiles upstream and downstream of curtain on (a) July 5 (no data were collected downstream of Iron Gate Dam due to Klamathon fire evacuation), (b) July 23, (c) July 26, and (d) August 2, 2018.**

### 5.4.3.7 Dissolved Oxygen

Dissolved oxygen concentrations (mg/L) observed during vertical profiles were similar at sites upstream and downstream of the curtain prior to curtain deployment (Figure 5-40a and b). After the curtain had been deployed to 4.6 m on July 24, dissolved oxygen concentrations were reduced from upstream to downstream of the curtain sites from the surface depth to approximately 3 m to 5 m in depth (Figure 5-40c and d). Dissolved oxygen concentration reduction ranged from approximately 0.5 mg/L to 6.5 mg/L during these periods and depth ranges. Dissolved oxygen concentrations in the Klamath River downstream of Iron Gate Dam were greater than 8 mg/L for the latter three dates (Figure 5-40b-d).

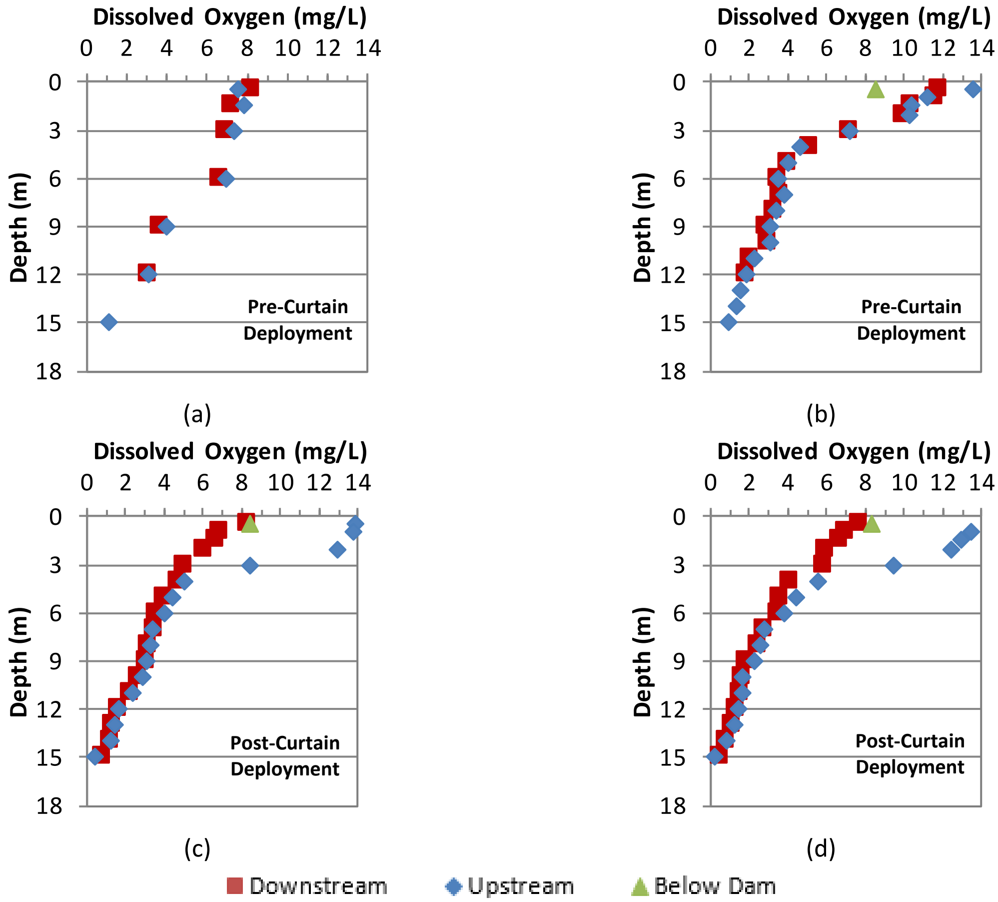



**Figure 5-40. Comparison of dissolved oxygen vertical profiles upstream and downstream of curtain on (a) July 5 (no data were collected downstream of Iron Gate Dam due to Klamathon fire evacuation), (b) July 23, (c) July 26, and (d) August 2, 2018.**

### 5.4.4 Secchi Depth

Secchi depths (m) observed during vertical profile sample collections in 2018 ranged from 0.85 m to 3.90 m between both upstream of the curtain and downstream of the curtain sites (Figure 5-41). Prior to curtain deployment, upstream of the curtain and downstream of the curtain Secchi depths were similar (3.65 m and 3.70 m at upstream of the curtain and downstream of the curtain sites, respectively). After curtain deployment, which coincided with increased concentrations of cyanobacteria, the downstream of the curtain Secchi depth was increased (clarity increased) by 2.05 m, 3.05 m, and 0.50 m on July 26, August 2, and August 16, respectively.

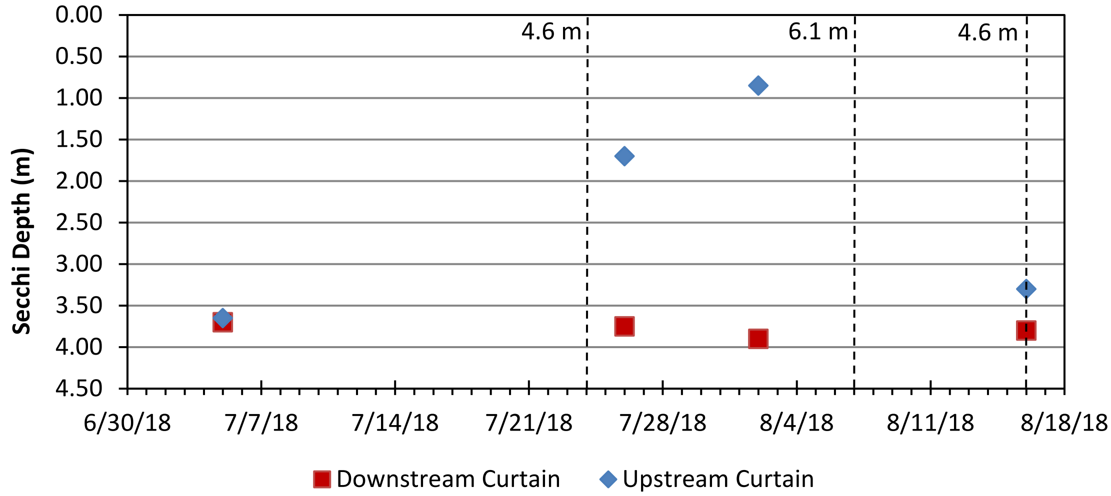



**Figure 5-41. Comparison of Secchi depth collected upstream and downstream of the curtain on July 5, July 26, August 2, and August 16, 2018 and deployed curtain depths (dashed line). Secchi depths were collected during the afternoon on August 16, 2018, while the curtain was furled to 4.6 m in the morning on August 16, 2018.**

## 5.4.5 Meteorological Data

Meteorological data collected in 2018 included air temperature, barometric pressure, relative humidity, precipitation, solar radiation, and wind speed (peak gusts, instantaneous, and average). The following discussion focuses on wind speed and air temperature data.

### 5.4.5.1 Wind Speed

Average 15-minute and daily average of the 15-minute average wind speeds (Figure 5-42) and monthly average 15-minute average wind speeds (Figure 5-24) demonstrate variation between subdaily, daily, and monthly averages. Daily average wind speeds were slower in 2018 than in 2015 or 2016 during the months of July and August (Figure 5-23 and Figure 5-24). Monthly average wind speeds were slower in 2018 than in 2015, 2016, or 2017 during the months of June, July, September, and October, and slower in 2018 than in 2015 and 2016 during the month of August (Figure 5-23 and Figure 5-24).

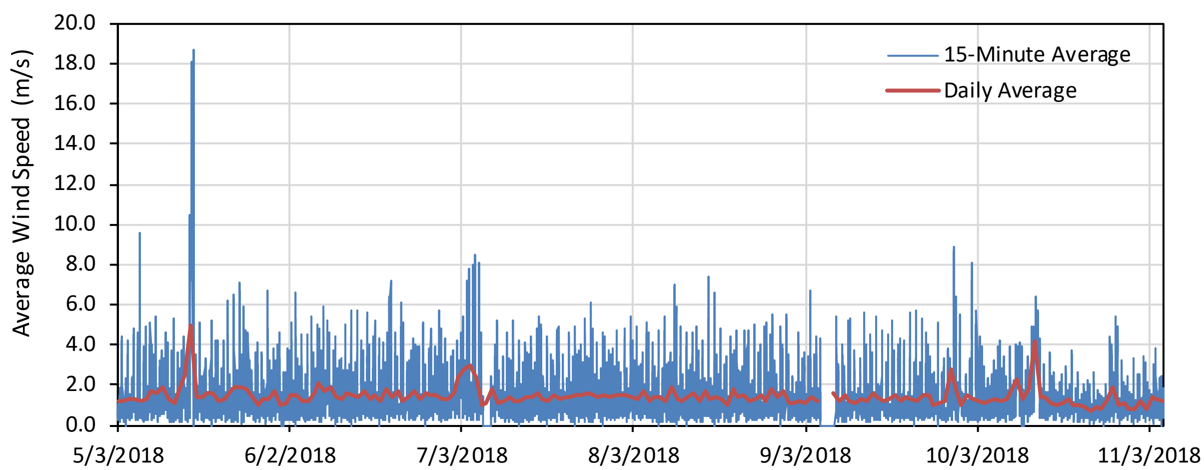



**Figure 5-42. 15-minute average and daily average of the 15-minute average wind speeds (m/s) at Iron Gate Dam from May 3 to November 6, 2018.**

### 5.4.5.2 Air Temperature

Air temperatures collected from the weather station at Iron Gate Dam represent short-term (subdaily to daily and multiple day) and long-term (monthly to seasonal) variations (Figure 5-43). Air temperatures increased gradually from mid to late June, peaking over 35°C in late July and early August before cooling gradually through the late summer and fall.

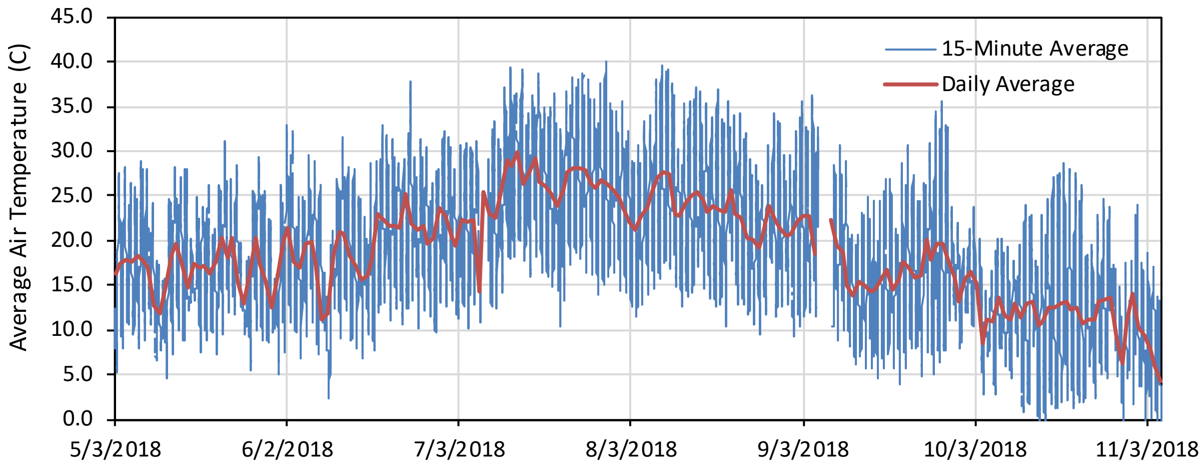



**Figure 5-43. 15-minute average and daily average of the 15-minute average air temperature (°C) at Iron Gate Dam from May 3 to November 6, 2018.**

# 6. Analysis and Discussion

The premise that the placement of a seasonal barrier curtain in Iron Gate Reservoir takes advantage of thermal stratification and associated vertical density differences in the water column and retains cyanobacteria in the near-surface waters within the reservoir while reducing releases of cyanobacteria and associated toxins to the downstream Klamath River was based on an understanding that:

- The majority of cyanobacteria resides in or near the surface waters (photic zone).
- Epilimnetic stratification minimizes mixing of surface waters with deeper epilimnetic waters.

As discussed in Section 3, three hypotheses were developed to frame the analysis characterizing the impacts of the dam on reducing cyanobacteria concentrations (in the absence of a curtain) and the impact of using a curtain to further reduce cyanobacteria concentrations.

- **H1**: The curtain is effective at reducing cyanobacteria loads in downstream waters by reducing the downstream movement of surface waters, which often contain high concentrations of cyanobacteria, from Iron Gate Reservoir into the Klamath River.
- **H2**: Iron Gate Dam, without a curtain present, provides some downstream reduction in cyanobacteria loads by reducing the downstream movement of surface waters, which often contain high concentrations of cyanobacteria, from Iron Gate Reservoir into the Klamath River.
- **H3**: The curtain in combination with Iron Gate Dam is effective at reducing cyanobacteria loads in downstream waters by reducing the downstream movement of surface waters, which often contain high concentrations of cyanobacteria, from Iron Gate Reservoir into the Klamath River.

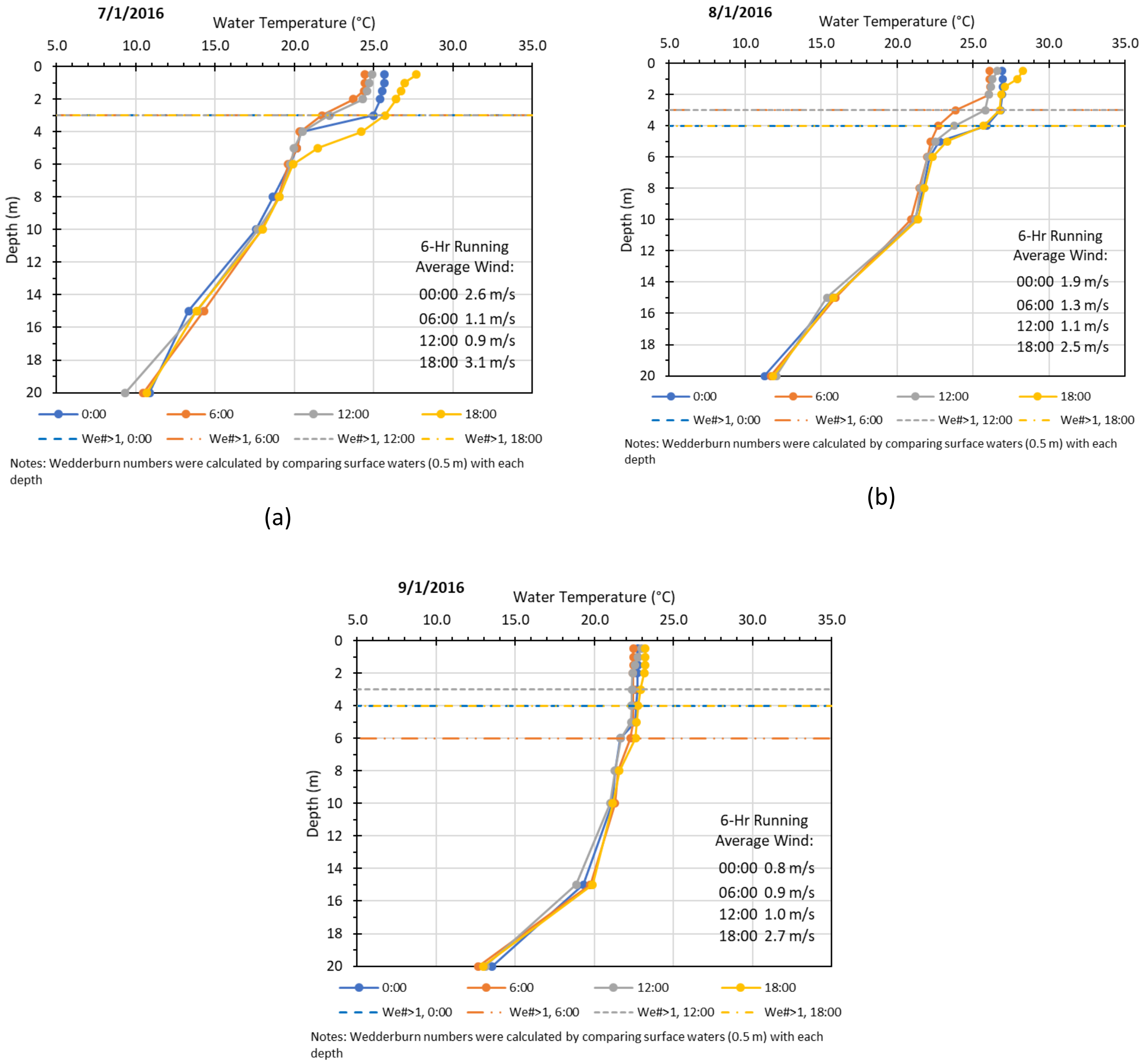
The role the barrier curtain and Iron Gate Dam play in reductions in cyanobacteria loads in the Klamath River downstream of the curtain and ultimately downstream of Iron Gate Dam is discussed herein. Data collected from 2015 through 2018 are employed in these analyses to integrate inter- and intra-annual variability over multiple years in order to assess overall curtain performance under a range of conditions.

## 6.1 Reduction in Downstream Loading Attributable to Curtain

Hypothesis 1, that the barrier curtain is effective at reducing the downstream movement of cyanobacteria by reducing the downstream movement of surface waters in the reservoir that would otherwise be released to downstream river reaches, was tested by comparing vertical profile grab sample data and sonde data collected within Iron Gate Reservoir at sites both upstream and downstream of the curtain during periods when the curtain was not deployed and when the curtain was deployed. When the curtain was deployed, effective curtain periods were determined based largely on *Wn* number analysis and curtain deployed data were sorted into three categories: high, medium, and low curtain effectiveness. The medium and low curtain effectiveness ratings were combined for analysis (Section 4.3.1.2).

### 6.1.1 Effective Curtain Periods

Effective curtain periods were determined through *Wn* calculations based on field data for 2016 through 2018 as described in Section 4.3.1.1. Generally, stratification and stability in the epilimnion occurred at shallower depths in July through mid-August (Figure 6-1a and b), after which stratification weakened with stability generally occurring at deeper depths (Figure 6-1c)**.** Thus, effective curtain depth depended on the depth and stability of epilimnetic stratification. While there are subdaily changes in the mixed layer due to thermal exchange at the air-water interface and wind patterns, the aforementioned seasonal conditions are typically consistent among years. Additional thermal profiles and *Wn* numbers by depth are provided in Appendix A.




(c)

**Figure 6-1. Thermal profiles at 6-hour intervals and 6-hour running average wind speeds with horizontal lines indicating the first sample depth where *Wn* > 1 for (a) July 1, (b) August 1, and (c) September 1, 2016.**

To assess stability of epilimnetic stratification, the percent time that *Wn* numbers were less than 1.0 (unstable) at depths of 3 m, 4 m, 5 m, 6 m, 8 m, and 10 m (suggesting that the mixed layer extended to each of these depths) upstream of the curtain was calculated for semimonthly and monthly periods for 2016 through 2018 (Table 6-1).[36] From July through August, stratification was generally shallower and stronger, as indicated by the relatively shallow depths at which stable conditions occurred (i.e., *Wn* >1.0).

[36] The number of hours with unstable *Wn* numbers was summed and divided by the total number of hours within each period. Insufficient water temperature data precluded the calculation for 2015 and early June 2016.

**Table 6-1. Percent of time with unstable *Wn* at upstream of the curtain depths 3 m, 4 m, 5 m, 6 m, 8 m, and 10 m for (a) semimonthly and (b) monthly periods, 2016 through 2018. Highlighting in red, yellow, and none denote sequentially less mixing.* Solid blue lines denote the curtain deployment depths and dates.**

| Period | | Percent of time that *Wn* was less than 1 (unstable) at depths: | | | | | |
|---|---|---|---|---|---|---|---|
| | | 3 m | 4 m | 5 m | 6 m | 8 m | 10 m |
| Start | End | Mixed for (% of time): | | | | | |
| (a) Semimonthly | | | | | | | |
| 6/1/16 | 6/15/16 | ------ Insufficient data for this period ----- | | | | | |
| 6/16/16 | 6/30/16 | 38% | 19% [6/28 4.6 m] | 12% | 4.2% [6/30 7.6 m] | 0.3% | 0.0% |
| 7/1/16 | 7/15/16 | 35% | 17% | 7.8% | 1.9% | 0.0% [7/12 9.1 m] | 0.0% [7/19 10.7 m] |
| 7/16/16 | 7/31/16 | 32% | 6.3% | 2.3% | 0.0% | 0.0% | 0.0% |
| 8/1/16 | 8/15/16 | 30% | 7.2% | 1.7% | 0.3% | 0.0% | 0.0% |
| 8/16/16 | 8/31/16 | 45% | 19% | 9.1% | 4.4% [8/23 6.1 m] | [8/22 7.6 m] 0.0% | 0.0% |
| 9/1/16 | 9/15/16 | 75% | 79% | 51% | 20% | 4.2% | 1.7% |
| 9/16/16 | 9/30/16 | 52% [9/29 3.0 m] | 29% | 17% | 4.4% | 0.0% | 0.0% |
| 10/1/16 | 10/15/16 | 74% | 64% | 57% | 44% | 31% | 23% |
| 10/16/16 | 10/31/16 | [11/9 1.5 m] 90% | 83% | 81% | 72% | 60% | 51% |
| 6/5/17 | 6/15/17 | 78% | 61% | 50% | 36% | 11% | 4.4% |
| 6/16/17 | 6/30/17 | 28% | 9.4% | 4.7% | 0.6% | 0.0% | 0.0% |
| 7/1/17 | 7/15/17 | 14% | 5.8% | 1.7% | 0.3% | 0.0% | 0.0% |
| 7/16/17 | 7/31/17 | 8.1% | 0.5% | 0.0% | 0.0% [7/25 7.6 m] | 0.0% | 0.0% |
| 8/1/17 | 8/15/17 | [8/11 1.5 m] 20% [8/10 3.0 m] | 4.7% [8/4 4.6 m] | 1.1% | 0.3% | 0.0% | 0.0% |
| 8/16/17 | 8/31/17 | 11% [8/28 3.0 m] | 1.6% | 0.3% | 0.0% | 0.0% | 0.0% |
| 9/1/17 | 9/15/17 | 90% | 66% | 50% | 39% | 27% | 16% |
| 9/16/17 | 9/30/17 | [9/21 1.5 m] 71% | 57% | 47% | 37% | 27% | 16% |
| 10/1/17 | 10/15/17 | 83% | 74% | 68% | 58% | 40% | 28% |
| 10/16/17 | 10/31/17 | 79% | 65% | 53% | 42% | 31% | 22% |
| 6/1/18 | 6/15/18 | 47% | 23% | 12% | 3.1% | 0.0% | 0.0% |
| 6/16/18 | 6/30/18 | 45% | 19% | 9.2% | 1.9% | 0.0% | 0.0% |
| 7/1/18 | 7/15/18 | 41% | 22% | 15% | 11% | 1.4% | 0.3% |
| 7/16/18 | 7/31/18 | 11% | 0.3% [7/24 4.6 m] | 0.0% | 0.0% | 0.0% | 0.0% |
| 8/1/18 | 8/15/18 | 19% | 2.2% | 0.3% | 0.0% [8/7 6.1 m] | 0.0% | 0.0% |
| 8/16/18 | 8/31/18 | 46% | 16% [8/16 4.6 m] | 6.5% | 0.8% | 0.0% | 0.0% |
| 9/1/18 | 9/15/18 | 95% | 54% | 36% | 19% | 3.3% | 0.3% |
| 9/16/18 | 9/30/18 | 58% | 39% | 30% | 17% [9/27 6.1 m] | 3.1% | 0.3% |
| 10/1/18 | 10/15/18 | 89% | 75% | 66% | 51% | 28% | 22% |
| 10/16/18 | 10/31/18 | [11/7 1.5 m] 68% | 48% | 39% | 26% | 11% | 3% |
| (b) Monthly | | | | | | | |
| Jun-2016 | Deploy 28th | ------ Insufficient data for this period ----- | | | | | |
| Jul-2016 | | 33% | 11% | 5.0% | 0.9% | 0.0% | 0.0% |
| Aug-2016 | | 38% | 13% | 5.5% | 2.4% | 0.0% | 0.0% |
| Sep-2016 | | 63% | 54% | 34% | 12% | 2.1% | 0.8% |
| Oct-2016 | | 82% | 74% | 69% | 59% | 46% | 37% |
| Jun-2017 | | 39% | 24% | 18% | 12% | 3.3% | 1.4% |
| Jul-2017 | Deploy 25th | 11% | 3.1% | 0.8% | 0.1% | 0.0% | 0.0% |
| Aug-2017 | | 16% | 3.1% | 0.7% | 0.1% | 0.0% | 0.0% |
| Sep-2017 | | 80% | 61% | 49% | 38% | 27% | 16% |
| Oct-2017 | | 81% | 69% | 60% | 50% | 35% | 25% |
| Jun-2018 | | 46% | 21% | 11% | 2.5% | 0.0% | 0.0% |
| Jul-2018 | Deploy 24th | 26% | 11% | 7.1% | 5.1% | 0.7% | 0.1% |
| Aug-2018 | | 33% | 9.4% | 3.5% | 0.4% | 0.0% | 0.0% |
| Sep-2018 | | 77% | 47% | 33% | 18% | 3.2% | 0.3% |
| Oct-2018 | | 78% | 61% | 52% | 38% | 19% | 12% |

* Key: ≤ 10.0% (no highlighting), >10.0% and ≤20.0% (yellow highlighting) and >20.0% (red highlighting).

## ANALYSIS AND DISCUSSION

Potential mixing of the surface waters to depths were calculated based on the percent mixing time for all years combined (Table 6-2). General guidelines for the effectiveness of various curtain depths through the summer season can be developed based on this information. For example, a minimum curtain depth of approximately 4 m would preclude mixing of surface waters under the curtain approximately 10 percent of the time or less in late July through early August.

**Table 6-2. Potential mixing of surface waters to depth, based on percent of time with unstable *Wn* numbers averaged for 2016 through 2018 semimonthly periods at upstream of the curtain depths 3 m, 4 m, 5 m, 6 m, 8 m, and 10 m.**

| | Percent of Time Mixing Occurs to Depth | | | |
|---|---|---|---|---|
| **Period (All Years)*** | **0.0 %** | **>0.0% and ≤10.0%** | **>10.0% and ≤20.0%** | **>20.0%** |
| June 16 to June 30 | 10 m | 5 m | 4 m | 3 m |
| July 1 to July 15 | - | 5 m | 4 m | 3 m |
| July 16 to July 31 | 6 m | 4 m | 3 m | - |
| August 1 to August 15 | 8 m | 4 m | - | 3 m |
| August 16 to August 31 | 8 m | 5 m | 4 m | 3 m |
| September 1 to September 15 | - | 10 m | 8 m | 6 m |
| September 16 to September 30 | - | 8 m | 6 m | 5 m |
| October 1 to October 15 | - | - | - | 10 m |
| October 16 to October 31 | - | - | - | 10 m |

* All three years (2016, 2017, and 2018) were assessed.

Throughout most of each season for 2016 through 2018, the curtain depth was less than the design depth of 10.7 m in part because deployment to deeper depths reduces levels of dissolved oxygen in water released to the Klamath River downstream of Iron Gate Dam. However, the analysis of percentage of effective time (using *Wn*) by depth indicates that many of these shallower deployment depths were still at effective depths (Table 6-1). Specific conclusions by year include:

a. In 2016, the curtain was generally effective (Table 6-1) at a deployment depth equal to or greater than 6.1 m from the end of June through August (Figure 5-1). Though the curtain remained at 6.1 m through the end of September, effectiveness decreased slightly in early September when mixing to 6 m occurred approximately 20 percent of the time in the first half of the month. Subsequently in late September, the curtain remained effective at 6.1 m. At the end of September low dissolved oxygen conditions in the Klamath River downstream of Iron Gate Dam required that the curtain be raised to 3 m, a less effective depth for retaining cyanobacteria in the near-surface waters within the reservoir, and the curtain was not effective during the month of October (Figure 6-2). Even if the curtain had been deployed to design depth in October, it would have only been effective 77 to 49 percent of the time (Table 6-1).

b. In 2017, the curtain was deployed to 7.6 m on July 25th and was generally effective, even after it was raised to 4.6 m in early August to manage dissolved oxygen conditions. The curtain was further raised to 3.0 m and then to 1.5 m within a week because of persistent low dissolved oxygen conditions downstream of Iron Gate Dam (Figure 6-3). By the end of August, dissolved oxygen conditions allowed the curtain to be lowered to 3.0 m where it remained through September 21, although mixing down to 3 to 4 m occurred approximately 57 to 90 percent of the time in early and late September (Table 6-1). From late September through October, the curtain remained fully furled at 1.5 m to minimize any curtain effects on dissolved oxygen conditions in the river (Figure 6-3).

c. In 2018, the curtain was generally effective once deployed in late July to a depth of 4.6 m and remained effective at 6.1 m in early August. Curtain effectiveness was reduced in late August when the curtain was raised to 4.6 m to manage dissolved oxygen concentrations in the river downstream of Iron Gate Dam (Figure 6-4). By late September, the curtain was lowered to 6.1 m, where it remained until it was fully furled in early November (depth of 1.5 m). However, based on the *Wn* values, the late September and October deployment depth (6.1 m) was a less effective depth (with mixing occurring to this depth for 26 to 51 percent of the time) for retaining cyanobacteria in the near-surface waters within the reservoir.

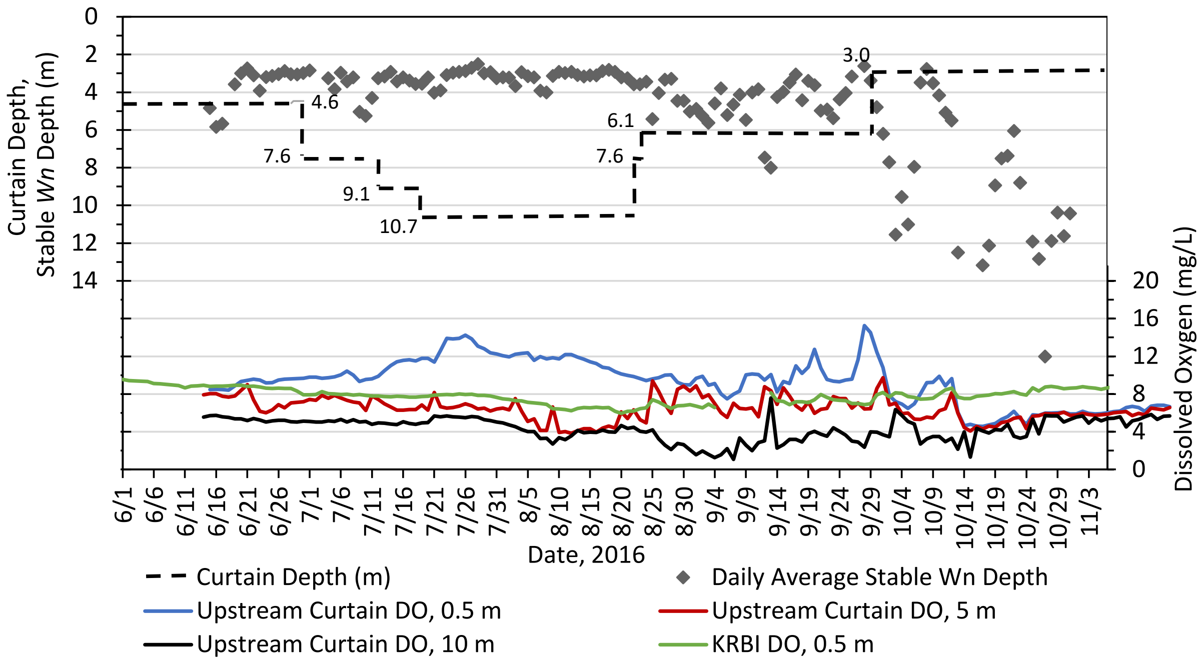



**Figure 6-2. 2016 average daily effective curtain depth (Wn >1), deployed curtain depths (m), and average dissolved oxygen (mg/L) in Iron Gate Reservoir upstream of the curtain at depths of 0.5 m, 5 m, and 10 m, and Klamath River below Iron Gate (KRBI) at 0.5 m.**

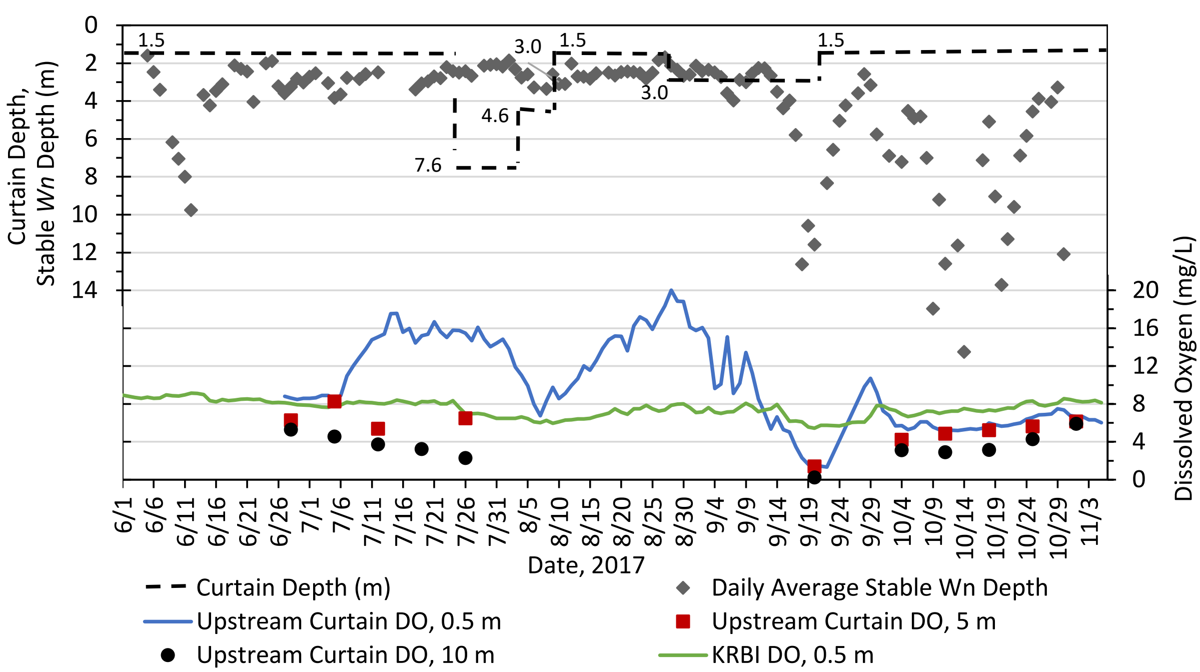



**Figure 6-3. 2017 average daily effective curtain depth (Wn >1), deployed curtain depths (m), and average dissolved oxygen (mg/L) in Iron Gate Reservoir upstream of the curtain at 0.5-m, 5-m, and 10-m depths, and Klamath River below Iron Gate (KRBI) at 0.5 m.**

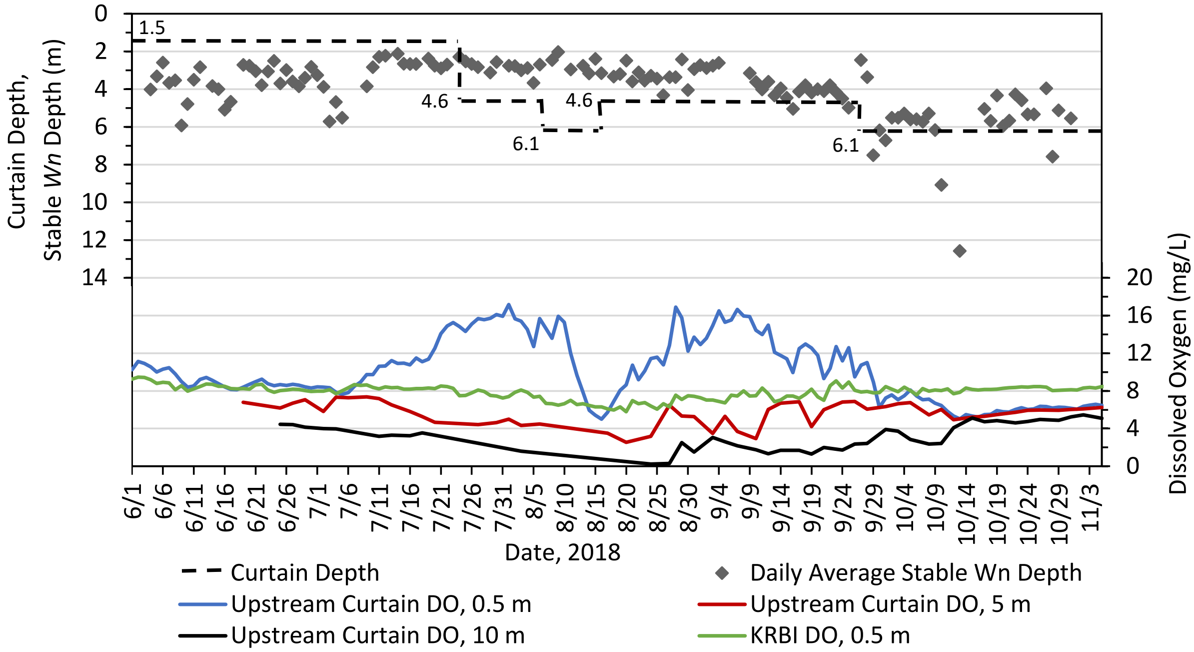



**Figure 6-4. 2018 average daily effective curtain depth (Wn >1), deployed curtain depths (m), and average dissolved oxygen (mg/L) in Iron Gate Reservoir upstream of the curtain at 0.5-m, 5-m, and 10-m depths, and Klamath River below Iron Gate (KRBI) at 0.5 m.**

In general, the curtain became less effective when not used at the design depth of 10.7 m. If the curtain had been consistently deployed to the design depth it would have prevented the downstream movement of the mixed upper layer (which contains elevated concentrations of cyanobacteria) during June, July, and August for greater than 90 percent of the deployment period and in September at least 84 percent of the deployment period. Mixing occurred often in October, even to a depth of 10 m. Therefore, the design depth of 10.7 m may not be as effective in October unless stratification persists at or above this depth such as in late October 2018.

Curtain deployment to depths greater than the mixed layer depth (Condition 1 in Figure 4-2) represents deployment depths that would have been deeper than the yellow highlighted cells in Table 6-1 when epilimnetic stratification existed. Periods that matched Condition 1 were defined as “high effectiveness.” Deployment of the curtain to deeper depths results in more water from deeper in the water column moving below the curtain (Watercourse 2016) and this deeper water has lower levels of dissolved oxygen (Figure 6-5). Dissolved oxygen concentrations upstream and downstream of the curtain converge between 6 m and 9 m when the curtain was deployed to a depth of 7.6 m (Figure 6-5b-e). PacifiCorp is required to manage the Klamath River downstream of Iron Gate Dam to meet specific dissolved oxygen targets to protect Coho Salmon (PacifiCorp 2012; NMFS 2012). Because of this, persistent low levels of dissolved oxygen in the river required that the curtain be raised to depths that were not only shallower than design depth, but at times shallower than the mixed layer depth, resulting in less effective deployment depths (Conditions 2 or 3 in Figure 4-2). Conditions 2 and 3 are represented by the yellow and red highlighted cells in Table 6-1 when epilimnetic stratification existed, and are defined as “medium/low effectiveness.” In subsequent sections, these definitions are used to assess curtain performance in retaining cyanobacteria in the near-surface waters of Iron Gate Reservoir and reducing releases of cyanobacteria and associated toxins to the downstream Klamath River.

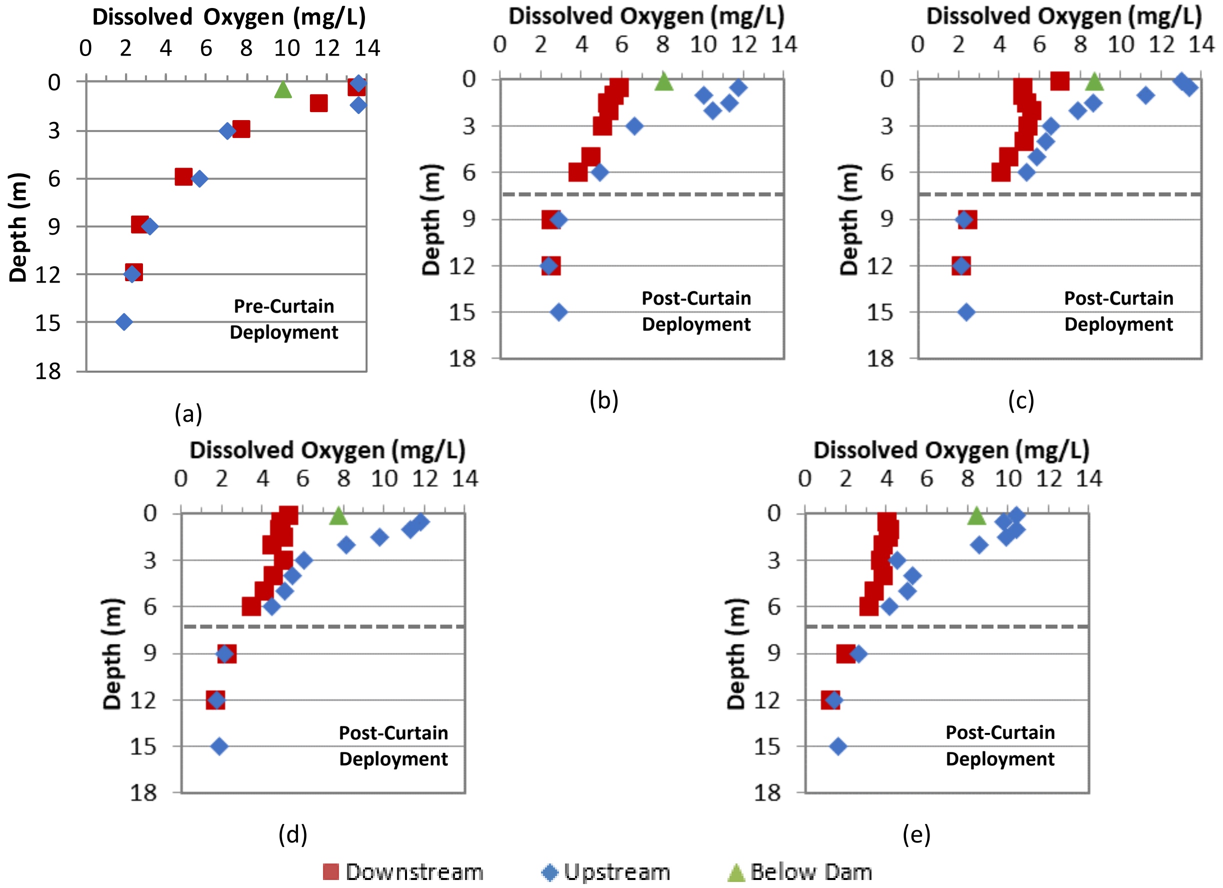



**Figure 6-5. Comparison of dissolved oxygen concentrations from data collected in vertical profiles upstream and downstream of the curtain and downstream of Iron Gate Dam on (a) July 24 (b) July 25 (c) July 26 (d) July 27 and (e) August 3, 2017. Horizontal dashed lines indicate curtain deployment depth on each date.**

## 6.1.2 Vertical Profile Grab Sample Analysis

Vertical profile grab sample data within Iron Gate Reservoir for total chlorophyll-*a*, total microcystin, total *Microcystis*, and total cyanobacteria upstream and downstream of the curtain were analyzed under different levels of curtain effectiveness, based on calculated *Wn*. Specifically, reductions associated with “high” and “medium/low” curtain effectiveness levels were assessed.

Vertical profile grab samples from the upstream and downstream of the curtain sites were paired (same date, sample depth) and compared for periods when the curtain was not deployed and during curtain deployments in 2015 through 2018. Total chlorophyll-*a*, total microcystin, total *Microcystis*, and total cyanobacteria sample pairs were categorized based on curtain effectiveness (high or medium/low) and sample depth (Section 4.3.1.2). Some sample pairs could not be categorized.[37] Additionally, some curtain deployed sample pairs were collected from a depth below the depth of the deployed curtain and were excluded from analysis because there was no barrier between these upstream and downstream of the curtain sample sites. Because there were a limited number of sample pairs at any one depth, grab sample pairs from various depths were combined for each effectiveness category. For total chlorophyll-*a*, total microcystin, total *Microcystis*, and total cyanobacteria there were a total of 109, 97, 67, and 67 sample pairs, respectively, with 84, 78, 48, and 48 being post-curtain sample pairs (Table

[37] Examples include insufficient data to determine *Wn* numbers and/or stratification conditions, or the 0- to 8-m integrated sample crossed the boundary between mixed layer depth or curtain deployment depth.

6-3). Of these post-curtain sample pairs, only those that were shallower than the depth of the deployed curtain and where sufficient data were available for *Wn* calculations (48, 44, 33, and 33, respectively) were assigned a curtain effectiveness rating. An additional 25, 19, 19, and 19 sample pairs collected when the curtain was not deployed were available and analyzed for total chlorophyll-*a*, total microcystin, total *Microcystis*, and total cyanobacteria, respectively.

**Table 6-3. 2015-2018 upstream and downstream of the curtain grab sample pairs.**

| Curtain Status, Curtain Effectiveness | Total Sample Pairs (*n*) by Constituent | | | |
|---|---|---|---|---|
| | Total Chlorophyll-*a* | Total Microcystin | Total *Microcystis* | Total Cyanobacteria |
| Deployed, high* | 31 | 30 | 22 | 22 |
| Deployed, medium/low* | 19 | 16 | 11 | 11 |
| Deployed, below curtain or not categorized | 34 | 32 | 15 | 15 |
| Not Deployed | 25 | 19 | 19 | 19 |
| Total | 109 | 97 | 67 | 67 |

* Only the sample pairs where the sample depth is shallower than the deployed curtain depth were considered in this analysis.

#### 6.1.2.1 Total Chlorophyll-*a*

A total of 109 sample pairs were collected with and without the curtain deployed in 2015 through 2018 and analyzed for total chlorophyll-*a* (Table 6-3). Of those, 75 sample pairs were used to assess the effectiveness of the curtain on chlorophyll-*a* concentrations with the sign and Wilcoxon signed-rank test results (see methods in Section 4.3.1.2. The EXO total algae sensorfor each effectiveness category (high and medium/low) and for sample pairs collected when the curtain was not deployed. There appeared to be a threshold effect where sample pairs with greater chlorophyll-*a* concentrations upstream of the curtain demonstrated greater reduction, or demonstrated reduction more often from upstream to downstream of the curtain. Therefore, sample pairs with upstream of the curtain concentrations of less than 5 µg/L chlorophyll-*a* were removed from the sample set and the statistical tests repeated.

**High Effectiveness**

Under the high effectiveness category, all 31 sample pairs demonstrated reduction in total chlorophyll-*a* concentrations when comparing the upstream and downstream of the curtain samples, with an average reduction of 76.2 µg/L (bias = -76.2 µg/L, Table 6-4). For this group of sample pairs collected during high effectiveness periods, there was a significant reduction in total chlorophyll-*a* concentrations from upstream to downstream of the curtain (p=0.000 for both tests) (Table 6-4). Chlorophyll-*a* concentrations upstream of the curtain remained significantly greater than downstream of the curtain even with the 25 percent uncertainty factor applied (Table 6-4, Figure 6-6).

For all 28 sample pairs with upstream of the curtain concentrations greater than 5 µg/L, the outcome was the same (p=0.000 for both tests), with an average reduction of 84.3 µg/L (Table 6-5).

**Medium/Low Effectiveness**

Under the medium/low effectiveness category, the effectiveness of the curtain was less consistent than under the high effectiveness category. The majority of the sample pairs (17 out of 19) showed a reduction in total chlorophyll-*a* concentrations (average reduction was 7.25 µg/L) from upstream to downstream of the curtain (Table 6-4, Figure 6-7). For this group of sample pairs collected during medium/low effectiveness periods, the sign and Wilcoxon signed-rank tests indicated that there was a significant reduction in chlorophyll-*a* concentrations from the upstream to downstream of the curtain sites (p=0.000 and 0.002, respectively). However, when the uncertainty factory (25 percent) was applied, the relationship switches and the majority of the sample pairs (10 out of 19) demonstrated an increase in total chlorophyll-*a* concentrations from upstream to downstream of the curtain, although this increase is not significant (p=0.409 and p=0.345 for sign and Wilcoxon signed-rank tests, respectively) (Table 6-4, Figure 6-7).

For the 11 sample pairs with upstream of the curtain concentrations greater than 5 µg/L, the outcome was similar, with a significant reduction from upstream to downstream of the curtain prior to (p=0.003 and p=0.010, for sign and Wilcoxon signed-rank tests, respectively) but not after (p=0.182 and p=0.268, for sign and Wilcoxon signed-rank tests, respectively) the uncertainty factor was applied, and an average reduction of 11.8 µg/L downstream of the curtain (Table 6-5). The conclusion is that when epilimnetic stratification conditions fall into the medium/low effectiveness category, the curtain depth was insufficient to consistently reduce chlorophyll-*a* concentrations downstream of the curtain and hence, in the river downstream of the dam.

### Curtain Not Deployed

As would be expected, the results comparing 25 sample pairs collected when the curtain was not deployed did not indicate a significant reduction (p=0.420 and p=0.355 for sign and Wilcoxon signed-rank tests, respectively) in chlorophyll-*a* concentrations from samples collected upstream to those collected downstream of the curtain (Table 6-4, Figure 6-8). For the 13 sample pairs with upstream of the curtain concentrations greater than 5 µg/L, the outcome was similar, with no significant reduction (p=0.291 and p=0.211 for sign and Wilcoxon signed-rank tests, respectively) in chlorophyll-*a* concentrations from samples collected upstream to those collected downstream of the curtain (Table 6-5). With the curtain fully furled, total chlorophyll-*a* concentrations in samples upstream and downstream of the curtain would be expected to be similar and not statistically different.

**Table 6-4. Number of sample pairs, hypothesized direction of difference, and sign and Wilcoxon signed-rank test results for each curtain effectiveness status at sample depth category for total chlorophyll-*a*. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| Curtain Status, curtain effectiveness | Sample Pairs (n) | Sign Test Results | | Wilcoxon Signed-Rank Test Results | | Mean Bias (mean Δ from UC to DC, µg/L) |
|---|---|---|---|---|---|---|
| | | Without uncertainty factor | Including uncertainty factor | Without uncertainty factor | Including uncertainty factor | |
| Deployed, high | 31 | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | -76.2 |
| Deployed, medium/low | 19 | **UC>DC, p=0.000** | DC>UC, p=0.409* | **UC>DC, p=0.002** | DC>UC, p=0.345* | -7.25 |
| Not deployed | 25 | UC>DC, p=0.420 | N/A | UC>DC, p=0.355 | N/A | -10.7 |

UC – upstream of curtain, DC – downstream of curtain, N/A – not applicable because p>0.05 without uncertainty factor.

* The relationship changes the outcome with the uncertainty factor applied, with more pairs demonstrating an increase in concentration from the upstream of curtain to the downstream of curtain site (DC>UC). Therefore, there is no reduction from the upstream of the curtain to the downstream of the curtain site after the uncertainty factor is applied.

**Table 6-5. Number of sample pairs, hypothesized direction of difference, and sign and Wilcoxon signed-rank test results for each curtain effectiveness status at sample depth category for total chlorophyll-*a* sample pairs with upstream curtain chlorophyll-*a* concentration at or above 5 µg/L. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| Curtain Status, curtain effectiveness | Sample Pairs (n) | Sign Test Results | | Wilcoxon Signed-Rank Test Results | | Mean Bias (mean Δ from UC to DC, µg/L) |
|---|---|---|---|---|---|---|
| | | Without 25% uncertainty factor | Including uncertainty factor | Without uncertainty factor | Including uncertainty factor | |
| Deployed, high | 28 | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | -84.3 |
| Deployed, medium/low | 11 | **UC>DC, p=0.003** | UC>DC, p=0.183 | **UC>DC, p=0.010** | UC>DC, p=0.268 | -11.8 |
| Not deployed | 13 | UC>DC, p=0.291 | N/A | UC>DC, p=0.211 | N/A | -20.8 |

UC – upstream of curtain, DC – downstream of curtain, N/A – not applicable because p>0.05 without uncertainty factor.

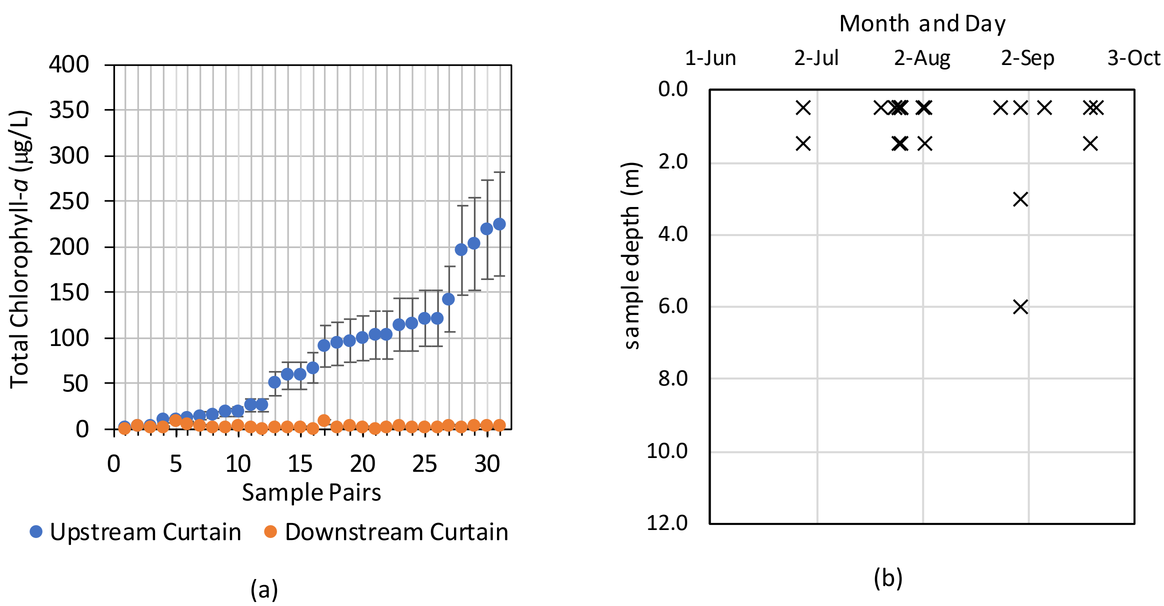



**Figure 6-6. (a) Total chlorophyll-*a* concentrations (µg/L) and uncertainty factors (error bars) for 31 sample pairs collected upstream and downstream of the curtain at different depths during periods categorized with high curtain effectiveness and (b) sample depth by date.**

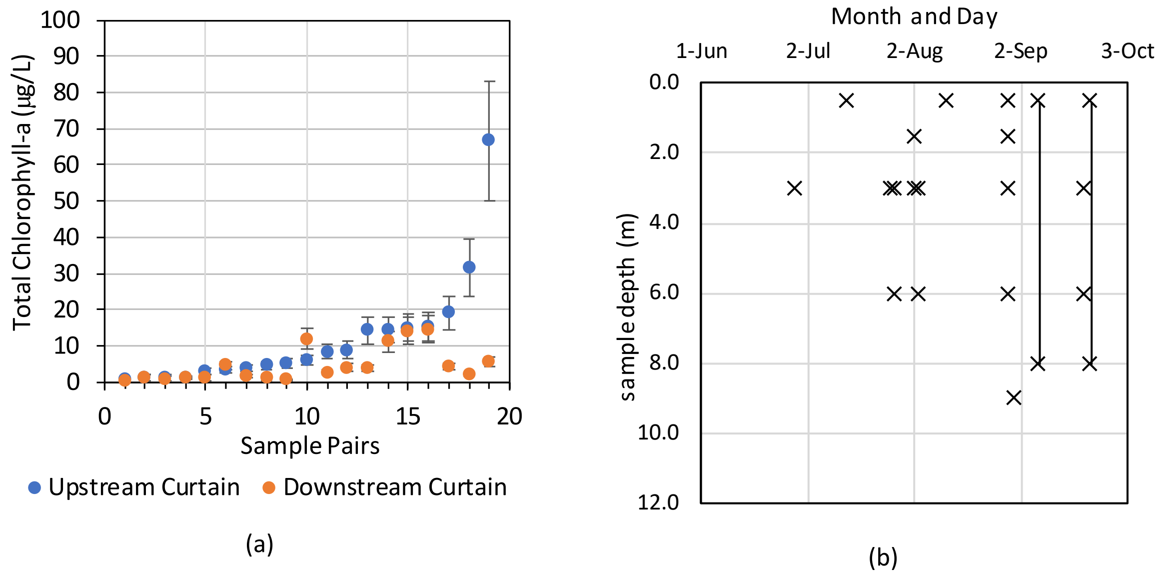



**Figure 6-7. (a) Total chlorophyll-*a* concentrations (µg/L) and uncertainty factors (error bars) for 19 sample pairs collected upstream and downstream of the curtain at different depths during periods categorized with medium/low curtain effectiveness and (b) sample depth by date (vertical line denotes integrated sample from 0 to 8 m).**

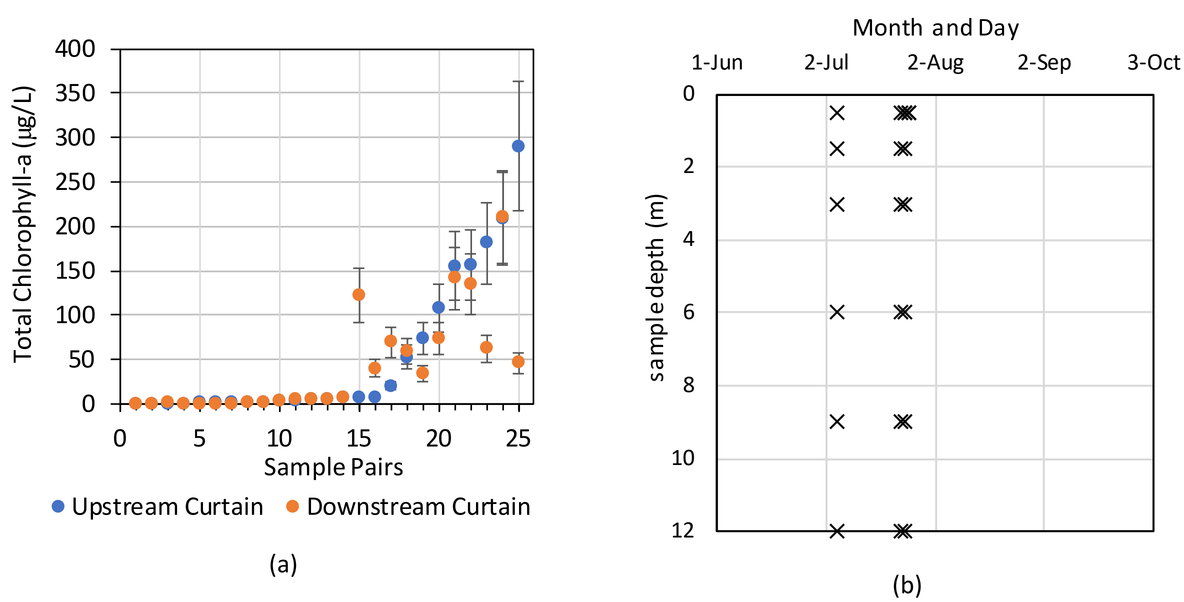



**Figure 6-8. Total chlorophyll-*a* concentrations (µg/L) and uncertainty factors (error bars) for 25 sample pairs collected upstream and downstream of the curtain at different depths when the curtain was not deployed and (b) sample depth by date.**

#### 6.1.2.2 Total Microcystin

A total of 97 sample pairs were collected with and without the curtain deployed in 2015 through 2018 and analyzed for total microcystin (Table 6-3). Of those, 65 sample pairs were used to assess the effectiveness of the curtain on reducing microcystin concentrations downstream of Iron Gate Dam with the sign and Wilcoxon signed-rank test results for each effectiveness category (high and medium/low), along with sign and Wilcoxon signed-rank test results for samples collected when the curtain was not deployed.

**High Effectiveness**

Under the high effectiveness category, 26 out of 30 sample pairs demonstrated reduction in total microcystin concentrations when comparing samples from upstream to downstream of the curtain, with an average reduction of 1.47 µg/L (Table 6-6, Figure 6-9). For this group of sample pairs collected during high effectiveness periods, total microcystin concentrations were significantly reduced (p=0.000 for both tests) from upstream of the curtain to downstream of the curtain sites. Reduction remained significant for this group even with the 25 percent uncertainty factor applied (p=0.050 and p=0.021 for sign and Wilcoxon signed-rank tests, respectively) (Table 6-6).

**Medium/Low Effectiveness**

Under the medium/low effectiveness category, the effectiveness of the curtain was less consistent than the high effectiveness category. The majority of the sample pairs (10 out of 16) experienced a reduction in total microcystin concentrations with an average reduction of 0.73 µg/L downstream of the curtain (Table 6-6, Figure 6-10). The sign test indicated a significant difference while the Wilcoxon signed-rank test did not (p=0.026 and p=0.099, respectively) from upstream to downstream of the curtain for this group (Table 6-6). When the uncertainty factor was applied, the relationship switches and the majority of the sample pairs (12 out of 16) demonstrated an increase in total microcystin concentrations downstream of the curtain (Table 6-6). Collectively this indicates that in the medium/low effectiveness category, the curtain depth was insufficient to consistently reduce microcystin concentrations in the river downstream of the curtain and hence, in the river downstream of the dam.

**Curtain Not Deployed**

When the curtain was not deployed, total microcystin concentrations were generally less in samples downstream of the curtain than upstream of the curtain (13 out of 19 sample pairs, average reduction of 0.54 µg/L) and there was a significant reduction (p=0.025 and p=0.026 for sign and Wilcoxon signed-rank tests, respectively) in total microcystin concentrations from upstream to downstream of the curtain (Table 6-6, Figure 6-11). When the uncertainty factory (25 percent) was applied, the relationship switches and the majority of the sample pairs (11 out of 19) demonstrated an increase in total microcystin concentrations downstream of the curtain, with the difference no longer significant under either test (p=0.241 and p=0.158 for the sign and Wilcoxon signed-rank tests, respectively) (Table 6-6).

**Table 6-6. Number of sample pairs, hypothesized direction of difference, and sign and Wilcoxon signed-rank test results for each curtain effectiveness status at sample depth category for total microcystin sample pairs. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| Curtain Status, curtain effectiveness | Sample Pairs (n) | Sign Test Results | | Wilcoxon Signed-Rank Test Results | | Mean Bias (mean Δ from UC to DC, µg/L) |
|---|---|---|---|---|---|---|
| | | Without uncertainty factor | Including uncertainty factor | Without uncertainty factor | Including uncertainty factor | |
| Deployed, high | 30 | **UC>DC, p=0.000** | **UC>DC, p=0.050** | **UC>DC, p=0.000** | **UC>DC, p=0.021** | -1.47 |
| Deployed, medium/low | 16 | **UC>DC, p=0.026** | DC>UC, p=0.023* | UC>DC, p=0.099 | N/A | -0.73 |
| Not deployed | 19 | **UC>DC, p=0.025** | DC>UC, p=0.241* | **UC>DC, p=0.026** | DC>UC, p=0.158* | -0.54 |

UC – upstream of curtain, DC – downstream of curtain, N/A – not applicable because p>0.05 without uncertainty factor.

* The relationship changes the outcome with the uncertainty factor applied, with more pairs demonstrating an increase in concentration from the upstream of curtain to the downstream of curtain site (DC>UC). Therefore, there is no reduction from the upstream of the curtain to the downstream of the curtain site after the uncertainty factor is applied.

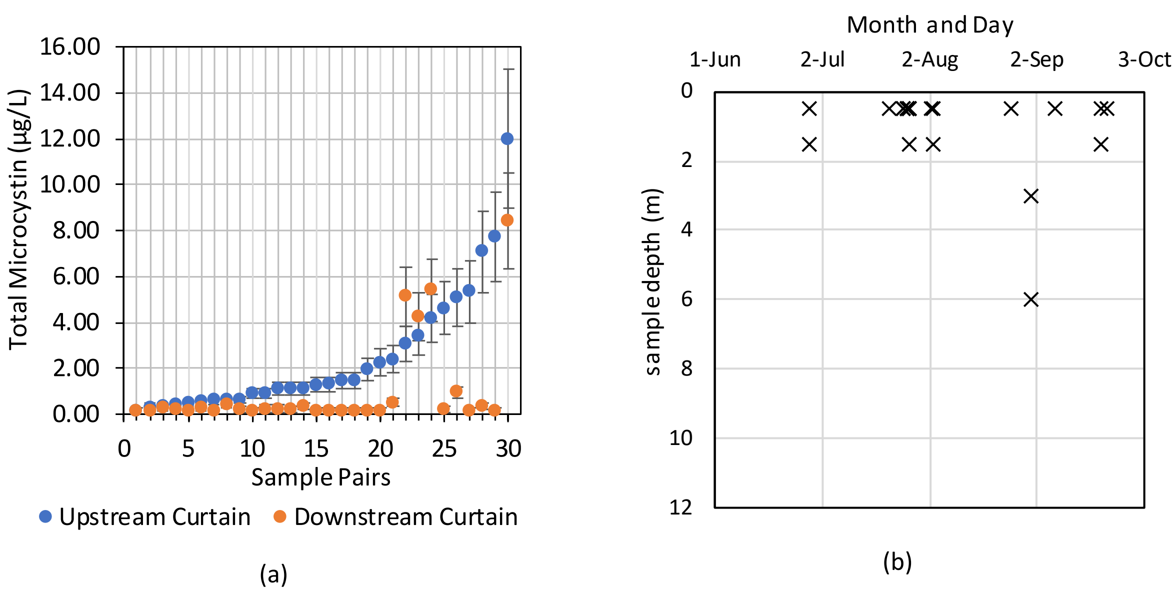



**Figure 6-9. (a) Total microcystin concentrations (µg/L) and uncertainty factors (error bars) for 30 sample pairs collected upstream and downstream of the curtain at different depths during periods categorized with high curtain effectiveness and (b) sample depths by date.**

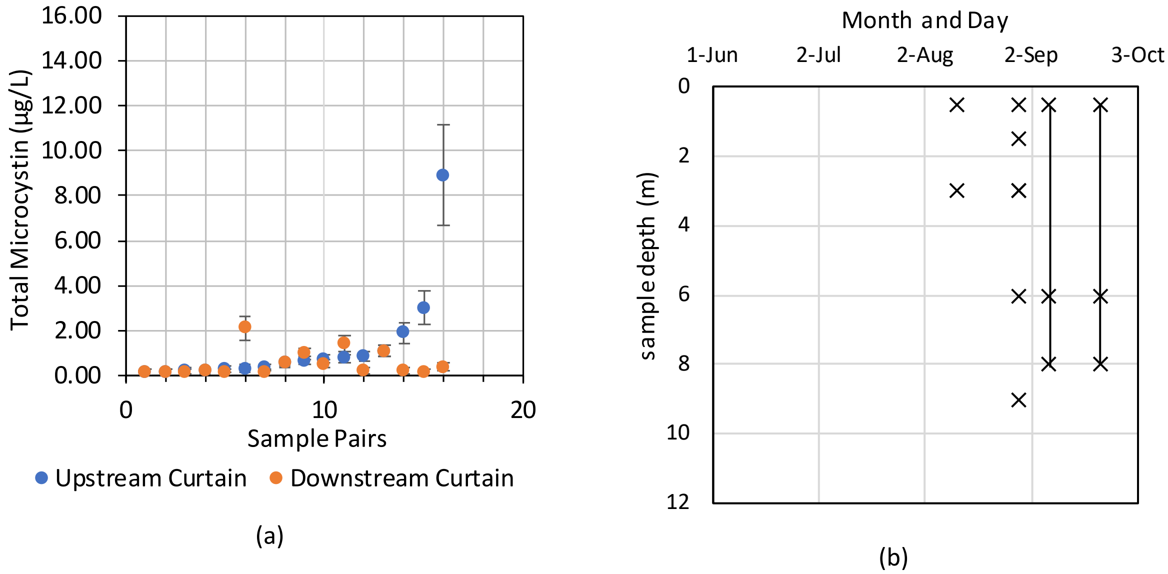



**Figure 6-10. (a) Total microcystin concentrations (µg/L) and uncertainty factors (error bars) for 16 sample pairs collected upstream and downstream of the curtain at different depths during periods categorized with medium/low curtain effectiveness and (b) sample depths by date (vertical line denotes integrated sample from 0 to 8 m).**

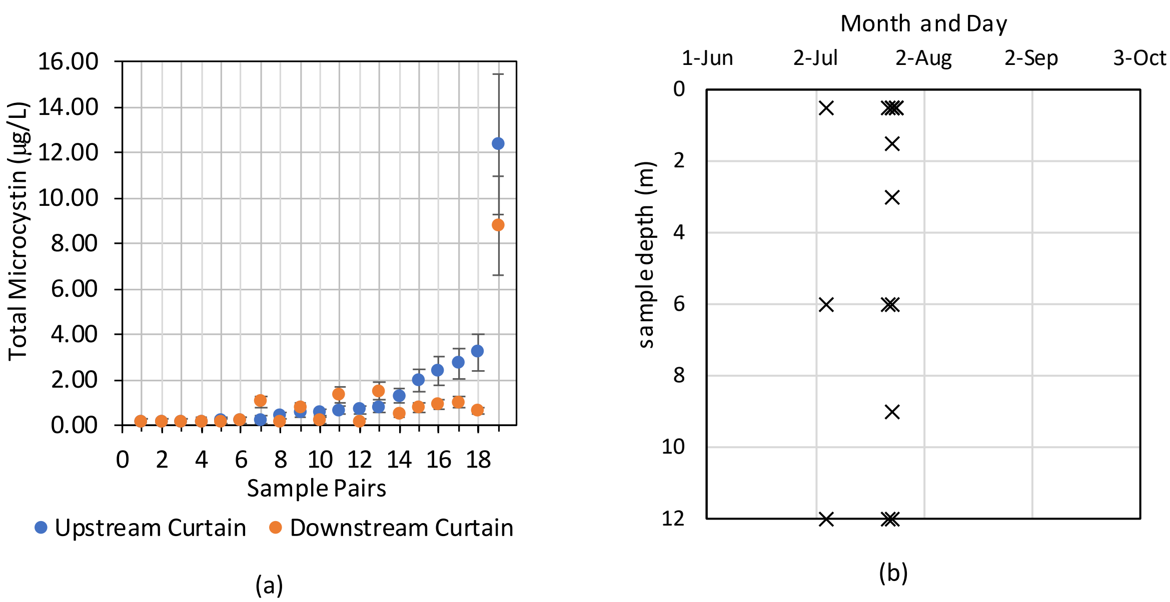



**Figure 6-11. (a) Total microcystin concentrations (µg/L) and uncertainty factors (error bars) for 19 sample pairs collected upstream and downstream of the curtain at different depths when the curtain was not deployed and (b) sample depths by date.**

In California, public health advisories are posted based on different total microcystin concentrations; the initial posting threshold is reached when total microcystin[38] concentrations exceed 0.8 µg/L (SWRCB 2016). A number of the sample pairs above had total microcystin concentrations that were below the 0.8 µg/L threshold. To assess the impacts of the curtain on periods when there were public health advisories, the analysis was repeated, but with only those sample pairs where the upstream concentration was 0.8 µg/L or greater (Table 6-7).

Removing all samples when the upstream curtain total microcystin value was less than 0.8 μg/L did not change the outcome, although p-values were altered and the number of sample pairs was reduced such that curtain not deployed pairs and medium/low curtain effectiveness and curtain not deployed pairs were close to (*n*=5 and *n*=6, respectively) or at the minimum number of pairs needed to perform the sign and Wilcoxon signed-rank test (*n*=5 for sign test and *n*=6 for Wilcoxon signed-rank test) (Table 6-7). For the group of sample pairs collected during high effectiveness periods (*n* = 21), upstream of the curtain total microcystin concentrations were significantly greater than downstream of the curtain total microcystin concentrations (p=0.001 for both tests), even after the uncertainty factor was applied (p=0.004 and p=0.037 for sign and Wilcoxon signed-rank tests, respectively) (Table 6-7). For the group of sample pairs collected during medium/low effectiveness periods (*n*=5), the majority of upstream of the curtain total microcystin concentrations were greater than downstream of the curtain sample concentrations (4 out of 5 with one tie), and the sign test indicated there was a significant difference in concentrations between sites upstream and downstream of the curtain before (p=0.023) but not after (p=0.090) the uncertainty was applied (Table 6-7). For the group of sample pairs collected when the curtain was not deployed (*n*=6), the tests indicated that upstream of the curtain total microcystin concentrations were initially significantly greater than downstream of the curtain sample concentrations (p=0.016 and p=0.014 for sign and Wilcoxon signed-rank tests, respectively); however, when the uncertainty factor was applied, the tests indicated that reduction in concentrations from upstream to downstream of the curtain sites was not significant (p=0.110 and p=0.173 for sign and Wilcoxon signed-rank tests, respectively) (Table 6-7).

**Table 6-7. Number of sample pairs, hypothesized direction of difference, and sign and Wilcoxon signed-rank test results for each curtain effectiveness status at sample depth category for total microcystin sample pairs with upstream curtain microcystin concentration at or above 0.80 μg/L. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| Curtain Status, curtain effectiveness | Sample Pairs (n) | Sign Test Results | | Wilcoxon Signed-Rank Test Results | | Mean Bias (mean Δ from UC to DC, μg/L) |
|---|---|---|---|---|---|---|
| | | Without uncertainty factor | Including uncertainty factor | Without uncertainty factor | Including uncertainty factor | |
| Deployed, high | 21 | **UC>DC, p=0.001** | **UC>DC, p=0.004** | **UC>DC, p=0.001** | **UC>DC, p=0.037** | -2.01 |
| Deployed, medium/low | 5 | **UC>DC, p=0.023** | UC>DC, p=0.090 | **Sample size too low to test** | | -2.73 |
| Not deployed | 6 | **UC>DC, p=0.016** | UC>DC, p=0.110 | **UC>DC, p=0.014** | UC>DC, p=0.173 | -1.89 |

UC – upstream of curtain, DC – downstream of curtain, N/A – not applicable because p>0.05 without uncertainty factor.

The curtain has approximately the same overall performance when assessing only those sample pairs where the upstream concentration was 0.8 μg/L or greater as when assessing all sample pairs. When the curtain effectiveness is high, the curtain is able to retain the water with high concentrations of microcystin upstream of the barrier, thereby reducing release of this water downstream into the Klamath River. When the curtain's effectiveness is in the medium/low category, the curtain is often not deployed to a deep enough depth to consistently reduce total microcystin concentrations in the area downstream of the curtain area and subsequently, the river downstream of the dam.

---

[38] The term "total" is used throughout this report to distinguish the total concentration of microcystin in the water sample in contrast to the free (not cell-bound) microcystin in the water sample. Although not analyzed in public health samples, filtrate from 2015-2018 samples collected upstream and downstream of the curtain were analyzed for free microcystin, are not included in this analysis, but are presented as "filtered microcystin" with concentrations reported in Sections 5.3.3.2 and 5.4.3.2.

#### 6.1.2.3 Total *Microcystis*

A total of 67 sample pairs were collected with and without the curtain deployed in 2015 through 2018 and analyzed for total *Microcystis* (Table 6-3). Of those, 52 sample pairs were used to assess the effectiveness of the curtain on reducing total *Microcystis* concentrations. The total *Microcystis* sign and Wilcoxon signed-rank test results for each effectiveness category (high and medium/low), along with sign and Wilcoxon signed-rank test results for samples collected when the curtain was not deployed, are discussed in the following sections.

**High Effectiveness**

Under the high effectiveness category, 21 out of 22 sample pairs demonstrated reduction in total *Microcystis* concentrations when comparing samples from upstream and downstream of the curtain, with an average reduction of 754,225 gene copies/mL (Table 6-8, Figure 6-12). For this group of sample pairs collected during high effectiveness periods, reduction of total *Microcystis* concentrations from upstream to downstream of the curtain was significant (p=0.000 for both tests); reduction remained significant even with the 25 percent uncertainty factor applied (p=0.000 and p=0.001 for sign and Wilcoxon signed-rank tests, respectively) (Table 6-8).

**Medium/Low Effectiveness**

The majority of the medium/low effectiveness sample pairs (8 out of 11) experienced a reduction in downstream *Microcystis* concentrations (average reduction was 114,260 gene copies/mL) (Table 6-8, Figure 6-13). The sign test results did not indicate a significant reduction in *Microcystis* concentrations (p=0.114) from upstream to downstream of the curtain for this group, while the Wilcoxon signed-rank test did (p=0.013) (Table 6-8). When the uncertainty factor was applied, the Wilcoxon signed-rank test indicated reduction in *Microcystis* concentrations from upstream to downstream of the curtain was no longer significant (p=0.212) (Table 6-8). Consistent with the other analysis, these results indicate that curtain depths under periods of medium or low effectiveness are insufficient to consistently reduce total *Microcystis* concentrations downstream of the curtain and hence in the river downstream of the dam.

**Curtain Not Deployed**

When the curtain was not deployed, approximately half (9 out of 19) of the samples from downstream of the curtain had total *Microcystis* concentrations less than samples from upstream of the curtain while approximately half (10 out of 19) were exactly the opposite with concentrations in samples from downstream of the curtain being greater than upstream of the curtain (Figure 6-14). As would be expected, the test results for the group of sample pairs collected while the curtain was fully-furled did not indicate a significant change (p=0.500 and p=0.374 for sign and Wilcoxon signed-rank tests, respectively) in total *Microcystis* concentrations between the upstream and downstream of the curtain sites (Table 6-8). With the curtain fully furled, the upstream and downstream total *Microcystis* concentrations would be expected to be similar and not statistically different (Figure 6-14).

**Table 6-8. Number of sample pairs, hypothesized direction of difference, and sign and Wilcoxon signed-rank test results for each curtain effectiveness status at sample depth category for total *Microcystis* sample pairs. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| Curtain Status, curtain effectiveness | Sample Pairs (n) | Sign Test Results | | Wilcoxon Signed-Rank Test Results | | Mean Bias (mean Δ from UC to DC, copies/mL) |
|---|---|---|---|---|---|---|
| | | Without uncertainty factor | Including uncertainty factor | Without uncertainty factor | Including uncertainty factor | |
| Deployed, high* | 22 | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.001** | -754,225 |
| Deployed, medium/low | 11 | UC>DC, p=0.114 | N/A | **UC>DC, p=0.013** | UC>DC, p=0.212 | -114,260 |
| Not deployed | 19 | DC>UC, p=0.500 | N/A | DC>UC, p=0.374 | N/A | -14,981 |

UC – upstream of curtain, DC – downstream of curtain, N/A – not applicable because p>0.05 without uncertainty factor.

* All 30 sample pairs had an upstream curtain total *Microcystis* concentration above 20,000 gene copies/mL.

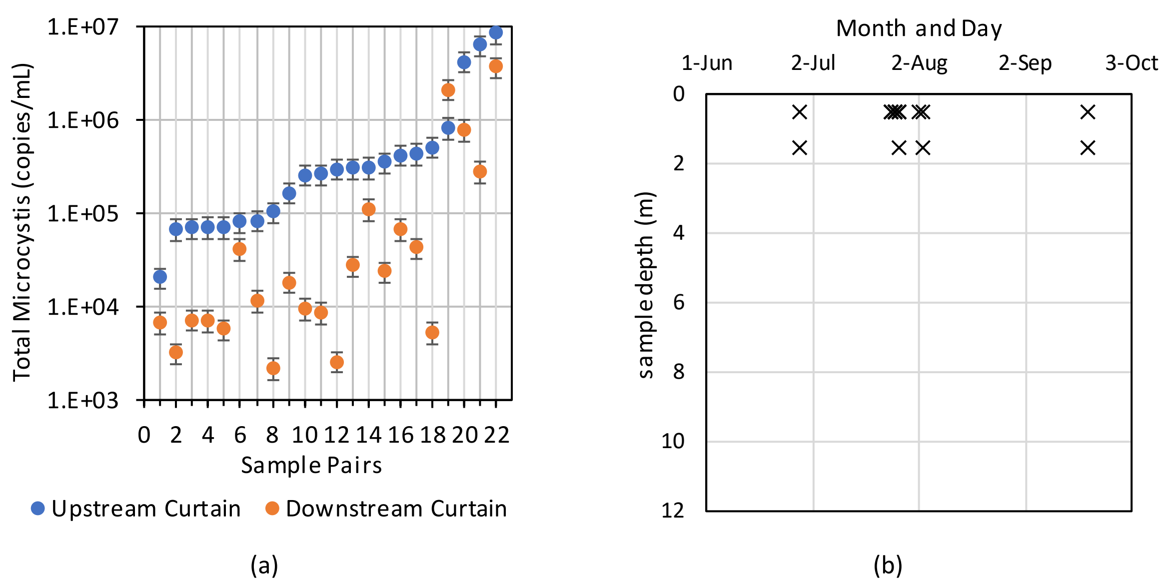



**Figure 6-12. (a) Total *Microcystis* concentrations (gene copies/mL) and uncertainty factors (error bars) for 22 sample pairs collected upstream and downstream of the curtain at different depths and periods categorized with high curtain effectiveness and (b) sample depth by date.**

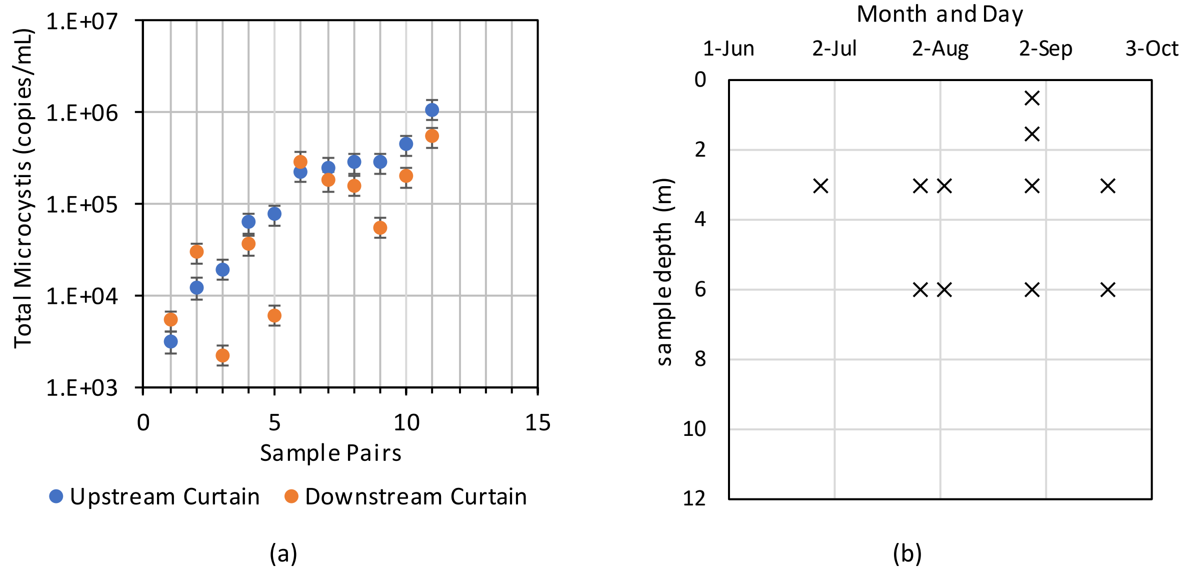



**Figure 6-13. (a) Total *Microcystis* concentrations (gene copies/mL) and uncertainty factors (error bars) for 11 sample pairs collected upstream and downstream of the curtain at different depths during periods categorized with medium/low curtain effectiveness and (b) sample depth by date.**

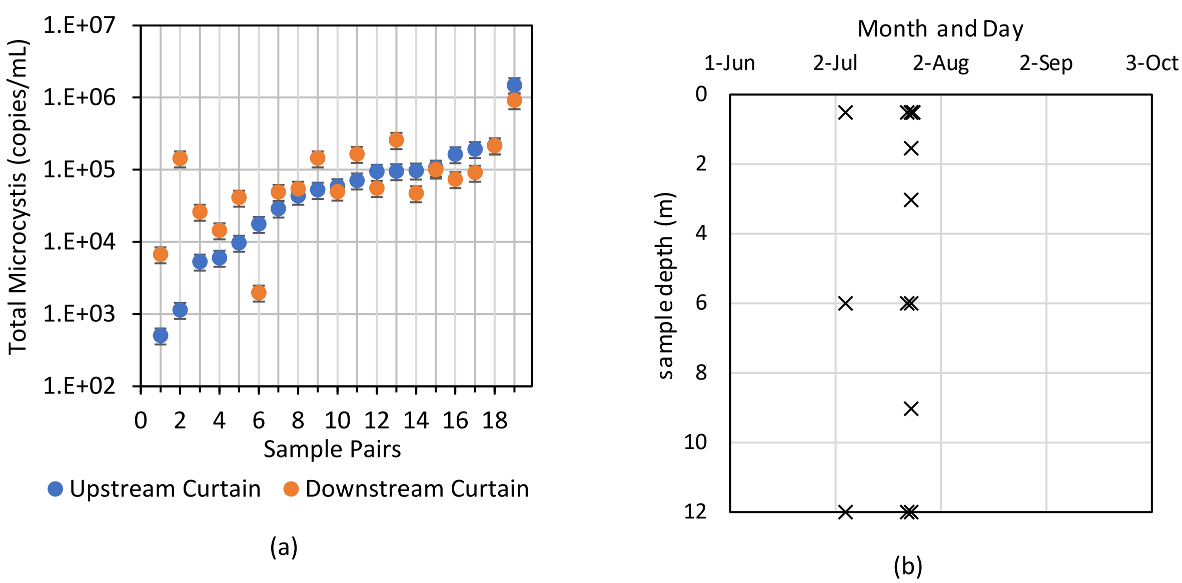



**Figure 6-14. (a) Total *Microcystis* concentrations (gene copies/mL) and uncertainty factors (error bars) for 19 sample pairs collected upstream and downstream of the curtain at different depths when the curtain was not deployed and (b) sample depths by date.**

Additionally, 20,000 gene copies/mL, determined by qPCR, is correlated to the California public health advisory level of 0.8 µg/L total microcystin (Otten et al. 2015). Therefore, sample pairs with upstream of the curtain concentrations of less than 20,000 gene copies/mL total *Microcystis* were removed from the sample set and the statistical tests repeated.

Removing all samples when the upstream curtain total *Microcystis* value was less 20,000 gene copies/mL did not change the outcome for the high effectiveness category, as all 22 sample pairs were already above this 20,000 gene copies/mL total *Microcystis* threshold, but it did slightly alter results for the medium/low effectiveness category, with the sign test demonstrating a lower p-value, indicating that upstream of the curtain total *Microcystis* concentrations were significantly greater than downstream of the curtain total microcystin concentrations, similar to the Wilcoxon signed-rank test (p=0.035 and p=0.013 for sign and Wilcoxon signed-rank tests, respectively) (Table 6-9). After the uncertainty factor was applied, neither tests demonstrated a significant reduction in total *Microcystis* concentrations from upstream to downstream of the curtain under medium/low effectiveness conditions (p=0.145 and p=0.164 for sign and Wilcoxon signed-rank tests, respectively) ( (Table 6-9).

Table 6-9). For the group of sample pairs collected when the curtain was not deployed (*n* = 13), neither test indicated a significant reduction from upstream to downstream of the curtain sample concentrations (p=0.291 and p=0.351 for sign and Wilcoxon signed-rank tests, respectively) (Table 6-9).

**Table 6-9. Number of sample pairs, hypothesized direction of difference, and sign and Wilcoxon signed-rank test results for each curtain effectiveness status at sample depth category for total *Microcystis* sample pairs with upstream curtain total *Microcystis* concentration at or above 20,000 gene copies/mL. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| Curtain Status, curtain effectiveness | Sample Pairs (n) | Sign Test Results | | Wilcoxon Signed-Rank Test Results | | Mean Bias (mean Δ from UC to DC, copies/mL) |
|---|---|---|---|---|---|---|
| | | Without uncertainty factor | Including uncertainty factor | Without uncertainty factor | Including uncertainty factor | |
| Deployed, high | 22 | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.001** | -754,225 |
| Deployed, medium/low | 8 | **UC>DC, p=0.035** | UC>DC, p=0.145 | **UC>DC, p=0.013** | UC>DC, p=0.164 | -157,375 |
| Not deployed | 13 | UC>DC, p=0.291 | N/A | UC>DC, p=0.351 | N/A | -36,756 |

UC – upstream of curtain, DC – downstream of curtain, N/A – not applicable because p>0.05 without uncertainty factor.

#### 6.1.2.4 Total Cyanobacteria

A total of 67 sample pairs were collected with and without the curtain deployed in 2015 through 2018 and analyzed for cyanobacteria (Table 6-3). Of those, 52 sample pairs were used to assess the effectiveness of the curtain on reducing total cyanobacteria concentrations downstream of Iron Gate Dam. There was not an obvious threshold, and all samples collected upstream of the curtain when the curtain was deployed had cyanobacteria concentrations greater than 20,000 gene copies/mL total cyanobacteria. Therefore, statistical tests were not repeated with a threshold applied. The total cyanobacteria sign and Wilcoxon signed-rank test results for each effectiveness category (high and medium/low), along with curtain not deployed conditions are discussed in the following sections.

**High Effectiveness**

Under the high effectiveness category, all 22 sample pairs demonstrated reduction in total cyanobacteria concentrations when comparing samples from the upstream and downstream of the curtain sites, with an average reduction of 155,756,228 gene copies/mL (Table 6-10, Figure 6-15). For this group of sample pairs collected during high effectiveness periods, reduction in total cyanobacteria concentrations was significant from upstream to downstream of the curtain (p=0.000 for both tests); reduction from upstream to downstream of the curtain remained significant (p=0.000 for both tests) even with the 25 percent uncertainty factor applied.

**Medium/Low Effectiveness**

Under the medium/low effectiveness category, the effectiveness of the curtain was less consistent than the high effectiveness category. The majority of the sample pairs (10 out of 11) experienced a reduction in total cyanobacteria concentrations (average reduction was 8,985,313 gene copies/mL) downstream of the curtain (Table 6-10, Figure 6-16). For the group of sample pairs collected during medium/low effectiveness periods, reduction in total cyanobacteria concentrations from upstream to downstream of the curtain was significant (p=0.006 and p=0.008 for sign and Wilcoxon signed-rank tests, respectively). However, when an uncertainty factor (25 percent) was applied, neither test indicated significant reduction (p=0.275 and p=0.124 for sign and Wilcoxon signed-rank tests, respectively) (Table 6-10), suggesting the curtain depth was insufficient to consistently reduce total cyanobacteria concentrations in the river downstream of Iron Gate Dam during periods of medium or low effectiveness.

### Curtain Not Deployed

When the curtain was not deployed, approximately one-third of sample pairs (6 out of 19) demonstrated reduction in total cyanobacteria concentrations in downstream of the curtain samples compared to concentrations in upstream of the curtain samples; approximately two-thirds of sample pairs (13 out of 19) demonstrated an increase in total cyanobacteria concentrations in samples downstream of the curtain compared to concentrations in upstream of the curtain samples (Figure 6-17). Although an increase in total cyanobacteria concentrations from upstream to downstream of the curtain occurred more often between sample pairs, the mean bias from upstream to downstream of the curtain was still negative (average reduction of 212,330 gene copies/mL) indicating that when total cyanobacteria concentrations upstream of the curtain were highest, reduction occurred. However, the sign and Wilcoxon signed-rank tests did not indicate a significant increase (p=0.084 and p=0.260, respectively) in total cyanobacteria concentrations from upstream to downstream of the curtain sites for this group of sample pairs (Table 6-10). Without a deployed curtain, total cyanobacteria concentrations in samples from upstream and downstream of the curtain are expected to be similar because of the lack of major impediments in the relatively short distance between sampling locations.

**Table 6-10. Number of sample pairs, hypothesized direction of difference, and sign and Wilcoxon signed-rank test results for each curtain effectiveness status at sample depth category for total cyanobacteria sample pairs. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| Curtain Status, curtain effectiveness | Sample Pairs (n) | Sign Test Results | | Wilcoxon Signed-Rank Test Results | | Mean Bias (mean Δ from UC to DC, copies/mL) |
|---|---|---|---|---|---|---|
| | | Without uncertainty factor | Including uncertainty factor | Without uncertainty factor | Including uncertainty factor | |
| Deployed, high | 30 | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | -155,756,228 |
| Deployed, medium/low | 11 | **UC>DC, p=0.006** | UC>DC, p=0.275 | **UC>DC, p=0.008** | UC>DC, p=0.124 | -8,985,313 |
| Not deployed | 19 | DC>UC, p=0.084 | N/A | DC>UC, p=0.260 | N/A | -212,330 |

UC – upstream of curtain, DC – downstream of curtain, N/A – not applicable because p>0.05 without uncertainty factor.

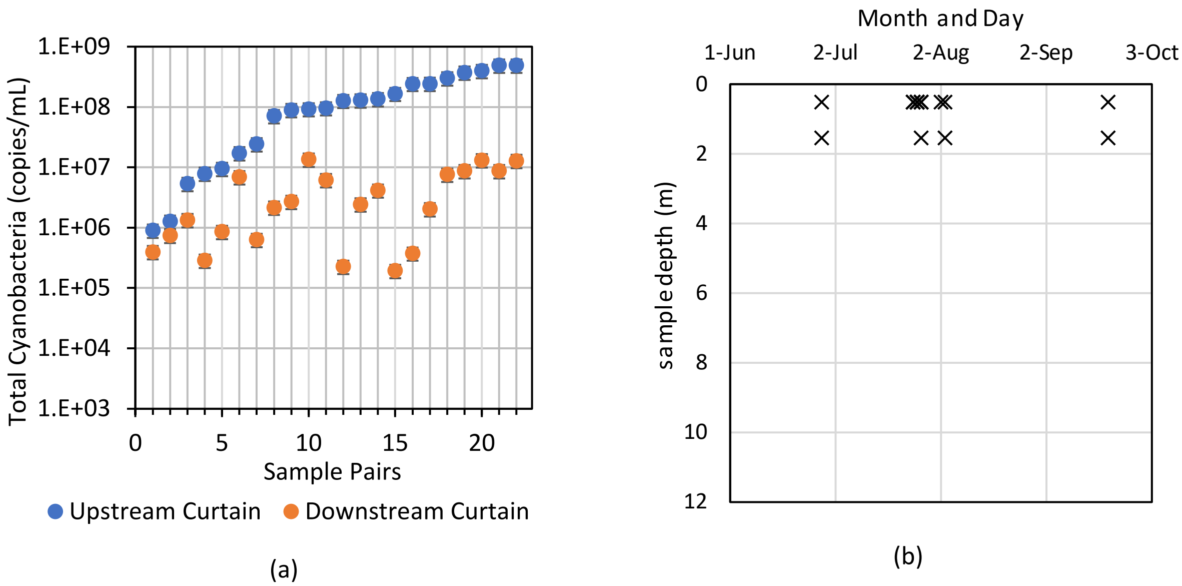



**Figure 6-15. (a) Total cyanobacteria concentrations (gene copies/mL) and uncertainty factors (error bars) for 22 sample pairs collected upstream and downstream of the curtain at different depths during periods categorized with high curtain effectiveness and (b) sample depth by date.**

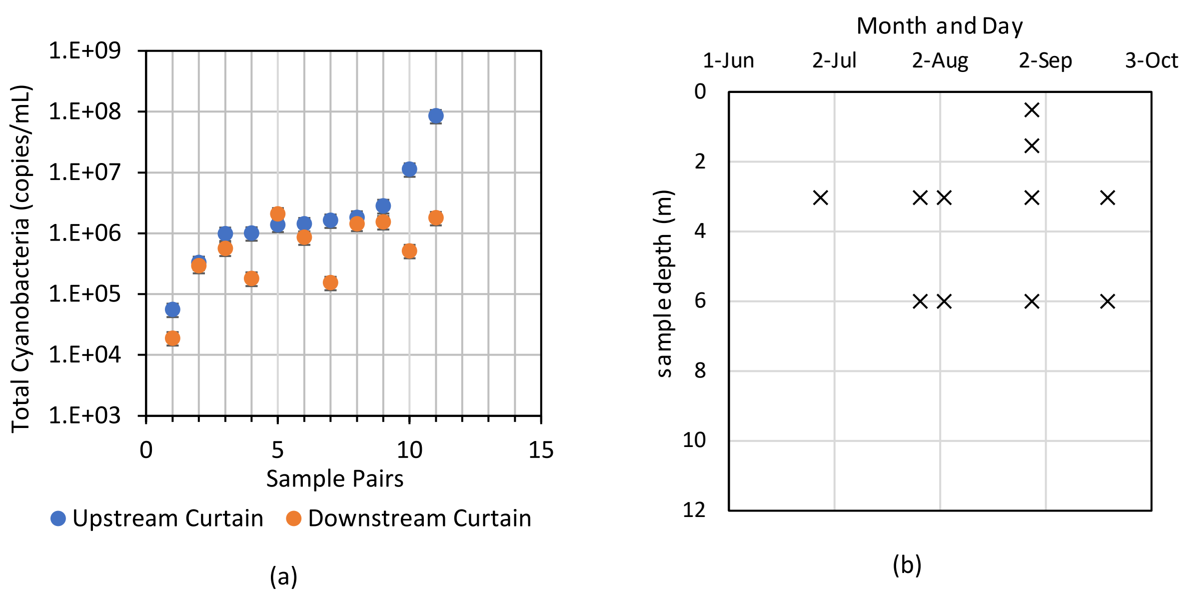



**Figure 6-16. (a) Total cyanobacteria concentrations (gene copies/mL) and uncertainty factors (error bars) for 11 sample pairs collected upstream and downstream of the curtain at different depths during periods categorized with medium/low curtain effectiveness and (b) sample depth by date.**

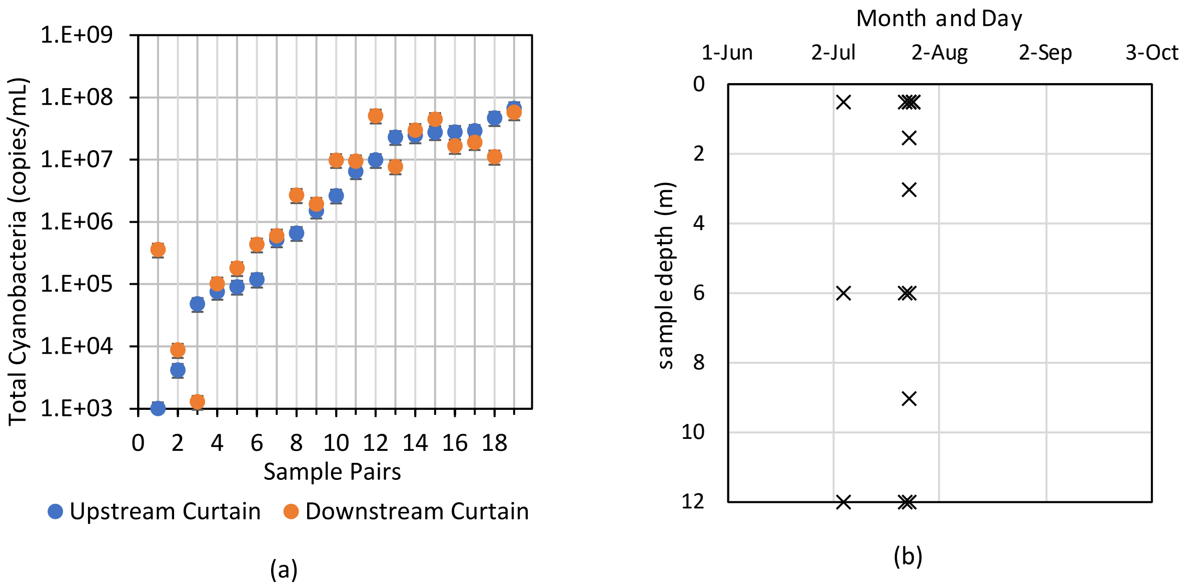



**Figure 6-17. (a) Total cyanobacteria concentrations (gene copies/mL) and uncertainty factors (error bars) for 19 sample pairs collected upstream and downstream of the curtain at different depths when the curtain was not deployed and (b) sample depths by date.**

### 6.1.2.5 Summary

When the curtain was categorized as being highly effective, total chlorophyll-*a*, total microcystin, total *Microcystis*, and total cyanobacteria concentrations were reduced downstream of the curtain because the depth to which the curtain was deployed extended deeper than the mixed layer. By preventing the surface waters from normally flowing towards the intake, the curtain becomes a barrier that retains cyanobacteria in waters upstream of the curtain. Because epilimnetic stratification inhibits mixing of the surface waters, which contain greater amounts of these constituents, with deeper waters, which contain less of these constituents, water released downstream of Iron Gate Dam contains reduced levels of total chlorophyll-*a*, total microcystin, total *Microcystis*, and total cyanobacteria. This result is consistent with the *Wn* number analysis, indicating that curtain deployment depths during periods of time when the *Wn* number indicated stable conditions, corresponded to periods of high curtain effectiveness and reduced downstream chlorophyll-*a*, total microcystin, total *Microcystis*, and total cyanobacteria concentrations.

When the curtain depth is at or near the depth of the mixed layer, the curtain still functions to retain surface waters in Iron Gate Reservoir, but it is not as effective as when it is deployed to depths below the mixed layer. While the concentrations of total chlorophyll-*a*, total microcystin, total *Microcystis*, and total cyanobacteria are likely to be less downstream of the curtain than observed upstream of the curtain, the curtain may not be deployed to sufficient depth to prevent some of the mixed layer waters from passing under the curtain. This finding is consistent with the *Wn* number analysis, indicating that deployments to depths where the *Wn* number is less than 1 are likely to be less effective at retaining surface waters with high concentrations of cyanobacteria in the reservoir.

Even though the curtain was not deployed to an effective depth during the medium/low effectiveness categories, a reduction in downstream curtain concentrations was often observed. This is especially apparent when concentrations of total chlorophyll-*a*, total microcystin, total *Microcystis*, and total cyanobacteria increase, suggesting that the curtain still reduces loading downstream of Iron Gate Dam during these times.

### 6.1.3 Sonde Data Analysis

Data collected by sondes deployed at observation buoys upstream and downstream of the curtain were compared for curtain not deployed and curtain deployed periods from June to October in 2015 through 2018. Water temperature, chlorophyll, and phycocyanin sample pairs collected at the upstream and downstream locations were categorized based on curtain effectiveness and sample depth (Section 4.3.1.2).[39]

As with the vertical profile grab data, certain sample pairs could not be categorized, and some curtain deployed sample pairs were collected from a depth below the depth of the deployed curtain and were excluded from analysis (see Section 6.1.2 and Section 4.3.1.2). Of the 575, 523, and 541 sample pairs at 0.5-m, 5-m, and 10-m depths that were available with water temperature, chlorophyll, and phycocyanin data, respectively, 371, 337, and 337, respectively, were curtain deployed sample pairs that occurred from June through October, could be categorized in terms of effectiveness, and were shallower than the deployed curtain (Table 6-11).

**Table 6-11. Sonde upstream and downstream of the curtain sample pairs analyzed for 2015-2018.**

| | | Total Sample Pairs (*n*) by Constituent | | |
|---|---|---|---|---|
| **Curtain Status, curtain effectiveness** | **Depth** | **Water Temperature** | **Chlorophyll** | **Phycocyanin** |
| Deployed, high* | 0.5 | 145 | 127 | 134 |
| Deployed, medium/low* | 0.5 | 129 | 124 | 129 |
| Not Deployed | 0.5 | 144 | 142 | 144 |
| **Total (0.5 m in Depth)** | **-** | **418** | **393** | **407** |
| Deployed, high* | 5 | 17 | 9 | 9 |
| Deployed, medium/low* | 5 | 56 | 51 | 52 |
| Not Deployed | 5 | 29 | 26 | 29 |
| **Total (5 m in Depth)** | **-** | **102** | **86** | **90** |
| Deployed, high* | 10 | 0 | 0 | 0 |
| Deployed, medium/low* | 10 | 22 | 13 | 13 |
| Not Deployed | 10 | 31 | 31 | 31 |
| **Total (10 m in Depth)** | **-** | **55** | **44** | **44** |
| | | | | |
| **Total Deployed (all depths)** | | **371** | **324** | **337** |
| **Total Not Deployed (all depths)** | | **204** | **199** | **204** |
| **Total** | | **575** | **523** | **541** |

* Only the sample pairs where the sample depth is shallower than the deployed curtain depth were considered in this analysis.

#### 6.1.3.1 Water Temperature

Water temperature sample pairs collected upstream and downstream of the curtain, were compared under different curtain effectiveness categories and when the curtain was not deployed for 0.5-m, 5-m, and 10-m sonde depths.

The results from the sign test indicate that during high and medium/low effectiveness periods, downstream of the curtain water temperatures are significantly cooler than upstream of the curtain water temperatures when comparing surface water temperatures (0.5 m in depth), as well as deeper depths (5 m and 10 m), including conditions where an uncertainty factor (0.1°C) was applied (Table 6-12,

[39] While collected, dissolved oxygen, pH, and specific conductance are not discussed herein.

Figure 6-18). P-values for both tests, before and after uncertainty factor, are all 0.001 or less[40] (Table 6-12). Without the curtain deployed, there was statistically significant reduction in water temperature from upstream of the curtain to downstream of the curtain at 0.5 m and 10 m; however, once the uncertainty factor was applied, reduction was no longer significant (Table 6-12). Under the high effectiveness and medium/low effectiveness curtain deployed categories, the curtain may be sufficient to reduce downstream surface water temperatures, with generally smaller reductions at deeper sampling depths and during lower effectiveness categories.

**Table 6-12. Number of sample pairs, hypothesized direction of difference, and sign and Wilcoxon signed-rank test results for sonde-collected water temperature (°C) during each curtain effectiveness category and when the curtain was not deployed for depths of 0.5, 5, and 10 m sample. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| | | | Sign Test Result | | Wilcoxon Signed-Rank Test Result | | |
|---|---|---|---|---|---|---|---|
| **Curtain Status, curtain effectiveness** | **Sample Depth (m)** | **Sample Pairs (n)** | **Without uncertainty factor** | **Including 0.1°C uncertainty factor** | **Without uncertainty factor** | **Including 0.1°C uncertainty factor** | **Mean Bias (mean Δ from UC to DC, °C)** |
| Deployed, high | 0.5 | 145 | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | -2.55 |
| Deployed, medium/low | 0.5 | 129 | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | -0.45 |
| Not deployed | 0.5 | 144 | **UC>DC, p=0.000** | UC>DC, p=0.401 | **UC>DC, p=0.000** | UC>DC, p=0.074 | -0.26 |
| Deployed, high | 5 | 17 | **UC>DC, p=0.000** | **UC>DC, p=0.001** | **UC>DC, p=0.000** | **UC>DC, p=0.001** | -0.94 |
| Deployed, medium/low | 5 | 56 | **UC>DC, p=0.000** | **UC>DC, p=0.001** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | -0.64 |
| Not deployed | 5 | 29 | DC>UC, p=0.203 | N/A | DC>UC, p=0.203 | N/A | -0.85 |
| Deployed, high | 10 | 2 | Too few sample pairs to perform test | | | | -1.25 |
| Deployed, medium/low | 10 | 22 | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | -0.97 |
| Not deployed | 10 | 31 | **UC>DC, p=0.021** | DC>UC, p=0.992* | **UC>DC, p=0.001** | DC>UC, p=0.003* | -0.11 |

UC – upstream of curtain, DC – downstream of curtain, N/A – not applicable because p>0.05 without uncertainty factor.

* The relationship changes the outcome with the uncertainty factor applied (DC>UC if original relationship was UC>DC, or UC>DC if original relationship was DC>UC). Therefore, the change between sites is no longer significant after the uncertainty factor is applied.

[40] The curtain deployed high effectiveness category at 10-m depth only included two sample pairs, thus, tests were not performed, but both pairs indicated reduction from upstream to downstream of the curtain.

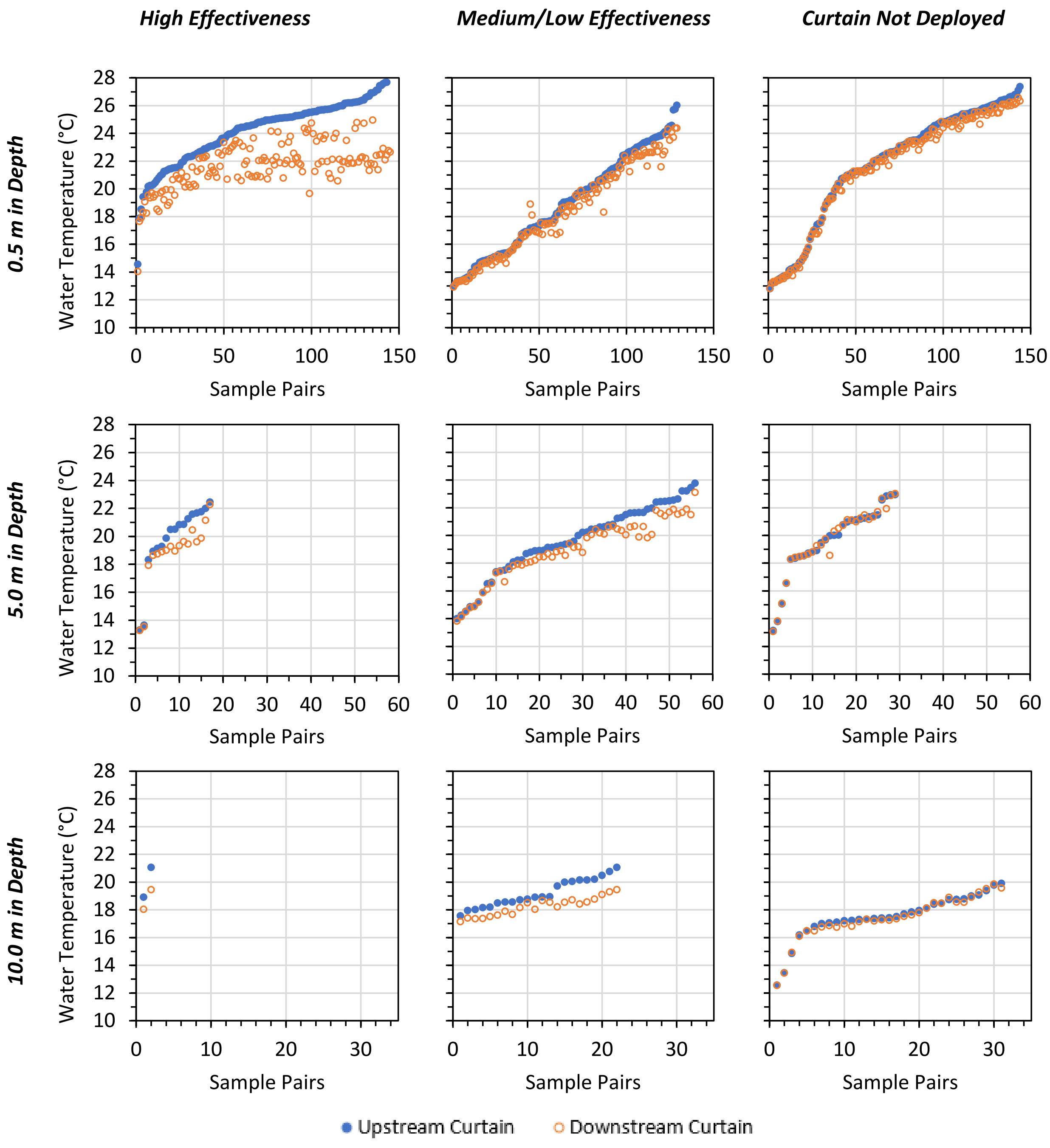



**Figure 6-18. Water temperature (°C) sample pairs upstream and downstream of the curtain at 0.5-m, 5.0-m, and 10.0-m depths for post-curtain high and medium/low effectiveness and curtain not deployed periods (uncertainty = 0.1 °C).**

### 6.1.3.2 Total Algae as Chlorophyll

Chlorophyll sample pairs collected at the upstream and downstream of the curtain sites, during post-curtain effectiveness periods and periods when the curtain was not deployed, were compared for sonde depths of 0.5 m, 5 m, and 10 m. Results for total algae from sonde data are variable (Figure 6-19), as these probes often exhibit spikes and dips when heterogeneous conditions exist (e.g., generated by large colonies) (YSI technical support, personal communication, March 19, 2020) and conditions can change quickly (i.e., daily, subdaily) during bloom periods. This analysis uses the RFU data because no relationship between RFU and concentrations (e.g., µg/L or cells/mL) of total algae has been developed for these sites. These data are useful in looking at seasonal trends, identification of blooms, as well as identification of differences between sites. As with other sonde data, daily averages (0.5 m in depth) and averages of data collected in the late morning (8:00 AM to 11:30 AM) at depths (5 m and 10 m in depth) were calculated prior to comparisons. Therefore, some of the variability from spikes and dips in the data were averaged out, while some spikes and/or blooms may result in high averages and mean bias values, especially if large spikes and/or blooms exist when sample pair numbers are few.

Although the tests indicated that there was a statistical difference between upstream and downstream curtain sites before the uncertainty factor was applied, the result was not statistically significant after the uncertainty factor (0.6 RFU) was applied for almost all categories (Table 6-13, Figure 6-19). This means that the differences from upstream to downstream were small and within the range of uncertainty. Sample pairs from 10-m depths at medium/low effectiveness demonstrated upstream of the curtain values that were significantly greater (p=0.006 and p=0.001 for the sign and Wilcoxon signed-rank tests, respectively) than downstream of the curtain. This relationship is still statistically significant with the uncertainty factor applied for the Wilcoxon signed-rank test (p=0.007) and but the sign test results are marginally not significant (p=0.083) (Table 6-13). All 13 of these sample pairs were from September 2015, when the upstream of the curtain sonde recorded large RFU values and the curtain was deployed to a depth of 10.7 m. Similarly, four of the nine sample pairs at 5-m depths collected during high curtain effectiveness were from September 2015. Both sets demonstrated a large mean bias from upstream to downstream of the curtain (-73.8 RFU and -46.1 RFU, respectively) (Table 6-13).

**Table 6-13. Number of sample pairs, hypothesized direction of difference, and sign and Wilcoxon signed-rank test results for sonde-collected total algae as chlorophyll (RFU) during each curtain period and curtain effectiveness for sample depths of 0.5, 5, and 10 m. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| | | | Sign Test Result | | Wilcoxon Signed-Rank Test Result | | |
|---|---|---|---|---|---|---|---|
| **Curtain Status, curtain effectiveness** | **Sample Depth (m)** | **Sample Pairs (n)** | **Without uncertainty factor** | **Including 0.6 RFU uncertainty factor** | **Without uncertainty factor** | **Including 0.6 RFU uncertainty factor** | **Mean Bias (mean Δ from UC to DC, RFU)** |
| Deployed, high | 0.5 | 127 | UC>DC, p=0.165 | N/A | UC>DC, p=0.055 | N/A | -0.2 |
| Deployed, medium/low | 0.5 | 124 | **DC>UC, p=0.006** | UC>DC, p=0.000* | DC>UC, p=0.352 | N/A | -0.3 |
| Not deployed | 0.5 | 142 | **DC>UC, p=0.000** | UC>DC, p=0.000* | DC>UC, p=0.134 | N/A | -0.3 |
| Deployed, high | 5 | 9 | **UC>DC, p=0.048** | DC>UC, p=0.369 | **UC>DC, p<0.05**** | DC>UC, p>0.05** | -46.1 |
| Deployed, medium/low | 5 | 51 | DC>UC, p=0.242 | N/A | DC>UC, p=0.374 | N/A | -3.1 |
| Not deployed | 5 | 26 | **DC>UC, p=0.000** | UC>DC, p=0.000* | **DC>UC, p=0.012** | UC>DC, p=0.000* | -0.1 |
| Deployed, high | 10 | 0 | - | - | - | - | - |
| Deployed, medium/low | 10 | 13 | **UC>DC, p=0.006** | UC>DC, p=0.083 | **UC>DC, p=0.001** | **UC>DC, p=0.007** | -73.8 |
| Not deployed | 10 | 31 | **DC>UC, p=0.004** | UC>DC, p=0.000* | **DC>UC, p=0.007** | UC>DC, p=0.000* | -0.2 |

UC – upstream of curtain, DC – downstream of curtain, N/A – not applicable because p>0.05 without uncertainty factor.

* The relationship changes the outcome with the uncertainty factor applied (DC>UC if original relationship was UC>DC, or UC>DC if original relationship was DC>UC). The change between sites is no longer significant after the uncertainty factor is applied.

** Sample size is not large enough to calculate an accurate W (test statistic), but results are reported as greater or less than 0.05.

When total algae levels were smaller (within the uncertainty factor of 0.6 RFU) it appears that levels were similar on either side of the curtain (Figure 6-19). Reductions in total algae levels were generally apparent from upstream to downstream of the curtain when levels of total algae upstream were relatively high (Figure 6-19). Therefore, data pairs with upstream of the curtain levels less than the uncertainty factor of 0.6 RFU were removed from the data set, and statistical tests rerun (Table 6-14). Without the sample pairs with low RFU values, results are similar, with a significant difference prior to but not after the uncertainty factor (0.6 RFU) was applied for almost all categories (Table 6-14). This means that the differences from upstream to downstream were small and within the range of uncertainty. Sample pairs from 10-m depths at medium/low effectiveness demonstrated upstream of the curtain values that were significantly greater than downstream of the curtain, even with the uncertainty factor. All 11 of these sample pairs were from September 2015, when the upstream of the curtain sonde recorded large RFU values and the curtain was deployed to a depth of 10.7 m. Similarly, four of the six sample pairs at 5-m depths collected during high curtain effectiveness were from September 2015. Both sets demonstrated a large mean bias from upstream to downstream of the curtain (-87.3 RFU and -69.2 RFU, respectively) (Table 6-14).

**Table 6-14. Number of sample pairs, hypothesized direction of difference, and sign and Wilcoxon signed-rank test results for sonde-collected total algae as chlorophyll (RFU) during each curtain period and curtain effectiveness for sample depths of 0.5, 5, and 10 m, for pairs with upstream of the curtain values equal or greater than 0.6 RFU. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| | | | Sign Test Result | | Wilcoxon Signed-Rank Test Result | | |
|---|---|---|---|---|---|---|---|
| **Curtain Status, curtain effectiveness** | **Sample Depth (m)** | **Sample Pairs (n)** | **Without uncertainty factor** | **Including 0.6 RFU uncertainty factor** | **Without uncertainty factor** | **Including 0.6 RFU uncertainty factor** | **Mean Bias (mean Δ from UC to DC, RFU)** |
| Deployed, high | 0.5 | 92 | **UC>DC, p=0.000** | DC>UC, p=0.000* | **UC>DC, p=0.003** | DC>UC, p=0.000* | -0.4 |
| Deployed, medium/low | 0.5 | 76 | **UC>DC, p=0.011** | DC>UC, p=0.000* | **UC>DC, p=0.000** | DC>UC, p=0.000* | -0.7 |
| Not deployed | 0.5 | 81 | DC>UC, p=0.369 | N/A | UC>DC, p=0.055 | N/A | -0.9 |
| Deployed, high | 5 | 6 | **UC>DC, p=0.007** | UC>DC, p=0.207 | **UC>DC, p<0.05**** | UC>DC, p>0.05** | -69.2 |
| Deployed, medium/low | 5 | 20 | **UC>DC, p=0.000** | DC>UC, p=0.013* | **UC>DC, p=0.001** | DC>UC, 0.006* | -8.3 |
| Not deployed | 5 | 8 | UC>DC, p=0.500 | N/A | UC>DC, p>0.050** | N/A | -0.9 |
| Deployed, high | 10 | 0 | - | - | - | - | - |
| Deployed, medium/low | 10 | 11 | **UC>DC, p=0.000** | **UC>DC, p=0.017** | **UC>DC, p=0.002** | **UC>DC, p=0.004** | -87.3 |
| Not deployed | 10 | 31 | **DC>UC, p=0.004** | UC>DC, p=0.000* | **UC>DC, p=0.007** | UC>DC, p=0.000* | -0.2 |

UC – upstream of curtain, DC – downstream of curtain, N/A – not applicable because p>0.05 without uncertainty factor.

* The relationship changes the outcome with the uncertainty factor applied (DC>UC if original relationship was UC>DC, or UC>DC if original relationship was DC>UC). Therefore, the change between sites is no longer significant after the uncertainty factor is applied.

**Sample size is not large enough to calculate an accurate W (test statistic), but results are reported as greater or less than 0.05.

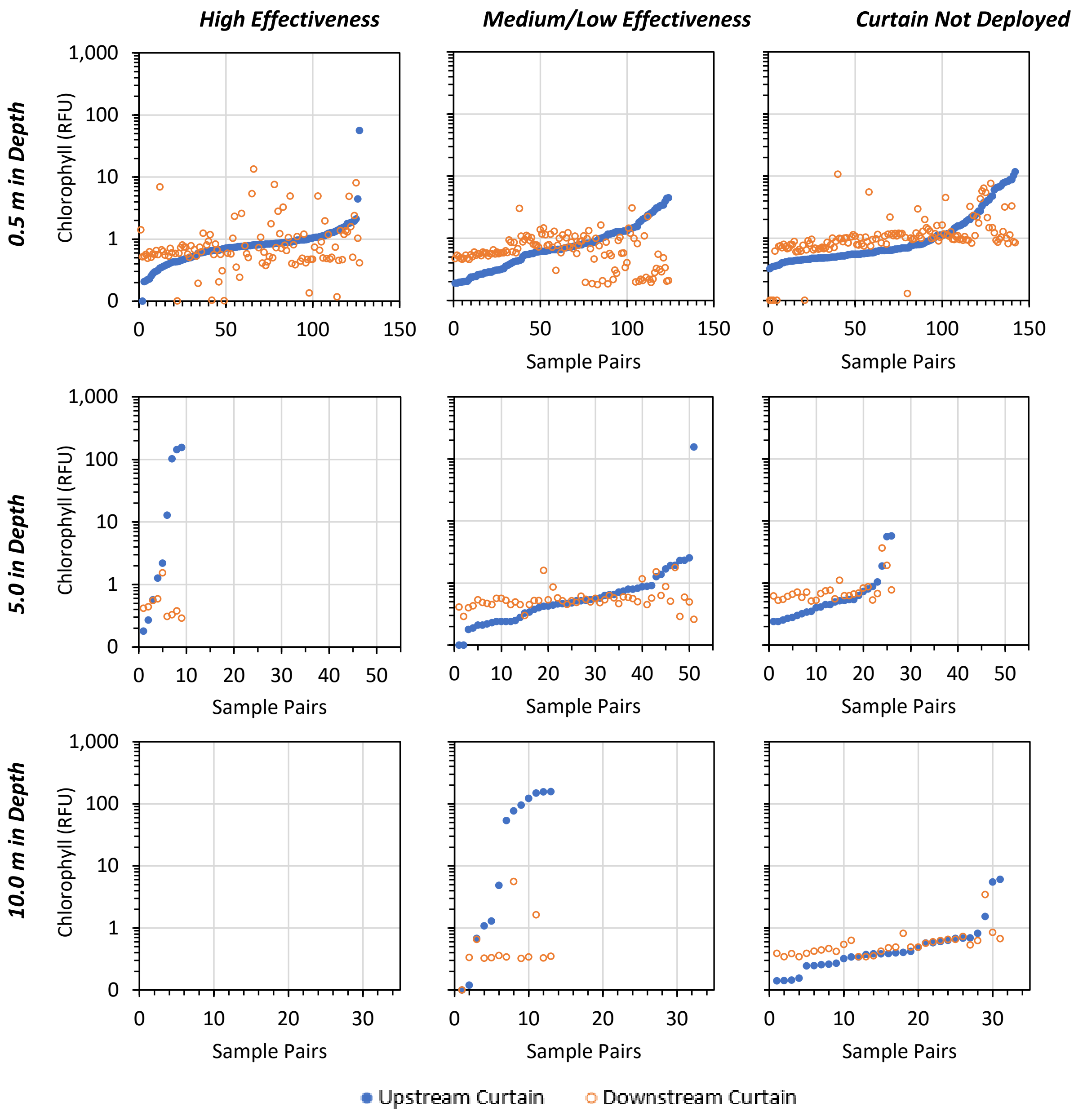



**Figure 6-19. Total algae as chlorophyll (RFU) sample pairs upstream and downstream of the curtain at 0.5-m, 5.0-m, and 10.0-m depths for post-curtain high and medium/low effectiveness and curtain not deployed periods (uncertainty = 0.6 RFU).**

### 6.1.3.3 Cyanobacteria as Phycocyanin

Phycocyanin sample pairs collected at the upstream and downstream of the curtain sites during post-curtain effectiveness periods and periods when the curtain was not deployed were compared for sonde depths of 0.5 m, 5 m, and 10 m. As with chlorophyll, the results for phycocyanin are typically variable (Figure 6-20). The phycocyanin probes often exhibit spikes and dips when heterogeneous conditions exist (e.g., large colonies) (YSI technical support, personal communication, March 19, 2020) and conditions can change quickly (i.e., daily, subdaily) during bloom periods. As with chlorophyll, these data use RFU data for phycocyanin data because no relationship has been developed between RFU and concentrations (e.g., µg/L or cells/mL) at these sites. These data are useful in looking at seasonal trends, identification of blooms, as well as identification of differences between sites. As with other sonde data, daily averages (0.5-m depth) and averages of data collected in the late morning (8:00 AM to 11:30 AM) at depths (5 m and 10 m in depth) were calculated prior to comparisons. Therefore, some of the variability from spikes and dips in the data were averaged out, while some spikes, blooms, or both, may result in high averages and mean bias values, especially if large spikes, blooms, or both, exist when sample pair numbers are few. Although the tests did determine some statistical differences (p<0.05) between upstream and downstream curtain sites before the uncertainty factor was applied, the results were not statistically different after the uncertainty factor (0.4 RFU) was applied for almost all categories (Table 6-15). This means that differences from upstream to downstream were small and within the range of uncertainty.

Similar to chlorophyll data, sample pairs from 10-m depths at medium/low effectiveness demonstrated upstream of the curtain values that were significantly greater (according to the Wilcoxon ranked-sign test, p=0.007) than downstream of the curtain, even with the uncertainty factor (p=0.032 for the Wilcoxon ranked-sign test) (Table 6-15). The sign test results indicated that the differences were not significant at the p<0.05 threshold (p=0.083). All 13 of these sample pairs were from September 2015, when the upstream of the curtain sonde recorded large RFU values and the curtain was deployed to a depth of 10.7 m. Similarly, four of the nine sample pairs at 5-m depths collected during high curtain effectiveness were from September 2015. Both sets demonstrated a large mean bias from upstream to downstream of the curtain (-35.1 RFU and -17.9 RFU, respectively) (Table 6-15).

**Table 6-15. Number of sample pairs, hypothesized direction of difference, and sign and Wilcoxon signed-rank test results comparing upstream curtain (UC) and downstream curtain (DC) concentrations for sonde-collected phycocyanin (RFU) during each curtain period and curtain effectiveness for 0.5-m, 5-m, and 10-m sample depths. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| | | | Sign Test Result | | Wilcoxon Signed-Rank Test Result | | |
|---|---|---|---|---|---|---|---|
| **Curtain Status, curtain effectiveness** | **Sample Depth (m)** | **Sample Pairs (n)** | **Without uncertainty factor** | **Including 0.4 RFU uncertainty factor** | **Without uncertainty factor** | **Including 0.4 RFU uncertainty factor** | **Mean Bias (mean Δ from UC to DC, RFU)** |
| Deployed, high | 0.5 | 134 | UC>DC, p=0.39 | N/A | **UC>DC, p=0.010** | DC>UC, p=0.004* | -1.3 |
| Deployed, medium/low | 0.5 | 129 | **UC>DC, p=0.000** | DC>UC, p=0.000* | **UC>DC, p=0.000** | DC>UC, p=0.076* | -1.2 |
| Not deployed | 0.5 | 144 | **UC>DC, p=0.000** | DC>UC, p=0.000* | **UC>DC, p=0.000** | DC>UC, p=0.000* | -1.0 |
| Deployed, high | 5 | 9 | DC>UC, p=0.369 | N/A | UC>DC, p>0.05** | N/A | -17.9 |
| Deployed, medium/low | 5 | 52 | **DC>UC, p=0.000** | UC>CC, p=0.000* | **DC>UC, p=0.000** | UC>DC, p=0.000* | -1.3 |
| Not deployed | 5 | 29 | DC>UC, p=0.138 | N/A | DC>UC, p=0.390 | N/A | -0.0 |
| Deployed, high | 10 | 0 | -- | -- | -- | -- | -- |
| Deployed, medium/low | 10 | 13 | UC>DC, p=0.083 | N/A | **UC>DC, p=0.007** | **UC>DC, p=0.032** | -35.1 |
| Not deployed | 10 | 31 | UC>DC, p=0.404 | N/A | UC>DC, p=0.239 | N/A | -0.2 |

UC – upstream of curtain, DC – downstream of curtain, N/A – not applicable because p>0.05 without uncertainty factor.

* The relationship changes the outcome with the uncertainty factor applied (DC>UC if original relationship was UC>DC, or UC>DC if original relationship was DC>UC). Therefore, the change between sites is no longer significant after the uncertainty factor is applied.

** Sample size is not large enough to calculate an accurate W (test statistic); results are reported as greater or less than 0.05.

## ANALYSIS AND DISCUSSION

When phycocyanin levels were lower (within the uncertainty factor of 0.4 RFU) it appears that levels were similar on either side of the curtain (Figure 6-20). Reductions in phycocyanin levels were generally apparent from upstream to downstream of the curtain when levels of total algae upstream were relatively high (Figure 6-20). Therefore, data pairs with upstream of the curtain levels less than the uncertainty factor of 0.4 RFU were removed from the data set, and statistical tests rerun (Table 6-16). Without the sample pairs with low RFU values, both statistical tests indicated a significant reduction in RFU values from upstream of curtain to downstream of curtain, both before and after the uncertainty was applied at the 0.5-m depth and high effectiveness (p=0.000 for both tests). For the medium/low effectiveness category at the 0.5-m depth, the sign and Wilcoxon signed-rank tests demonstrated a significant (p=0.000 for both tests) reduction in RFU values from upstream of the curtain to downstream of the curtain before the uncertainty factor was applied, and the Wilcoxon signed-rank test demonstrated a significant reduction after the uncertainty factor was applied (p=0.009). This is attributed to the Wilcoxon signed-rank test factoring in the magnitude of the differences, not only the sign of the differences. At 5-m deployment depths for all categories and 10-m depths at high and curtain not deployed categories, there were not enough sample pairs to run statistical tests, although mean bias from upstream to downstream indicated reduction (Table 6-16). At 10-m sample depths, medium/low effectiveness categories there was a significant reduction from upstream to downstream of the curtain before and after uncertainty was applied for both tests (p=0.001 and p<0.05 for the sign and Wilcoxon ranked-sign test respectively, Table 6-16). Large average bias value for 5-m and 10-m depths when the curtain was deployed (-40.4 RFU, -36.4 RFU, and -50.9 RFU for 5-m high, 5-m low/medium, and 10-m low/medium categories, respectively) were influenced by a large portion of the sample pairs being from September 2015, when large RFU values were collected by the upstream of the curtain sonde data and the curtain was deployed to a depth of 10.7 m (Table 6-16).

**Table 6-16. Number of sample pairs, hypothesized direction of difference, and sign and Wilcoxon signed-rank test results comparing upstream curtain (UC) and downstream curtain (DC) concentrations for sonde-collected phycocyanin (RFU) during each curtain period and curtain effectiveness for sample depths of 0.5, 5, and 10 m for pairs with upstream of the curtain concentrations equal to or greater than 0.4 RFU. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| Curtain Status, curtain effectiveness | Sample Depth (m) | Sample Pairs (n) | Sign Test Result: Without uncertainty factor | Sign Test Result: Including 0.4 RFU uncertainty factor | Wilcoxon Signed-Rank Test Result: Without uncertainty factor | Wilcoxon Signed-Rank Test Result: Including 0.4 RFU uncertainty factor | Mean Bias (mean Δ from UC to DC, RFU) |
|---|---|---|---|---|---|---|---|
| Deployed, high | 0.5 | 54 | **UC>DC, p=0.000** | **UC>DC, p=0.007** | **UC>DC, p=0.000** | **UC>DC, p=0.000** | -3.8 |
| Deployed, medium/low | 0.5 | 82 | **UC>DC, p=0.000** | DC>UC, p=0.413 | **UC>DC, p=0.000** | **UC>DC, p=0.009** | -2.0 |
| Not deployed | 0.5 | 69 | **UC>DC, p=0.000** | DC>UC, p=0.452 | **UC>DC, p=0.000** | UC>DC, p=0.224 | -2.1 |
| Deployed, high | 5 | 4 | Sample size too small to run tests | | | | -40.4 |
| Deployed, medium/low | 5 | 2 | Sample size too small to run tests | | | | -36.4 |
| Not deployed | 5 | 3 | Sample size too small to run tests | | | | -0.8 |
| Deployed, high | 10 | 0 | -- | -- | -- | -- | -- |
| Deployed, medium/low | 10 | 9 | **UC>DC, p=0.001** | **UC>DC, p=0.010** | **UC>DC, p<0.05*** | **UC>DC, p<0.05*** | -50.9 |
| Not deployed | 10 | 3 | Sample size too small to run tests | | | | -1.7 |

JC – upstream of curtain, DC – downstream of curtain, N/A – not applicable because p>0.05 without uncertainty factor.
* Sample size is not large enough to calculate an accurate W (test statistic), but results are reported as greater or less than 0.05.

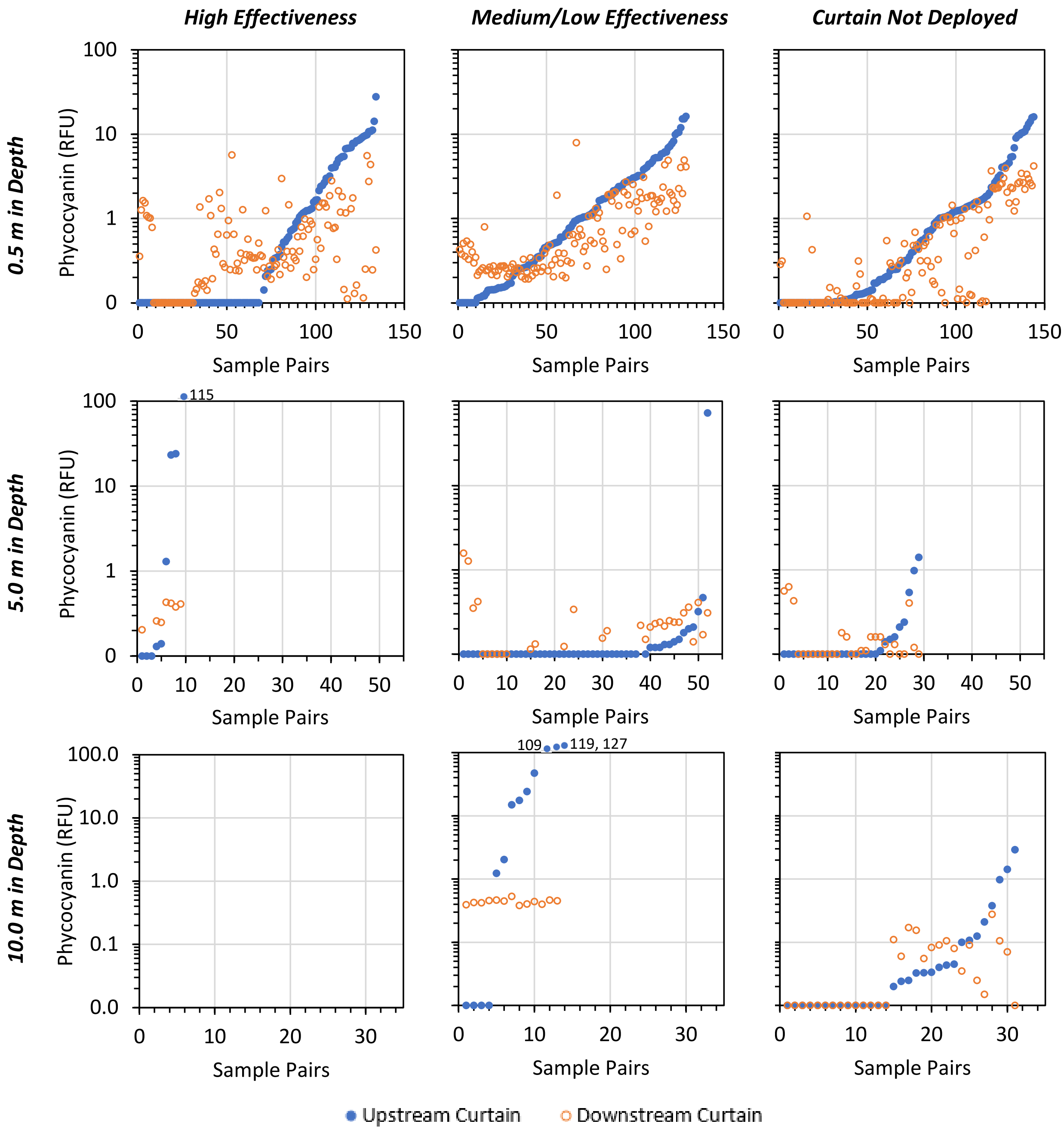



**Figure 6-20. Cyanobacteria as phycocyanin (RFU) sample pairs upstream and downstream of the curtain at 0.5-m, 5.0-m, and 10.0-m depths for post-curtain high and medium/low effectiveness and curtain not deployed periods (uncertainty = 0.4 RFU).**

### 6.1.3.4 Summary

When the curtain was not deployed, daily average water temperature, chlorophyll, and cyanobacteria values were not significantly different between the upstream and downstream sides of the curtain at 0.5-m, 5-m, and 10-m depths. This is not unexpected given the lack of substantial impediments and the relatively short distance between sampling sites.

**ANALYSIS AND DISCUSSION**

Under periods when the *Wn* metric rated the curtain as highly effective (*Wn* > 1.0 at a given curtain depth), daily average water temperatures were significantly warmer upstream of the curtain compared to downstream of the curtain at the surface (0.5 m), 5-m, and 10-m depths; although there was a decreased difference at deeper sample depths (5 m and 10 m) during highly effective periods. This indicates that the curtain is effective at reducing water temperature in downstream releases. Neither statistical test indicated a significant reduction in average chlorophyll levels between the upstream and downstream sides of the curtain, even when RFU values were large (at or above 0.4 RFU upstream of the curtain), except for a small set of sample pairs collected at 10 m in September 2015 during medium to low effectiveness when the curtain was deployed to 10.7 m (Table 6-13 and Table 6-14). Reduction in average phycocyanin from upstream to downstream was generally observed at the 0.5-m depth, and the 10-m depth, when RFU values were large (at or above 0.4 RFU upstream of the curtain) and the curtain was deployed (Table 6-16).

## 6.2 Reduction in Downstream Loading Attributable to Iron Gate Dam

Hypothesis 2 states that Iron Gate Dam, without a curtain, reduces the release of cyanobacteria from the reservoir into the Klamath River. This hypothesis was tested by comparing grab sample chlorophyll-*a* data collected within Iron Gate Reservoir at the log boom with grab sample chlorophyll-*a* data collected in the Klamath River downstream of Iron Gate Dam during periods that the curtain was not present or was fully furled (depth of 1.5 m). The log boom and downstream of Iron Gate Dam sites were selected because these data sets extend for well over a decade, and include considerable data prior to installation of the curtain in Iron Gate Reservoir.

### 6.2.1 Analysis

This analysis uses the differences in total chlorophyll-*a* concentrations for sample pairs at the Iron Gate log boom (0- to 8-m integrated sample) and the Klamath River downstream of Iron Gate Dam (0.5-m sample), on dates prior to curtain installment or when the curtain was not deployed, where a negative change indicates a reduction in the downstream concentration. Using data from 2004 through 2018 results demonstrate increases in chlorophyll-*a* downstream of the dam up to 13 µg/L to decreases of 27 µg/L. The average chlorophyll-*a* reduction across all sample pairs was 1.0 µg/L and percent reduction[41] of the site averages was 14 percent (*n* = 90) (Figure 6-21).

[41] Percent reduction was calculated as: (mean chlorophyll-*a* concentration at the log boom – mean chlorophyll-*a* concentration at the river) / mean chlorophyll-*a* concentration at the log boom * 100. Mean concentrations were calculated across all sample dates of interest.

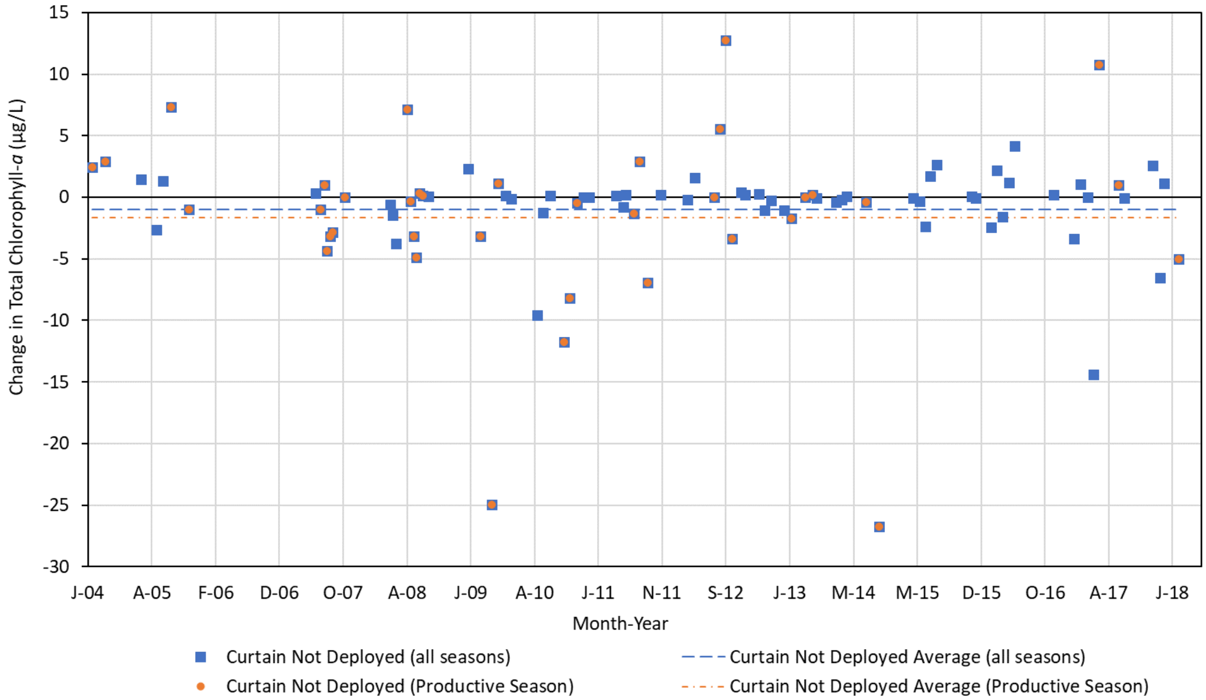



**Figure 6-21. Change in total chlorophyll-*a* concentrations from the Iron Gate log boom (0- to 8-m integrated sample) to the Klamath River downstream of Iron Gate Dam (0.5-m sample) when the curtain was not present or was not deployed during all seasons and the productive season. Average bias is indicated for each data set (dashed lines).**

The ability of Iron Gate Dam to reduce total chlorophyll-*a* is expected to be most observable during the productive season when total chlorophyll-*a* concentrations are generally much greater than other times of year. Differences in total chlorophyll-*a* concentrations for sample pairs at the Iron Gate Reservoir log boom and the Klamath River downstream of Iron Gate Dam were plotted during the productive season which is considered to be July through October, as well as during all seasons, for comparison (Figure 6-21). Review of these sample pairs indicates that there was an average reduction of 1.6 µg/L (16 percent reduction between site averages) from upstream of Iron Gate Dam to the Klamath River downstream during the productive season ($n$ = 37). For about half the samples collected during the productive season, total chlorophyll-*a* concentrations at the log boom were greater than concentrations downstream of the dam (Figure 6-22).

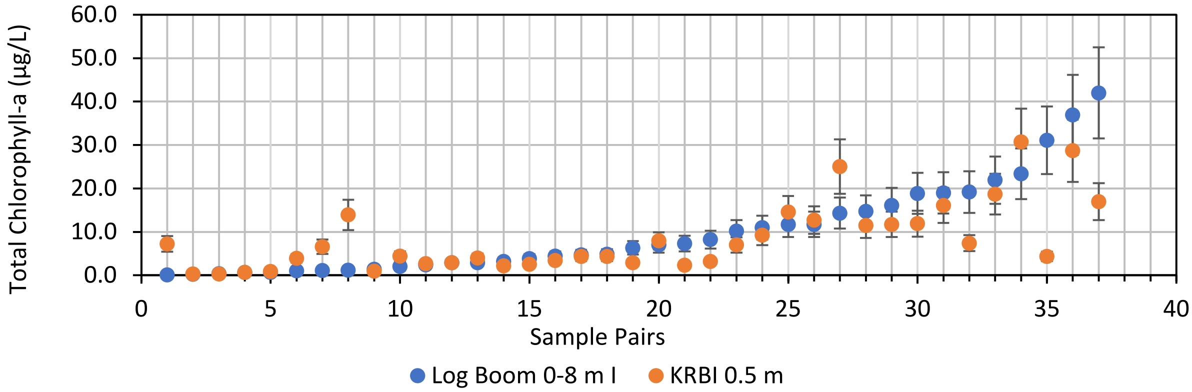



**Figure 6-22. Total chlorophyll-*a* concentrations at the log boom (0- to 8-m integrated sample) and in the Klamath River downstream of Iron Gate Dam (KRBI) (0.5-m sample) for sample pairs in July through October when the curtain was not present or not deployed (error bars are the uncertainty factor of 25 percent or the reporting limit, whichever is greater).**

The differences between total chlorophyll-*a* sample concentrations at the Iron Gate Reservoir log boom and the Klamath River downstream of Iron Gate Dam collected during periods when the curtain was not deployed were used to evaluate the hypothesis that Iron Gate Dam, without a curtain, reduces the release of cyanobacteria from the reservoir into the Klamath River. Total chlorophyll-*a* concentrations from samples collected during all seasons, and during the productive season before the curtain was installed or when the curtain was not deployed were evaluated with the sign and Wilcoxon signed-rank tests (Table 6-17). Although the majority of sample pairs during all seasons and during the productive season demonstrate a reduction in total chlorophyll-*a* concentrations from the reservoir to the river (47 out of 90 and 21 out of 37, respectively), and mean bias was negative indicating reduction, the sign and Wilcoxon signed-rank tests did not indicate that reduction was significant (p>0.05 for all tests) (Table 6-17).

**Table 6-17. Total chlorophyll-*a* sample pairs, hypothesized direction of difference, sign and Wilcoxon signed-rank test results, and mean bias between log boom 0- to 8-m integrated sample and Klamath River below Iron Gate pairs when the curtain was not present or not deployed. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| Curtain Status, season | Sample Pairs (n) | Sign Test Results | | Wilcoxon Signed-Rank Test Results | | Mean Bias (mean Δ from LB to KR, µg/L) |
|---|---|---|---|---|---|---|
| | | Without uncertainty factor | Including uncertainty factor | Without uncertainty factor | Including uncertainty factor | |
| Not installed/deployed, all seasons, 2004-2018 | 90 | LB>KR, p=0.260 | N/A | LB>KR, p=0.062 | N/A | -1.0 |
| Not installed/deployed, July-October, 2004-2018 | 37 | LB>KR, p=0.122 | N/A | LB>KR, p=0.091 | N/A | -1.6 |

LB – log boom 0- to 8-m integrated sample, KR – Klamath River below Iron Gate 0.5 m, N/A – not applicable because p>0.05 without uncertainty factor.

To determine if there was a difference between periods when the curtain was not installed and when it was installed but not deployed, sample pairs collected from 2004-2014 (from all seasons, and from the productive season) were compared to sample pairs collected from 2015-2018 when the curtain was not deployed (from all seasons and from the productive season) (Table 6-18). Sample pairs were limited for the 2015-2018 curtain not deployed groups, but the outcome for the curtain not installed pairs was similar to that of the curtain installed but not deployed groups.

**Table 6-18. Total chlorophyll-*a* sample pairs, hypothesized direction of difference, sign and Wilcoxon signed-rank test results, and mean bias between log boom 0- to 8-m integrated sample and Klamath River downstream of Iron Gate Dam sample pairs when the curtain was not present (2004-2014) or present but not deployed (2015-2018). Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| Curtain Status, season | Sample Pairs (n) | Sign Test Results | | Wilcoxon Signed-Rank Test Results | | Mean Bias (mean Δ from LB to KR, µg/L) |
|---|---|---|---|---|---|---|
| | | Without uncertainty factor | Including uncertainty factor | Without uncertainty factor | Including uncertainty factor | |
| Not installed, all seasons, 2004-2014 | 71 | LB>KR, p=0.198 | N/A | **LB>KR, p=0.034** | KR>LB, p=0.000* | -1.1 |
| Installed, not deployed all seasons, 2015-2018 | 19 | KR>LB, p=0.409 | N/A | LB>KR, p=0.468 | N/A | -0.51 |
| Not installed, July-October, 2004-2014 | 34 | LB>KR, p=0.108 | N/A | LB>KR, p=0.063 | N/A | -2.0 |
| Installed, not deployed, July-October, 2015-2018 | 3 | Not enough samples to perform test | | | | 2.2 |

LB – log boom 0- to 8-m integrated sample, KR – Klamath River below Iron Gate 0.5 m, N/A – not applicable because p>0.05 without uncertainty factor.

* The relationship changes the outcome with the uncertainty factor applied, with more pairs demonstrating an increase in concentration from the log boom to the river site (KR>LB). Therefore, there is no reduction from the log boom to the river site after the uncertainty factor is applied.

The sign test indicated that for the sample pairs collected when the curtain was not installed, throughout all seasons, there was not a significant difference (p=0.198) between the log boom and river values, while the Wilcoxon signed-rank tests did indicate a significant reduction (p=0.034) in chlorophyll-*a* concentrations from the log boom to the Klamath River downstream of Iron Gate Dam before but not after the uncertainty factor was applied (Table 6-18). For the remainder of the sets of sample pairs, the sign test and the Wilcoxon signed-rank tests did not indicate a significant reduction in chlorophyll-*a* concentrations from the log boom to the Klamath River downstream of Iron Gate Dam (Table 6-18). Reduction was generally observed when log boom concentrations were larger (i.e., 5 µg/L or greater) although in some cases the error bars for a sample pair are overlapping (Figure 6-22). A threshold of 5 µg/L chlorophyll-*a* was applied to the data set and all sample pairs with chlorophyll-*a* less than 5 µg/L were removed to further evaluate the effect of the dam when concentrations were relatively higher and when any reduction would be most observable (July through October) (Table 6-19). During these conditions, the majority of sample pairs (24 out of 33 and 14 of 19 for all seasons and July through October, respectively) exhibited reduction in total chlorophyll-*a* concentrations from the reservoir to the river downstream of the dam, and the sign (p=0.008 and 0.032 for all season and July-October, respectively) and Wilcoxon signed-rank tests (p=0.001 and 0.011 for all season and July-October, respectively) indicated that there was a significant reduction prior to but not after the uncertainty factor was applied (Table 6-19). In fact, application of the uncertainty factor flipped the relationship with the Klamath River values being greater than those at the log boom.

**Table 6-19. Total chlorophyll-*a* sample pairs, hypothesized direction of difference, sign and Wilcoxon signed-rank test results, and mean bias between log boom 0- to 8-m integrated sample and Klamath River below Iron Gate pairs when the curtain was not present or not deployed and concentration of log boom samples was greater than or equal to 5.0 µg/L. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| Curtain Status, season | Sample Pairs (n) | Sign Test Results | | Wilcoxon Signed-Rank Test Results | | Mean Bias (mean Δ from LB to KR, µg/L) |
|---|---|---|---|---|---|---|
| | | Without uncertainty factor | Including uncertainty factor | Without uncertainty factor | Including uncertainty factor | |
| Not installed/deployed, all seasons, 2004-2018 | 33 | **LB>KR, p=0.008** | KR>LB, p=0.019* | **LB>KR, p=0.001** | KR>LB, p=0.004* | -3.8 |
| Not installed/deployed, July-October, 2004-2018 | 19 | **LB>KR, p=0.032** | KR>LB, p=0.084* | **LB>KR, p=0.011** | KR>LB, p=0.056* | -4.6 |

LB – log boom 0- to 8-m integrated sample, KR – Klamath River below Iron Gate 0.5 m, N/A – not applicable because p>0.05 without uncertainty factor.

* The relationship changes the outcome with the uncertainty factor applied, with more pairs demonstrating an increase in concentration from the log boom to the river site (KR>LB). Therefore, there is no reduction from the log boom to the river site after the uncertainty factor is applied.

To determine if there was a difference between periods when the curtain was not installed and when it was installed but not deployed, sample pairs collected from 2004-2014 prior to curtain installation (from all seasons, and from the productive season) were compared to sample pairs collected from 2015-2018 for pairs at or above the 5 µg/L threshold when the curtain was installed but not deployed [from all seasons (not shown) and from the productive season (Figure 6-23, Table 6-20)]. Sample pairs were limited for the 2015-2018 curtain not deployed groups, but the outcome for all groups was not significant after the uncertainty factors had been applied. Prior to the uncertainty factor application, the curtain not installed groups demonstrated reduction from the log boom to the river (p=0.002 and 0.021 for all season and July-October, respectively). Sample size was reduced for the curtain installed but not deployed groups, and it was not possible to test the July-October set of sample pairs (n=1). Additionally, average change from the log boom to the river for each group except for the curtain installed but not deployed July-October group (n=1) was negative, indicating reduction occurred more often when concentrations were large.

**Table 6-20. Total chlorophyll-*a* sample pairs, hypothesized direction of difference, sign and Wilcoxon signed-rank test results, and mean bias between log boom 0- to 8-m integrated sample and Klamath River below Iron Gate pairs when the curtain was not present (2004-2014) or present but not deployed (2015-2018) and concentration of log boom sample was greater than or equal to 5.0 µg/L. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| | | Sign Test Results | | Wilcoxon Signed-Rank Test Results | | |
|---|---|---|---|---|---|---|
| **Curtain Status, season** | **Sample Pairs (n)** | **Without uncertainty factor** | **Including uncertainty factor** | **Without uncertainty factor** | **Including uncertainty factor** | **Mean Bias (mean Δ from LB to KR, µg/L)** |
| Not installed, all seasons, 2004-2014 | 24 | **LB>KR, p=0.002** | KR>LB, p=0.007* | **LB>KR, p=0.001** | KR>LB, p=0.010* | -4.6 |
| Installed, not deployed all seasons, 2015-2018 | 9 | KR>LB, p=0.369 | N/A | LB>KR, p>0.05** | N/A | -1.85 |
| Not installed, July-October, 2004-2014 | 16 | **LB>KR, p=0.021** | KR>LB, p=0.210* | **LB>KR, p=0.008** | KR>LB, p=0.205* | -5.9 |
| Installed, not deployed, July-October, 2015-2018 | 1 | Not enough samples to perform test | | | | 10.73 |

LB – log boom 0- to 8-m integrated sample, KR – Klamath River below Iron Gate 0.5 m, N/A – not applicable because p>0.05 without uncertainty factor.

* The relationship changes the outcome with the uncertainty factor applied, with more pairs demonstrating an increase in concentration from the log boom to the river site (KR>LB). Therefore, there is no reduction from the log boom to the river site after the uncertainty factor is applied.

** Sample size is not large enough to calculate an accurate W (test statistic), but results are reported as greater or less than 0.05.

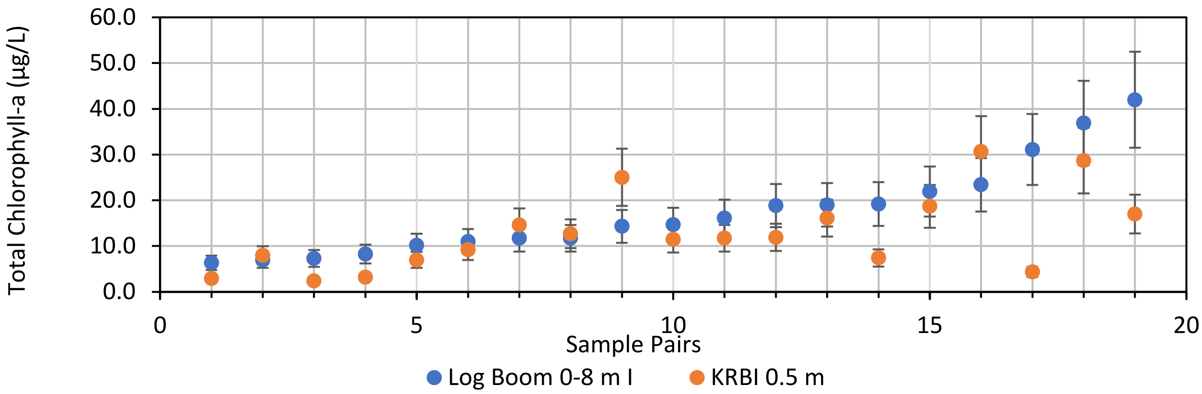



**Figure 6-23. Total chlorophyll-*a* concentrations at the log boom (0- to 8-m integrated sample) and in the Klamath River downstream of Iron Gate Dam (KRBI) (0.5-m sample) for sample pairs in July through October when the curtain was not present or not deployed, and when concentrations at the log boom were greater than or equal to 5 µg/L (error bars are the uncertainty factor of 25 percent or the reporting limit, whichever is greater).**

### 6.2.2 Summary

The sign and Wilcoxon signed-rank test results indicated that Iron Gate Dam alone does not significantly reduce chlorophyll-*a* concentrations in the river downstream of the dam during periods that the curtain was not present and/or not deployed, after an uncertainty factor has been applied to address system heterogeneity and laboratory analysis uncertainty (Table 6-18 and Table 6-19). Average bias often demonstrated reduction from the log boom to the Klamath River downstream of Iron Gate Dam, indicating that when total chlorophyll-*a* concentrations at the log boom were highest, reduction occurred, although this reduction was minimal (average bias of -1.0 μg/L for samples across all seasons and -1.6 μg/L during productive periods) (Table 6-17).

## 6.3 Reduction in Downstream Loading Attributable to Curtain and Dam

Hypothesis 3, that the curtain in combination with the dam is effective at reducing the downstream movement of cyanobacteria by retaining surface waters in the reservoir, which contain high concentrations of cyanobacteria that would otherwise be released to downstream river reaches, was tested by comparing chlorophyll-*a* data collected within Iron Gate Reservoir at the log boom and chlorophyll-*a* data collected in the river downstream of Iron Gate Dam during periods when the curtain was deployed[42]. Effective curtain periods were determined based on *Wn* analysis and curtain deployed data were sorted into two categories (see Section 6.1.1 for details): high curtain effectiveness and medium/low curtain effectiveness.

### 6.3.1 Analysis

Thirteen total chlorophyll-*a* sample pairs at the Iron Gate log boom (0- to 8-m integrated sample) and from the Klamath River downstream of Iron Gate Dam (0.5-m sample) were collected after curtain installment in 2015 and during curtain deployment periods in 2015 through 2018. One of these pairs was collected in November and was removed from the analysis because this is outside of the productive season (July through October). Sample pairs were organized by curtain effectiveness (high and medium/low) (Section 4.3.1.2). Curtain effectiveness could not be determined for one post-curtain productive season sample because there was not adequate data to determine *Wn* and/or stratification conditions.

Change in total chlorophyll-*a* concentrations from the Iron Gate log boom (0- to 8-m integrated sample) to the Klamath River downstream of Iron Gate Dam (0.5-m sample) during curtain deployment periods in 2015 through 2018 demonstrated consistent reduction (Figure 6-24). Percent reduction of total chlorophyll-*a* for all curtain deployed productive season sample pairs was 44 percent, with an average reduction of 9.0 μg/L (average bias is -9 μg/L, $n$ = 12) (Figure 6-24). If just those samples collected during periods of high curtain effectiveness are considered, the percent reduction between total chlorophyll-*a* site averages was 59 percent, with an average reduction 11.9 μg/L (average bias is -11.9 μg/L, $n$ = 6) (Figure 6-24).

[42] Curtain deployed data were only available during the productive season (i.e., July through October).

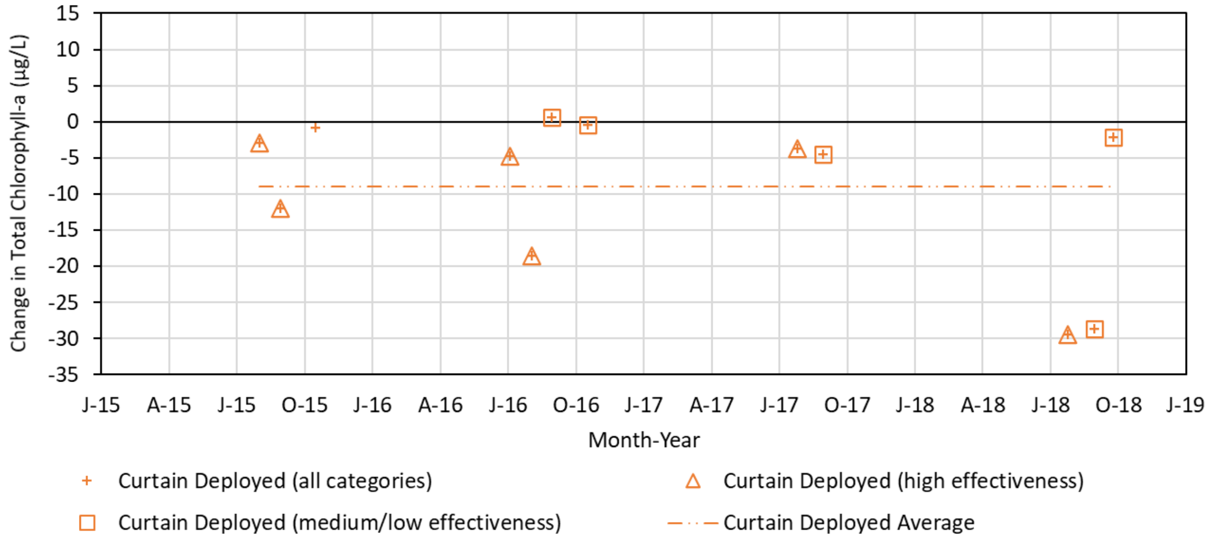



**Figure 6-24. Curtain effectiveness and change in total chlorophyll-*a* concentrations from curtain deployed sample pairs collected at the Iron Gate Reservoir log boom (0- to 8-m integrated) and the Klamath River downstream of Iron Gate Dam (0.5-m depth) during the productive season, 2015 through 2018.**

During the curtain deployment period for all effectiveness categories, there were no increases in chlorophyll-*a* concentrations from the log boom to the river greater than the minimum uncertainty factor (the reporting limit of 0.89 µg/L). The one sample pair that did demonstrate an increase from the log boom to the river occurred in September during a period of medium/low curtain effectiveness (+0.63 µg/L; Figure 6-24). Medium/low curtain effectiveness pairs occurred in September and October when the curtain was deployed to between 3 and 6.1 m. The *Wn* at these depths on these days were a mix with only one date showing stable conditions at the actual deployment depth through the day (Table 6-21). Had the curtain been deployed to the design depth of 10.7 m, the curtain would have been more effective because *Wn* at the design depth indicated stable conditions with the exception of a single day (Table 6-21).

**Table 6-21. Curtain depth and *Wn* at curtain depth and design depth (10.7 m) for post-curtain deployment log boom (0- to 8-m integrated depths) and Klamath River below Iron Gate (0.5-m depth) sample pairs with medium/low curtain effectiveness.**

| Date | Curtain Depth (m) | *Wn* at Curtain Depth | *Wn* at 10.7 m |
|---|---|---|---|
| September 6, 2016 | 6.1 | > 1.0 (most of day) | > 1.0 |
| October 25, 2016 | 3.0 | < 1.0 | > 1.0 |
| September 11, 2017 | 3.0 | > 1.0 | > 1.0 |
| September 17, 2018 | 4.6 | > 1.0 (half of day) | > 1.0 |
| October 13, 2018 | 6.1 | < 1.0 | < 1.0 (most of day) |

## ANALYSIS AND DISCUSSION

The sign and Wilcoxon signed-rank tests were used to evaluate the hypothesis that the barrier curtain in combination with Iron Gate Dam is effective at reducing the downstream movement of cyanobacteria waters by retaining surface waters in the reservoir. Most of the curtain deployed, productive season pairs (11 of 12) collected during medium to low curtain effectiveness periods (4 of 5), and all pairs collected during high curtain effectiveness periods (6 of 6) demonstrated reduction in total chlorophyll-*a* concentrations (Figure 6-25). Chlorophyll-*a* levels were reduced from upstream to downstream by 44 percent, 29 percent, and 59 percent during the productive season, all curtain deployed samples, and curtain deployed samples collected during periods of medium to low and high curtain effectiveness, respectively (average bias of -9.0 µg/L, -7.0 µg/L, and -11.9 µg/L, respectively). Statistical evaluation indicated reduction from the log boom to the river was significant ($p<0.05$) for all productive season curtain deployed pairs ($p=0.002$ for both tests) and high curtain effectiveness pairs ($p=0.016$ and $p=0.014$ for the sign and Wilcoxon ranked-sign tests, respectively); however, when the uncertainty factor (25 percent or the reporting limit, whichever was greater) was applied, the tests indicated that reduction was no longer significant (p-value ranged from 0.058 to 0.348, Table 6-22). Sample size was low for the high effectiveness period and 1 out of 6 pairs no longer demonstrated reduction after the uncertainty factor was applied, resulting in the not significant outcome.

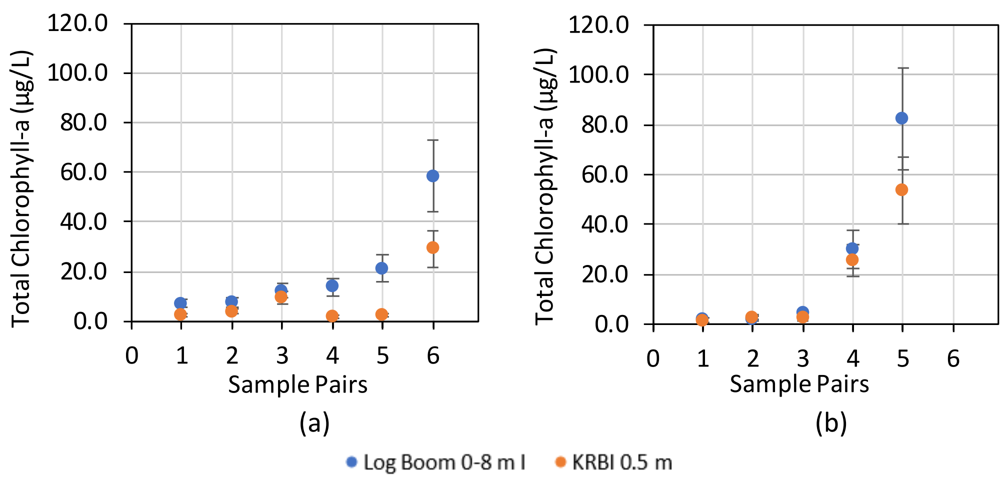



**Figure 6-25. Total chlorophyll-*a* concentrations for curtain deployment periods with (a) high effectiveness and (b) medium/low effectiveness (error bars are the uncertainty factor of 25 percent or the reporting limit, whichever is greater).**

**Table 6-22. Total chlorophyll-*a* sample pairs, hypothesized direction of difference, sign and Wilcoxon signed-rank test results, and mean bias between log boom 0- to 8-m integrated sample and Klamath River below Iron Gate pairs when the curtain was deployed. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| Curtain Status, effectiveness | Sample Pairs (n) | Sign Test Results | | Wilcoxon Signed-Rank Test Results | | Mean Bias (mean Δ from LB to KR, µg/L) |
|---|---|---|---|---|---|---|
| | | Without uncertainty factor | Including uncertainty factor | Without uncertainty factor | Including uncertainty factor | |
| Curtain Deployed, Productive season (July – October), high curtain effectiveness | 6 | **LB>KR, p=0.016** | LB>KR, p=0.110 | **LB>KR, p=0.014** | LB>KR, p=0.058 | -11.9 |
| Curtain Deployed, Productive season (July – October), medium/low curtain effectiveness | 5 | LB>KR, p=0.090 | N/A | LB>KR, p>0.05* | N/A | -7.0 |
| Curtain Deployed, Productive season, all effectiveness categories (July – October) | 12 | **LB>KR, p=0.002** | LB>KR, p=0.282 | **LB>KR, p=0.002** | LB>KR, p=0.348 | -9.0 |

LB – log boom 0- to 8-m integrated sample, KR – Klamath River below Iron Gate 0.5 m, N/A – not applicable because p>0.05 without uncertainty factor.

*Sample size is not large enough to calculate an accurate W (test statistic), but results are reported as greater or less than 0.05.

A threshold of 5.0 µg/L total chlorophyll-*a* was applied to data sets, such that sample pairs with log boom concentrations less than this were removed from the data set, and statistical tests reran to determine whether results changed during periods with higher concentrations of total chlorophyll-*a* in the reservoir (Table 6-23). All six sample pairs collected during high curtain effectiveness periods had log boom concentrations greater than 7.0 µg/L total chlorophyll-*a*, and therefore, results for this set of data are no different than when run without the threshold applied (Table 6-23 and Table 6-22). Sample pairs collected during periods of medium to low curtain effectiveness only included two pairs with log boom had log boom concentrations greater than 5.0 µg/L total chlorophyll-*a*, not enough to run statistical tests. Results for all curtain deployed sample pairs collected from July to October, with log boom concentrations greater than 5.0 µg/L total chlorophyll-*a*, were similar to without the threshold applied with a significant difference before but not after the uncertainty factor was applied (Table 6-23 and Table 6-22).

**Table 6-23. Total chlorophyll-*a* sample pairs, hypothesized direction of difference, sign and Wilcoxon signed-rank test results, and mean bias between log boom 0- to 8-m integrated sample and Klamath River below Iron Gate pairs when the curtain was deployed and concentration of log boom sample was greater than or equal to 5.0 µg/L. Results without the uncertainty factor are bold if the p-value is less than or equal to 0.050 and results with the uncertainty factor are bold if the p-value is less than or equal to 0.050 and the relationship is consistent after applying the uncertainty factor (i.e., does not change the outcome).**

| Curtain Status, season | Sample Pairs (n) | Sign Test Results | | Wilcoxon Signed-Rank Test Results | | Mean Bias (mean Δ from UC to DC, µg/L) |
|---|---|---|---|---|---|---|
| | | Without uncertainty factor | Including uncertainty factor | Without uncertainty factor | Including uncertainty factor | |
| Curtain Deployed, Productive season (July – October), high curtain effectiveness | 6 | **LB>KR, p=0.016** | LB>KR, p=0.110 | **LB>KR, p=0.014** | LB>KR, p=0.058 | -11.9 |
| Curtain Deployed, Productive season (July – October), medium/low curtain effectiveness | 2 | Not enough samples to perform tests | | | | -16.6 |
| Curtain Deployed, Productive season, all effectiveness categories (July – October) | 8 | **LB>KR, p=0.004** | LB>KR, p=0.364 | **LB>KR, p=0.006** | LB>KR, p=0.288 | -13.1 |

LB – log boom 0- to 8-m integrated sample, KR – Klamath River below Iron Gate 0.5 m, N/A – not applicable because p>0.05 without uncertainty factor.

### 6.3.2 Summary

The sign and Wilcoxon signed-rank test results indicated that Iron Gate Dam in combination with the deployed curtain does not significantly reduce chlorophyll-*a* concentrations in the river downstream of the dam after an uncertainty factor has been applied to address system heterogeneity and laboratory analysis uncertainty. Still, average bias always demonstrated reduction from the log boom to the Klamath River downstream of Iron Gate Dam, indicating that when total chlorophyll-*a* concentrations at the log boom were highest, reduction occurred (average bias of -9 µg/L for all curtain deployed samples and -11.9 µg/L for all curtain deployed samples collected during high curtain effectiveness periods) (Table 6-22).

# 7. Summary, Recommendations, and Conclusions

As part of the KHSA IM 11 Interim Water Quality Improvements, this report describes the continued evaluation of Intake Barrier System for water quality improvement from Iron Gate Powerhouse releases. Specifically, this work evaluated the intake barrier curtain in Iron Gate Reservoir using information collected from 2015 through 2018 to evaluate the efficacy of the curtain to retain biomass from blooms of cyanobacteria and potential associated toxins (i.e., microcystin) in the reservoir, thereby reducing releases of such matter to the river.

The curtain is located across the southwest corner of Iron Gate Reservoir just upstream of the existing powerhouse intake tower. The curtain itself is made of an impermeable coated nylon fabric that spans a horizontal length of approximately 245 m and has been shaped to fit the reservoir section profile with a design depth of 10.7 m. Reservoir depth at the mid-span of the curtain is approximately 25.6 m and approximately 10.7 m at the intake tower. When the curtain is completely furled (rolled up), the bottom edge of the curtain is approximately 1.5 m deep.

The barrier curtain is intended to take advantage of thermal stratification and associated vertical water density differences to retain near-surface waters in the reservoir while withdrawing deeper waters that contain less cyanobacteria than surface waters. Density differences not only segregate warmer surface waters from cooler, deeper waters, but also resist vertical mixing (e.g., wind mixing). Throughout the late spring, summer, and early fall, waters within the epilimnion may exhibit weak intermittent stratification, forming epilimnetic thermoclines within approximately the top 8 to 10 m in the vicinity of the dam.

## 7.1 Hypotheses

The premise that placement of a seasonal barrier curtain in Iron Gate Reservoir could take advantage of thermal stratification and associated vertical density differences in the water column, retain cyanobacteria in the near-surface waters within the reservoir, and reduce releases of cyanobacteria and associated toxins to the downstream Klamath River was based on an understanding that:

- The majority of cyanobacteria exist in or near surface waters (photic zone).
- Epilimnetic stratification minimizes mixing of surface waters with deeper epilimnetic waters.

Three hypotheses were developed to frame the analysis and characterize the effectiveness of using a barrier curtain to reduce algae concentrations downstream of Iron Gate Dam. Specifically:

- **H1**: The curtain is effective at reducing cyanobacteria loads in downstream waters by reducing the downstream movement of surface waters, which often contain high concentrations of cyanobacteria, from Iron Gate Reservoir into the Klamath River.

- **H2**: Iron Gate Dam, without a curtain, provides some downstream reduction in cyanobacteria loads by reducing the downstream movement of surface waters, which often contain high concentrations of cyanobacteria, from Iron Gate Reservoir into the Klamath River.

- **H3**: The curtain in combination with Iron Gate Dam is effective at reducing cyanobacteria loads in downstream waters by reducing the downstream movement of surface waters, which often contain high concentrations of cyanobacteria, from Iron Gate Reservoir into the Klamath River.

# 7.2 Methods

Planktonic algae concentrate in the photic zone where they take advantage of light for photosynthesis. Buoyancy compensating cyanobacteria, such as *Microcystis* spp., have the distinct advantage of controlling their position in the water column which enables them to seek water depths with conditions (e.g., light, nutrients) optimal for growth. Available data indicate that during summer, cyanobacteria in Iron Gate Reservoir generally occupy approximately the top 3 m of the water column where light conditions are optimal for photosynthesis, but may distribute over greater depths. Curtain deployment depth can be managed to take advantage of epilimnetic stratification, retain cyanobacteria in near-surface waters, and reduce releases to the Klamath River.

Epilimnetic stratification was characterized using the Wedderburn number (*Wn*), a dimensionless parameter that relates the stability of stratification (density and depth) to mixing energy (primarily wind velocity in this case). The *Wn* accounts for depth of the mixed layer, change in density (temperature) between layers, and wind mixing effects. To assess the hypotheses, three curtain effectiveness conditions were defined by *Wn* (Figure 7-1):

- Condition 1: Epilimnetic thermocline shallower than the curtain depth
- Condition 2: Epilimnetic thermocline at curtain depth
- Condition 3: Epilimnetic thermocline is deeper than curtain depth or stratification was nonexistent or weak

Condition 1 represents generally deeper deployment depths up to design depth (10.7 m), and is consistent with the original design for high curtain effectiveness (left panel in Figure 7-1). Condition 2 represents deployments that are typically shallower than design depth, but may still be still effective (center panel in Figure 7-1). Condition 3 occurs when the curtain is not deployed to design depth. Ideally the curtain would be placed at design depth at the beginning of the cyanobacteria bloom period and remain at that depth until cyanobacteria conditions abated in the reservoir. However, low dissolved oxygen in deeper waters of the epilimnion can constrain curtain depth, leading to curtain deployment depths that are shallower than design depth. Under certain circumstances, this constraint results in the curtain depth being reduced to the point that effectiveness is compromised (e.g., Condition 3, right panel in Figure 7-1).

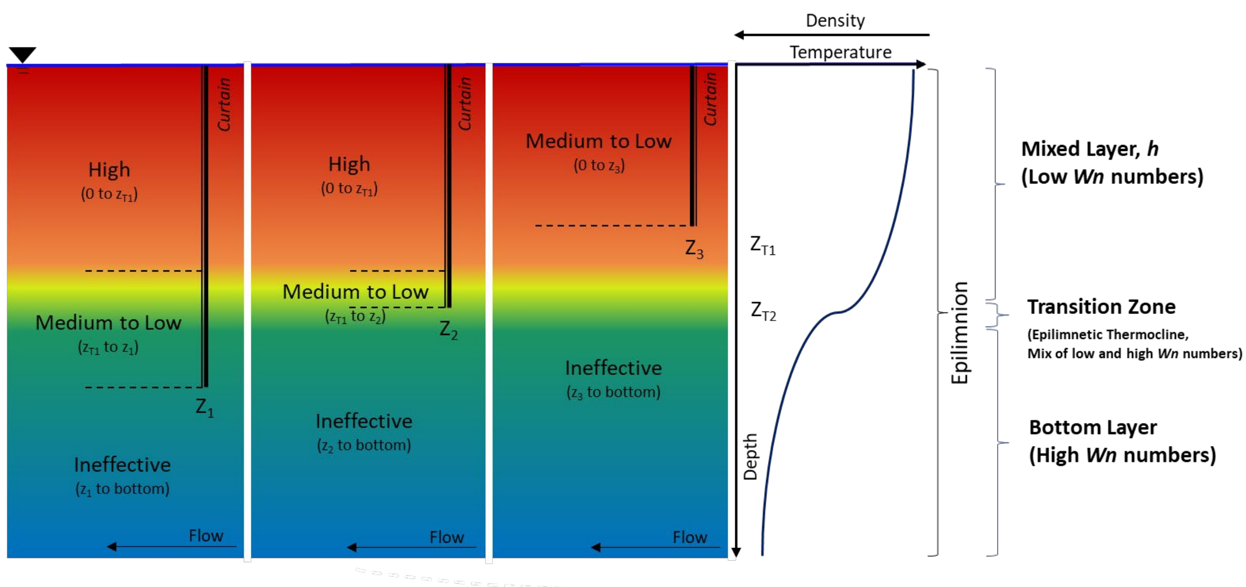



**Figure 7-1. Curtain deployment conditions and potential curtain effectiveness.**

## 7.3 Results

Results include a comparison of curtain deployment depth patterns over the 2015-2018 summer and fall seasons, a brief recap of ADCP data, and presentation of data collected in 2017 and 2018. Curtain deployment depths over the various years illustrate how depths have deviated from design depth for a variety of reasons. The ADCP data were revisited to determine if the 2015 survey identified appreciable vertical velocities along the curtain; a condition that would suggest potential vertical mixing under the curtain. Analysis of the vertical velocity component did not display evidence of downward (or upward) moving waters near the bottom of the curtain, or at any location within the water column, that could affect stratification upstream of the curtain. Finally, the sonde data, thermograph data, vertical profile samples, autosampler data (2017 only) and meteorological conditions for 2017 and 2018 were summarized.

## 7.4 Analysis and Discussion

Efficacy of the placement of a seasonal barrier curtain in Iron Gate Reservoir to reduce releases of cyanobacteria and associated toxins to the downstream Klamath River was tested using the three hypotheses. Field data 2015 through 2018 and additional relevant data from other ongoing monitoring efforts (i.e., IM 11 and IM 15) were analyzed and the role that the barrier curtain and Iron Gate Dam play in cyanobacteria reduction downstream of the curtain and downstream of the dam was assessed. Data from all years were employed in these analyses to integrate inter- and intra-annual variability over multiple years in order to assess overall curtain performance under a range of conditions.

### 7.4.1 Reduction in Downstream Loading Attributable to Curtain

Effective curtain periods were determined based on *Wn* analysis and data collected during curtain deployments were sorted into two conditions: high curtain effectiveness, and medium/low curtain effectiveness. The *Wn* analysis indicates that surface waters of Iron Gate Reservoir are more strongly stratified in July and August than in September and October. If the curtain can be deployed deep enough, this improves curtain effectiveness in July and August compared to September and October. Vertical profile grab samples of total chlorophyll-*a, Microcystis*, and microcystin, demonstrated that the curtain significantly reduced concentrations downstream of the curtain ($p \leq 0.05$) when compared to upstream for periods of high curtain effectiveness, even when these curtain depths were less than the design depth. For medium/low effectiveness periods when considering uncertainty in the data sets consistent reductions were not statistically significant ($p>0.05$).

The results of analysis of sonde data (chlorophyll and phycocyanin) were less clear. Analysis of sonde water temperature data indicated a significant systematic reduction downstream of the curtain. Analysis results for chlorophyll were mixed, with no significant difference between upstream and downstream of the curtain at 0.5-m and 5-m depths ($p>0.05$), even when assessing pairs with upstream of the curtain RFU values at or above a threshold of 0.6 RFU, but a significant difference was demonstrated at the 10-m depth. Analysis results for phycocyanin were also mixed, with no significant difference between upstream and downstream of the curtain ($p>0.05$) at 0.5-m and 5-m depths. However, when phycocyanin RFU values upstream of the curtain were higher ($\geq$0.4 RFU), reductions in phycocyanin were generally apparent from upstream to downstream of the curtain and a significant reduction occurred.

### 7.4.2 Reduction in Downstream Loading Attributable to Iron Gate Dam

The presence of Iron Gate Dam has been hypothesized to reduce the release of cyanobacteria from the reservoir into the Klamath River. Total chlorophyll-*a* was used as the parameter to assess conditions created by the dam without the curtain present. Comparing conditions at the log boom in Iron Gate Reservoir and the Klamath River downstream of Iron Gate Dam without a curtain yielded no statistically significant ($p>0.05$) reduction in chlorophyll-*a* for the sample sets analyzed when considering uncertainty in the data sets, although average bias demonstrated some reduction may occur.

### 7.4.3 Reduction in Downstream Loading Attributable to Combined Curtain and Iron Gate Dam

The presence of Iron Gate Dam as well as the curtain has been hypothesized to reduce the release of cyanobacteria from the reservoir into the Klamath River. Total chlorophyll-*a* was used as the parameter to assess conditions created by curtain deployment in conjunction with the presence of Iron Gate Dam. Comparing conditions at the log boom in Iron Gate Reservoir and the Klamath River downstream of Iron Gate Dam when the curtain was deployed yielded no statistically significant ($p>0.05$) reduction in concentrations of chlorophyll-*a* when considering uncertainty in the data sets, although average bias demonstrated reduction occurs. Visual inspection of the sample data indicates that chlorophyll-*a* concentrations were less downstream of Iron Gate Dam than in the reservoir. Further, sample sizes were low ($n=6$ for high curtain effectiveness periods) and a single sample pair with results inconsistent with the other sample pairs results in the entire data set being not statistically significant at $p<0.05$. Additional sample pairs, especially during times with greater cyanobacterial concentration, may provide further insight.

## 7.5 Recommendations

Through the data assessment and analysis completed herein, the following recommendations have been developed:

- Continue the targeted curtain not deployed and curtain deployed monitoring to expand the data set. These data, drawn from multiple years, can be used to continue to integrate inter- and intra-annual variability and represent overall curtain performance under a range of conditions. Monitoring should include curtain not deployed (at least one set) and curtain deployed (at least two sets) of grab samples for chlorophyll-*a*, microcystin, *Microcystis*, and cyanobacteria, with increased sampling at shallower depths. Recommended sampling depths remain 0.5 m, 1.5 m, 3 m, 5 m, 6 m, 9 m, and 12 m. Removing the 15-m sample depth upstream of the curtain is recommended because there is no downstream curtain pair (i.e., the downstream curtain site is generally shallower than 15 m).
- Continue sonde vertical profiling at 3 times per week to current depths (15 m upstream and 12 m downstream).
- Consider analysis of sonde data at other depths (e.g., 3 m). Although not available for 2016, these data may provide additional insight into curtain performance, especially since the curtain was often deployed to a depth less than 5 m.
- Consider the effect of large spikes in sonde chlorophyll and phycocyanin average RFU values used in the assessment.

## 7.6 Conclusions

Overall, the barrier curtain, when deployed to an effective depth, retains the near-surface waters within the reservoir along with the cyanobacteria and related toxins found in this water, and reduces release of this material to the downstream Klamath River. The main challenge to maintaining an effective depth is low dissolved oxygen levels in the deeper waters of the epilimnion that constrain the deployment depth.

Shallower deployment depths reduce the effectiveness of the curtain by not taking full advantage of thermal stratification and associated vertical density differences in the water column, and the behavioral aspect of cyanobacteria to use buoyancy compensation ability to remain in the near-surface waters within the reservoir. Continued monitoring of the curtain will improve the characterization of curtain performance and provide managers with more information useful in refining operations of the curtain under a variety of reservoir conditions to reduce releases of cyanobacteria to downstream Klamath River reaches.

# 8. References


California State Water Resources Control Board (SWRCB). 2016. 2016 Guidance Document Updates in California Guidelines for Cyanobacteria in Recreational Inland Waters – Voluntary. Available at: https://mywaterquality.ca.gov/habs/resources/habs_response.html.

Deas, M. L. and E. Miao. 2010. Exploratory Velocity Measurements in Iron Gate Reservoir with an Acoustic Doppler Current Profiler. Prepared for PacifiCorp. July 12. 14 pp.

Deas, M. L. and E. Miao. 2014. Assessment of an Intake Barrier for Water Quality Control at Iron Gate Reservoir – 2013 Study Results. Prepared for PacifiCorp. April 25. 34 pp.

Dreher, T. W., L. P. Collart, R. S. Mueller, K. H. Halsey, R. J. Bildfell, P. Schreder, A. Sobhakumari, R. Ferry. 2019. Anabaena/Dolichospermum the source of lethal microcystin levels responsible for a large cattle toxicosis event. Toxicon X. Vil 1. https://doi.org/10.1016/j.toxcx.2018.100003.

Eslinger, D. L. and R. L. Iverson. 2001. "The effects of convective and wind-driven mixing on spring phytoplankton dynamics in the Southeastern Bering Sea middle shelf domain." Continental Shelf Research 21(6–7), 627-650.

Fantin-Cruz, I. O. Pedrollo, C. C. Bonecker, and P. Zeilhofer. 2015. Key factors in vertical mixing processes in a reservoir bordering Pantanal floodplain, Brazil. Hydrologic Sciences Journal. 60(9) 1508-1519.

Fischer, H. B., E. J. List, R. C. Y. Koh, J. Imberger, and N. H. Brooks. 1979. Mixing in inland and coastal waters. Academic Press, New York, NY.

Harmel, R. D., R. J. Cooper, R. M. Slade, R. L. Haney, and J. G. Arnold. 2006. Cumulative uncertainty in measured streamflow and water quality data for small watersheds. Transactions of the American Society of Agricultural and Biological Engineers (ASABE). Vol. 49 (3), pp. 689-701.

Helsel, Dennis R. and Robert M. Hirch. 2002. Statistical Methods in Water Resources. In: Techniques of Water-Resources Investigations of the United States Geological Survey Book 4, Hydrologic Analysis and Interpretation. United States Geological Survey. September 2002. 510 pp. Available at: http://water.usgs.gov/pubs/twri/twri4a3/.

Henry, R., J. G. Tundisi, M. C. Calijuri, and M. S. R. Ibanez. 1997. A comparative study of thermal structure, heat content and stability of stratification in three lakes. In: J.G. Tundisi and T. Saijo, eds. Limnological studies on the Rio Doce Valley lakes. São Carlos, Brazil: Brazilian Academy of Sciences, UFSCar, 69–77.

Hoff, P. D. 2010. A First Course in Bayesian Statistical Methods. Springer. New York. 274 pp.

Horne, A. J. and C.R. Goldman. 1994. *Limnology*. McGraw Hill, New York. 576 pp.

Huisman J., J. Sharples, J. M. Stroom, P. M. Visser, W E. A. Kardinaal, J. M. H. Verspagen, and B. Sommeijer. 2004. Changes in turbulent mixing shift competition for light between phytoplankton species. Ecology, 85(11), 2960-2970.

Imboden, D. M. and A. Wüst, A. 1995. Mixing Mechanisms in Lakes. In: A. Lerman, I. Dm, and J. Gat, eds. Physics and chemistry of lakes. Berlin: Springer, 83–135.

Kalff, J. Limnology. 2002. Prentice Hall. New Jersey. 592 pp.

Miao, E. and M. L. Deas. 2014. Assessment of an Intake Barrier for Water Quality Control at Iron Gate Reservoir – 2013 Study Results. Prepared for PacifiCorp. April. 34 pp.

**REFERENCES**


Moisander, P.H. 2008. Presentation to the Klamath Blue-Green Algae Work Group (Sacramento) – Diversity and nutrient limitation of *Microcystis* in Klamath River reservoirs. University of California Santa Cruz, Ocean Sciences Department.

Moisander, P.H., M. Ochiai, and A. Lincoff. 2009. Nutrient limitation of *Microcystis* in northern California Klamath River reservoirs. Harmful Algae 8: 889-897.

National Marine Fisheries Service (NMFS). 2012. Biological Opinion on the proposed issuance of an Incidental Take permit to PacifiCorp Energy for implementation of the PacifiCorp Klamath Hydroelectric Project: Interim Operations Habitat Conservation Plan for Coho Salmon. February 22. File No. 151422SWR2010AR00523.

Otten, T. G., H. Xu, B. Qin, G. Zhu, H. W. Paerl. 2012. Spatiotemporal patterns and ecophysiology of toxigenic microcystis blooms in Lake Taihu, China: implications for water quality management. Environ Sci Technol. 46(6): 3480-3488.

Otten, T. G., J. R. Crosswell, S. Mackey, T. W. Dreher. 2015. Application of molecular tools for microbial source tracking and public health risk assessment of a Microcystis bloom traversing 300 km of the Klamath River Harmful Algae, 46 (2015), pp. 71-81.

PacifiCorp. 2008. Quality Assurance Project Plan. Baseline Water Quality Monitoring by PacifiCorp, Interim Measure 12, Part 2.

PacifiCorp. 2012. PacifiCorp Klamath Hydroelectric Project: Interim Operations Habitat Conservation Plan for Coho Salmon PacifiCorp. February.

PacifiCorp. 2016. Iron Gate Reservoir 2016 Intake Barrier Study Plan. 9 pp. July.

PacifiCorp. 2017. 2016 Evaluation of Intake Barrier Curtain in Iron Gate Reservoir to Improve Water Quality in the Klamath River. October. 113 pp.

Reynolds, C. S., R .L. Oliver, and A. E. Walsby. 1987. Cyanobacterial dominance: The role of buoyancy regulation in dynamic lake environments, New Zealand. Journal of Marine and Freshwater Research, 21:3, 379-390.

Rode, M. and U. Suhr. 2007. Uncertainties in selected river water quality data. Hydrology and Earth Systems Sciences. Vol. 11, pp. 863-874.

Serra, T. J. Vidal, X. Casamitjana, M. Soler, and J. Colomer. 2007. “The role of surface vertical mixing in phytoplankton distribution in a stratified reservoir.” Limnol. Oceanogr., 52(2), 620–634.

Silva, R. J. N. da. 2013. Setting target measurement uncertainty in water analysis. Water, Vol. 5, pp. 1279-1302.

Stanley, E. H., S. M. Collins, N. R. Lottig, S. K. Oliver, K. E. Webster, K. S. Cheruvelil, and P. A. Soranno. 2019. Biases in lake water quality sampling and implications for macroscale research. Limnology and Oceanography. Vol. 64, pp. 1572-1585.

Walsby, A. E., P. K. Hayes, R. Boje, and L. J. Stal. 1997. “The selective advantage of buoyancy provided by gas vesicles for planktonic cyanobacteria in the Baltic Sea.” New Phytol. 136, 407-417.

Watercourse Engineering, Inc. (Watercourse). 2013a. KHSA IM11: Iron Gate Reservoir Intake Cover for Water Quality Control, 2011. Prepared for PacifiCorp.

Watercourse Engineering Inc. (Watercourse). 2013b. 2012 Assessment of an Intake Cover for Water Quality Control at Iron Gate Reservoir. Prepared for PacifiCorp Energy. July.

Watercourse Engineering Inc. (Watercourse). 2015. Localized Treatment of Long Gulch Cove in Iron Gate Reservoir Using Hydrogen Peroxide Based Algaecide. Prepared for PacifiCorp Energy. April. 58 pp.

Watercourse Engineering, Inc. (Watercourse). 2016. Water Quality Effects of an Intake Barrier Curtain to Reduce Algae Concentrations Downstream of Iron Gate Reservoir. Prepared for PacifiCorp. July. 67 pp.

Watercourse Engineering Inc. (Watercourse). 2018. October 2017 Iron Gate Barrier chlorophyll-a biofouling correction. Prepared for PacifiCorp. January. 2 pp.

Xylem, Inc. (YSI). 2017. EXO User Manual: Advanced water quality monitoring platform, Revision G. April.

Xylem, Inc. (YSI). 2020. Personal communication (telephone) between YSI technical support and Brooke Mejica, Watercourse Engineering, Inc. March 19.

# Appendix A
# 2017 and 2018 Data

# Appendix A – 2017 and 2018 Data

This appendix presents 2017 and 2018 sonde data not presented in the Intake Barrier Curtain Summary Report (A.1); a presentation of sample pair numbers by depth, year, parameter, and season (A.2); and *Wn* by depth and temperature vertical profiles by month (A.3).

## A.1 Sonde Data

Included in this section are the sonde and vertical profile (when applicable) data for pH and specific conductance collected in 2017 and 2018.

### A.1.1 Sonde Data: pH (2017)

In 2017, daily average pH values from 0.5 m in depth upstream and downstream of the curtain ranged from 7.6 to nearly 10 during the curtain deployment period. Daily average pH values from 0.5 m in depth upstream and downstream of the curtain were similar or slightly reduced (by 0.0-0.3 pH units) downstream of the curtain until the curtain was deployed to 7.6 m in depth on July 25, and after the curtain was furled to 4.5 m, 3.0 m, and then 1.5 m in depth in August (Figure A-1). During the period the curtain was deployed to 7.6 m in depth, the 0.5-m downstream pH dropped by 1.7 to 1.4 pH units.

Daily average pH values at 5 m in depth upstream and downstream of the curtain ranged from 7.6 to 7.8 pH units during the curtain deployment period (Figure A-1). Daily average pH at the 5-m depth upstream and downstream of the curtain were generally similar until curtain deployment and after the curtain was furled, except on July 6 and July 26 where pH was reduced (by 0.7 to 0.9 pH units) downstream of the curtain. A gap in upstream curtain sonde data precludes comparisons at 5 m in depth during curtain deployment except for on July 26, where daily average pH was reduced (by 0.7 pH units) downstream of the curtain, and September 20, when daily average pH values were similar.

Daily average pH values at 10 m in depth upstream and downstream of the curtain ranged from 7.0 to over 7.5 pH units during the curtain deployment period (Figure A-1). Daily average pH values at the 10-m depth upstream and downstream of the curtain were reduced (by up to 0.3 pH units) downstream of the curtain until the curtain was deployed, were similar to downstream of the curtain on July 26 during curtain deployment, and were similar to downstream of the curtain after the curtain was furled to 3.0 m or 1.5 m in depth in September.

Daily average pH values at KRBI range from approximately 7.5 to over 9 pH units during the curtain deployment period (Figure A-1). Daily average pH values at in the Klamath River downstream of Iron Gate Dam followed a similar pattern to pH at 0.5 m in depth downstream of the curtain, but were approximately 1 pH unit less.

### A.1.1 Vertical Profile Data: pH (2017)

In 2017, pH values upstream and downstream of the curtain were similar for periods when the curtain was not deployed; however, once the curtain was deployed, pH was reduced downstream of the curtain compared to upstream of the curtain from surface depths to approximately 6 m (Figure A-2).

### A.1.1 Sonde Data: pH (2018)

In 2018, daily average pH at a depth of 0.5 m upstream and downstream of the curtain ranged from 7.4 to 10.1 during the curtain deployment period (Figure A-3). pH values were similar until the curtain was deployed on July 24. After curtain deployment to a depth of 4.6 m, downstream of the curtain daily average pH values at a depth of 0.5 m decreased relative to the upstream of the curtain pH values.

## APPENDIX A – 2017 AND 2018 DATA

Upstream of the curtain pH values remained greater than downstream of the curtain pH values until mid-to-late September, when seasonal reduction in solar radiation, water temperatures, and increased frequency of mixing led to the convergence of the upstream and downstream of the curtain pH values for the remainder of the deployment period (i.e., through early November).

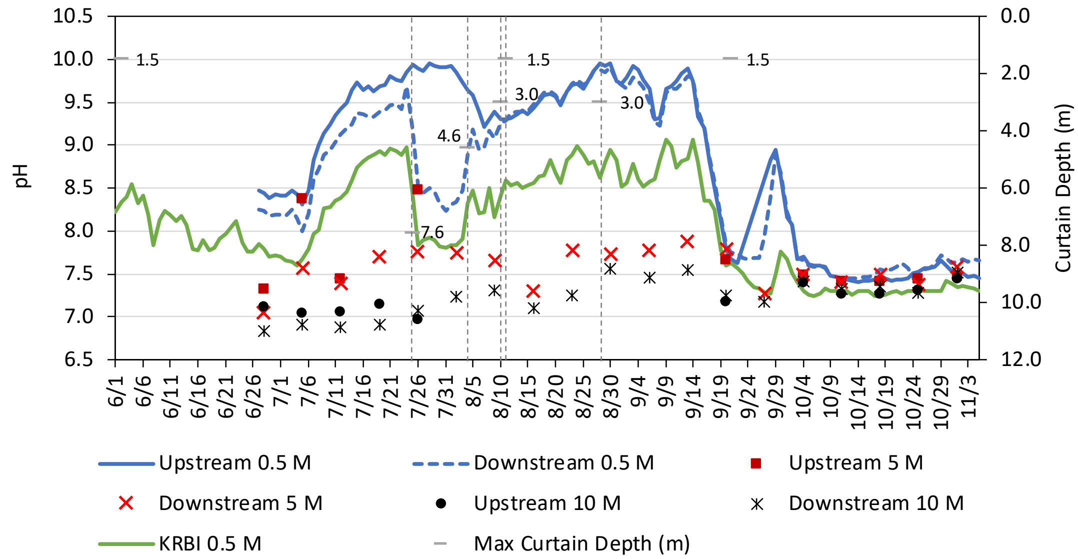



**Figure A-1. Daily average pH at three depths (0.5 m, 5 m, and 10 m) upstream and downstream of the curtain and in the Klamath River below Iron Gate Dam (KRBI) and deployed curtain depth (m). Vertical dashed lines indicate curtain deployment dates of July 25, August 4, August 11, August 28, and September 21, 2017.**

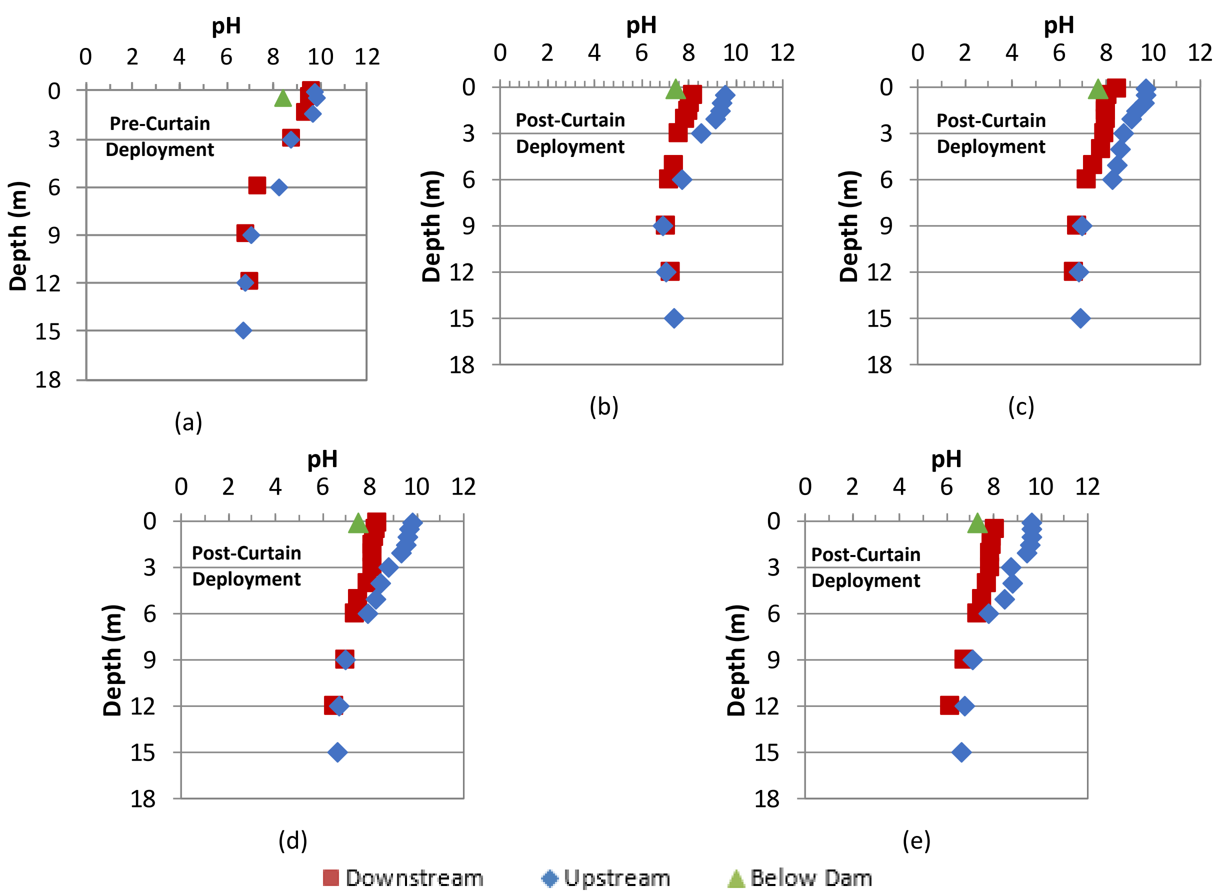



**Figure A-2. pH vertical profiles upstream and downstream of the curtain and downstream of Iron Gate Dam before curtain deployment on (a) July 24, (b) July 25, (c) July 26, (d) July 27, and (e) August 3, 2017.**

Daily average pH values at the 5-m depth upstream and downstream of the curtain were similar until early-August, after which there was considerable variability in pH values upstream and downstream of the curtain (Figure A-3). Generally, pH values upstream of the curtain were greater than pH values downstream of the curtain, but there were periods where the inverse occurred. By early October, pH values at sites upstream and downstream of the curtain at 5 m in depth converged. During the curtain deployment period, daily average pH values at the 5-m depth ranged from 7.3 to 8.7.

At the 10-m depth, daily average pH values upstream and downstream of the curtain were similar throughout the deployment period and were fairly stable (Figure A-3). Daily average pH values ranged from 7.1 to 7.6 during the curtain deployment period.

Daily average pH values at in the Klamath river downstream of Iron Gate Dam were typically less than those observed upstream and downstream of the curtain at 0.5m depth, but greater than those observed at the 5-m and 10-m depths (Figure A-3). Daily average pH values ranged from 7.2 to 8.8 in the Klamath River below Iron Gate dam during the curtain deployment period.

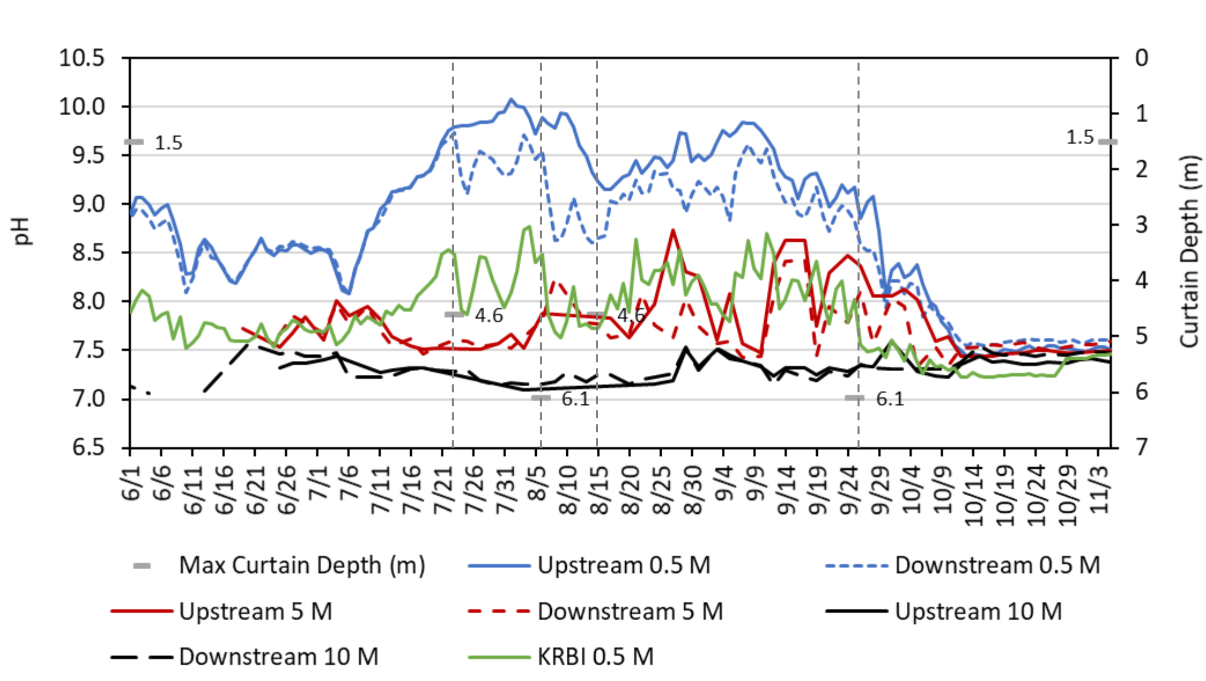



**Figure A-3. Daily average sonde pH at three depths (0.5 m, 5 m, and 10 m) upstream and downstream of the curtain and in the Klamath River below Iron Gate Dam (KRBI) and curtain deployment depths (m) in 2018. Vertical dashed lines indicate initial and interim curtain deployment on July 24 (initial), August 7 and 16, and September 27, 2018 (final furling of the curtain occurred on November 7, 2018).**

## A.1.2 Vertical Profile Data: pH (2018)

pH values upstream and downstream of the curtain are similar for periods when the curtain was not deployed; however, once the curtain was deployed, pH was reduced downstream of the curtain compared to upstream of the curtain from surface depths to approximately 4 or 5 m (Figure A-4).

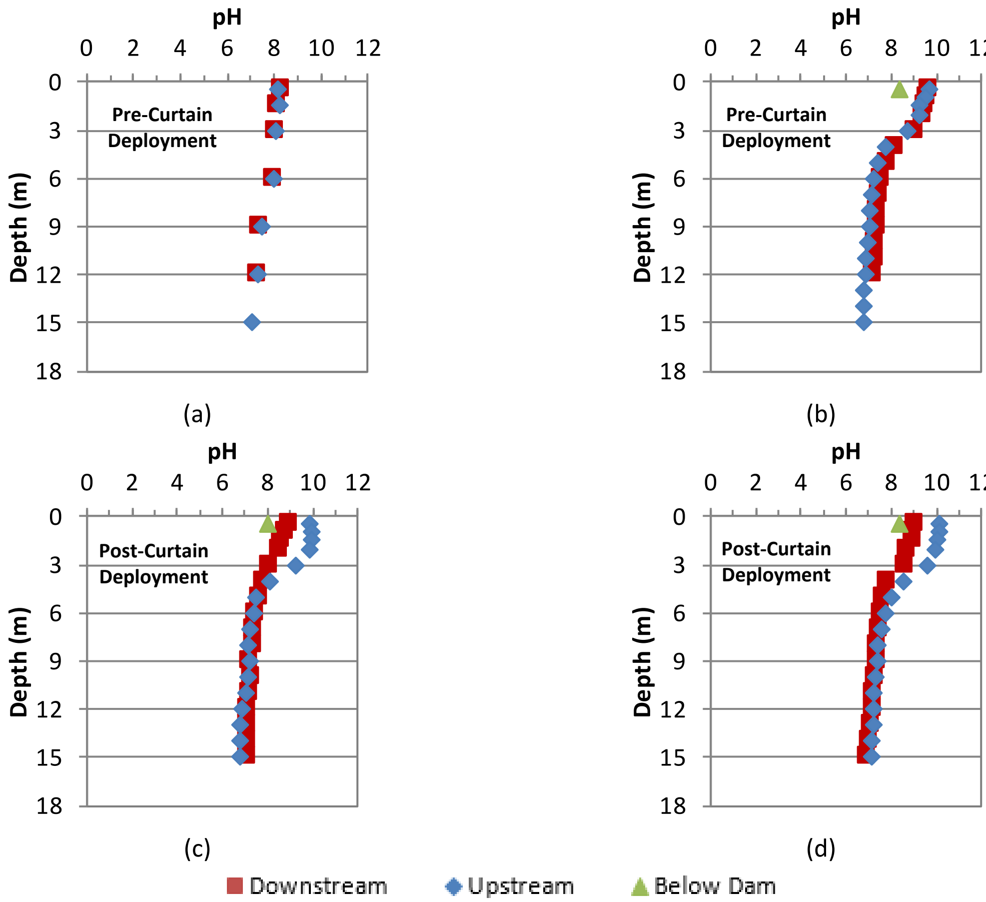



**Figure A-4. pH vertical profiles upstream and downstream of the curtain on (a) July 5 (no data were collected downstream of the dam because of the Klamathon fire forced evacuation), (b) July 23, (c) July 26, and (d) August 2, 2018.**

## A.1.3 Specific Conductance (2017)

In 2017, daily average specific conductance values from a depth of 0.5 m upstream and downstream of the curtain ranged from approximately 132 to 153 µS/cm during the curtain deployment period (Figure A-5). Daily average specific conductance values from a depth of 0.5 m upstream of the curtain were consistently equal to or less than values from a depth of 0.5 m downstream of the curtain through August; values were roughly similar for the remainder of the season. During curtain deployment to 7.6 m, downstream of the curtain daily average specific conductance values at a depth of 0.5 m ranged from 143 to 136 µS/cm.

Daily average specific conductance values at a depth of 5 m downstream of the curtain ranged from 137 to 143 µS/cm during the curtain deployment period (Figure A-5). Daily average specific conductance values at the 5-m depth upstream and downstream of the curtain were similar before and after curtain deployment. A gap in upstream curtain sonde data precludes comparisons at 5 m during curtain deployment except on July 26 where specific conductance was reduced downstream of the curtain (by 3.4 µS/cm), and September 20, when specific conductance values were similar (downstream was reduced by less than 1 µS/cm).

Daily average specific conductance at 10 m in depth upstream and downstream of the curtain ranged from 135 to over 143 µS/cm during the curtain deployment period (Figure A-5). Daily average specific conductance values at the 10-m depth upstream and downstream of the curtain were greater downstream than upstream of the curtain until the curtain was deployed. A gap in upstream curtain sonde data precludes comparisons at 10 m during curtain deployment except on July 26 where daily average specific conductance values were similar on both sides of the curtain. Daily average specific conductance values were similar at both sides of the curtain after the curtain was furled to 3.0 m or 1.5 m in September.

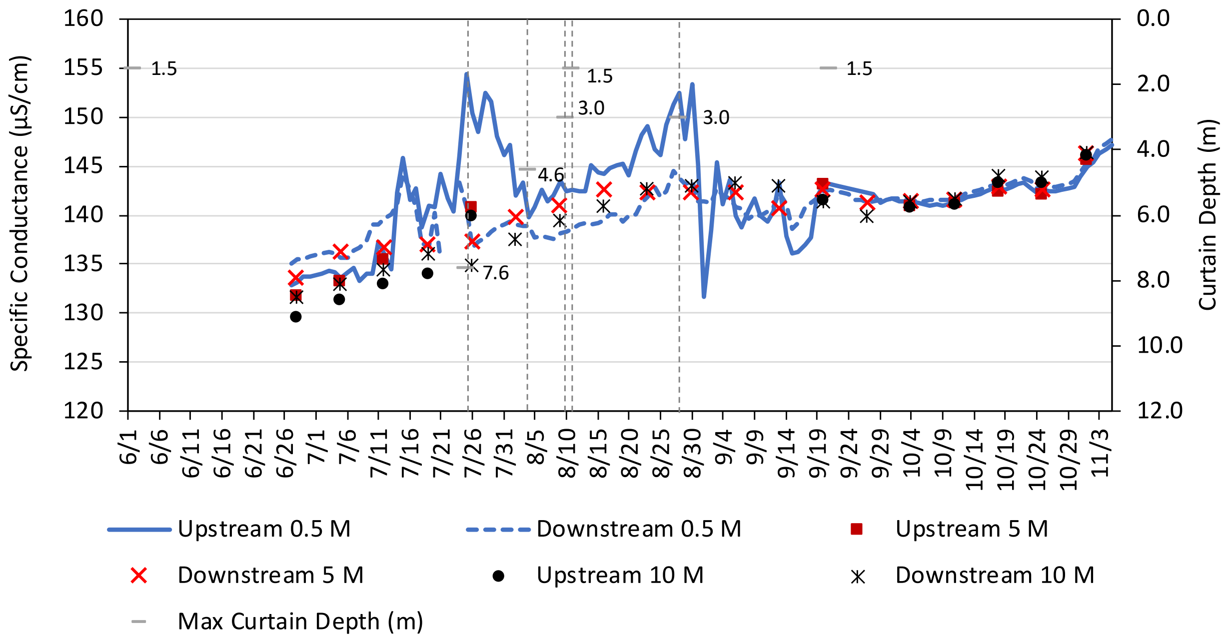



**Figure A-5. Daily average specific conductance (µS/cm) at three depths (0.5 m, 5 m, and 10 m) upstream and downstream of the curtain and curtain deployment depth (m) in 2017. Vertical dashed lines indicate initial and interim curtain deployment on July 25 (initial), August 4, August 11 (furled), and August 28 (final furling of the curtain occurred on September 21, 2017).**

## A.1.4 Specific Conductance (2018)

Daily average specific conductance 0.5 m upstream and downstream of the curtain ranged from 137 to 153 µS/cm during the curtain deployment period. Specific conductance values upstream and downstream of the curtain were generally similar until the curtain was deployed on July 24 (Figure A-6). After curtain deployment to 4.6 m, the 0.5-m upstream sonde data showed increases in specific conductance relative to the downstream specific conductance. Specific conductance remained variable until mid-to-late August, after which the upstream and downstream specific conductance were similar.

Specific conductance values at the 5-m depth upstream and downstream of the curtain were similar throughout the deployment period. There were a few periods when the downstream specific conductance values were greater than the upstream but the difference was typically less than 5 µS/cm. During the deployment period specific conductance ranged from 140 to 153 µS/cm.

At the 10-m depth, the specific conductance values upstream and downstream of the curtain were similar throughout the deployment period. Specific conductance ranged from 138 to 159 µS/cm during the deployment period.

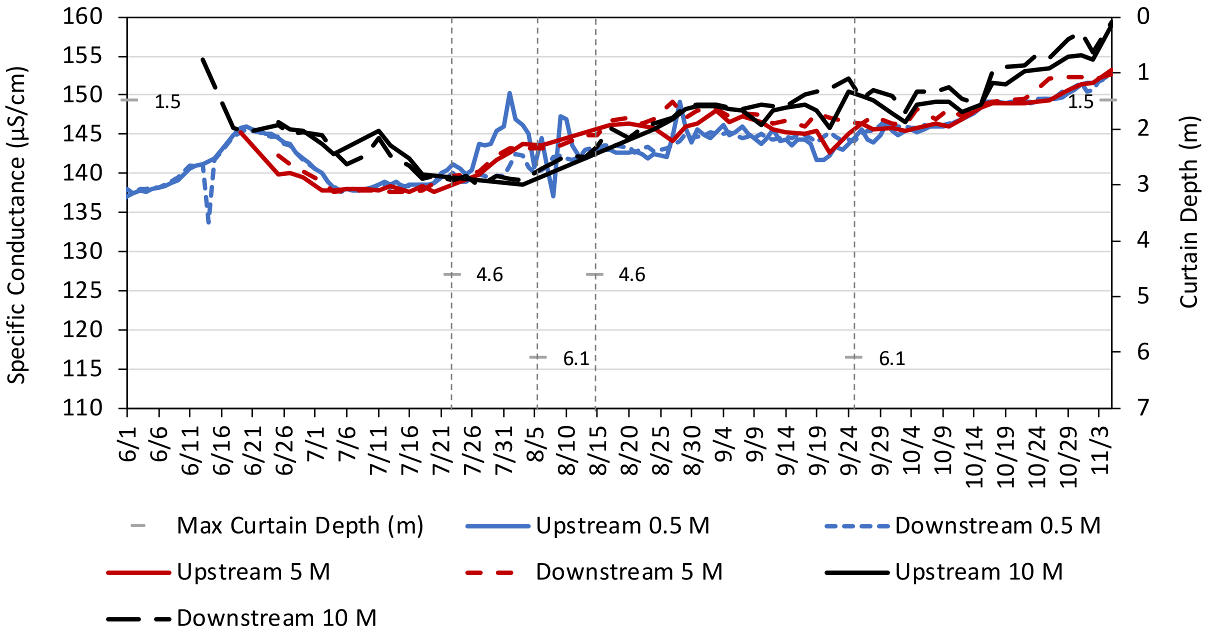



**Figure A-6. Daily average sonde specific conductance (µS/cm) at three depths (0.5 m, 5 m, and 10 m) upstream and downstream of the curtain and curtain deployment depth (m) in 2018. Vertical dashed lines indicate initial and interim curtain deployment on July 24 (initial), August 7 and 16, and September 27, 2018 (final furling of the curtain occurred on November 7, 2018).**

## A.2 Sample Pairs

Tables describing number of sample pairs by year, sample depths, and parameters collected are presented and include information on depths by year and parameter (Table A-1), and number of sample pairs by depth and parameter (Table A-2). Iron Gate Reservoir log boom and KRBI chlorophyll-*a* grab sample pairs were reported by year, season, and curtain not deployed or curtain deployed periods (

Table A-3 and Table A-4).

**Table A-1. Sample depths available for curtain not deployed and curtain deployed grab sample pairs, by year and parameter.**

| | Sample Depths (m) | | | |
|---|---|---|---|---|
| **Year** | **Total Chlorophyll-*a*** | **Total Microcystin** | **Total *Microcystis*** | **Total Cyanobacteria** |
| 2015 | 0.5, 1.5, 3, 6, 9, 12, 15, 0-8 | 0.5, 1.5, 3, 6, 9, 12, 15, 0-8 | Not Collected | Not Collected |
| 2016 | 0.5, 1.5, 3, 6, 9, 12 | 0.5, 1.5, 3, 6, 9, 12 | 0.5, 1.5, 3, 6, 9, 12 | 0.5, 1.5, 3, 6, 9, 12 |
| 2017 | 0.5, 1.5, 3, 6, 9, 12 | 0.5, 1.5, 3, 6, 9, 12 | 0.5, 1.5, 3, 6, 9, 12 | 0.5, 1.5, 3, 6, 9, 12 |
| 2018* | 0.5, 1.5, 3, 6, 9, 12 | 0.5, 6, 12 | 0.5, 6, 12 | 0.5, 6, 12 |

* In 2018, total microcystin, total *Microcystis*, and total cyanobacteria samples were collected at the additional depths of 1.5 m, 3 m, and 9 m but not analyzed. These samples are archived at Bend Genetics.

**Table A-2. Number of 2015-2018 curtain not deployed and curtain deployed (and above the depth of the deployed curtain) grab sample pairs available by sample depth and parameter.**

| Sample Depth (m) | Total Chlorophyll-*a* Sample Pairs (n) | Total Microcystin Sample Pairs (n) | Total *Microcystis* Sample Pairs (n) | Total Cyanobacteria Sample Pairs (n) |
|---|---|---|---|---|
| 0.5 | 38 | 38 | 29 | 29 |
| 1.5 | 10 | 6 | 6 | 6 |
| 3 | 11 | 7 | 6 | 6 |
| 6 | 8 | 8 | 7 | 7 |
| 9 | 4 | 2 | 1 | 1 |
| 12 | 3 | 3 | 3 | 3 |
| 15 | 0 | 0 | 0 | 0 |
| 0-8 Integrated | 2 | 2 | 0 | 0 |
| All Depths | 76 | 66 | 52 | 52 |

**Table A-3. Number of curtain not deployed sample pairs (n) during 2015-2018 at the Iron Gate Reservoir log boom and downstream of Iron Gate Dam.**

| Year | All Months Sample Pairs (n) | July through October Sample Pairs (n) |
|---|---|---|
| 2004 | 2 | 2 |
| 2005 | 5 | 2 |
| 2006 | 0 | 0 |
| 2007 | 7 | 6 |
| 2008 | 10 | 6 |
| 2009 | 6 | 3 |
| 2010 | 8 | 3 |
| 2011 | 7 | 3 |
| 2012 | 8 | 4 |
| 2013 | 8 | 3 |
| 2014 | 5 | 2 |
| 2015 | 7 | 0 |
| 2016 | 6 | 0 |
| 2017 | 7 | 2 |
| 2018 | 4 | 1 |
| All Years | 90 | 37 |

**Table A-4. Number of curtain deployed* sample pairs (n) during 2015- 2018 at the log boom in Iron Gate Reservoir and downstream of Iron Gate Dam.**

| Year | All Months Sample Pairs (n) | July through October Sample Pairs (n) |
|---|---|---|
| 2015 | 3 | 3 |
| 2016 | 5 | 4 |
| 2017 | 2 | 2 |
| 2018 | 3 | 3 |
| All Years | 13 | 12 |

*All curtain deployed sample pairs were collected from July through October except for one sample pair collected in November 2016.

# A.3 Wedderburn Numbers and Temperature Profiles

Fifteen-minute average wind speeds from the Iron Gate Dam meteorological station, *Wn,* and depth vs. depth *Wn* in Iron Gate Reservoir upstream of the curtain are displayed for the first date of each month that thermograph data were available for calculations (Table A-5 to Table A-34). Water temperature profiles from the thermograph array in Iron Gate Reservoir upstream of the curtain demonstrate seasonal changes in stratification for 2016 through 2018 (Figure A-7 to Figure A-9).

**Table A-5. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain June 15, 2016. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 6/15/2016 0:00 | 1.2 | -0.01 | -0.03 | 0.00 | -0.07 | 0.00 | -0.22 | 2.2 | 53 | 119 | 588 | 1313 |
| 6/15/2016 1:00 | 0.8 | 0.00 | -0.02 | 0.00 | -0.16 | 0.29 | 0.00 | 1.5 | 110 | 260 | 1326 | 3061 |
| 6/15/2016 2:00 | 1.1 | -0.01 | -0.03 | 0.00 | -0.08 | 0.00 | 0.00 | 11 | 55 | 130 | 627 | 1497 |
| 6/15/2016 3:00 | 1.4 | 0.00 | -0.01 | 0.02 | 0.00 | 0.18 | 0.30 | 5.9 | 33 | 93 | 372 | 875 |
| 6/15/2016 4:00 | 1.2 | 0.00 | -0.01 | 0.05 | 0.07 | 0.26 | 0.42 | 6.9 | 43 | 123 | 531 | 1226 |
| 6/15/2016 5:00 | 2.1 | 0.00 | -0.01 | 0.00 | -0.02 | 0.00 | 0.06 | 3.2 | 14 | 41 | 160 | 363 |
| 6/15/2016 6:00 | 1.4 | 0.00 | -0.01 | 0.02 | 0.00 | 0.17 | 0.42 | 6.5 | 32 | 88 | 340 | 769 |
| 6/15/2016 7:00 | 0.5 | 0.00 | -0.06 | 0.13 | 0.00 | 0.73 | 1.2 | 48 | 220 | 754 | 2908 | 6476 |
| 6/15/2016 8:00 | 1.7 | 0.00 | 0.00 | 0.02 | 0.03 | 0.17 | 0.28 | 3.2 | 17 | 55 | 234 | 520 |
| 6/15/2016 9:00 | 1.1 | 0.00 | 0.00 | 0.08 | 0.23 | 0.74 | 1.2 | 8.7 | 49 | 150 | 624 | 1391 |
| 6/15/2016 10:00 | 0.7 | 0.05 | 0.16 | 0.57 | 1.8 | 4.6 | 7.6 | 33 | 145 | 425 | 1619 | 3732 |
| 6/15/2016 11:00 | 0.9 | 0.06 | 0.18 | 0.65 | 2.5 | 5.7 | 11 | 22 | 97 | 251 | 953 | 2238 |
| 6/15/2016 12:00 | 0.6 | 0.15 | 0.82 | 3.1 | 9.1 | 20 | 40 | 85 | 262 | 678 | 2286 | 5562 |
| 6/15/2016 13:00 | 1.9 | 0.03 | 0.12 | 0.31 | 0.91 | 2.1 | 3.9 | 9.2 | 27 | 61 | 203 | 512 |
| 6/15/2016 14:00 | 5.5 | 0.00 | 0.01 | 0.04 | 0.11 | 0.25 | 0.46 | 0.90 | 2.8 | 7.5 | 25 | 62 |
| 6/15/2016 15:00 | 1.2 | 0.03 | 0.24 | 0.74 | 2.4 | 5.3 | 9.8 | 19 | 53 | 134 | 504 | 1288 |
| 6/15/2016 16:00 | 1.7 | 0.01 | 0.10 | 0.46 | 1.3 | 3.0 | 5.2 | 9.3 | 29 | 69 | 274 | 684 |
| 6/15/2016 17:00 | 1.0 | -0.01 | -0.03 | 0.00 | 0.09 | 5.9 | 11 | 20 | 70 | 173 | 673 | 1708 |
| 6/15/2016 18:00 | 3.0 | 0.00 | 0.00 | 0.00 | 0.03 | 0.43 | 0.96 | 1.8 | 7.7 | 19 | 76 | 189 |
| 6/15/2016 19:00 | 0.9 | -0.01 | -0.03 | -0.04 | -0.20 | -0.20 | 5.5 | 13 | 68 | 170 | 799 | 1945 |
| 6/15/2016 20:00 | 0.8 | -0.01 | -0.02 | 0.13 | 0.61 | 2.6 | 10 | 37 | 97 | 226 | 1011 | 2367 |
| 6/15/2016 21:00 | 0.4 | -0.06 | -0.11 | 0.99 | 4.1 | 29 | 94 | 217 | 528 | 1256 | 5686 | 12919 |
| 6/15/2016 22:00 | 1.1 | -0.01 | -0.02 | 0.03 | 0.00 | 0.30 | 2.9 | 17 | 42 | 92 | 646 | 1392 |
| 6/15/2016 23:00 | 1.3 | 0.00 | -0.01 | 0.02 | 0.00 | 0.22 | 1.4 | 9.4 | 29 | 60 | 443 | 981 |

**Table A-6. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain June 15, 2016. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 6/15/2016 0:00 | 1.2 | -0.01 | -0.03 | 0.10 | -0.07 | 0.13 | -0.22 | 2.6 | 43 | 29 | 232 | 200 |
| 6/15/2016 1:00 | 0.8 | 0.00 | -0.04 | 0.08 | -0.16 | 0.59 | -0.48 | 1.5 | 93 | 75 | 535 | 534 |
| 6/15/2016 2:00 | 1.1 | -0.01 | -0.02 | 0.08 | -0.08 | 0.16 | 0.00 | 11 | 31 | 37 | 241 | 293 |
| 6/15/2016 3:00 | 1.4 | 0.00 | -0.01 | 0.05 | -0.05 | 0.18 | 0.00 | 5.5 | 19 | 36 | 115 | 162 |
| 6/15/2016 4:00 | 1.2 | 0.00 | -0.02 | 0.10 | -0.07 | 0.13 | 0.00 | 6.2 | 26 | 49 | 181 | 215 |
| 6/15/2016 5:00 | 2.1 | 0.00 | 0.00 | 0.02 | -0.02 | 0.04 | 0.06 | 3.1 | 6.7 | 17 | 48 | 59 |
| 6/15/2016 6:00 | 1.4 | 0.00 | -0.01 | 0.04 | -0.04 | 0.17 | 0.14 | 5.9 | 17 | 34 | 99 | 124 |
| 6/15/2016 7:00 | 0.5 | 0.00 | -0.09 | 0.36 | -0.37 | 0.73 | 0.00 | 46 | 114 | 359 | 855 | 979 |
| 6/15/2016 8:00 | 1.7 | 0.00 | 0.00 | 0.04 | -0.03 | 0.11 | 0.00 | 2.7 | 9.8 | 25 | 79 | 78 |
| 6/15/2016 9:00 | 1.1 | 0.00 | 0.00 | 0.11 | 0.00 | 0.30 | 0.00 | 6.9 | 29 | 64 | 205 | 211 |
| 6/15/2016 10:00 | 0.7 | 0.05 | 0.10 | 0.29 | 0.19 | 1.2 | 0.00 | 21 | 73 | 173 | 466 | 647 |
| 6/15/2016 11:00 | 0.9 | 0.06 | 0.11 | 0.33 | 0.66 | 0.86 | 1.8 | 5.8 | 48 | 86 | 273 | 415 |
| 6/15/2016 12:00 | 0.6 | 0.15 | 0.88 | 1.7 | 0.52 | 2.1 | 6.8 | 26 | 90 | 231 | 524 | 1149 |
| 6/15/2016 13:00 | 1.9 | 0.03 | 0.11 | 0.05 | 0.05 | 0.37 | 0.31 | 3.5 | 8.7 | 15 | 46 | 116 |
| 6/15/2016 14:00 | 5.5 | 0.00 | 0.01 | 0.01 | 0.01 | 0.04 | 0.05 | 0.21 | 0.95 | 2.8 | 5.6 | 14 |
| 6/15/2016 15:00 | 1.2 | 0.03 | 0.30 | 0.27 | 0.37 | 0.59 | 0.97 | 4.3 | 16 | 43 | 144 | 303 |
| 6/15/2016 16:00 | 1.7 | 0.01 | 0.14 | 0.32 | 0.03 | 0.38 | 0.31 | 1.5 | 9.8 | 21 | 84 | 152 |
| 6/15/2016 17:00 | 1.0 | -0.01 | -0.02 | 0.08 | 0.09 | 5.8 | 1.1 | 3.9 | 28 | 55 | 200 | 395 |
| 6/15/2016 18:00 | 3.0 | 0.00 | 0.00 | 0.01 | 0.02 | 0.37 | 0.24 | 0.36 | 3.8 | 5.5 | 24 | 42 |
| 6/15/2016 19:00 | 0.9 | -0.01 | -0.03 | 0.05 | -0.10 | 0.20 | 5.8 | 5.2 | 37 | 55 | 298 | 402 |
| 6/15/2016 20:00 | 0.8 | -0.01 | 0.00 | 0.24 | 0.24 | 1.4 | 5.8 | 22 | 24 | 64 | 359 | 434 |
| 6/15/2016 21:00 | 0.4 | -0.06 | 0.00 | 1.7 | 1.4 | 21 | 45 | 78 | 107 | 368 | 2049 | 2122 |
| 6/15/2016 22:00 | 1.1 | -0.01 | 0.00 | 0.11 | -0.08 | 0.30 | 2.4 | 13 | 8.3 | 22 | 321 | 180 |
| 6/15/2016 23:00 | 1.3 | 0.00 | -0.01 | 0.05 | -0.06 | 0.22 | 1.1 | 7.2 | 9.7 | 13 | 225 | 145 |

**Table A-7. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain July 1, 2016. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 7/1/2016 0:00 | 0.7 | 0.00 | 0.19 | 0.83 | 6.4 | 89 | 152 | 243 | 520 | 939 | 2996 | 6045 |
| 7/1/2016 1:00 | 0.5 | 0.00 | 0.15 | 2.2 | 33 | 179 | 304 | 485 | 1048 | 1905 | 6123 | 12368 |
| 7/1/2016 2:00 | 1.2 | 0.01 | 0.03 | 0.87 | 9.9 | 29 | 52 | 83 | 181 | 318 | 1042 | 2157 |
| 7/1/2016 3:00 | 0.8 | 0.00 | 0.00 | 1.2 | 22 | 65 | 118 | 189 | 413 | 741 | 2358 | 4928 |
| 7/1/2016 4:00 | 1.3 | 0.00 | 0.00 | 0.38 | 5.4 | 19 | 36 | 57 | 127 | 235 | 742 | 1556 |
| 7/1/2016 5:00 | 1.5 | 0.00 | 0.00 | 0.45 | 5.1 | 16 | 28 | 46 | 96 | 176 | 583 | 1276 |
| 7/1/2016 6:00 | 1.4 | 0.00 | 0.02 | 0.61 | 6.1 | 17 | 30 | 50 | 103 | 193 | 638 | 1414 |
| 7/1/2016 7:00 | 0.4 | 0.08 | 0.00 | 10 | 79 | 264 | 458 | 731 | 1565 | 2916 | 9700 | 21319 |
| 7/1/2016 8:00 | 0.7 | 0.00 | -0.16 | 0.71 | 22 | 73 | 131 | 207 | 462 | 847 | 2775 | 6172 |
| 7/1/2016 9:00 | 1.5 | 0.01 | 0.01 | 0.31 | 3.2 | 16 | 29 | 45 | 98 | 178 | 600 | 1321 |
| 7/1/2016 10:00 | 0.8 | 0.08 | 0.25 | 1.3 | 12 | 58 | 102 | 157 | 331 | 625 | 2076 | 4614 |
| 7/1/2016 11:00 | 1.0 | 0.03 | 0.16 | 0.59 | 10 | 36 | 65 | 99 | 206 | 393 | 1286 | 2825 |
| 7/1/2016 12:00 | 1.0 | 0.08 | 0.23 | 0.99 | 13 | 39 | 72 | 112 | 233 | 447 | 1442 | 3200 |
| 7/1/2016 13:00 | 1.8 | 0.05 | 0.14 | 0.57 | 3.8 | 13 | 23 | 36 | 74 | 138 | 449 | 991 |
| 7/1/2016 14:00 | 3.5 | 0.05 | 0.11 | 0.33 | 1.4 | 4.4 | 7.8 | 12 | 25 | 44 | 137 | 286 |
| 7/1/2016 15:00 | 1.4 | 0.29 | 0.66 | 2.6 | 11 | 33 | 60 | 92 | 186 | 320 | 981 | 1985 |
| 7/1/2016 16:00 | 4.6 | 0.02 | 0.06 | 0.21 | 0.93 | 2.5 | 5.7 | 9.0 | 18 | 31 | 96 | 192 |
| 7/1/2016 17:00 | 4.3 | 0.03 | 0.08 | 0.20 | 0.84 | 2.3 | 6.0 | 9.6 | 19 | 34 | 102 | 207 |
| 7/1/2016 18:00 | 2.9 | 0.04 | 0.10 | 0.30 | 1.3 | 4.2 | 12 | 22 | 44 | 77 | 232 | 473 |
| 7/1/2016 19:00 | 2.8 | 0.02 | 0.09 | 0.27 | 0.83 | 2.6 | 7.5 | 22 | 44 | 77 | 238 | 497 |
| 7/1/2016 20:00 | 1.9 | 0.07 | 0.22 | 0.59 | 2.0 | 5.5 | 27 | 46 | 92 | 160 | 516 | 1050 |
| 7/1/2016 21:00 | 1.9 | 0.12 | 0.27 | 0.71 | 2.3 | 5.1 | 27 | 45 | 90 | 162 | 503 | 1023 |
| 7/1/2016 22:00 | 0.8 | 0.08 | 0.24 | 1.0 | 4.5 | 24 | 107 | 176 | 364 | 676 | 2201 | 4565 |
| 7/1/2016 23:00 | 0.7 | 0.14 | 0.46 | 1.8 | 7.3 | 43 | 170 | 279 | 569 | 1029 | 3446 | 7292 |

# APPENDIX A – 2017 AND 2018 DATA

**Table A-8. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain July 1, 2016. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 7/1/2016 0:00 | 0.7 | 0.00 | 0.29 | 0.56 | 4.1 | 76 | 5.8 | 15 | 60 | 93 | 600 | 505 |
| 7/1/2016 1:00 | 0.5 | 0.00 | 0.24 | 2.6 | 27 | 114 | 8.6 | 31 | 127 | 201 | 1251 | 1041 |
| 7/1/2016 2:00 | 1.2 | 0.01 | 0.02 | 1.1 | 7.4 | 9.5 | 4.0 | 5.5 | 23 | 25 | 224 | 219 |
| 7/1/2016 3:00 | 0.8 | 0.00 | 0.00 | 1.6 | 19 | 22 | 10 | 13 | 53 | 71 | 469 | 534 |
| 7/1/2016 4:00 | 1.3 | 0.00 | 0.00 | 0.52 | 4.3 | 8.1 | 5.1 | 3.6 | 18 | 28 | 145 | 172 |
| 7/1/2016 5:00 | 1.5 | 0.00 | 0.00 | 0.62 | 3.9 | 5.9 | 1.8 | 3.6 | 9.9 | 20 | 128 | 179 |
| 7/1/2016 6:00 | 1.4 | 0.00 | 0.03 | 0.77 | 4.4 | 5.5 | 1.2 | 5.1 | 9.1 | 24 | 140 | 209 |
| 7/1/2016 7:00 | 0.4 | 0.08 | -0.21 | 14 | 50 | 110 | 21 | 47 | 180 | 365 | 2158 | 3039 |
| 7/1/2016 8:00 | 0.7 | 0.00 | -0.25 | 1.5 | 20 | 31 | 9.9 | 12 | 67 | 95 | 596 | 928 |
| 7/1/2016 9:00 | 1.5 | 0.01 | -0.03 | 0.40 | 2.3 | 9.7 | 2.2 | 2.4 | 12 | 19 | 137 | 189 |
| 7/1/2016 10:00 | 0.8 | 0.08 | 0.17 | 0.94 | 8.8 | 34 | 6.9 | 4.1 | 34 | 84 | 460 | 692 |
| 7/1/2016 11:00 | 1.0 | 0.03 | 0.16 | 0.32 | 8.4 | 16 | 5.1 | 2.1 | 20 | 56 | 274 | 403 |
| 7/1/2016 12:00 | 1.0 | 0.08 | 0.15 | 0.64 | 10 | 14 | 7.0 | 4.2 | 21 | 66 | 297 | 476 |
| 7/1/2016 13:00 | 1.8 | 0.05 | 0.08 | 0.35 | 2.2 | 5.1 | 2.2 | 1.4 | 6.7 | 17 | 95 | 144 |
| 7/1/2016 14:00 | 3.5 | 0.05 | 0.03 | 0.11 | 0.51 | 1.6 | 0.56 | 0.56 | 1.8 | 3.6 | 26 | 31 |
| 7/1/2016 15:00 | 1.4 | 0.29 | 0.23 | 1.5 | 3.6 | 12 | 5.6 | 3.3 | 12 | 20 | 175 | 169 |
| 7/1/2016 16:00 | 4.6 | 0.02 | 0.02 | 0.12 | 0.34 | 0.64 | 1.6 | 0.56 | 1.0 | 2.3 | 17 | 15 |
| 7/1/2016 17:00 | 4.3 | 0.03 | 0.04 | 0.02 | 0.30 | 0.66 | 2.2 | 0.59 | 1.3 | 2.5 | 17 | 18 |
| 7/1/2016 18:00 | 2.9 | 0.04 | 0.04 | 0.10 | 0.44 | 1.7 | 4.9 | 3.8 | 3.3 | 6.1 | 39 | 42 |
| 7/1/2016 19:00 | 2.8 | 0.02 | 0.08 | 0.08 | 0.08 | 1.0 | 3.1 | 11 | 3.1 | 5.5 | 44 | 53 |
| 7/1/2016 20:00 | 1.9 | 0.07 | 0.17 | 0.12 | 0.38 | 1.5 | 18 | 5.5 | 6.5 | 11 | 105 | 95 |
| 7/1/2016 21:00 | 1.9 | 0.12 | 0.08 | 0.14 | 0.31 | 0.66 | 19 | 4.1 | 5.8 | 16 | 93 | 91 |
| 7/1/2016 22:00 | 0.8 | 0.08 | 0.17 | 0.65 | 1.7 | 15 | 67 | 17 | 31 | 83 | 465 | 470 |
| 7/1/2016 23:00 | 0.7 | 0.14 | 0.33 | 1.0 | 2.3 | 28 | 99 | 26 | 43 | 105 | 779 | 853 |

**Table A-9. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain August 1, 2016. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 8/1/2016 0:00 | 1.4 | -0.01 | -0.02 | 0.00 | 0.33 | 5.3 | 33 | 57 | 113 | 200 | 796 | 1798 |
| 8/1/2016 1:00 | 0.9 | 0.00 | -0.02 | 0.06 | 0.31 | 25 | 80 | 133 | 267 | 476 | 1861 | 4150 |
| 8/1/2016 2:00 | 1.3 | -0.01 | -0.04 | 0.00 | 2.6 | 20 | 40 | 64 | 131 | 228 | 971 | 2064 |
| 8/1/2016 3:00 | 0.8 | 0.00 | -0.07 | 0.07 | 18 | 60 | 108 | 169 | 344 | 601 | 2615 | 5507 |
| 8/1/2016 4:00 | 0.9 | -0.01 | -0.05 | 0.05 | 13 | 41 | 75 | 118 | 239 | 437 | 1819 | 3849 |
| 8/1/2016 5:00 | 1.1 | 0.00 | -0.03 | 0.04 | 7.1 | 24 | 46 | 73 | 151 | 274 | 1099 | 2498 |
| 8/1/2016 6:00 | 2.6 | 0.00 | -0.01 | 0.01 | 1.5 | 4.5 | 8.4 | 13 | 27 | 49 | 199 | 454 |
| 8/1/2016 7:00 | 1.5 | 0.00 | -0.02 | 0.00 | 4.0 | 13 | 26 | 41 | 82 | 144 | 578 | 1381 |
| 8/1/2016 8:00 | 0.9 | 0.01 | 0.04 | 0.19 | 6.3 | 31 | 62 | 101 | 206 | 366 | 1348 | 3461 |
| 8/1/2016 9:00 | 0.6 | 0.08 | 0.30 | 1.2 | 13 | 62 | 142 | 238 | 484 | 880 | 3226 | 8144 |
| 8/1/2016 10:00 | 1.2 | 0.01 | 0.10 | 0.36 | 2.3 | 17 | 40 | 69 | 141 | 248 | 971 | 2375 |
| 8/1/2016 11:00 | 1.1 | 0.02 | 0.16 | 0.58 | 2.6 | 23 | 50 | 84 | 174 | 297 | 1234 | 2825 |
| 8/1/2016 12:00 | 1.4 | 0.08 | 0.19 | 0.57 | 2.2 | 14 | 33 | 56 | 113 | 192 | 814 | 1748 |
| 8/1/2016 13:00 | 1.6 | 0.05 | 0.13 | 0.40 | 2.4 | 11 | 25 | 41 | 83 | 142 | 619 | 1322 |
| 8/1/2016 14:00 | 1.2 | 0.05 | 0.18 | 0.64 | 4.8 | 21 | 46 | 75 | 151 | 258 | 1133 | 2469 |
| 8/1/2016 15:00 | 0.6 | 0.18 | 0.73 | 3.1 | 16 | 91 | 165 | 266 | 533 | 901 | 3933 | 8580 |
| 8/1/2016 16:00 | 4.3 | 0.00 | 0.01 | 0.10 | 0.41 | 2.0 | 4.1 | 6.4 | 13 | 21 | 89 | 191 |
| 8/1/2016 17:00 | 3.7 | 0.01 | 0.07 | 0.20 | 0.95 | 3.3 | 6.9 | 11 | 21 | 36 | 134 | 289 |
| 8/1/2016 18:00 | 3.4 | 0.01 | 0.09 | 0.23 | 0.69 | 2.3 | 6.9 | 12 | 24 | 41 | 154 | 332 |
| 8/1/2016 19:00 | 3.2 | 0.01 | 0.03 | 0.17 | 0.62 | 1.3 | 7.6 | 13 | 27 | 45 | 174 | 377 |
| 8/1/2016 20:00 | 2.8 | 0.01 | 0.06 | 0.18 | 0.59 | 1.8 | 9.1 | 16 | 33 | 57 | 221 | 476 |
| 8/1/2016 21:00 | 1.8 | 0.03 | 0.07 | 0.21 | 0.92 | 10 | 22 | 36 | 71 | 123 | 495 | 1052 |
| 8/1/2016 22:00 | 1.4 | 0.01 | 0.04 | 0.21 | 1.1 | 10 | 35 | 58 | 117 | 199 | 822 | 1824 |
| 8/1/2016 23:00 | 0.4 | 0.00 | 0.00 | 1.4 | 11 | 179 | 509 | 819 | 1658 | 2840 | 11705 | 27172 |

**Table A-10. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain August 1, 2016. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 8/1/2016 0:00 | 1.4 | -0.01 | -0.02 | 0.06 | 0.33 | 4.6 | 25 | 7.0 | 7.0 | 16 | 246 | 288 |
| 8/1/2016 1:00 | 0.9 | 0.00 | -0.04 | 0.15 | 0.15 | 25 | 39 | 12 | 18 | 43 | 559 | 630 |
| 8/1/2016 2:00 | 1.3 | -0.01 | -0.04 | 0.11 | 2.6 | 15 | 7.1 | 4.1 | 9.5 | 17 | 326 | 248 |
| 8/1/2016 3:00 | 0.8 | 0.00 | -0.11 | 0.31 | 18 | 25 | 8.6 | 7.6 | 26 | 44 | 901 | 626 |
| 8/1/2016 4:00 | 0.9 | -0.01 | -0.04 | 0.22 | 13 | 15 | 7.4 | 6.7 | 16 | 48 | 595 | 450 |
| 8/1/2016 5:00 | 1.1 | 0.00 | -0.05 | 0.14 | 7.0 | 9.9 | 6.9 | 3.9 | 14 | 29 | 342 | 411 |
| 8/1/2016 6:00 | 2.6 | 0.00 | -0.01 | 0.03 | 1.5 | 1.5 | 0.97 | 0.64 | 2.5 | 4.2 | 63 | 76 |
| 8/1/2016 7:00 | 1.5 | 0.00 | -0.01 | 0.05 | 4.0 | 5.3 | 4.2 | 2.2 | 4.9 | 12 | 180 | 271 |
| 8/1/2016 8:00 | 0.9 | 0.01 | 0.03 | 0.13 | 5.8 | 18 | 11 | 8.2 | 16 | 32 | 368 | 823 |
| 8/1/2016 9:00 | 0.6 | 0.08 | 0.23 | 0.75 | 9.6 | 37 | 38 | 26 | 36 | 93 | 873 | 1859 |
| 8/1/2016 10:00 | 1.2 | 0.01 | 0.14 | 0.18 | 1.3 | 12 | 13 | 9.3 | 11 | 19 | 293 | 499 |
| 8/1/2016 11:00 | 1.1 | 0.02 | 0.19 | 0.31 | 0.95 | 18 | 13 | 9.2 | 15 | 17 | 402 | 477 |
| 8/1/2016 12:00 | 1.4 | 0.08 | 0.08 | 0.19 | 0.58 | 10 | 9.7 | 5.6 | 8.4 | 9.6 | 273 | 222 |
| 8/1/2016 13:00 | 1.6 | 0.05 | 0.06 | 0.17 | 1.2 | 6.8 | 5.9 | 3.7 | 5.9 | 8.1 | 215 | 163 |
| 8/1/2016 14:00 | 1.2 | 0.05 | 0.14 | 0.32 | 3.0 | 11 | 12 | 6.0 | 11 | 14 | 396 | 337 |
| 8/1/2016 15:00 | 0.6 | 0.18 | 0.65 | 2.0 | 7.2 | 60 | 14 | 20 | 33 | 41 | 1362 | 1181 |
| 8/1/2016 16:00 | 4.3 | 0.00 | 0.01 | 0.09 | 0.13 | 1.2 | 0.82 | 0.33 | 0.62 | 1.1 | 29 | 24 |
| 8/1/2016 17:00 | 3.7 | 0.01 | 0.08 | 0.04 | 0.40 | 1.4 | 1.5 | 0.61 | 0.97 | 1.4 | 38 | 37 |
| 8/1/2016 18:00 | 3.4 | 0.01 | 0.10 | 0.05 | 0.04 | 0.92 | 3.2 | 1.8 | 1.5 | 2.0 | 43 | 43 |
| 8/1/2016 19:00 | 3.2 | 0.01 | 0.02 | 0.12 | 0.15 | 0.12 | 5.4 | 1.8 | 1.9 | 2.2 | 50 | 50 |
| 8/1/2016 20:00 | 2.8 | 0.01 | 0.07 | 0.07 | 0.08 | 0.64 | 6.1 | 2.6 | 2.6 | 3.6 | 65 | 61 |
| 8/1/2016 21:00 | 1.8 | 0.03 | 0.02 | 0.07 | 0.34 | 8.5 | 5.0 | 3.0 | 3.8 | 7.8 | 155 | 125 |
| 8/1/2016 22:00 | 1.4 | 0.01 | 0.05 | 0.16 | 0.53 | 8.0 | 18 | 6.4 | 7.5 | 11 | 266 | 272 |
| 8/1/2016 23:00 | 0.4 | 0.00 | 0.00 | 1.9 | 6.8 | 158 | 212 | 59 | 118 | 161 | 3778 | 4830 |

**Table A-11. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain September 1, 2016. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 9/1/2016 0:00 | 0.6 | 0.00 | 0.00 | 0.11 | 0.30 | 2.4 | 5.9 | 66 | 157 | 289 | 1357 | 5661 |
| 9/1/2016 1:00 | 0.4 | 0.00 | 0.00 | 0.29 | 0.00 | 3.2 | 7.8 | 73 | 399 | 705 | 3212 | 15029 |
| 9/1/2016 2:00 | 0.8 | -0.01 | -0.03 | 0.00 | -0.16 | 0.00 | -0.51 | 7.6 | 73 | 127 | 710 | 3004 |
| 9/1/2016 3:00 | 0.8 | 0.00 | -0.02 | 0.06 | 0.00 | 0.31 | 0.00 | 14 | 67 | 131 | 751 | 3016 |
| 9/1/2016 4:00 | 1.1 | 0.00 | -0.01 | 0.03 | 0.00 | 0.17 | 0.28 | 7.2 | 37 | 73 | 394 | 1734 |
| 9/1/2016 5:00 | 1.6 | 0.00 | -0.01 | 0.00 | -0.04 | 0.00 | 0.00 | 1.9 | 14 | 27 | 157 | 760 |
| 9/1/2016 6:00 | 0.8 | 0.00 | -0.02 | 0.06 | 0.00 | 0.30 | 0.50 | 5.9 | 56 | 106 | 555 | 2975 |
| 9/1/2016 7:00 | 1.3 | 0.00 | -0.01 | 0.00 | 0.00 | 0.00 | 0.18 | 4.8 | 21 | 41 | 192 | 1040 |
| 9/1/2016 8:00 | 1.1 | 0.00 | -0.01 | 0.03 | 0.00 | 0.17 | 0.00 | 9.5 | 35 | 66 | 411 | 1588 |
| 9/1/2016 9:00 | 0.3 | 0.25 | 0.00 | 1.5 | 4.3 | 14 | 18 | 175 | 618 | 1106 | 6963 | 25725 |
| 9/1/2016 10:00 | 0.8 | 0.01 | -0.03 | 0.17 | 0.64 | 1.9 | 3.6 | 20 | 71 | 133 | 843 | 2914 |
| 9/1/2016 11:00 | 1.1 | 0.03 | 0.06 | 0.26 | 0.63 | 1.6 | 2.6 | 12 | 41 | 80 | 473 | 1691 |
| 9/1/2016 12:00 | 1.4 | 0.05 | 0.14 | 0.42 | 1.3 | 2.6 | 4.5 | 13 | 31 | 58 | 272 | 1007 |
| 9/1/2016 13:00 | 3.4 | 0.01 | 0.01 | 0.05 | 0.18 | 0.38 | 0.78 | 2.1 | 5.3 | 10 | 44 | 185 |
| 9/1/2016 14:00 | 0.7 | 0.08 | 0.19 | 0.84 | 3.0 | 6.9 | 15 | 37 | 121 | 228 | 1009 | 4522 |
| 9/1/2016 15:00 | 2.7 | 0.00 | 0.02 | 0.08 | 0.26 | 0.71 | 1.2 | 2.8 | 8.3 | 15 | 62 | 281 |
| 9/1/2016 16:00 | 4.6 | 0.00 | 0.00 | 0.02 | 0.12 | 0.33 | 0.63 | 1.1 | 3.3 | 6.1 | 22 | 99 |
| 9/1/2016 17:00 | 3.3 | 0.00 | 0.00 | 0.02 | 0.16 | 0.45 | 0.80 | 2.1 | 6.7 | 13 | 42 | 200 |
| 9/1/2016 18:00 | 1.6 | 0.00 | 0.00 | 0.05 | 0.52 | 1.6 | 3.2 | 5.4 | 26 | 52 | 189 | 874 |
| 9/1/2016 19:00 | 1.9 | 0.00 | 0.01 | 0.10 | 0.36 | 0.93 | 1.7 | 2.9 | 17 | 35 | 132 | 583 |
| 9/1/2016 20:00 | 2.0 | 0.00 | 0.00 | 0.03 | 0.15 | 0.40 | 0.91 | 1.7 | 14 | 28 | 112 | 504 |
| 9/1/2016 21:00 | 0.6 | 0.00 | -0.04 | 0.10 | 0.79 | 3.6 | 6.0 | 12 | 138 | 275 | 1159 | 5115 |
| 9/1/2016 22:00 | 0.7 | 0.00 | -0.04 | 0.00 | 0.23 | 1.3 | 3.7 | 15 | 121 | 224 | 912 | 4293 |
| 9/1/2016 23:00 | 1.1 | 0.00 | -0.01 | 0.03 | 0.09 | 0.52 | 1.1 | 14 | 46 | 80 | 336 | 1684 |

**Table A-12. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain September 1, 2016. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 9/1/2016 0:00 | 0.6 | 0.00 | 0.00 | 0.15 | 0.00 | 1.8 | 2.0 | 58 | 29 | 33 | 507 | 2581 |
| 9/1/2016 1:00 | 0.4 | 0.00 | 0.00 | 0.39 | -0.80 | 3.2 | 2.6 | 61 | 229 | 58 | 1167 | 7419 |
| 9/1/2016 2:00 | 0.8 | -0.01 | 0.00 | 0.08 | -0.16 | 0.31 | -0.51 | 8.3 | 51 | 9.6 | 307 | 1384 |
| 9/1/2016 3:00 | 0.8 | 0.00 | -0.04 | 0.15 | -0.16 | 0.31 | -0.51 | 14 | 35 | 21 | 331 | 1334 |
| 9/1/2016 4:00 | 1.1 | 0.00 | -0.02 | 0.09 | -0.09 | 0.17 | 0.00 | 6.7 | 21 | 13 | 165 | 823 |
| 9/1/2016 5:00 | 1.6 | 0.00 | -0.01 | 0.04 | -0.04 | 0.08 | 0.00 | 1.9 | 9.2 | 3.8 | 71 | 383 |
| 9/1/2016 6:00 | 0.8 | 0.00 | -0.04 | 0.15 | -0.15 | 0.30 | 0.00 | 5.2 | 39 | 15 | 228 | 1587 |
| 9/1/2016 7:00 | 1.3 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.18 | 4.5 | 10 | 6.8 | 72 | 557 |
| 9/1/2016 8:00 | 1.1 | 0.00 | -0.02 | 0.09 | -0.09 | 0.17 | -0.28 | 9.5 | 15 | 8.5 | 192 | 680 |
| 9/1/2016 9:00 | 0.3 | 0.25 | -0.70 | 2.1 | 0.00 | 5.5 | -4.54 | 148 | 254 | 103 | 3259 | 10568 |
| 9/1/2016 10:00 | 0.8 | 0.01 | -0.08 | 0.31 | 0.16 | 0.62 | 0.51 | 14 | 30 | 17 | 397 | 1117 |
| 9/1/2016 11:00 | 1.1 | 0.03 | 0.00 | 0.18 | -0.09 | 0.35 | 0.00 | 7.7 | 17 | 13 | 213 | 673 |
| 9/1/2016 12:00 | 1.4 | 0.05 | 0.09 | 0.15 | 0.10 | 0.10 | 0.16 | 6.7 | 5.7 | 7.4 | 101 | 414 |
| 9/1/2016 13:00 | 3.4 | 0.01 | 0.00 | 0.03 | 0.03 | 0.04 | 0.15 | 0.92 | 1.2 | 1.3 | 16 | 85 |
| 9/1/2016 14:00 | 0.7 | 0.08 | 0.06 | 0.57 | 0.70 | 0.91 | 3.7 | 14 | 45 | 31 | 354 | 2171 |
| 9/1/2016 15:00 | 2.7 | 0.00 | 0.02 | 0.06 | 0.04 | 0.20 | 0.05 | 0.96 | 2.7 | 1.8 | 20 | 136 |
| 9/1/2016 16:00 | 4.6 | 0.00 | 0.00 | 0.02 | 0.05 | 0.10 | 0.08 | 0.16 | 1.1 | 0.70 | 5.8 | 48 |
| 9/1/2016 17:00 | 3.3 | 0.00 | 0.00 | 0.02 | 0.10 | 0.13 | 0.06 | 0.89 | 2.4 | 1.8 | 9.5 | 99 |
| 9/1/2016 18:00 | 1.6 | 0.00 | 0.00 | 0.06 | 0.39 | 0.59 | 0.55 | 0.62 | 14 | 8.8 | 51 | 429 |
| 9/1/2016 19:00 | 1.9 | 0.00 | 0.02 | 0.10 | 0.09 | 0.23 | 0.19 | 0.28 | 11 | 6.1 | 38 | 276 |
| 9/1/2016 20:00 | 2.0 | 0.00 | 0.00 | 0.03 | 0.08 | 0.10 | 0.25 | 0.37 | 9.1 | 5.3 | 35 | 242 |
| 9/1/2016 21:00 | 0.6 | 0.00 | -0.07 | 0.26 | 0.53 | 2.1 | 0.00 | 2.6 | 102 | 48 | 385 | 2428 |
| 9/1/2016 22:00 | 0.7 | 0.00 | -0.06 | 0.11 | 0.23 | 0.89 | 1.5 | 9.8 | 80 | 27 | 289 | 2128 |
| 9/1/2016 23:00 | 1.1 | 0.00 | -0.02 | 0.09 | 0.00 | 0.35 | 0.28 | 12 | 18 | 5.3 | 111 | 866 |

**Table A-13. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain October 1, 2016. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 10/1/2016 0:00 | 1.4 | -0.01 | -0.02 | -0.02 | -0.08 | 0.00 | 0.00 | 9.0 | 20 | 35 | 98 | 221 |
| 10/1/2016 1:00 | 1.6 | 0.00 | -0.01 | 0.01 | 0.03 | 0.12 | 1.6 | 7.2 | 15 | 27 | 73 | 163 |
| 10/1/2016 2:00 | 1.6 | 0.00 | -0.01 | 0.01 | 0.00 | 0.13 | 3.2 | 7.0 | 16 | 28 | 72 | 197 |
| 10/1/2016 3:00 | 1.3 | 0.00 | -0.02 | 0.02 | 0.00 | 0.10 | 1.3 | 8.9 | 23 | 40 | 107 | 276 |
| 10/1/2016 4:00 | 1.5 | 0.00 | -0.01 | 0.01 | 0.00 | 0.07 | 0.44 | 6.2 | 15 | 25 | 71 | 166 |
| 10/1/2016 5:00 | 1.0 | 0.01 | -0.01 | 0.05 | 0.00 | 0.15 | 0.24 | 9.9 | 30 | 50 | 144 | 331 |
| 10/1/2016 6:00 | 1.5 | 0.00 | -0.01 | 0.00 | -0.03 | -0.07 | -0.22 | 0.82 | 10 | 20 | 57 | 154 |
| 10/1/2016 7:00 | 1.8 | 0.00 | -0.01 | 0.00 | -0.02 | 0.00 | -0.08 | 0.00 | 7.7 | 13 | 38 | 92 |
| 10/1/2016 8:00 | 1.3 | 0.00 | 0.00 | 0.04 | 0.10 | 0.29 | 0.32 | 0.48 | 16 | 28 | 81 | 188 |
| 10/1/2016 9:00 | 1.0 | 0.00 | -0.01 | 0.03 | 0.08 | 0.32 | 0.26 | 0.78 | 24 | 42 | 124 | 292 |
| 10/1/2016 10:00 | 0.4 | 0.04 | 0.08 | 0.71 | 1.5 | 4.8 | 6.4 | 14 | 148 | 279 | 790 | 1902 |
| 10/1/2016 11:00 | 2.5 | 0.01 | 0.01 | 0.05 | 0.14 | 0.33 | 0.50 | 1.1 | 5.3 | 8.9 | 24 | 56 |
| 10/1/2016 12:00 | 2.3 | 0.01 | 0.02 | 0.06 | 0.20 | 0.46 | 0.76 | 2.8 | 6.7 | 11 | 29 | 69 |
| 10/1/2016 13:00 | 1.5 | 0.01 | 0.02 | 0.08 | 0.28 | 0.69 | 1.1 | 5.2 | 14 | 23 | 58 | 175 |
| 10/1/2016 14:00 | 3.8 | 0.01 | 0.01 | 0.03 | 0.10 | 0.21 | 0.36 | 1.2 | 2.7 | 4.4 | 11 | 35 |
| 10/1/2016 15:00 | 2.6 | 0.01 | 0.03 | 0.07 | 0.21 | 0.46 | 0.99 | 2.6 | 5.7 | 9.5 | 24 | 65 |
| 10/1/2016 16:00 | 3.9 | 0.00 | 0.01 | 0.02 | 0.07 | 0.15 | 0.53 | 1.0 | 2.3 | 3.8 | 9.7 | 26 |
| 10/1/2016 17:00 | 3.1 | 0.00 | 0.01 | 0.02 | 0.07 | 0.16 | 0.72 | 1.4 | 3.3 | 5.4 | 14 | 39 |
| 10/1/2016 18:00 | 2.3 | 0.00 | 0.00 | 0.01 | 0.03 | 0.18 | 0.95 | 2.0 | 4.8 | 8.6 | 24 | 65 |
| 10/1/2016 19:00 | 2.7 | 0.00 | 0.00 | 0.00 | -0.01 | 0.00 | 0.22 | 1.3 | 2.8 | 5.2 | 15 | 44 |
| 10/1/2016 20:00 | 1.0 | 0.00 | -0.02 | 0.00 | -0.08 | 0.00 | -0.25 | 3.3 | 17 | 33 | 96 | 264 |
| 10/1/2016 21:00 | 1.5 | 0.00 | -0.01 | 0.00 | -0.03 | 0.00 | 0.00 | 0.54 | 7.1 | 14 | 45 | 146 |
| 10/1/2016 22:00 | 2.0 | 0.00 | -0.01 | 0.01 | -0.02 | 0.00 | -0.07 | 0.88 | 4.5 | 8.7 | 25 | 80 |
| 10/1/2016 23:00 | 1.7 | 0.00 | -0.01 | 0.00 | 0.00 | 0.05 | 0.18 | 1.6 | 6.2 | 12 | 35 | 101 |

**Table A-14. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain October 1, 2016. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 10/1/2016 0:00 | 1.4 | -0.01 | -0.01 | 0.04 | -0.04 | 0.16 | 0.00 | 9.0 | 2.8 | 2.5 | 13 | 35 |
| 10/1/2016 1:00 | 1.6 | 0.00 | -0.01 | 0.03 | 0.00 | 0.06 | 1.4 | 4.8 | 1.8 | 2.2 | 7.1 | 25 |
| 10/1/2016 2:00 | 1.6 | 0.00 | -0.01 | 0.03 | -0.03 | 0.13 | 3.0 | 2.1 | 2.6 | 2.0 | 5.3 | 54 |
| 10/1/2016 3:00 | 1.3 | 0.00 | -0.03 | 0.08 | -0.05 | 0.10 | 1.1 | 7.0 | 5.6 | 2.5 | 11 | 67 |
| 10/1/2016 4:00 | 1.5 | 0.00 | -0.01 | 0.03 | -0.03 | 0.07 | 0.33 | 5.5 | 3.0 | 1.2 | 8.7 | 30 |
| 10/1/2016 5:00 | 1.0 | 0.01 | -0.04 | 0.11 | -0.15 | 0.15 | 0.00 | 9.5 | 10.0 | 1.8 | 21 | 56 |
| 10/1/2016 6:00 | 1.5 | 0.00 | -0.01 | 0.03 | -0.03 | 0.00 | -0.11 | 1.1 | 7.7 | 3.3 | 7.1 | 41 |
| 10/1/2016 7:00 | 1.8 | 0.00 | -0.01 | 0.02 | -0.02 | 0.05 | -0.08 | 0.11 | 6.7 | 0.28 | 6.0 | 20 |
| 10/1/2016 8:00 | 1.3 | 0.00 | -0.01 | 0.05 | 0.00 | 0.10 | -0.16 | 0.00 | 13 | 1.8 | 12 | 34 |
| 10/1/2016 9:00 | 1.0 | 0.00 | -0.02 | 0.08 | 0.00 | 0.16 | -0.26 | 0.39 | 20 | 3.0 | 19 | 55 |
| 10/1/2016 10:00 | 0.4 | 0.04 | 0.00 | 0.72 | -0.50 | 1.9 | -1.61 | 4.7 | 106 | 37 | 105 | 381 |
| 10/1/2016 11:00 | 2.5 | 0.01 | 0.00 | 0.03 | 0.00 | 0.05 | -0.04 | 0.37 | 2.8 | 0.32 | 2.1 | 10 |
| 10/1/2016 12:00 | 2.3 | 0.01 | 0.00 | 0.03 | 0.03 | 0.06 | 0.00 | 1.7 | 1.3 | 0.38 | 2.2 | 13 |
| 10/1/2016 13:00 | 1.5 | 0.01 | 0.00 | 0.05 | 0.07 | 0.14 | 0.00 | 3.5 | 3.7 | 0.43 | 3.3 | 57 |
| 10/1/2016 14:00 | 3.8 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.02 | 0.63 | 0.48 | 0.07 | 0.82 | 12 |
| 10/1/2016 15:00 | 2.6 | 0.01 | 0.00 | 0.02 | 0.01 | 0.05 | 0.23 | 1.1 | 0.79 | 0.29 | 1.4 | 18 |
| 10/1/2016 16:00 | 3.9 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.29 | 0.22 | 0.40 | 0.07 | 0.62 | 6.7 |
| 10/1/2016 17:00 | 3.1 | 0.00 | 0.00 | 0.01 | 0.00 | 0.03 | 0.45 | 0.27 | 0.69 | 0.10 | 1.4 | 10 |
| 10/1/2016 18:00 | 2.3 | 0.00 | 0.00 | 0.02 | 0.00 | 0.12 | 0.65 | 0.59 | 0.94 | 0.78 | 2.6 | 18 |
| 10/1/2016 19:00 | 2.7 | 0.00 | 0.00 | 0.01 | -0.01 | 0.02 | 0.22 | 0.95 | 0.34 | 0.69 | 2.1 | 14 |
| 10/1/2016 20:00 | 1.0 | 0.00 | -0.04 | 0.08 | -0.08 | 0.15 | -0.25 | 3.6 | 9.2 | 5.6 | 14 | 72 |
| 10/1/2016 21:00 | 1.5 | 0.00 | -0.02 | 0.04 | -0.03 | 0.07 | 0.00 | 0.54 | 5.3 | 2.3 | 9.6 | 51 |
| 10/1/2016 22:00 | 2.0 | 0.00 | 0.00 | 0.03 | -0.04 | 0.04 | -0.07 | 0.98 | 2.5 | 1.3 | 3.4 | 29 |
| 10/1/2016 23:00 | 1.7 | 0.00 | -0.01 | 0.03 | 0.00 | 0.05 | 0.09 | 1.3 | 2.9 | 2.0 | 4.5 | 31 |

**Table A-15. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain June 6, 2017. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 |
| 6/6/2017 0:00 | 0.8 | 1.1 | 2.6 | 6.2 | 19 | 40 | 74 | 115 | 239 | 435 | 1552 | 3407 |
| 6/6/2017 1:00 | 1.2 | 0.40 | 0.99 | 2.4 | 7.6 | 16 | 29 | 46 | 95 | 181 | 634 | 1375 |
| 6/6/2017 2:00 | 1.6 | 0.15 | 0.45 | 1.1 | 3.5 | 7.4 | 14 | 22 | 45 | 86 | 323 | 681 |
| 6/6/2017 3:00 | 1.9 | 0.00 | 0.28 | 0.73 | 2.2 | 5.0 | 9.8 | 15 | 30 | 58 | 228 | 486 |
| 6/6/2017 4:00 | 2.0 | 0.00 | 0.00 | 0.59 | 1.9 | 4.4 | 8.5 | 14 | 27 | 53 | 203 | 435 |
| 6/6/2017 5:00 | 1.8 | 0.00 | 0.00 | 0.59 | 1.9 | 5.0 | 9.5 | 15 | 31 | 60 | 242 | 520 |
| 6/6/2017 6:00 | 1.6 | 0.00 | -0.01 | 0.19 | 2.3 | 5.7 | 11 | 18 | 36 | 76 | 304 | 659 |
| 6/6/2017 7:00 | 1.8 | 0.00 | 0.00 | 0.12 | 1.5 | 3.8 | 7.2 | 13 | 27 | 57 | 230 | 500 |
| 6/6/2017 8:00 | 1.6 | 0.04 | 0.08 | 0.29 | 2.5 | 6.1 | 11 | 19 | 41 | 85 | 318 | 680 |
| 6/6/2017 9:00 | 0.4 | 1.5 | 3.2 | 10 | 39 | 107 | 194 | 338 | 714 | 1467 | 5345 | 11334 |
| 6/6/2017 10:00 | 0.9 | 0.22 | 0.54 | 1.7 | 7.8 | 19 | 37 | 62 | 128 | 260 | 974 | 2119 |
| 6/6/2017 11:00 | 0.4 | 2.8 | 5.6 | 18 | 67 | 149 | 258 | 433 | 868 | 1699 | 5988 | 12775 |
| 6/6/2017 12:00 | 0.4 | 3.7 | 8.8 | 23 | 70 | 159 | 279 | 449 | 890 | 1679 | 5567 | 11686 |
| 6/6/2017 13:00 | 1.2 | 0.66 | 1.3 | 3.5 | 11 | 22 | 40 | 63 | 127 | 237 | 783 | 1628 |
| 6/6/2017 14:00 | 1.3 | 0.53 | 1.1 | 3.0 | 9.7 | 20 | 36 | 57 | 114 | 213 | 697 | 1479 |
| 6/6/2017 15:00 | 2.1 | 0.15 | 0.30 | 0.82 | 2.8 | 6.0 | 11 | 18 | 36 | 67 | 227 | 489 |
| 6/6/2017 16:00 | 3.8 | 0.03 | 0.07 | 0.21 | 0.62 | 1.4 | 2.6 | 4.2 | 9.3 | 18 | 61 | 133 |
| 6/6/2017 17:00 | 1.7 | 0.13 | 0.31 | 0.88 | 2.7 | 6.4 | 12 | 19 | 41 | 80 | 281 | 612 |
| 6/6/2017 18:00 | 3.8 | 0.00 | 0.02 | 0.19 | 0.84 | 1.8 | 3.1 | 5.0 | 10 | 20 | 67 | 142 |
| 6/6/2017 19:00 | 2.1 | 0.10 | 0.24 | 0.74 | 2.8 | 7.1 | 12 | 20 | 41 | 76 | 260 | 544 |
| 6/6/2017 20:00 | 1.3 | 0.07 | 0.23 | 0.90 | 5.8 | 15 | 25 | 40 | 94 | 194 | 628 | 1349 |
| 6/6/2017 21:00 | 1.4 | 0.03 | 0.14 | 0.85 | 4.9 | 12 | 22 | 37 | 77 | 148 | 507 | 1104 |
| 6/6/2017 22:00 | 2.2 | 0.00 | 0.01 | 0.45 | 1.9 | 4.6 | 8.7 | 14 | 28 | 52 | 195 | 426 |
| 6/6/2017 23:00 | 1.1 | 0.00 | 0.00 | 1.6 | 7.1 | 18 | 32 | 52 | 108 | 216 | 716 | 1617 |

**Table A-16. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain June 6, 2017. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 6/6/2017 0:00 | 0.8 | 1.1 | 1.1 | 0.43 | 2.0 | 2.5 | 7.3 | 4.0 | 22 | 46 | 399 | 484 |
| 6/6/2017 1:00 | 1.2 | 0.40 | 0.45 | 0.28 | 0.80 | 0.72 | 3.5 | 2.0 | 8.6 | 26 | 158 | 183 |
| 6/6/2017 2:00 | 1.6 | 0.15 | 0.30 | 0.13 | 0.39 | 0.56 | 1.8 | 0.88 | 4.2 | 12 | 91 | 78 |
| 6/6/2017 3:00 | 1.9 | 0.00 | 0.43 | 0.12 | 0.14 | 0.75 | 1.6 | 0.62 | 1.8 | 8.2 | 69 | 59 |
| 6/6/2017 4:00 | 2.0 | 0.00 | 0.00 | 0.80 | 0.29 | 0.60 | 1.3 | 0.85 | 1.4 | 9.4 | 58 | 55 |
| 6/6/2017 5:00 | 1.8 | 0.00 | 0.00 | 0.80 | 0.30 | 1.2 | 1.2 | 1.3 | 2.2 | 9.0 | 76 | 66 |
| 6/6/2017 6:00 | 1.6 | 0.00 | 0.00 | 0.27 | 1.7 | 1.2 | 1.5 | 1.6 | 2.8 | 15 | 95 | 88 |
| 6/6/2017 7:00 | 1.8 | 0.00 | 0.00 | 0.16 | 1.2 | 0.78 | 0.95 | 1.7 | 2.8 | 13 | 72 | 68 |
| 6/6/2017 8:00 | 1.6 | 0.04 | 0.01 | 0.15 | 1.7 | 1.2 | 1.0 | 2.1 | 5.3 | 17 | 89 | 85 |
| 6/6/2017 9:00 | 0.4 | 1.5 | 0.86 | 4.4 | 9.4 | 31 | 17 | 49 | 74 | 288 | 1432 | 1343 |
| 6/6/2017 10:00 | 0.9 | 0.22 | 0.24 | 0.66 | 3.1 | 4.0 | 4.9 | 6.8 | 11 | 49 | 273 | 288 |
| 6/6/2017 11:00 | 0.4 | 2.8 | 0.87 | 6.7 | 18 | 18 | 12 | 47 | 55 | 275 | 1507 | 1567 |
| 6/6/2017 12:00 | 0.4 | 3.7 | 3.6 | 3.8 | 7.7 | 22 | 15 | 33 | 48 | 225 | 1231 | 1302 |
| 6/6/2017 13:00 | 1.2 | 0.66 | 0.23 | 0.74 | 1.1 | 1.2 | 3.2 | 3.1 | 8.4 | 29 | 171 | 171 |
| 6/6/2017 14:00 | 1.3 | 0.53 | 0.30 | 0.66 | 1.2 | 0.65 | 3.4 | 3.9 | 6.6 | 27 | 149 | 176 |
| 6/6/2017 15:00 | 2.1 | 0.15 | 0.05 | 0.19 | 0.55 | 0.42 | 1.0 | 1.3 | 3.1 | 7.6 | 53 | 63 |
| 6/6/2017 16:00 | 3.8 | 0.03 | 0.03 | 0.06 | 0.05 | 0.20 | 0.29 | 0.28 | 1.3 | 2.6 | 15 | 18 |
| 6/6/2017 17:00 | 1.7 | 0.13 | 0.13 | 0.26 | 0.26 | 1.1 | 1.00 | 1.5 | 5.3 | 13 | 71 | 83 |
| 6/6/2017 18:00 | 3.8 | 0.00 | 0.01 | 0.21 | 0.31 | 0.15 | 0.09 | 0.36 | 0.97 | 2.7 | 16 | 16 |
| 6/6/2017 19:00 | 2.1 | 0.10 | 0.08 | 0.27 | 0.74 | 1.6 | 0.74 | 0.98 | 3.7 | 9.8 | 61 | 59 |
| 6/6/2017 20:00 | 1.3 | 0.07 | 0.18 | 0.52 | 3.3 | 3.3 | 0.55 | 2.4 | 18 | 39 | 131 | 172 |
| 6/6/2017 21:00 | 1.4 | 0.03 | 0.13 | 0.72 | 2.5 | 2.9 | 1.3 | 4.0 | 7.4 | 22 | 121 | 151 |
| 6/6/2017 22:00 | 2.2 | 0.00 | 0.02 | 0.58 | 0.66 | 0.85 | 1.1 | 0.75 | 2.1 | 6.2 | 55 | 58 |
| 6/6/2017 23:00 | 1.1 | 0.00 | 0.00 | 2.2 | 2.6 | 3.8 | 2.2 | 4.8 | 9.6 | 39 | 158 | 259 |

**Table A-17. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain July 1, 2017. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 |
| 7/1/2017 0:00 | 2.0 | 0.00 | -0.01 | 0.03 | 1.7 | 9.2 | 17 | 27 | 57 | 108 | 340 | 708 |
| 7/1/2017 1:00 | 0.2 | -0.16 | -0.28 | 0.64 | 121 | 949 | 1991 | 3195 | 7052 | 13247 | 42439 | 87624 |
| 7/1/2017 2:00 | 1.3 | 0.00 | -0.01 | 0.04 | 2.6 | 19 | 36 | 60 | 124 | 248 | 806 | 1599 |
| 7/1/2017 3:00 | 0.4 | 0.00 | 0.00 | 3.8 | 25 | 162 | 306 | 498 | 1025 | 2030 | 6575 | 13091 |
| 7/1/2017 4:00 | 1.0 | -0.02 | -0.04 | 0.73 | 6.5 | 30 | 54 | 89 | 192 | 364 | 1210 | 2412 |
| 7/1/2017 5:00 | 1.1 | -0.01 | -0.01 | 1.0 | 6.7 | 25 | 46 | 72 | 175 | 319 | 957 | 1984 |
| 7/1/2017 6:00 | 1.1 | -0.01 | -0.01 | 0.09 | 6.2 | 23 | 44 | 69 | 159 | 308 | 904 | 1950 |
| 7/1/2017 7:00 | 0.7 | 0.00 | 0.15 | 2.4 | 21 | 62 | 118 | 187 | 427 | 834 | 2564 | 5525 |
| 7/1/2017 8:00 | 0.7 | 0.12 | 0.99 | 3.9 | 25 | 71 | 127 | 205 | 436 | 827 | 2670 | 5715 |
| 7/1/2017 9:00 | 1.0 | 0.09 | 0.31 | 1.4 | 13 | 32 | 57 | 94 | 194 | 356 | 1168 | 2518 |
| 7/1/2017 10:00 | 1.2 | 0.19 | 0.42 | 1.3 | 12 | 28 | 48 | 76 | 166 | 300 | 951 | 2065 |
| 7/1/2017 11:00 | 2.2 | 0.06 | 0.14 | 0.42 | 3.7 | 8.4 | 15 | 23 | 47 | 89 | 268 | 597 |
| 7/1/2017 12:00 | 1.5 | 0.20 | 0.51 | 1.9 | 9.7 | 21 | 37 | 58 | 115 | 215 | 655 | 1419 |
| 7/1/2017 13:00 | 2.8 | 0.01 | 0.02 | 0.50 | 2.7 | 6.5 | 11 | 17 | 35 | 64 | 200 | 429 |
| 7/1/2017 14:00 | 1.3 | 0.04 | 0.14 | 0.54 | 11 | 28 | 49 | 77 | 154 | 283 | 906 | 1857 |
| 7/1/2017 15:00 | 1.6 | 0.11 | 0.28 | 1.0 | 7.5 | 22 | 40 | 64 | 124 | 224 | 721 | 1432 |
| 7/1/2017 16:00 | 2.2 | 0.00 | 0.02 | 0.21 | 1.1 | 7.5 | 18 | 29 | 58 | 105 | 339 | 690 |
| 7/1/2017 17:00 | 1.4 | 0.04 | 0.30 | 0.92 | 2.9 | 9.4 | 43 | 69 | 140 | 249 | 819 | 1647 |
| 7/1/2017 18:00 | 1.4 | 0.09 | 0.26 | 0.74 | 3.0 | 7.7 | 44 | 71 | 146 | 263 | 868 | 1729 |
| 7/1/2017 19:00 | 2.3 | 0.06 | 0.12 | 0.30 | 0.87 | 2.9 | 13 | 25 | 51 | 98 | 306 | 608 |
| 7/1/2017 20:00 | 1.3 | 0.10 | 0.17 | 0.45 | 1.7 | 7.5 | 36 | 66 | 139 | 275 | 854 | 1727 |
| 7/1/2017 21:00 | 3.3 | 0.00 | 0.00 | 0.01 | 0.22 | 1.0 | 6.2 | 9.8 | 21 | 43 | 130 | 273 |
| 7/1/2017 22:00 | 0.9 | 0.10 | 0.17 | 0.55 | 4.7 | 14 | 84 | 135 | 290 | 584 | 1775 | 3620 |
| 7/1/2017 23:00 | 0.5 | 0.02 | 0.29 | 1.5 | 12 | 99 | 228 | 370 | 757 | 1486 | 4781 | 9616 |

**Table A-18. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain July 1, 2017. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 7/1/2017 0:00 | 2.0 | 0.00 | -0.01 | 0.06 | 1.7 | 5.8 | 1.3 | 2.5 | 5.4 | 15 | 67 | 75 |
| 7/1/2017 1:00 | 0.2 | -0.16 | 0.00 | 1.7 | 119 | 712 | 422 | 221 | 968 | 1734 | 8597 | 8750 |
| 7/1/2017 2:00 | 1.3 | 0.00 | 0.00 | 0.07 | 2.5 | 14 | 5.1 | 6.0 | 11 | 44 | 170 | 115 |
| 7/1/2017 3:00 | 0.4 | 0.00 | 0.00 | 5.2 | 14 | 114 | 37 | 41 | 86 | 347 | 1370 | 966 |
| 7/1/2017 4:00 | 1.0 | -0.02 | 0.00 | 1.1 | 4.5 | 17 | 4.2 | 8.6 | 23 | 51 | 269 | 180 |
| 7/1/2017 5:00 | 1.1 | -0.01 | 0.00 | 1.4 | 3.9 | 11 | 5.2 | 4.1 | 35 | 35 | 158 | 204 |
| 7/1/2017 6:00 | 1.1 | -0.01 | 0.00 | 0.17 | 5.9 | 11 | 6.3 | 3.7 | 27 | 47 | 140 | 253 |
| 7/1/2017 7:00 | 0.7 | 0.00 | 0.24 | 2.8 | 15 | 21 | 14 | 11 | 69 | 133 | 462 | 714 |
| 7/1/2017 8:00 | 0.7 | 0.12 | 1.2 | 2.2 | 14 | 22 | 8.6 | 16 | 47 | 114 | 553 | 713 |
| 7/1/2017 9:00 | 1.0 | 0.09 | 0.24 | 1.0 | 8.9 | 6.9 | 3.7 | 9.1 | 17 | 40 | 251 | 326 |
| 7/1/2017 10:00 | 1.2 | 0.19 | 0.12 | 0.48 | 8.4 | 4.4 | 1.5 | 5.2 | 20 | 30 | 188 | 278 |
| 7/1/2017 11:00 | 2.2 | 0.06 | 0.04 | 0.14 | 2.5 | 1.2 | 0.72 | 1.3 | 3.6 | 12 | 45 | 91 |
| 7/1/2017 12:00 | 1.5 | 0.20 | 0.24 | 1.0 | 4.4 | 2.5 | 1.4 | 2.7 | 6.7 | 27 | 115 | 188 |
| 7/1/2017 13:00 | 2.8 | 0.01 | 0.01 | 0.62 | 1.3 | 1.2 | 0.52 | 0.64 | 2.2 | 7.5 | 37 | 54 |
| 7/1/2017 14:00 | 1.3 | 0.04 | 0.12 | 0.30 | 9.0 | 7.2 | 3.1 | 3.8 | 9.5 | 32 | 183 | 176 |
| 7/1/2017 15:00 | 1.6 | 0.11 | 0.14 | 0.54 | 4.7 | 6.7 | 4.9 | 3.5 | 4.4 | 23 | 147 | 104 |
| 7/1/2017 16:00 | 2.2 | 0.00 | 0.03 | 0.23 | 0.53 | 5.3 | 5.9 | 1.9 | 3.3 | 10 | 71 | 62 |
| 7/1/2017 17:00 | 1.4 | 0.04 | 0.35 | 0.35 | 0.35 | 3.7 | 27 | 5.6 | 9.9 | 21 | 178 | 133 |
| 7/1/2017 18:00 | 1.4 | 0.09 | 0.16 | 0.22 | 0.94 | 1.8 | 32 | 5.3 | 11 | 26 | 190 | 128 |
| 7/1/2017 19:00 | 2.3 | 0.06 | 0.01 | 0.04 | 0.04 | 1.2 | 7.9 | 6.1 | 4.3 | 14 | 58 | 43 |
| 7/1/2017 20:00 | 1.3 | 0.10 | 0.00 | 0.10 | 0.39 | 4.3 | 24 | 12 | 14 | 47 | 159 | 146 |
| 7/1/2017 21:00 | 3.3 | 0.00 | 0.00 | 0.01 | 0.21 | 0.58 | 4.5 | 0.63 | 2.5 | 7.8 | 23 | 30 |
| 7/1/2017 22:00 | 0.9 | 0.10 | 0.00 | 0.21 | 3.1 | 4.7 | 61 | 9.5 | 34 | 106 | 308 | 331 |
| 7/1/2017 23:00 | 0.5 | 0.02 | 0.40 | 1.2 | 7.4 | 76 | 64 | 29 | 60 | 244 | 980 | 780 |

**Table A-19. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain August 1, 2017. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 |
| 8/1/2017 0:00 | 1.0 | 0.00 | 0.02 | 0.53 | 21 | 46 | 78 | 125 | 249 | 447 | 1766 | 3716 |
| 8/1/2017 1:00 | 0.8 | -0.02 | -0.03 | 0.19 | 27 | 59 | 103 | 156 | 327 | 587 | 2255 | 4868 |
| 8/1/2017 2:00 | 1.0 | -0.01 | -0.03 | 0.02 | 16 | 37 | 67 | 104 | 218 | 413 | 1472 | 3268 |
| 8/1/2017 3:00 | 0.5 | 0.00 | -0.07 | 4.3 | 58 | 136 | 238 | 381 | 786 | 1460 | 5616 | 11927 |
| 8/1/2017 4:00 | 1.1 | 0.00 | 0.30 | 2.0 | 12 | 30 | 53 | 88 | 172 | 322 | 1298 | 2674 |
| 8/1/2017 5:00 | 0.6 | -0.03 | 1.3 | 8.7 | 47 | 107 | 182 | 302 | 630 | 1149 | 4575 | 9574 |
| 8/1/2017 6:00 | 0.7 | -0.01 | 0.06 | 3.7 | 25 | 64 | 114 | 183 | 396 | 811 | 2878 | 6294 |
| 8/1/2017 7:00 | 0.5 | -0.04 | 0.97 | 9.9 | 58 | 133 | 234 | 363 | 793 | 1606 | 5954 | 13227 |
| 8/1/2017 8:00 | 1.2 | 0.01 | 0.34 | 2.8 | 10 | 22 | 39 | 60 | 129 | 258 | 970 | 2198 |
| 8/1/2017 9:00 | 1.1 | 0.05 | 0.24 | 1.5 | 12 | 27 | 47 | 78 | 166 | 315 | 1206 | 2635 |
| 8/1/2017 10:00 | 2.4 | 0.04 | 0.07 | 0.41 | 2.9 | 6.3 | 11 | 18 | 38 | 71 | 272 | 581 |
| 8/1/2017 11:00 | 1.8 | 0.16 | 0.29 | 1.0 | 6.1 | 14 | 24 | 38 | 80 | 148 | 531 | 1142 |
| 8/1/2017 12:00 | 1.4 | 0.56 | 1.0 | 2.8 | 13 | 29 | 51 | 83 | 166 | 302 | 1026 | 2134 |
| 8/1/2017 13:00 | 1.7 | 0.40 | 0.76 | 2.2 | 9.1 | 20 | 35 | 55 | 110 | 194 | 691 | 1372 |
| 8/1/2017 14:00 | 3.0 | 0.23 | 0.42 | 1.1 | 4.0 | 8.8 | 15 | 23 | 46 | 79 | 262 | 513 |
| 8/1/2017 15:00 | 1.6 | 1.1 | 2.0 | 5.1 | 18 | 38 | 64 | 98 | 190 | 328 | 1030 | 2035 |
| 8/1/2017 16:00 | 2.7 | 0.42 | 0.78 | 2.0 | 6.8 | 14 | 24 | 36 | 70 | 121 | 371 | 733 |
| 8/1/2017 17:00 | 3.5 | 0.02 | 0.40 | 1.0 | 3.6 | 8.1 | 14 | 21 | 42 | 71 | 220 | 439 |
| 8/1/2017 18:00 | 2.8 | 0.11 | 0.32 | 1.6 | 5.4 | 13 | 23 | 35 | 69 | 118 | 363 | 718 |
| 8/1/2017 19:00 | 3.2 | 0.03 | 0.26 | 0.71 | 3.1 | 9.1 | 16 | 25 | 48 | 81 | 261 | 515 |
| 8/1/2017 20:00 | 2.5 | 0.09 | 0.38 | 0.98 | 3.2 | 13 | 24 | 37 | 73 | 123 | 405 | 807 |
| 8/1/2017 21:00 | 1.7 | 0.36 | 0.67 | 1.8 | 6.4 | 28 | 48 | 75 | 147 | 252 | 833 | 1674 |
| 8/1/2017 22:00 | 1.8 | 0.18 | 0.33 | 1.1 | 4.0 | 18 | 35 | 57 | 112 | 197 | 672 | 1352 |
| 8/1/2017 23:00 | 1.4 | 0.20 | 0.48 | 1.5 | 11 | 30 | 54 | 84 | 166 | 291 | 1010 | 2093 |

## APPENDIX A – 2017 AND 2018 DATA

**Table A-20. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain August 1, 2017. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 8/1/2017 0:00 | 1.0 | 0.00 | 0.03 | 0.65 | 20 | 3.7 | 2.9 | 8.4 | 14 | 43 | 537 | 420 |
| 8/1/2017 1:00 | 0.8 | -0.02 | 0.00 | 0.35 | 26 | 6.7 | 4.3 | 2.8 | 33 | 56 | 658 | 635 |
| 8/1/2017 2:00 | 1.0 | -0.01 | -0.03 | 0.12 | 15 | 6.9 | 4.9 | 4.8 | 21 | 57 | 379 | 487 |
| 8/1/2017 3:00 | 0.5 | 0.00 | -0.11 | 6.0 | 46 | 22 | 13 | 26 | 67 | 178 | 1643 | 1425 |
| 8/1/2017 4:00 | 1.1 | 0.00 | 0.48 | 1.8 | 6.8 | 6.3 | 2.5 | 9.6 | 7.0 | 41 | 407 | 263 |
| 8/1/2017 5:00 | 0.6 | -0.03 | 2.2 | 7.8 | 23 | 16 | 4.0 | 31 | 59 | 124 | 1410 | 1046 |
| 8/1/2017 6:00 | 0.7 | -0.01 | 0.12 | 4.8 | 15 | 15 | 7.3 | 14 | 48 | 158 | 734 | 877 |
| 8/1/2017 7:00 | 0.5 | -0.04 | 1.6 | 11 | 31 | 18 | 14 | 14 | 102 | 300 | 1642 | 1978 |
| 8/1/2017 8:00 | 1.2 | 0.01 | 0.50 | 2.7 | 2.8 | 1.7 | 2.1 | 2.1 | 16 | 45 | 275 | 357 |
| 8/1/2017 9:00 | 1.1 | 0.05 | 0.22 | 1.2 | 7.9 | 3.8 | 2.2 | 7.4 | 19 | 44 | 351 | 365 |
| 8/1/2017 10:00 | 2.4 | 0.04 | 0.01 | 0.34 | 1.8 | 0.62 | 0.48 | 1.8 | 4.0 | 9.0 | 78 | 72 |
| 8/1/2017 11:00 | 1.8 | 0.16 | 0.02 | 0.48 | 3.3 | 1.7 | 1.2 | 2.6 | 7.4 | 18 | 138 | 146 |
| 8/1/2017 12:00 | 1.4 | 0.56 | 0.08 | 0.55 | 5.2 | 4.2 | 2.6 | 6.3 | 11 | 31 | 240 | 224 |
| 8/1/2017 13:00 | 1.7 | 0.40 | 0.07 | 0.69 | 3.0 | 2.4 | 1.7 | 2.6 | 6.0 | 16 | 178 | 98 |
| 8/1/2017 14:00 | 3.0 | 0.23 | 0.03 | 0.21 | 0.93 | 1.0 | 0.38 | 0.91 | 2.1 | 5.0 | 58 | 31 |
| 8/1/2017 15:00 | 1.6 | 1.1 | 0.14 | 0.83 | 3.5 | 3.0 | 1.2 | 3.4 | 6.1 | 21 | 197 | 138 |
| 8/1/2017 16:00 | 2.7 | 0.42 | 0.06 | 0.38 | 1.1 | 0.67 | 0.47 | 1.1 | 2.2 | 7.8 | 66 | 50 |
| 8/1/2017 17:00 | 3.5 | 0.02 | 0.56 | 0.21 | 0.70 | 1.00 | 0.41 | 0.69 | 1.8 | 4.1 | 40 | 33 |
| 8/1/2017 18:00 | 2.8 | 0.11 | 0.20 | 1.1 | 1.0 | 2.4 | 1.5 | 1.1 | 3.4 | 5.7 | 66 | 50 |
| 8/1/2017 19:00 | 3.2 | 0.03 | 0.32 | 0.17 | 1.2 | 3.0 | 0.65 | 1.1 | 2.2 | 3.7 | 53 | 35 |
| 8/1/2017 20:00 | 2.5 | 0.09 | 0.36 | 0.17 | 0.47 | 6.4 | 3.1 | 1.5 | 3.1 | 5.8 | 87 | 60 |
| 8/1/2017 21:00 | 1.7 | 0.36 | 0.05 | 0.43 | 1.4 | 15 | 2.2 | 3.5 | 6.3 | 14 | 182 | 135 |
| 8/1/2017 22:00 | 1.8 | 0.18 | 0.02 | 0.49 | 0.93 | 10.0 | 5.8 | 3.9 | 5.7 | 15 | 159 | 110 |
| 8/1/2017 23:00 | 1.4 | 0.20 | 0.18 | 0.61 | 6.8 | 8.2 | 4.7 | 3.3 | 8.8 | 22 | 246 | 214 |

**Table A-21. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain September 1, 2017. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 |
| 9/1/2017 0:00 | 0.7 | -0.01 | -0.02 | 0.72 | 12 | 33 | 57 | 90 | 176 | 298 | 1236 | 4419 |
| 9/1/2017 1:00 | 0.4 | -0.02 | 0.04 | 1.4 | 28 | 69 | 118 | 186 | 363 | 617 | 2555 | 9795 |
| 9/1/2017 2:00 | 0.5 | -0.02 | -0.10 | 0.23 | 21 | 53 | 93 | 148 | 283 | 488 | 1885 | 8012 |
| 9/1/2017 3:00 | 0.3 | -0.14 | -0.25 | 2.1 | 50 | 130 | 221 | 344 | 667 | 1139 | 4463 | 19069 |
| 9/1/2017 4:00 | 0.6 | -0.03 | -0.05 | 0.22 | 9.2 | 34 | 59 | 91 | 178 | 305 | 1662 | 5221 |
| 9/1/2017 5:00 | 0.2 | -0.57 | -1.01 | 5.7 | 47 | 271 | 506 | 856 | 1698 | 2851 | 19280 | 56646 |
| 9/1/2017 6:00 | 0.2 | -0.18 | -0.64 | 2.2 | 32 | 165 | 303 | 499 | 1046 | 1785 | 10378 | 36733 |
| 9/1/2017 7:00 | 0.7 | -0.02 | -0.06 | 0.07 | 4.8 | 16 | 27 | 46 | 95 | 173 | 915 | 3498 |
| 9/1/2017 8:00 | 0.4 | 0.04 | -0.06 | 0.97 | 18 | 62 | 109 | 185 | 370 | 656 | 3389 | 13790 |
| 9/1/2017 9:00 | 0.4 | 0.00 | 0.00 | 1.1 | 17 | 40 | 75 | 123 | 246 | 428 | 2114 | 8862 |
| 9/1/2017 10:00 | 0.1 | 8.7 | 20 | 81 | 387 | 1217 | 2250 | 3652 | 7222 | 12282 | 71590 | 222275 |
| 9/1/2017 11:00 | 1.9 | 0.05 | 0.10 | 0.30 | 1.5 | 3.5 | 6.0 | 9.6 | 19 | 32 | 200 | 519 |
| 9/1/2017 12:00 | 1.9 | 0.07 | 0.15 | 0.42 | 2.0 | 4.2 | 7.0 | 11 | 22 | 36 | 201 | 537 |
| 9/1/2017 13:00 | 1.7 | 0.17 | 0.35 | 0.83 | 3.4 | 6.8 | 12 | 18 | 34 | 57 | 265 | 722 |
| 9/1/2017 14:00 | 0.8 | 1.0 | 2.2 | 5.4 | 20 | 43 | 72 | 112 | 211 | 344 | 1468 | 3979 |
| 9/1/2017 15:00 | 1.1 | 0.91 | 1.8 | 4.4 | 14 | 31 | 51 | 79 | 150 | 244 | 867 | 2267 |
| 9/1/2017 16:00 | 1.5 | 0.66 | 1.3 | 3.1 | 9.8 | 20 | 34 | 52 | 98 | 160 | 512 | 1324 |
| 9/1/2017 17:00 | 1.3 | 0.79 | 1.5 | 3.7 | 12 | 24 | 40 | 61 | 116 | 187 | 596 | 1603 |
| 9/1/2017 18:00 | 1.8 | 0.49 | 0.95 | 2.2 | 7.1 | 14 | 24 | 37 | 69 | 112 | 358 | 941 |
| 9/1/2017 19:00 | 0.7 | 2.6 | 5.2 | 12 | 39 | 80 | 135 | 206 | 390 | 634 | 2067 | 5576 |
| 9/1/2017 20:00 | 1.2 | 0.92 | 1.8 | 4.4 | 14 | 28 | 47 | 72 | 138 | 223 | 747 | 2030 |
| 9/1/2017 21:00 | 3.6 | 0.09 | 0.18 | 0.42 | 1.3 | 2.7 | 4.7 | 7.2 | 14 | 22 | 73 | 205 |
| 9/1/2017 22:00 | 0.6 | 2.7 | 5.1 | 13 | 41 | 87 | 149 | 226 | 431 | 704 | 2393 | 7159 |
| 9/1/2017 23:00 | 1.2 | 0.52 | 0.97 | 2.6 | 7.8 | 18 | 30 | 46 | 89 | 144 | 538 | 1657 |

**Table A-22. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain September 1, 2017. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 9/1/2017 0:00 | 0.7 | -0.01 | 0.00 | 1.0 | 10.0 | 9.4 | 2.8 | 4.1 | 8.3 | 14 | 403 | 1757 |
| 9/1/2017 1:00 | 0.4 | -0.02 | 0.13 | 1.8 | 24 | 13 | 4.7 | 9.3 | 15 | 31 | 830 | 4164 |
| 9/1/2017 2:00 | 0.5 | -0.02 | -0.11 | 0.63 | 20 | 12 | 5.2 | 9.5 | 6.2 | 30 | 556 | 3704 |
| 9/1/2017 3:00 | 0.3 | -0.14 | 0.00 | 3.6 | 44 | 33 | 6.3 | 14 | 23 | 62 | 1344 | 8851 |
| 9/1/2017 4:00 | 0.6 | -0.03 | 0.00 | 0.44 | 8.6 | 16 | 1.8 | 4.0 | 6.6 | 18 | 707 | 1783 |
| 9/1/2017 5:00 | 0.2 | -0.57 | 0.00 | 11 | 31 | 179 | 58 | 100 | 93 | 113 | 9389 | 17525 |
| 9/1/2017 6:00 | 0.2 | -0.18 | -0.50 | 4.9 | 26 | 102 | 31 | 46 | 103 | 96 | 4620 | 14456 |
| 9/1/2017 7:00 | 0.7 | -0.02 | -0.05 | 0.29 | 4.6 | 6.2 | 1.2 | 5.3 | 8.7 | 19 | 380 | 1484 |
| 9/1/2017 8:00 | 0.4 | 0.04 | -0.20 | 1.5 | 15 | 26 | 7.2 | 21 | 23 | 57 | 1382 | 6165 |
| 9/1/2017 9:00 | 0.4 | 0.00 | 0.00 | 1.5 | 14 | 6.6 | 7.8 | 11 | 15 | 30 | 830 | 4054 |
| 9/1/2017 10:00 | 0.1 | 8.7 | 6.4 | 50 | 163 | 458 | 238 | 292 | 375 | 624 | 31928 | 74683 |
| 9/1/2017 11:00 | 1.9 | 0.05 | 0.02 | 0.10 | 0.69 | 0.50 | 0.27 | 0.67 | 0.86 | 1.1 | 94 | 126 |
| 9/1/2017 12:00 | 1.9 | 0.07 | 0.04 | 0.11 | 0.88 | 0.21 | 0.00 | 0.65 | 0.83 | 1.0 | 87 | 140 |
| 9/1/2017 13:00 | 1.7 | 0.17 | 0.07 | 0.07 | 1.0 | 0.20 | 0.43 | 0.80 | 0.51 | 1.3 | 98 | 196 |
| 9/1/2017 14:00 | 0.8 | 1.0 | 0.51 | 0.63 | 4.9 | 3.8 | 1.1 | 5.0 | 2.7 | 4.5 | 496 | 1066 |
| 9/1/2017 15:00 | 1.1 | 0.91 | 0.31 | 0.50 | 2.0 | 2.5 | 0.87 | 2.6 | 2.1 | 3.4 | 222 | 563 |
| 9/1/2017 16:00 | 1.5 | 0.66 | 0.15 | 0.36 | 1.1 | 1.0 | 0.76 | 1.3 | 1.1 | 1.8 | 104 | 320 |
| 9/1/2017 17:00 | 1.3 | 0.79 | 0.20 | 0.32 | 1.4 | 0.89 | 0.91 | 1.4 | 1.3 | 1.5 | 119 | 423 |
| 9/1/2017 18:00 | 1.8 | 0.49 | 0.12 | 0.13 | 0.88 | 0.56 | 0.20 | 0.62 | 0.98 | 1.2 | 72 | 235 |
| 9/1/2017 19:00 | 0.7 | 2.6 | 0.95 | 0.92 | 4.7 | 3.1 | 3.2 | 3.8 | 6.1 | 7.7 | 438 | 1479 |
| 9/1/2017 20:00 | 1.2 | 0.92 | 0.27 | 0.42 | 1.4 | 0.89 | 1.9 | 1.4 | 2.9 | 1.9 | 169 | 547 |
| 9/1/2017 21:00 | 3.6 | 0.09 | 0.03 | 0.04 | 0.16 | 0.09 | 0.25 | 0.11 | 0.30 | 0.20 | 16 | 59 |
| 9/1/2017 22:00 | 0.6 | 2.7 | 0.62 | 2.5 | 3.9 | 6.3 | 5.6 | 4.2 | 9.0 | 11 | 559 | 2278 |
| 9/1/2017 23:00 | 1.2 | 0.52 | 0.08 | 0.55 | 0.67 | 2.3 | 0.93 | 1.1 | 2.8 | 0.93 | 151 | 551 |

**Table A-23. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain October 1, 2017. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 |
| 10/1/2017 0:00 | 3.0 | 0.00 | 0.00 | 0.00 | -0.02 | -0.02 | -0.06 | 0.04 | 0.77 | 5.0 | 19 | 41 |
| 10/1/2017 1:00 | 1.7 | 0.00 | -0.01 | 0.01 | -0.01 | 0.03 | -0.05 | 0.20 | 1.6 | 15 | 59 | 129 |
| 10/1/2017 2:00 | 2.1 | 0.00 | -0.01 | -0.01 | -0.07 | -0.10 | -0.23 | -0.17 | 0.96 | 5.3 | 35 | 77 |
| 10/1/2017 3:00 | 0.8 | -0.01 | -0.04 | -0.02 | -0.17 | -0.11 | -0.54 | -0.27 | -0.50 | 15 | 196 | 462 |
| 10/1/2017 4:00 | 1.6 | 0.00 | 0.00 | 0.01 | 0.00 | 0.06 | 0.00 | 0.15 | 1.1 | 6.5 | 57 | 130 |
| 10/1/2017 5:00 | 0.4 | -0.08 | -0.25 | -0.11 | -0.92 | -0.58 | -2.97 | 7.4 | 47 | 247 | 1156 | 2529 |
| 10/1/2017 6:00 | 1.1 | 0.00 | -0.01 | 0.02 | 0.00 | 0.13 | 0.00 | 0.99 | 14 | 43 | 127 | 275 |
| 10/1/2017 7:00 | 0.7 | 0.01 | -0.04 | 0.03 | -0.08 | 0.15 | -0.25 | 4.1 | 34 | 89 | 278 | 613 |
| 10/1/2017 8:00 | 1.5 | 0.00 | -0.01 | 0.01 | 0.00 | 0.07 | 0.00 | 0.51 | 6.9 | 21 | 64 | 188 |
| 10/1/2017 9:00 | 0.8 | 0.00 | 0.00 | 0.10 | 0.14 | 0.52 | 0.44 | 4.6 | 24 | 81 | 245 | 751 |
| 10/1/2017 10:00 | 2.9 | 0.00 | 0.00 | 0.00 | -0.01 | 0.01 | -0.02 | 0.07 | 1.4 | 5.3 | 16 | 45 |
| 10/1/2017 11:00 | 0.6 | 0.00 | 0.00 | 0.14 | 0.19 | 0.77 | 0.62 | 2.9 | 25 | 115 | 360 | 968 |
| 10/1/2017 12:00 | 1.0 | 0.03 | 0.06 | 0.21 | 0.59 | 1.5 | 2.2 | 4.0 | 13 | 45 | 152 | 360 |
| 10/1/2017 13:00 | 2.5 | 0.00 | 0.00 | 0.00 | 0.02 | 0.12 | 0.23 | 0.41 | 1.0 | 7.8 | 26 | 59 |
| 10/1/2017 14:00 | 1.6 | 0.00 | -0.01 | 0.02 | 0.10 | 0.25 | 0.42 | 0.79 | 6.4 | 15 | 67 | 148 |
| 10/1/2017 15:00 | 0.9 | 0.01 | 0.00 | 0.10 | 0.27 | 0.71 | 0.89 | 1.7 | 14 | 36 | 184 | 412 |
| 10/1/2017 16:00 | 1.7 | 0.00 | -0.01 | 0.01 | 0.01 | 0.08 | 0.05 | 0.21 | 2.5 | 10 | 58 | 137 |
| 10/1/2017 17:00 | no data | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| 10/1/2017 18:00 | 3.0 | 0.00 | 0.00 | 0.00 | 0.01 | 0.08 | 0.13 | 0.24 | 0.60 | 2.8 | 19 | 44 |
| 10/1/2017 19:00 | 0.9 | -0.02 | -0.04 | 0.00 | -0.09 | 0.00 | -0.29 | 0.44 | 2.4 | 13 | 175 | 405 |
| 10/1/2017 20:00 | 1.3 | 0.00 | -0.01 | 0.01 | -0.06 | -0.04 | -0.21 | -0.11 | 0.59 | 4.7 | 81 | 189 |
| 10/1/2017 21:00 | 0.7 | -0.02 | -0.07 | -0.03 | -0.26 | -0.17 | -0.85 | -0.42 | 0.79 | 11 | 327 | 753 |
| 10/1/2017 22:00 | 1.6 | 0.00 | -0.01 | 0.01 | -0.03 | 0.00 | -0.10 | 0.00 | 0.29 | 19 | 58 | 134 |
| 10/1/2017 23:00 | 2.5 | 0.00 | -0.01 | 0.00 | -0.02 | -0.02 | -0.08 | -0.06 | 0.00 | 7.0 | 20 | 46 |

# APPENDIX A – 2017 AND 2018 DATA

**Table A-24. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain October 1, 2017. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 10/1/2017 0:00 | 3.0 | 0.00 | 0.00 | 0.01 | -0.01 | 0.02 | -0.03 | 0.12 | 0.60 | 3.3 | 5.4 | 5.3 |
| 10/1/2017 1:00 | 1.7 | 0.00 | -0.01 | 0.03 | -0.03 | 0.05 | -0.09 | 0.27 | 1.1 | 11 | 17 | 18 |
| 10/1/2017 2:00 | 2.1 | 0.00 | -0.01 | 0.03 | -0.04 | 0.04 | -0.06 | 0.18 | 1.1 | 3.4 | 17 | 11 |
| 10/1/2017 3:00 | 0.8 | -0.01 | -0.03 | 0.11 | -0.11 | 0.22 | -0.36 | 0.53 | 0.00 | 14 | 120 | 87 |
| 10/1/2017 4:00 | 1.6 | 0.00 | -0.01 | 0.03 | -0.03 | 0.06 | -0.10 | 0.15 | 0.71 | 4.3 | 31 | 22 |
| 10/1/2017 5:00 | 0.4 | -0.08 | -0.15 | 0.61 | -0.62 | 1.2 | -2.01 | 12 | 29 | 154 | 432 | 353 |
| 10/1/2017 6:00 | 1.1 | 0.00 | -0.02 | 0.07 | -0.07 | 0.13 | -0.22 | 0.99 | 11 | 18 | 20 | 36 |
| 10/1/2017 7:00 | 0.7 | 0.01 | -0.08 | 0.15 | -0.15 | 0.30 | -0.50 | 4.4 | 23 | 30 | 53 | 88 |
| 10/1/2017 8:00 | 1.5 | 0.00 | -0.01 | 0.04 | -0.04 | 0.07 | -0.12 | 0.51 | 5.2 | 9.3 | 11 | 58 |
| 10/1/2017 9:00 | 0.8 | 0.00 | 0.00 | 0.13 | -0.13 | 0.26 | -0.42 | 3.9 | 14 | 39 | 41 | 248 |
| 10/1/2017 10:00 | 2.9 | 0.00 | 0.00 | 0.01 | -0.01 | 0.04 | -0.03 | 0.09 | 1.1 | 2.7 | 3.1 | 13 |
| 10/1/2017 11:00 | 0.6 | 0.00 | 0.00 | 0.19 | -0.20 | 0.39 | -0.65 | 1.9 | 17 | 67 | 70 | 254 |
| 10/1/2017 12:00 | 1.0 | 0.03 | 0.02 | 0.11 | 0.00 | 0.29 | -0.24 | 0.72 | 4.6 | 22 | 35 | 69 |
| 10/1/2017 13:00 | 2.5 | 0.00 | 0.00 | 0.01 | 0.01 | 0.08 | 0.04 | 0.06 | 0.21 | 5.6 | 5.5 | 10 |
| 10/1/2017 14:00 | 1.6 | 0.00 | -0.01 | 0.05 | 0.03 | 0.06 | 0.00 | 0.16 | 4.3 | 4.0 | 24 | 22 |
| 10/1/2017 15:00 | 0.9 | 0.01 | -0.02 | 0.13 | 0.00 | 0.17 | -0.28 | 0.42 | 9.1 | 12 | 74 | 64 |
| 10/1/2017 16:00 | 1.7 | 0.00 | -0.01 | 0.03 | 0.00 | 0.05 | -0.09 | 0.14 | 1.8 | 5.5 | 26 | 26 |
| 10/1/2017 17:00 | no data | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| 10/1/2017 18:00 | 3.0 | 0.00 | 0.00 | 0.01 | 0.02 | 0.05 | 0.00 | 0.04 | 0.14 | 1.7 | 9.0 | 8.1 |
| 10/1/2017 19:00 | 0.9 | -0.02 | -0.02 | 0.13 | -0.09 | 0.18 | -0.29 | 0.87 | 1.4 | 8.0 | 108 | 71 |
| 10/1/2017 20:00 | 1.3 | 0.00 | -0.01 | 0.04 | -0.09 | 0.08 | -0.14 | 0.20 | 0.69 | 3.4 | 52 | 35 |
| 10/1/2017 21:00 | 0.7 | -0.02 | -0.04 | 0.17 | -0.18 | 0.34 | -0.57 | 0.85 | 1.4 | 8.9 | 223 | 130 |
| 10/1/2017 22:00 | 1.6 | 0.00 | -0.02 | 0.05 | -0.06 | 0.06 | -0.10 | 0.15 | 0.25 | 16 | 11 | 24 |
| 10/1/2017 23:00 | 2.5 | 0.00 | -0.01 | 0.01 | -0.01 | 0.02 | -0.04 | 0.06 | 0.09 | 6.3 | 3.0 | 7.4 |

**Table A-25. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain June 1, 2018. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 |
| 6/1/2018 0:00 | 0.5 | -0.05 | -0.14 | 0.00 | -0.59 | 0.00 | 0.00 | 77 | 336 | 931 | 2905 | 5914 |
| 6/1/2018 1:00 | 0.3 | 0.00 | -0.38 | 0.00 | 0.00 | 2.3 | 7.7 | 461 | 1376 | 3719 | 11422 | 22657 |
| 6/1/2018 2:00 | 0.6 | -0.01 | -0.05 | 0.04 | -0.11 | 0.21 | -0.35 | 87 | 228 | 639 | 2075 | 4044 |
| 6/1/2018 3:00 | 0.8 | -0.01 | -0.04 | 0.05 | 0.00 | 0.00 | 0.00 | 45 | 121 | 355 | 1233 | 2398 |
| 6/1/2018 4:00 | 1.4 | -0.01 | -0.03 | -0.04 | -0.16 | -0.24 | 2.5 | 15 | 36 | 113 | 376 | 740 |
| 6/1/2018 5:00 | 1.3 | 0.00 | -0.01 | 0.02 | -0.02 | 0.05 | 6.1 | 17 | 41 | 130 | 415 | 821 |
| 6/1/2018 6:00 | 1.3 | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| 6/1/2018 7:00 | 1.3 | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| 6/1/2018 8:00 | 0.5 | -0.01 | -0.03 | 0.40 | 0.78 | 2.8 | 56 | 116 | 284 | 898 | 2857 | 5886 |
| 6/1/2018 9:00 | 0.4 | -0.03 | 0.37 | 2.3 | 7.6 | 19 | 155 | 272 | 711 | 1813 | 6165 | 12953 |
| 6/1/2018 10:00 | 0.8 | 0.20 | 0.40 | 1.2 | 3.7 | 7.7 | 36 | 73 | 187 | 414 | 1478 | 3045 |
| 6/1/2018 11:00 | 0.3 | 2.4 | 5.1 | 13 | 43 | 102 | 282 | 518 | 1333 | 2830 | 9550 | 19439 |
| 6/1/2018 12:00 | 0.5 | 1.3 | 2.4 | 6.5 | 21 | 45 | 105 | 203 | 478 | 1013 | 3409 | 6936 |
| 6/1/2018 13:00 | 0.7 | 0.88 | 2.7 | 6.9 | 21 | 44 | 98 | 165 | 368 | 719 | 2428 | 4890 |
| 6/1/2018 14:00 | no data | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| 6/1/2018 15:00 | 2.7 | 0.14 | 0.29 | 0.69 | 2.0 | 4.6 | 8.9 | 14 | 28 | 55 | 178 | 355 |
| 6/1/2018 16:00 | 0.7 | 2.5 | 4.9 | 12 | 33 | 72 | 141 | 222 | 447 | 859 | 2668 | 5312 |
| 6/1/2018 17:00 | 0.6 | 3.1 | 6.4 | 15 | 44 | 94 | 177 | 287 | 579 | 1123 | 3460 | 6841 |
| 6/1/2018 18:00 | 1.7 | -0.02 | 0.03 | 0.32 | 6.8 | 14 | 25 | 44 | 86 | 152 | 504 | 998 |
| 6/1/2018 19:00 | 2.1 | -0.01 | -0.01 | 0.12 | 1.0 | 8.6 | 15 | 26 | 52 | 87 | 307 | 613 |
| 6/1/2018 20:00 | 0.7 | -0.10 | 0.35 | 4.8 | 32 | 69 | 123 | 205 | 409 | 725 | 2618 | 5137 |
| 6/1/2018 21:00 | 2.7 | 0.04 | 0.13 | 0.37 | 1.8 | 3.9 | 7.4 | 13 | 26 | 51 | 172 | 335 |
| 6/1/2018 22:00 | 0.4 | 1.5 | 2.7 | 8.2 | 65 | 175 | 348 | 580 | 1180 | 2523 | 8559 | 16861 |
| 6/1/2018 23:00 | 1.5 | 0.02 | 0.04 | 0.40 | 3.5 | 9.3 | 18 | 29 | 59 | 133 | 471 | 938 |

**Table A-26. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain June 1, 2018. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 6/1/2018 0:00 | 0.5 | -0.05 | -0.08 | 0.44 | -0.59 | 1.2 | 0.00 | 77 | 168 | 352 | 547 | 531 |
| 6/1/2018 1:00 | 0.3 | 0.00 | -0.60 | 1.2 | 0.00 | 2.3 | 3.9 | 449 | 452 | 1355 | 2048 | 1611 |
| 6/1/2018 2:00 | 0.6 | -0.01 | -0.05 | 0.21 | -0.22 | 0.43 | -0.70 | 88 | 58 | 244 | 436 | 234 |
| 6/1/2018 3:00 | 0.8 | -0.01 | -0.03 | 0.19 | -0.13 | 0.00 | 0.00 | 45 | 32 | 145 | 302 | 135 |
| 6/1/2018 4:00 | 1.4 | -0.01 | -0.01 | 0.04 | -0.04 | 0.08 | 2.9 | 11 | 7.0 | 50 | 84 | 48 |
| 6/1/2018 5:00 | 1.3 | 0.00 | -0.02 | 0.07 | -0.09 | 0.09 | 6.1 | 8.0 | 7.9 | 58 | 83 | 57 |
| 6/1/2018 6:00 | 1.3 | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| 6/1/2018 7:00 | 1.3 | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| 6/1/2018 8:00 | 0.5 | -0.01 | 0.00 | 0.62 | -0.32 | 1.2 | 51 | 33 | 59 | 398 | 568 | 579 |
| 6/1/2018 9:00 | 0.4 | -0.03 | 0.66 | 1.9 | 1.3 | 3.8 | 124 | 40 | 179 | 604 | 1442 | 1452 |
| 6/1/2018 10:00 | 0.8 | 0.20 | 0.07 | 0.36 | 0.45 | 0.57 | 23 | 19 | 45 | 103 | 381 | 299 |
| 6/1/2018 11:00 | 0.3 | 2.4 | 1.3 | 2.6 | 6.1 | 17 | 113 | 96 | 323 | 620 | 2196 | 1745 |
| 6/1/2018 12:00 | 0.5 | 1.3 | 0.15 | 1.5 | 2.7 | 4.0 | 32 | 46 | 87 | 221 | 779 | 620 |
| 6/1/2018 13:00 | 0.7 | 0.88 | 1.8 | 1.0 | 1.7 | 3.0 | 25 | 19 | 53 | 115 | 559 | 401 |
| 6/1/2018 14:00 | no data | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| 6/1/2018 15:00 | 2.7 | 0.14 | 0.06 | 0.04 | 0.09 | 0.72 | 1.2 | 0.85 | 1.8 | 9.0 | 36 | 27 |
| 6/1/2018 16:00 | 0.7 | 2.5 | 0.71 | 0.77 | 1.4 | 6.9 | 21 | 11 | 30 | 127 | 495 | 392 |
| 6/1/2018 17:00 | 0.6 | 3.1 | 1.3 | 0.89 | 2.0 | 8.2 | 22 | 24 | 39 | 174 | 627 | 470 |
| 6/1/2018 18:00 | 1.7 | -0.02 | 0.10 | 0.34 | 5.9 | 1.0 | 1.5 | 6.1 | 4.5 | 12 | 111 | 70 |
| 6/1/2018 19:00 | 2.1 | -0.01 | 0.01 | 0.19 | 0.70 | 6.6 | 0.37 | 4.3 | 2.6 | 4.1 | 77 | 47 |
| 6/1/2018 20:00 | 0.7 | -0.10 | 0.83 | 5.5 | 18 | 6.6 | 9.1 | 22 | 24 | 62 | 689 | 323 |
| 6/1/2018 21:00 | 2.7 | 0.04 | 0.09 | 0.11 | 0.77 | 0.40 | 0.94 | 1.8 | 1.8 | 8.4 | 39 | 20 |
| 6/1/2018 22:00 | 0.4 | 1.5 | 0.19 | 2.9 | 42 | 47 | 60 | 59 | 89 | 565 | 1991 | 1113 |
| 6/1/2018 23:00 | 1.5 | 0.02 | 0.01 | 0.42 | 2.4 | 2.4 | 2.8 | 2.1 | 4.4 | 34 | 119 | 69 |

**Table A-27. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain July 1, 2018. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 |
| 7/1/2018 0:00 | 0.6 | 0.00 | 0.00 | 0.48 | 2.2 | 11 | 52 | 154 | 331 | 596 | 2373 | 6301 |
| 7/1/2018 1:00 | 1.8 | 0.00 | 0.00 | 0.04 | 0.34 | 1.4 | 10 | 19 | 39 | 73 | 280 | 747 |
| 7/1/2018 2:00 | 0.6 | 0.00 | 0.00 | 0.66 | 3.3 | 12 | 83 | 165 | 357 | 676 | 2519 | 6865 |
| 7/1/2018 3:00 | 0.8 | 0.01 | -0.01 | 0.08 | 1.2 | 13 | 40 | 75 | 160 | 315 | 1174 | 3114 |
| 7/1/2018 4:00 | 0.8 | 0.00 | 0.00 | 0.23 | 3.4 | 18 | 48 | 85 | 191 | 349 | 1287 | 3351 |
| 7/1/2018 5:00 | 0.9 | 0.00 | -0.02 | 0.05 | 2.7 | 14 | 39 | 65 | 150 | 270 | 1041 | 2681 |
| 7/1/2018 6:00 | 1.0 | 0.00 | -0.01 | 0.05 | 1.4 | 9.9 | 28 | 45 | 108 | 192 | 779 | 2037 |
| 7/1/2018 7:00 | 0.7 | -0.01 | -0.02 | 0.12 | 5.8 | 29 | 67 | 112 | 242 | 454 | 1799 | 4860 |
| 7/1/2018 8:00 | 0.7 | -0.01 | -0.02 | 0.29 | 6.0 | 29 | 70 | 118 | 259 | 480 | 1746 | 5095 |
| 7/1/2018 9:00 | 0.6 | 0.19 | 0.44 | 1.7 | 10 | 53 | 104 | 174 | 373 | 680 | 2336 | 7032 |
| 7/1/2018 10:00 | 1.2 | 0.07 | 0.20 | 0.57 | 1.8 | 12 | 27 | 44 | 95 | 171 | 573 | 1685 |
| 7/1/2018 11:00 | 0.6 | 0.71 | 1.4 | 3.7 | 21 | 76 | 141 | 226 | 478 | 853 | 2736 | 7843 |
| 7/1/2018 12:00 | 0.7 | 0.46 | 1.7 | 5.0 | 22 | 67 | 125 | 194 | 401 | 709 | 2255 | 6309 |
| 7/1/2018 13:00 | 1.2 | 0.02 | 0.13 | 1.8 | 8.5 | 23 | 43 | 68 | 137 | 233 | 766 | 2133 |
| 7/1/2018 14:00 | 1.5 | 0.00 | 0.00 | 0.04 | 4.1 | 12 | 24 | 39 | 79 | 137 | 464 | 1262 |
| 7/1/2018 15:00 | 2.2 | 0.00 | 0.00 | 0.04 | 0.23 | 3.6 | 9.2 | 17 | 37 | 63 | 226 | 601 |
| 7/1/2018 16:00 | 2.0 | 0.01 | 0.07 | 0.26 | 0.90 | 2.1 | 10 | 23 | 49 | 83 | 289 | 764 |
| 7/1/2018 17:00 | 1.7 | 0.03 | 0.16 | 0.48 | 1.6 | 3.7 | 8.2 | 25 | 71 | 124 | 416 | 1092 |
| 7/1/2018 18:00 | 2.1 | 0.11 | 0.20 | 0.49 | 1.5 | 3.5 | 6.2 | 17 | 49 | 86 | 294 | 737 |
| 7/1/2018 19:00 | 2.2 | 0.07 | 0.12 | 0.31 | 0.89 | 2.5 | 5.1 | 13 | 39 | 70 | 285 | 620 |
| 7/1/2018 20:00 | 3.7 | 0.01 | 0.02 | 0.06 | 0.17 | 0.71 | 1.2 | 3.2 | 12 | 22 | 91 | 203 |
| 7/1/2018 21:00 | 2.6 | 0.00 | 0.00 | 0.01 | 0.03 | 0.37 | 1.1 | 4.3 | 21 | 39 | 164 | 382 |
| 7/1/2018 22:00 | 0.9 | 0.00 | 0.00 | 0.10 | 0.41 | 3.5 | 8.3 | 73 | 184 | 340 | 1317 | 3332 |
| 7/1/2018 23:00 | 2.2 | 0.00 | -0.01 | 0.00 | 0.15 | 0.84 | 1.8 | 13 | 29 | 55 | 199 | 511 |

## APPENDIX A – 2017 AND 2018 DATA

**Table A-28. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain July 1, 2018. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 7/1/2018 0:00 | 0.6 | 0.00 | 0.00 | 0.66 | 0.81 | 7.3 | 33 | 76 | 40 | 58 | 731 | 1617 |
| 7/1/2018 1:00 | 1.8 | 0.00 | -0.01 | 0.06 | 0.23 | 0.75 | 7.8 | 3.5 | 3.5 | 9.5 | 82 | 194 |
| 7/1/2018 2:00 | 0.6 | 0.00 | 0.00 | 0.90 | 1.5 | 5.3 | 64 | 41 | 43 | 93 | 702 | 1857 |
| 7/1/2018 3:00 | 0.8 | 0.01 | -0.04 | 0.14 | 0.98 | 11 | 18 | 16 | 17 | 52 | 328 | 797 |
| 7/1/2018 4:00 | 0.8 | 0.00 | 0.00 | 0.31 | 2.8 | 11 | 19 | 13 | 28 | 39 | 352 | 823 |
| 7/1/2018 5:00 | 0.9 | 0.00 | -0.03 | 0.12 | 2.6 | 8.3 | 16 | 6.5 | 26 | 26 | 306 | 643 |
| 7/1/2018 6:00 | 1.0 | 0.00 | 0.00 | 0.09 | 1.2 | 7.2 | 12 | 3.7 | 21 | 17 | 246 | 505 |
| 7/1/2018 7:00 | 0.7 | -0.01 | 0.00 | 0.22 | 5.5 | 17 | 19 | 12 | 29 | 59 | 551 | 1292 |
| 7/1/2018 8:00 | 0.7 | -0.01 | 0.00 | 0.45 | 5.2 | 17 | 23 | 13 | 35 | 57 | 467 | 1559 |
| 7/1/2018 9:00 | 0.6 | 0.19 | 0.15 | 0.90 | 5.7 | 32 | 17 | 18 | 44 | 73 | 558 | 2260 |
| 7/1/2018 10:00 | 1.2 | 0.07 | 0.11 | 0.18 | 0.21 | 8.3 | 6.9 | 4.6 | 11 | 17 | 129 | 522 |
| 7/1/2018 11:00 | 0.6 | 0.71 | 0.16 | 0.93 | 10 | 35 | 15 | 16 | 50 | 77 | 557 | 2329 |
| 7/1/2018 12:00 | 0.7 | 0.46 | 1.3 | 1.6 | 8.1 | 24 | 14 | 8.0 | 35 | 59 | 448 | 1796 |
| 7/1/2018 13:00 | 1.2 | 0.02 | 0.15 | 2.1 | 3.4 | 6.2 | 5.7 | 3.7 | 8.5 | 12 | 165 | 601 |
| 7/1/2018 14:00 | 1.5 | 0.00 | 0.00 | 0.07 | 3.9 | 3.7 | 4.9 | 2.6 | 5.7 | 10 | 107 | 341 |
| 7/1/2018 15:00 | 2.2 | 0.00 | -0.01 | 0.06 | 0.12 | 3.2 | 3.2 | 3.4 | 4.2 | 3.7 | 59 | 154 |
| 7/1/2018 16:00 | 2.0 | 0.01 | 0.08 | 0.14 | 0.17 | 0.29 | 6.9 | 8.0 | 4.8 | 4.6 | 70 | 194 |
| 7/1/2018 17:00 | 1.7 | 0.03 | 0.17 | 0.16 | 0.29 | 0.56 | 2.0 | 13 | 21 | 9.2 | 95 | 273 |
| 7/1/2018 18:00 | 2.1 | 0.11 | 0.01 | 0.05 | 0.16 | 0.57 | 0.34 | 8.0 | 15 | 6.2 | 70 | 165 |
| 7/1/2018 19:00 | 2.2 | 0.07 | 0.01 | 0.05 | 0.02 | 0.78 | 0.97 | 4.8 | 14 | 6.5 | 90 | 84 |
| 7/1/2018 20:00 | 3.7 | 0.01 | 0.00 | 0.01 | 0.00 | 0.38 | 0.05 | 1.4 | 5.3 | 2.6 | 29 | 31 |
| 7/1/2018 21:00 | 2.6 | 0.00 | 0.00 | 0.02 | 0.02 | 0.31 | 0.50 | 2.6 | 11 | 4.9 | 55 | 69 |
| 7/1/2018 22:00 | 0.9 | 0.00 | 0.00 | 0.13 | 0.14 | 2.7 | 2.6 | 60 | 43 | 40 | 389 | 765 |
| 7/1/2018 23:00 | 2.2 | 0.00 | -0.01 | 0.02 | 0.15 | 0.55 | 0.41 | 10 | 4.3 | 6.6 | 54 | 121 |

**Table A-29. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain August 1, 2018. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 |
| 8/1/2018 0:00 | 1.2 | 0.00 | -0.01 | 0.08 | 7.9 | 23 | 40 | 64 | 135 | 242 | 874 | 2223 |
| 8/1/2018 1:00 | 0.6 | 0.02 | -0.03 | 0.45 | 30 | 88 | 156 | 251 | 518 | 991 | 3518 | 8682 |
| 8/1/2018 2:00 | 0.8 | 0.00 | -0.03 | 0.35 | 11 | 37 | 68 | 112 | 239 | 454 | 1605 | 3962 |
| 8/1/2018 3:00 | 1.2 | 0.01 | 0.00 | 0.12 | 4.5 | 19 | 33 | 54 | 116 | 212 | 790 | 1907 |
| 8/1/2018 4:00 | 1.2 | 0.00 | -0.01 | 0.97 | 4.1 | 18 | 31 | 52 | 112 | 203 | 779 | 1868 |
| 8/1/2018 5:00 | 1.5 | 0.00 | 0.00 | 0.49 | 3.2 | 10 | 18 | 31 | 67 | 125 | 466 | 1141 |
| 8/1/2018 6:00 | 1.3 | 0.00 | -0.01 | 0.52 | 4.3 | 13 | 23 | 41 | 87 | 170 | 610 | 1586 |
| 8/1/2018 7:00 | 0.9 | 0.01 | 0.00 | 0.86 | 7.0 | 23 | 43 | 71 | 159 | 299 | 1103 | 3054 |
| 8/1/2018 8:00 | 1.6 | 0.00 | -0.01 | 0.32 | 2.8 | 7.6 | 13 | 22 | 51 | 102 | 358 | 1028 |
| 8/1/2018 9:00 | 1.3 | -0.01 | -0.02 | 0.18 | 3.9 | 11 | 18 | 31 | 73 | 142 | 513 | 1492 |
| 8/1/2018 10:00 | 1.1 | 0.04 | 0.12 | 0.48 | 4.4 | 18 | 34 | 55 | 123 | 236 | 846 | 2418 |
| 8/1/2018 11:00 | 0.6 | 0.34 | 0.74 | 2.4 | 16 | 61 | 112 | 182 | 390 | 720 | 2675 | 7476 |
| 8/1/2018 12:00 | 1.2 | 0.38 | 0.76 | 2.0 | 8.8 | 25 | 44 | 71 | 143 | 253 | 907 | 2431 |
| 8/1/2018 13:00 | 1.7 | 0.28 | 0.59 | 1.5 | 6.6 | 15 | 27 | 43 | 84 | 145 | 511 | 1280 |
| 8/1/2018 14:00 | 0.8 | 1.6 | 3.2 | 7.8 | 33 | 73 | 127 | 200 | 400 | 685 | 2318 | 5690 |
| 8/1/2018 15:00 | 2.9 | 0.09 | 0.18 | 0.55 | 2.1 | 4.8 | 8.4 | 13 | 27 | 48 | 167 | 419 |
| 8/1/2018 16:00 | 3.5 | 0.03 | 0.07 | 0.26 | 1.1 | 2.5 | 4.5 | 7.5 | 16 | 29 | 103 | 260 |
| 8/1/2018 17:00 | 3.1 | 0.02 | 0.05 | 0.13 | 1.1 | 3.2 | 6.0 | 9.8 | 20 | 37 | 134 | 325 |
| 8/1/2018 18:00 | 2.6 | 0.02 | 0.05 | 0.27 | 1.0 | 5.6 | 10 | 16 | 34 | 60 | 209 | 502 |
| 8/1/2018 19:00 | 2.4 | 0.01 | 0.08 | 0.27 | 1.1 | 2.5 | 11 | 19 | 37 | 66 | 245 | 583 |
| 8/1/2018 20:00 | 0.7 | 0.23 | 0.88 | 2.4 | 7.2 | 26 | 122 | 185 | 390 | 747 | 2624 | 6328 |
| 8/1/2018 21:00 | 1.4 | 0.05 | 0.11 | 0.36 | 1.7 | 7.6 | 29 | 47 | 101 | 193 | 663 | 1612 |
| 8/1/2018 22:00 | 1.8 | 0.01 | 0.05 | 0.22 | 0.90 | 7.5 | 17 | 27 | 56 | 105 | 383 | 961 |
| 8/1/2018 23:00 | 0.7 | 0.00 | 0.04 | 1.2 | 3.7 | 61 | 111 | 176 | 372 | 710 | 2527 | 6548 |

**Table A-30. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain August 1, 2018. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 8/1/2018 0:00 | 1.2 | 0.00 | -0.02 | 0.13 | 7.7 | 7.3 | 2.5 | 4.0 | 13 | 23 | 231 | 516 |
| 8/1/2018 1:00 | 0.6 | 0.02 | -0.09 | 0.70 | 29 | 28 | 11 | 19 | 44 | 144 | 898 | 1867 |
| 8/1/2018 2:00 | 0.8 | 0.00 | -0.04 | 0.56 | 9.6 | 17 | 6.0 | 11 | 27 | 63 | 406 | 852 |
| 8/1/2018 3:00 | 1.2 | 0.01 | -0.02 | 0.16 | 4.1 | 9.9 | 1.8 | 5.7 | 13 | 23 | 220 | 385 |
| 8/1/2018 4:00 | 1.2 | 0.00 | -0.02 | 1.3 | 1.4 | 9.7 | 1.6 | 5.3 | 14 | 20 | 227 | 369 |
| 8/1/2018 5:00 | 1.5 | 0.00 | 0.00 | 0.67 | 1.8 | 4.1 | 1.00 | 4.2 | 7.9 | 15 | 130 | 240 |
| 8/1/2018 6:00 | 1.3 | 0.00 | 0.00 | 0.72 | 2.8 | 4.7 | 1.8 | 6.6 | 8.5 | 27 | 159 | 389 |
| 8/1/2018 7:00 | 0.9 | 0.01 | -0.03 | 1.2 | 4.6 | 9.7 | 4.4 | 6.5 | 23 | 40 | 302 | 852 |
| 8/1/2018 8:00 | 1.6 | 0.00 | -0.01 | 0.46 | 1.9 | 2.2 | 0.88 | 1.7 | 9.2 | 18 | 90 | 305 |
| 8/1/2018 9:00 | 1.3 | -0.01 | -0.02 | 0.30 | 3.4 | 3.2 | 0.55 | 4.1 | 12 | 23 | 135 | 455 |
| 8/1/2018 10:00 | 1.1 | 0.04 | 0.08 | 0.29 | 3.0 | 9.8 | 3.8 | 4.3 | 18 | 35 | 220 | 715 |
| 8/1/2018 11:00 | 0.6 | 0.34 | 0.22 | 1.0 | 9.3 | 29 | 11 | 15 | 45 | 85 | 741 | 2123 |
| 8/1/2018 12:00 | 1.2 | 0.38 | 0.13 | 0.34 | 3.3 | 7.5 | 3.3 | 4.9 | 11 | 20 | 236 | 636 |
| 8/1/2018 13:00 | 1.7 | 0.28 | 0.16 | 0.17 | 2.5 | 2.6 | 1.7 | 1.7 | 4.7 | 8.6 | 129 | 286 |
| 8/1/2018 14:00 | 0.8 | 1.6 | 0.60 | 0.81 | 11 | 8.6 | 5.9 | 9.5 | 25 | 38 | 537 | 1204 |
| 8/1/2018 15:00 | 2.9 | 0.09 | 0.02 | 0.20 | 0.58 | 0.63 | 0.51 | 0.87 | 2.0 | 4.1 | 40 | 95 |
| 8/1/2018 16:00 | 3.5 | 0.03 | 0.02 | 0.13 | 0.34 | 0.42 | 0.37 | 0.67 | 1.5 | 3.3 | 27 | 59 |
| 8/1/2018 17:00 | 3.1 | 0.02 | 0.02 | 0.04 | 0.77 | 0.92 | 0.79 | 0.84 | 1.8 | 3.9 | 35 | 67 |
| 8/1/2018 18:00 | 2.6 | 0.02 | 0.03 | 0.22 | 0.24 | 3.7 | 0.73 | 1.2 | 2.9 | 5.4 | 52 | 99 |
| 8/1/2018 19:00 | 2.4 | 0.01 | 0.10 | 0.13 | 0.36 | 0.33 | 6.7 | 2.3 | 2.7 | 5.0 | 68 | 112 |
| 8/1/2018 20:00 | 0.7 | 0.23 | 0.73 | 0.59 | 0.47 | 12 | 79 | 3.0 | 40 | 109 | 656 | 1273 |
| 8/1/2018 21:00 | 1.4 | 0.05 | 0.03 | 0.15 | 0.75 | 4.2 | 16 | 4.5 | 12 | 27 | 159 | 331 |
| 8/1/2018 22:00 | 1.8 | 0.01 | 0.05 | 0.13 | 0.30 | 5.7 | 4.2 | 2.0 | 5.7 | 13 | 103 | 216 |
| 8/1/2018 23:00 | 0.7 | 0.00 | 0.07 | 1.6 | 0.26 | 53 | 11 | 10.0 | 39 | 101 | 648 | 1591 |

**Table A-31. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain September 1, 2018. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 |
| 9/1/2018 0:00 | 1.6 | 0.00 | 0.03 | 0.12 | 0.49 | 2.8 | 8.1 | 15 | 31 | 53 | 146 | 667 |
| 9/1/2018 1:00 | 1.5 | 0.00 | -0.01 | 0.08 | 0.21 | 1.1 | 7.0 | 15 | 30 | 52 | 142 | 702 |
| 9/1/2018 2:00 | 0.8 | 0.00 | 0.00 | 0.16 | 1.1 | 6.5 | 23 | 49 | 103 | 172 | 478 | 2329 |
| 9/1/2018 3:00 | 0.8 | 0.00 | -0.02 | 0.05 | 1.3 | 8.1 | 21 | 44 | 93 | 154 | 445 | 2232 |
| 9/1/2018 4:00 | 0.9 | 0.00 | -0.02 | 0.09 | 1.3 | 6.3 | 15 | 27 | 68 | 114 | 371 | 1727 |
| 9/1/2018 5:00 | 0.9 | 0.00 | -0.02 | 0.04 | 1.1 | 5.5 | 11 | 22 | 60 | 105 | 353 | 1699 |
| 9/1/2018 6:00 | 0.9 | -0.01 | -0.03 | 0.04 | 0.22 | 4.2 | 7.9 | 16 | 51 | 89 | 299 | 1499 |
| 9/1/2018 7:00 | 1.0 | -0.01 | -0.03 | 0.03 | 0.35 | 1.9 | 3.4 | 11 | 38 | 66 | 220 | 1207 |
| 9/1/2018 8:00 | 0.9 | 0.00 | -0.02 | 0.04 | 0.24 | 2.5 | 4.9 | 22 | 48 | 83 | 284 | 1649 |
| 9/1/2018 9:00 | 1.1 | 0.02 | 0.05 | 0.16 | 0.54 | 3.0 | 7.3 | 18 | 40 | 67 | 229 | 1156 |
| 9/1/2018 10:00 | 0.4 | 0.62 | 1.3 | 3.7 | 13 | 28 | 57 | 142 | 310 | 517 | 1917 | 7215 |
| 9/1/2018 11:00 | 1.0 | 0.17 | 0.36 | 0.99 | 2.8 | 6.6 | 14 | 33 | 71 | 118 | 459 | 1512 |
| 9/1/2018 12:00 | 0.6 | 0.76 | 1.8 | 4.8 | 14 | 39 | 78 | 126 | 251 | 416 | 1379 | 4136 |
| 9/1/2018 13:00 | 0.2 | 6.2 | 16 | 40 | 132 | 324 | 653 | 1022 | 2018 | 3319 | 10175 | 32166 |
| 9/1/2018 14:00 | 0.2 | 8.0 | 17 | 43 | 139 | 366 | 685 | 1078 | 2091 | 3490 | 10041 | 34765 |
| 9/1/2018 15:00 | 0.4 | 5.0 | 9.8 | 24 | 71 | 164 | 301 | 476 | 916 | 1479 | 4021 | 12841 |
| 9/1/2018 16:00 | 2.1 | 0.24 | 0.47 | 1.1 | 3.2 | 7.3 | 13 | 21 | 39 | 63 | 165 | 511 |
| 9/1/2018 17:00 | 1.2 | 0.55 | 1.8 | 4.4 | 13 | 28 | 50 | 77 | 149 | 244 | 625 | 1872 |
| 9/1/2018 18:00 | 2.5 | 0.04 | 0.19 | 1.1 | 3.3 | 7.0 | 12 | 19 | 37 | 61 | 154 | 435 |
| 9/1/2018 19:00 | 1.3 | 0.25 | 0.52 | 1.6 | 5.5 | 12 | 28 | 52 | 101 | 166 | 432 | 1336 |
| 9/1/2018 20:00 | 1.3 | 0.21 | 0.42 | 1.2 | 4.1 | 9.4 | 23 | 41 | 82 | 136 | 362 | 1197 |
| 9/1/2018 21:00 | 3.9 | 0.02 | 0.03 | 0.08 | 0.32 | 0.72 | 2.3 | 3.8 | 7.7 | 13 | 35 | 126 |
| 9/1/2018 22:00 | 1.1 | 0.12 | 0.23 | 0.59 | 2.9 | 12 | 25 | 41 | 83 | 136 | 379 | 1477 |
| 9/1/2018 23:00 | 0.6 | 0.04 | 0.15 | 0.61 | 4.8 | 32 | 68 | 112 | 221 | 361 | 1108 | 4186 |

**Table A-32. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain September 1, 2018. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 9/1/2018 0:00 | 1.6 | 0.00 | 0.03 | 0.08 | 0.16 | 1.9 | 3.4 | 3.1 | 2.0 | 3.8 | 16 | 325 |
| 9/1/2018 1:00 | 1.5 | 0.00 | -0.01 | 0.13 | 0.00 | 0.67 | 5.2 | 4.4 | 2.2 | 3.0 | 15 | 359 |
| 9/1/2018 2:00 | 0.8 | 0.00 | 0.00 | 0.22 | 0.61 | 4.4 | 13 | 14 | 9.8 | 5.3 | 58 | 1179 |
| 9/1/2018 3:00 | 0.8 | 0.00 | -0.04 | 0.15 | 1.2 | 5.5 | 7.9 | 12 | 9.8 | 3.6 | 65 | 1148 |
| 9/1/2018 4:00 | 0.9 | 0.00 | -0.03 | 0.18 | 1.1 | 3.7 | 4.9 | 3.9 | 16 | 4.4 | 79 | 850 |
| 9/1/2018 5:00 | 0.9 | 0.00 | -0.03 | 0.12 | 0.95 | 3.4 | 2.2 | 5.0 | 17 | 7.3 | 81 | 854 |
| 9/1/2018 6:00 | 0.9 | -0.01 | -0.03 | 0.16 | 0.11 | 3.7 | 1.0 | 4.5 | 18 | 6.6 | 69 | 771 |
| 9/1/2018 7:00 | 1.0 | -0.01 | -0.02 | 0.13 | 0.27 | 1.2 | 0.29 | 5.5 | 16 | 4.4 | 49 | 651 |
| 9/1/2018 8:00 | 0.9 | 0.00 | -0.03 | 0.12 | 0.12 | 2.1 | 0.74 | 14 | 7.0 | 4.4 | 68 | 914 |
| 9/1/2018 9:00 | 1.1 | 0.02 | 0.02 | 0.08 | 0.08 | 1.9 | 2.4 | 7.4 | 4.9 | 3.1 | 54 | 598 |
| 9/1/2018 10:00 | 0.4 | 0.62 | 0.37 | 0.95 | 2.4 | 2.8 | 11 | 57 | 40 | 18 | 530 | 3017 |
| 9/1/2018 11:00 | 1.0 | 0.17 | 0.08 | 0.25 | 0.10 | 1.00 | 3.6 | 11 | 8.3 | 3.7 | 137 | 549 |
| 9/1/2018 12:00 | 0.6 | 0.76 | 0.78 | 0.88 | 0.77 | 12 | 13 | 9.3 | 15 | 12 | 304 | 1322 |
| 9/1/2018 13:00 | 0.2 | 6.2 | 7.1 | 6.9 | 20 | 65 | 118 | 46 | 103 | 72 | 1816 | 11079 |
| 9/1/2018 14:00 | 0.2 | 8.0 | 4.6 | 5.9 | 20 | 92 | 81 | 55 | 75 | 121 | 1419 | 13367 |
| 9/1/2018 15:00 | 0.4 | 5.0 | 1.4 | 2.2 | 5.6 | 24 | 31 | 26 | 28 | 7.6 | 428 | 4482 |
| 9/1/2018 16:00 | 2.1 | 0.24 | 0.07 | 0.06 | 0.15 | 0.97 | 1.1 | 0.80 | 0.81 | 0.54 | 13 | 171 |
| 9/1/2018 17:00 | 1.2 | 0.55 | 1.4 | 0.37 | 0.60 | 2.5 | 3.7 | 3.1 | 5.0 | 4.5 | 41 | 597 |
| 9/1/2018 18:00 | 2.5 | 0.04 | 0.17 | 0.86 | 0.39 | 0.48 | 0.34 | 1.3 | 1.6 | 0.94 | 8.9 | 127 |
| 9/1/2018 19:00 | 1.3 | 0.25 | 0.12 | 0.57 | 1.1 | 1.1 | 8.4 | 9.9 | 3.7 | 3.4 | 33 | 447 |
| 9/1/2018 20:00 | 1.3 | 0.21 | 0.06 | 0.32 | 0.88 | 1.2 | 7.2 | 7.0 | 5.3 | 3.3 | 34 | 437 |
| 9/1/2018 21:00 | 3.9 | 0.02 | 0.00 | 0.02 | 0.11 | 0.09 | 1.1 | 0.33 | 0.52 | 0.31 | 4.4 | 50 |
| 9/1/2018 22:00 | 1.1 | 0.12 | 0.02 | 0.08 | 1.2 | 6.6 | 4.9 | 3.6 | 5.8 | 1.9 | 47 | 638 |
| 9/1/2018 23:00 | 0.6 | 0.04 | 0.13 | 0.38 | 3.1 | 22 | 16 | 10 | 11 | 6.1 | 198 | 1756 |

**Table A-33. Fifteen-minute average wind speeds and *Wn* by depth in Iron Gate Reservoir upstream of the curtain October 1, 2018. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 | Avg of 0.1, 0.5 |
| 10/1/2018 0:00 | 0.5 | 0.00 | -0.04 | 0.10 | 0.00 | 0.53 | 0.00 | 1.3 | 9.6 | 83 | 331 | 856 |
| 10/1/2018 1:00 | 1.1 | 0.01 | 0.00 | 0.08 | 0.15 | 0.42 | 0.49 | 1.0 | 2.5 | 19 | 79 | 202 |
| 10/1/2018 2:00 | 0.9 | 0.00 | -0.02 | 0.02 | -0.05 | 0.09 | 0.16 | 0.23 | 1.3 | 24 | 114 | 303 |
| 10/1/2018 3:00 | 1.0 | 0.00 | -0.02 | 0.01 | -0.04 | 0.07 | -0.12 | 0.18 | 0.98 | 24 | 81 | 236 |
| 10/1/2018 4:00 | 1.3 | 0.00 | -0.01 | 0.00 | -0.04 | 0.00 | -0.14 | 0.00 | 0.00 | 12 | 44 | 133 |
| 10/1/2018 5:00 | 0.8 | 0.00 | -0.02 | 0.04 | 0.00 | 0.21 | 0.00 | 0.51 | 0.96 | 25 | 107 | 326 |
| 10/1/2018 6:00 | 1.5 | 0.00 | 0.00 | 0.02 | 0.02 | 0.10 | -0.06 | 0.09 | 0.48 | 3.2 | 37 | 111 |
| 10/1/2018 7:00 | 1.3 | 0.00 | -0.01 | 0.02 | -0.05 | 0.00 | -0.15 | 0.00 | 0.00 | 3.9 | 45 | 140 |
| 10/1/2018 8:00 | 0.6 | -0.01 | -0.05 | 0.04 | -0.11 | 0.21 | -0.35 | 0.53 | 0.98 | 21 | 218 | 691 |
| 10/1/2018 9:00 | 0.8 | -0.01 | -0.03 | 0.02 | -0.06 | 0.13 | -0.21 | 0.31 | 0.57 | 24 | 137 | 405 |
| 10/1/2018 10:00 | 0.4 | 0.00 | -0.10 | 0.42 | 0.60 | 3.5 | 3.8 | 5.7 | 16 | 136 | 629 | 1887 |
| 10/1/2018 11:00 | 0.8 | 0.00 | -0.02 | 0.05 | 0.00 | 0.25 | 0.00 | 0.62 | 2.4 | 28 | 127 | 412 |
| 10/1/2018 12:00 | 0.9 | 0.02 | 0.03 | 0.14 | 0.39 | 0.95 | 1.3 | 2.3 | 5.2 | 29 | 112 | 324 |
| 10/1/2018 13:00 | 1.0 | 0.04 | 0.10 | 0.29 | 0.89 | 1.9 | 3.1 | 5.0 | 9.3 | 32 | 100 | 287 |
| 10/1/2018 14:00 | 1.5 | 0.03 | 0.06 | 0.18 | 0.55 | 1.2 | 1.9 | 3.0 | 5.9 | 12 | 55 | 153 |
| 10/1/2018 15:00 | 1.5 | 0.01 | 0.02 | 0.11 | 0.36 | 0.86 | 1.4 | 2.3 | 4.6 | 13 | 53 | 146 |
| 10/1/2018 16:00 | 1.0 | 0.00 | -0.01 | 0.13 | 0.69 | 1.7 | 2.8 | 4.9 | 9.9 | 31 | 122 | 325 |
| 10/1/2018 17:00 | 1.1 | 0.01 | 0.03 | 0.18 | 0.69 | 1.6 | 2.5 | 4.3 | 8.5 | 24 | 97 | 268 |
| 10/1/2018 18:00 | 1.1 | 0.00 | -0.01 | 0.09 | 0.37 | 0.87 | 1.7 | 2.5 | 5.2 | 26 | 99 | 272 |
| 10/1/2018 19:00 | 1.4 | 0.00 | -0.01 | 0.01 | -0.02 | 0.19 | 0.43 | 1.0 | 1.9 | 14 | 54 | 148 |
| 10/1/2018 20:00 | 1.7 | 0.00 | -0.01 | 0.01 | 0.01 | 0.19 | 0.22 | 0.59 | 1.3 | 9.8 | 38 | 110 |
| 10/1/2018 21:00 | 1.0 | 0.00 | -0.02 | 0.04 | 0.11 | 0.65 | 1.1 | 2.3 | 4.3 | 26 | 107 | 302 |
| 10/1/2018 22:00 | 0.4 | 0.02 | -0.03 | 0.36 | 1.4 | 4.2 | 7.0 | 12 | 23 | 142 | 580 | 1595 |
| 10/1/2018 23:00 | 1.3 | 0.00 | -0.01 | 0.02 | 0.10 | 0.49 | 0.64 | 1.2 | 2.2 | 19 | 73 | 195 |

**Table A-34. Fifteen-minute average wind speeds and depth vs. depth *Wn* by depth in Iron Gate Reservoir upstream of the curtain October 1, 2018. Red highlighting indicates *Wn* < 1 (within the mixed layer), and wind speeds > 3.0 m/s.**

| Date Time, GMT-07:00 | 15-min Avg. Wind (m/s) | Depth vs. depth *Wn* at various depths (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 | 20 |
| | | vs. | | | | | | | | | | |
| | | Avg of 0.1, 0.5 | 1 | 1.5 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 15 |
| 10/1/2018 0:00 | 0.5 | 0.00 | -0.06 | 0.26 | -0.27 | 0.53 | -0.87 | 1.3 | 6.3 | 61 | 102 | 207 |
| 10/1/2018 1:00 | 1.1 | 0.01 | -0.02 | 0.09 | -0.06 | 0.12 | -0.20 | 0.30 | 0.48 | 13 | 26 | 48 |
| 10/1/2018 2:00 | 0.9 | 0.00 | -0.05 | 0.09 | -0.10 | 0.19 | 0.00 | 0.00 | 0.75 | 19 | 43 | 78 |
| 10/1/2018 3:00 | 1.0 | 0.00 | -0.02 | 0.07 | -0.07 | 0.14 | -0.23 | 0.35 | 0.57 | 20 | 19 | 72 |
| 10/1/2018 4:00 | 1.3 | 0.00 | -0.01 | 0.04 | -0.04 | 0.08 | -0.14 | 0.21 | 0.00 | 11 | 12 | 43 |
| 10/1/2018 5:00 | 0.8 | 0.00 | -0.03 | 0.10 | -0.11 | 0.21 | -0.34 | 0.51 | 0.00 | 22 | 36 | 107 |
| 10/1/2018 6:00 | 1.5 | 0.00 | -0.01 | 0.03 | -0.04 | 0.07 | -0.23 | 0.17 | 0.28 | 2.2 | 22 | 35 |
| 10/1/2018 7:00 | 1.3 | 0.00 | -0.01 | 0.04 | -0.09 | 0.09 | -0.15 | 0.22 | 0.00 | 3.5 | 26 | 48 |
| 10/1/2018 8:00 | 0.6 | -0.01 | -0.06 | 0.22 | -0.22 | 0.43 | -0.71 | 1.1 | 0.00 | 17 | 126 | 239 |
| 10/1/2018 9:00 | 0.8 | -0.01 | -0.03 | 0.13 | -0.13 | 0.25 | -0.41 | 0.62 | 0.00 | 20 | 61 | 127 |
| 10/1/2018 10:00 | 0.4 | 0.00 | -0.15 | 0.87 | -0.58 | 2.3 | -1.95 | 0.00 | 4.7 | 99 | 231 | 604 |
| 10/1/2018 11:00 | 0.8 | 0.00 | -0.03 | 0.13 | -0.13 | 0.25 | -0.42 | 0.62 | 1.0 | 22 | 45 | 147 |
| 10/1/2018 12:00 | 0.9 | 0.02 | 0.00 | 0.10 | 0.00 | 0.18 | -0.30 | 0.45 | 0.76 | 19 | 33 | 98 |
| 10/1/2018 13:00 | 1.0 | 0.04 | 0.04 | 0.11 | 0.07 | 0.15 | 0.00 | 0.34 | 0.00 | 15 | 20 | 85 |
| 10/1/2018 14:00 | 1.5 | 0.03 | 0.01 | 0.07 | 0.04 | 0.14 | -0.12 | 0.18 | 0.27 | 2.3 | 20 | 43 |
| 10/1/2018 15:00 | 1.5 | 0.01 | 0.01 | 0.07 | 0.07 | 0.14 | 0.00 | 0.18 | 0.27 | 5.1 | 17 | 41 |
| 10/1/2018 16:00 | 1.0 | 0.00 | -0.02 | 0.20 | 0.32 | 0.32 | 0.00 | 0.79 | 0.61 | 13 | 37 | 85 |
| 10/1/2018 17:00 | 1.1 | 0.01 | 0.02 | 0.15 | 0.19 | 0.25 | -0.20 | 0.61 | 0.49 | 9.6 | 30 | 74 |
| 10/1/2018 18:00 | 1.1 | 0.00 | -0.02 | 0.13 | 0.13 | 0.13 | 0.22 | 0.00 | 0.54 | 16 | 29 | 74 |
| 10/1/2018 19:00 | 1.4 | 0.00 | -0.01 | 0.04 | -0.04 | 0.22 | 0.12 | 0.37 | 0.00 | 10 | 15 | 40 |
| 10/1/2018 20:00 | 1.7 | 0.00 | -0.01 | 0.04 | -0.03 | 0.16 | -0.09 | 0.26 | 0.21 | 6.9 | 12 | 33 |
| 10/1/2018 21:00 | 1.0 | 0.00 | -0.04 | 0.11 | 0.00 | 0.43 | 0.00 | 0.72 | 0.00 | 17 | 35 | 87 |
| 10/1/2018 22:00 | 0.4 | 0.02 | -0.10 | 0.58 | 0.39 | 1.5 | 0.00 | 1.9 | 0.00 | 94 | 186 | 440 |
| 10/1/2018 23:00 | 1.3 | 0.00 | -0.01 | 0.05 | 0.05 | 0.29 | -0.16 | 0.24 | 0.00 | 14 | 21 | 51 |

## APPENDIX A – 2017 AND 2018 DATA

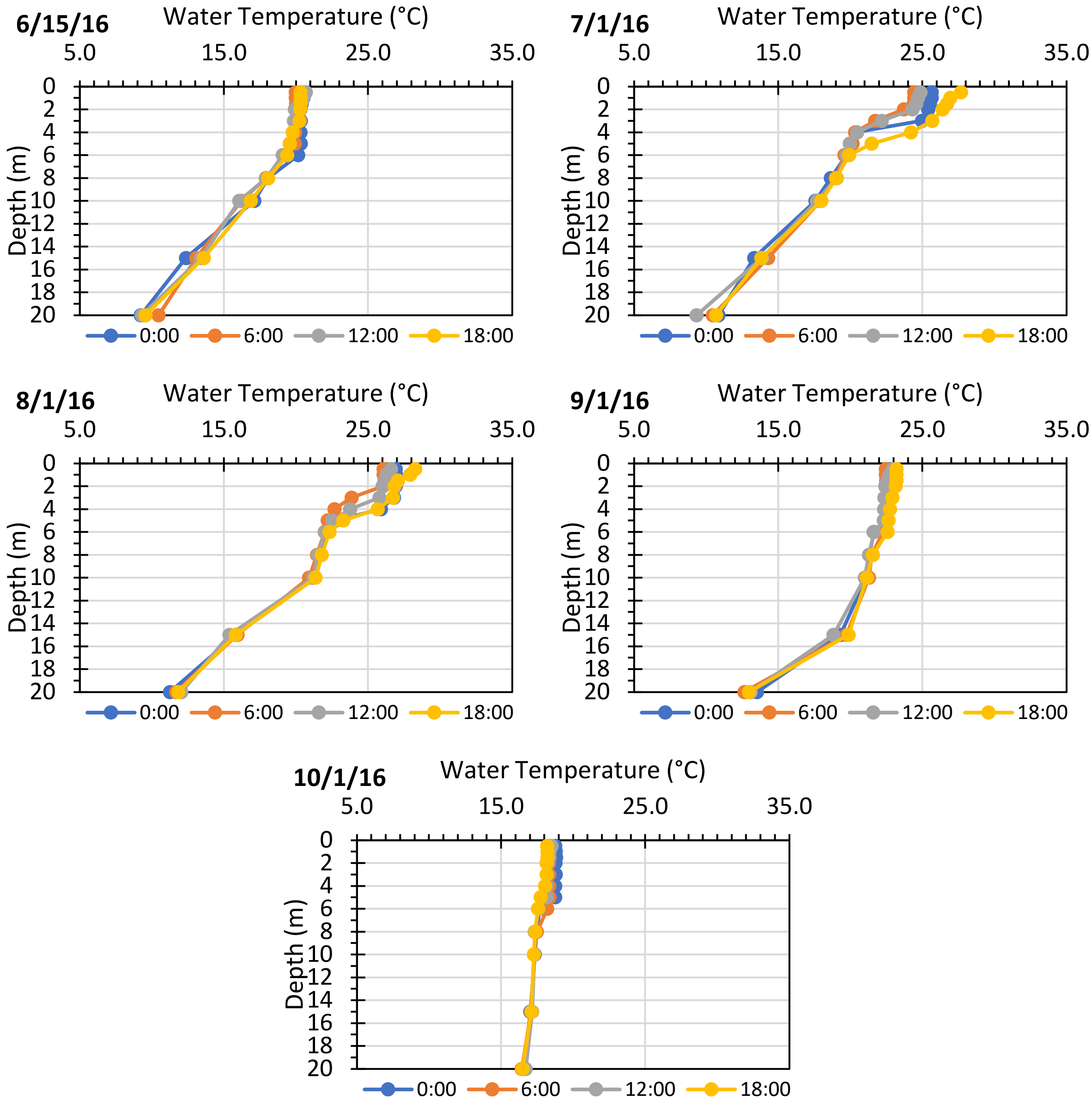



**Figure A-7. Water temperature profiles at 6 hour intervals from thermograph arrays upstream of the curtain on June 15, July 1, August 1, September 1, and October 1, 2016.**

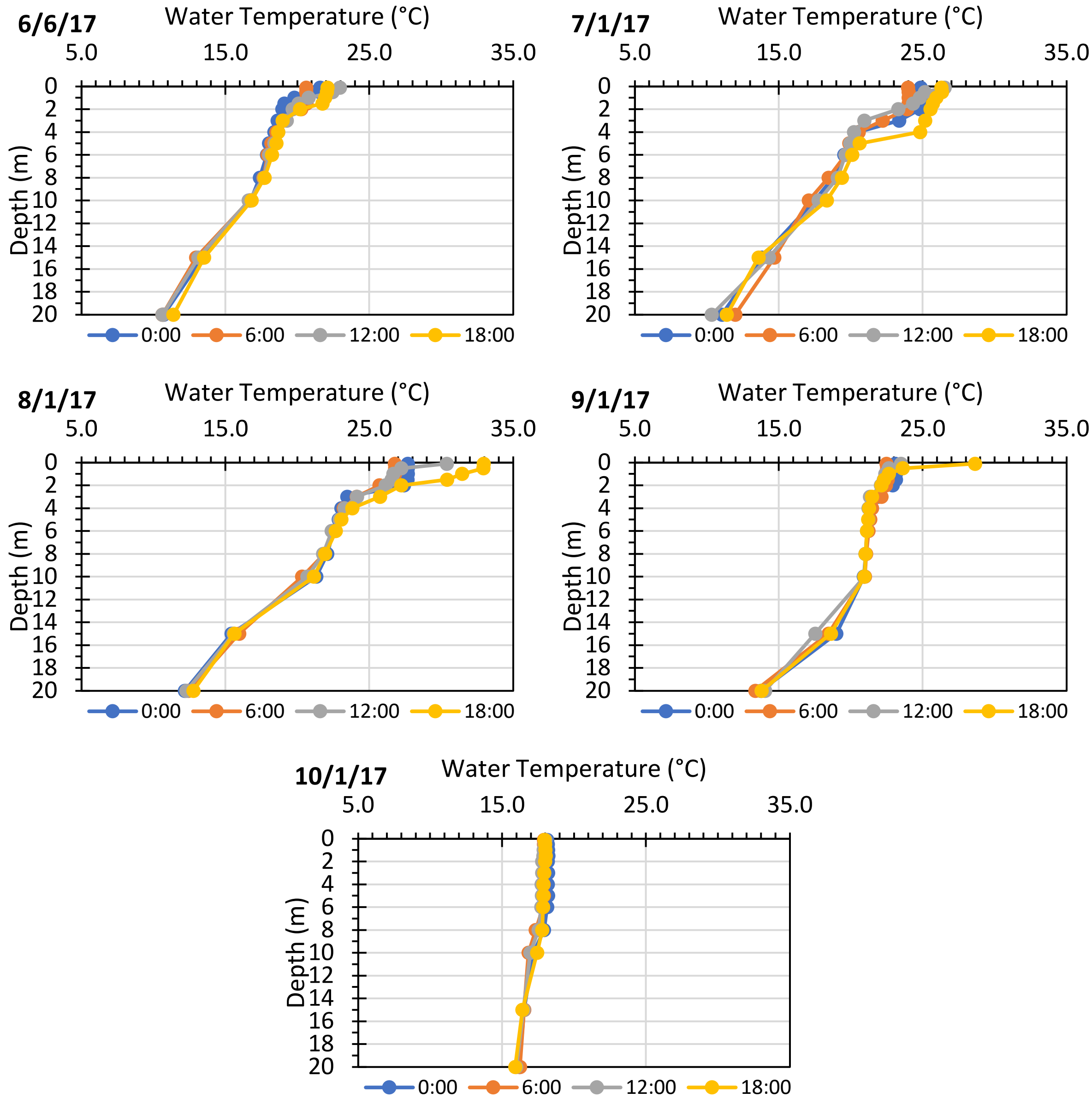



**Figure A-8. Water temperature profiles at 6 hour intervals from thermograph arrays upstream of the curtain on June 6, July 1, August 1, September 1, and October 1, 2017.**

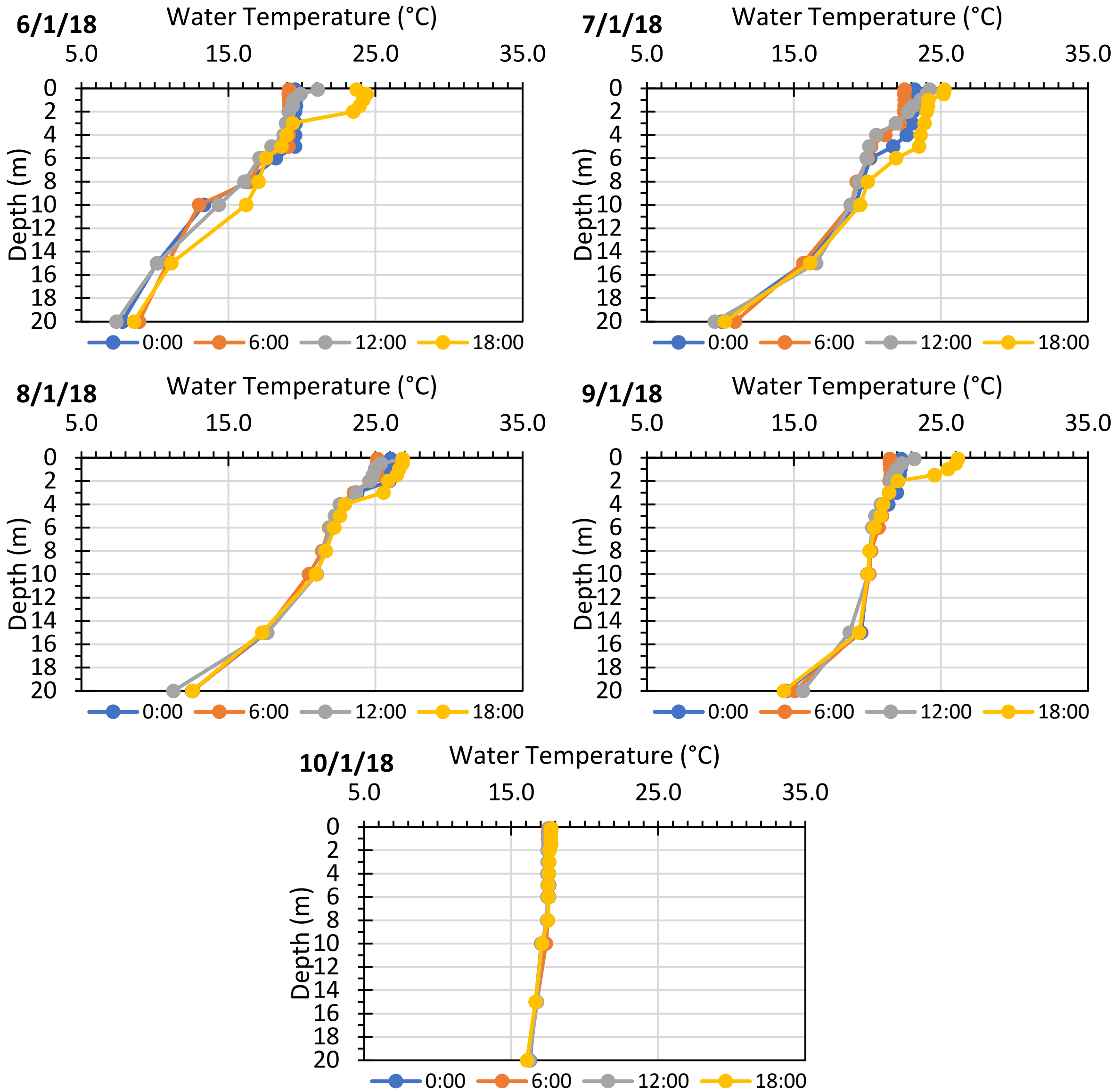



**Figure A-9. Water temperature profiles at 6 hour intervals from thermograph arrays upstream of the curtain on June 1, July 1, August 1, September 1, and October 1, 2018.**

# Appendix B
# Yurok Tribe Comments on April 2020 Interim Measures Implementation Committee Presentation

# Appendix B – Yurok Tribe Comments on April 2020 Interim Measures Implementation Committee Presentation

Yurok Tribe comments on the April 2020 Interim Measures Implementation Committee (IMIC) barrier curtain presentation, and comment resolutions, are presented below (Table B-1).

**Table B-1. Yurok Tribe comments on April 2020 IMIC barrier curtain presentation, from letter to Demian Ebert, Pacific Power, dated May 1, 2020, and comment resolutions.**

| Comment # | Location | Comment | Resolution |
|---|---|---|---|
| 1 | page 1, 1 | "We agree with the general framework of the approach but would like to see an alternate statistical method explored, and to consider re-analyzing the data with a threshold. Please consider incorporating these into the draft report." | The nonparametric Wilcoxon Signed-Rank Test was employed in addition to the non-parametric Sign Test, and results for this test has been added to the draft barrier report. Additionally, threshold values were developed and applied to data sets. Specifically:<br>1) Log boom vs. Klamath River below Iron Gate (KRBI): The log boom chlorophyll-*a* vs Klamath River below Iron Gate chlorophyll-*a* sample pairs were evaluated using the Wilcoxon Signed Rank Test in addition to the Sign Test. A threshold of 5 µg/L chlorophyll-*a* (log boom site concentration) has been applied to sample pairs, and Sign Test and Wilcoxon Signed Rank Test were applied using this threshold.<br>2) Upstream vs. Downstream curtain grab sample pairs:<br>a. A threshold of 5 µg/L (upstream of the curtain concentration) was applied to the data and Sign test and Wilcoxon Signed-Rank tests re-ran with this threshold.<br>b. A threshold of 0.8 µg/L microcystin had already been applied to upstream vs. downstream curtain grab sample data; results are reported in the draft report text but were not presented in the April 2020 IMIC presentation. Relevant tables and text presenting the results of this analysis have been added to the draft report. The Wilcoxon Signed-Rank Test has also be employed and results for this test added to the draft report. |

**Table B-1. Yurok Tribe comments on April 2020 IMIC barrier curtain presentation, from letter to Demian Ebert, Pacific Power, dated May 1, 2020, and comment resolutions.**

| Comment # | Location | Comment | Resolution |
|---|---|---|---|
| | | | c. A threshold of 20,000 total *Microcystis* gene copies/mL (corresponds to approximately 5,660 total *Microcystis* cells/mL, and 0.8 µg/L microcystin) has been applied to upstream of the curtain vs. downstream of the curtain grab sample data. This relationship was developed from the Klamath River from KHSA monitoring data (Otten et al. 2015).<br>d. Total cyanobacteria concentrations were all at least 58 times the reporting limit of 100 gene copies/mL, and most much higher than this (minimum and average of all 2015-2018 upstream curtain grab sample concentrations are 5,839 gene copies/mL total cyanobacteria and 88,543,919 gene copies/mL total cyanobacteria, respectively). There was no obvious threshold effect where the upstream of the curtain samples are consistently higher than downstream of the curtain samples over a particular concentration. Therefore, no threshold has been applied to total cyanobacteria data sets. As additional data are collected over a wide range of conditions, this may be reassessed.<br>3) Upstream vs. Downstream curtain sonde sample pairs: all paired data sets were re-analyzed using the Wilcoxon Signed Rank Test and results added to the draft report. Additionally, thresholds for the total algae as chlorophyll (0.6 RFU) and total cyanobacteria as phycocyanin (0.4 RFU) were applied to sonde data, and statistical tests (Sign Test and Wilcoxon Signed Rank Test) re-ran for pairs with the upstream curtain value at or above the threshold, and results added to the draft report. |
| 2 | page 1, ¶3 | "PacifiCorp concluded from the analyses in the April 16, 2020 presentation that when the curtain is not deployed, "Iron Gate Dam does not significantly reduce chlorophyll-*a* released into the Klamath River," or in | In the draft report, significant differences are noted as having a p-value less than or equal to 0.05 (within 95% confidence interval). For all comparisons, the actual p-value and hypothesized direction of the difference is also reported. The draft report also describes the number of sample pairs exhibiting reduction between the reservoir and the river. The draft report notes that reduction was generally observed when log boom concentrations were larger. The analysis of sample pairs when log boom concentrations were at or above a threshold value of 5 µg/L chlorophyll-*a* has been added to the draft |

**Table B-1. Yurok Tribe comments on April 2020 IMIC barrier curtain presentation, from letter to Demian Ebert, Pacific Power, dated May 1, 2020, and comment resolutions.**

| Comment # | Location | Comment | Resolution |
|---|---|---|---|
| | | other words that chlorophyll-*a* concentrations in the 0-8m depth integrated samples at the Iron Gate Reservoir log boom (KRBI). Because this result contrasts with previous analyses, we are attempting to understand why PacifiCorp's analyses have reached a different conclusion." | report. Additionally, the Wilcoxon Signed Rank Test was used to analyze the data and those results are presented. Different sets of data (i.e., all sample pairs from periods with no deployed curtain, sample pairs from the productive season with no deployed curtain, and sample pairs with a log boom value at or above the threshold value for each category) and p-values for each are presented in the draft report. Conclusions have been updated to reflect updated statistical analyses. |
| 3 | page 2, ¶1 | (comment related to comment #2, above) "For example, Genzoli and Kann (2017) found for paired samples collected on the same day at the log boom in Irongate [sic] Reservoir and in the Klamath River below Irongate [sic], that the below Irongate [sic] samples averaged 37% lower for microcystin toxin and 23% lower for *Microcystis* cell density when compared to the integrated 0-8 m samples from the log boom." | It is unclear if similar results should be expected from the different data set and analysis in Genzoli and Kann (2017) [*Microcystis* and microcystin used in Genzoli and Kann (2017) versus chlorophyll-*a* used in the barrier report]. The barrier report does not present an analysis of log boom vs KRBI microcystin toxin or *Microcystis* cell density but rather compares chlorophyll-*a* data between these two sites. Chlorophyll-*a* is often a good indicator of algae biomass concentrations. Changes related to the updated threshold and Wilcoxon Signed Rank test analyses have been added to the draft report. |
| | Page 3, ¶2 | "However, above ~5 µg/L, the log boom chlorophyll-*a* concentrations were generally higher than the river concentrations (16 of 22 paired samples were higher at the log boom). This suggests an algal | A 5 µg/L threshold for chlorophyll-*a* has been applied to the data and the remaining sample pairs evaluated. |

**Table B-1. Yurok Tribe comments on April 2020 IMIC barrier curtain presentation, from letter to Demian Ebert, Pacific Power, dated May 1, 2020, and comment resolutions.**

| Comment # | Location | Comment | Resolution |
|---|---|---|---|
| | | biomass threshold whereby the effect of the dam is more pronounced at higher levels, and that parsing the statistical tests to include values greater than varying thresholds is appropriate. PacifiCorp noted a similar effect for the upstream and downstream curtain analysis, noting that "the concentration reductions from UC to DC are greatest when UC concentrations are greatest" (IMIC slide 56)." | |
| | Page 3, ¶4 | Recreation of Table 1 | We checked that the values listed in Table 1 of the comment letter approximated the actual values. The largest difference between estimated values and actual values was 1.1 µg/L, while the average difference was -0.2 µg/L. We ran the nonparametric Sign test and nonparametric Wilcoxon Signed Rank Test on both sets (estimated and actual data sets) of "curtain not deployed, July-October" data, as well as the parametric paired t-test on the differences between paired KRBI and log boom values. We noted an error; three of the sample pairs were outside of the July-October window. This will be fixed and the one-tailed p-values provided in the report.<br><br>Results of statistical testing on estimated values and actual values demonstrate that the two-tailed p-value is reported in Table 2 of the May 1, 2020 letter, except for the paired t-test, where it appears the one-tailed p-value was reported. The draft barrier report includes one-tailed p-values, as the direction of the difference was hypothesized. Results of testing with estimated data and actual data are provided for comparison. The applicable one-tailed p-values are bold. |

**Table B-1. Yurok Tribe comments on April 2020 IMIC barrier curtain presentation, from letter to Demian Ebert, Pacific Power, dated May 1, 2020, and comment resolutions.**

<table>
<tr><th>Comment #</th><th>Location</th><th>Comment</th><th>Resolution</th></tr>
<tr><td></td><td></td><td></td><td>
<table>
<tr><td colspan="10">Statistical Tests with full data sets (approximated in 5-1-2020 letter and actual data):</td></tr>
<tr><td colspan="2">sign test result with approximated values</td><td colspan="2">sign test result with actual values</td><td colspan="2">Wilcoxon test result with approximated values</td><td colspan="2">Wilcoxon test result with actual values</td><td colspan="2">t-test with ap valu</td></tr>
<tr><td>two-tailed p</td><td>one-tailed p</td><td>two-tailed p</td><td>one-tailed p</td><td>two-tailed p</td><td>one-tailed p</td><td>two-tailed p</td><td>one-tailed p</td><td>two-tailed p</td><td>c</td></tr>
<tr><td>0.377</td><td>0.189</td><td>0.417</td><td>0.209</td><td>0.193</td><td>0.097</td><td>0.210</td><td>0.105</td><td>0.135</td><td></td></tr>
</table>
<table>
<tr><td colspan="10">Statistical Tests with data sets with 5 ug/L threshold applied (approximated in 5-1-2020 letter and actual data):</td></tr>
<tr><td colspan="2">sign test result with approximated values excluding < 5 ug/L</td><td colspan="2">sign test result with actual values excluding < 5 ug/L</td><td colspan="2">Wilcoxon test result with approximated values excluding < 5 ug/L</td><td colspan="2">Wilcoxon test result with actual values excluding < 5 ug/L</td><td colspan="2">t-test with ap values exclud</td></tr>
<tr><td>two-tailed p</td><td>one-tailed p</td><td>two-tailed p</td><td>one-tailed p</td><td>two-tailed p</td><td>one-tailed p</td><td>two-tailed p</td><td>one-tailed p</td><td>two-tailed p</td><td>c</td></tr>
<tr><td>0.052</td><td>0.026</td><td>0.078</td><td>0.039</td><td>0.013</td><td>0.007</td><td>0.016</td><td>0.008</td><td>0.019</td><td></td></tr>
</table>
With these preliminary data (error described above included), all of the tests indicate that prior to applying a threshold, the p-values do not demonstrate a significant difference in chlorophyll-a between pre-curtain July-October log boom and KRBI samples at the 95% confidence interval. After applying the threshold of 5 µg/L, all of the tests demonstrate that there is a significant difference in chlorophyll-a between pre-curtain July-October log boom and KRBI samples at the 95% confidence interval. This holds for the corrected data sets; however, after applying the uncertainty factor (25% of the result or the RL, whichever is greater), there is no longer a significant reduction, and in some cases, the relationship reverses (river concentrations greater than log boom).
Data sets were found to not be normally distributed and thus, the t-test result is not included in the report (see response to comment 4).
</td></tr>
<tr><td>4</td><td>page 5, ¶1</td><td>"Although PacifiCorp's draft analyses used the non-parametric Sign Test to compare chlorophyll-a in paired samples from Iron Gate Reservoir log boom and Klamath River Below</td><td>The analyses has been updated using the non-parametric Wilcoxon Signed-Rank Test and the results added to the draft report. Data values are skewed left (not normally distributed), even for data sets that only include the productive season (i.e., July through October) or data sets that only include pairs with concentrations over a specific threshold (e.g., 5 µg/L chlorophyll-a). Therefore, a nonparametric rather than parametric test is appropriate. Still, as noted in comment, the parametric paired t-test may be used</td></tr>
</table>

**Table B-1. Yurok Tribe comments on April 2020 IMIC barrier curtain presentation, from letter to Demian Ebert, Pacific Power, dated May 1, 2020, and comment resolutions.**

| Comment # | Location | Comment | Resolution |
|---|---|---|---|
| | | Iron Gate (KRBI), tests that consider the magnitude of the differences between paired samples, as well as that take into account the hypothesized direction of the difference provide greater power to detect significant differences. For example, other tests that could be applied include the non-parametric Wilcoxon Signed Rank Test or the parametric Paired T-Test. | when the differences between pairs are known to be normally distributed (Hesel and Hirch 2002, pp. 137). The distribution of differences between pairs was evaluated to determine if a parametric paired t-test is appropriate. The difference between pre-curtain July-October log boom and KRBI samples (n=37) was not normally distributed [skewness of -1.59 (indicating data are skewed left) and kurtosis of 4.68 (indicating a heavy tail)]. We tested a total of 22 data sets examining the difference between log boom versus KRBI chlorophyll-*a* (variations of no curtain deployed, curtain deployed, all months, July-October months, curtain effectiveness categories, threshold of 5 µg/L applied, and uncertainty values applied). The only data set that appeared normally distributed was the difference between pre-curtain July-October log boom and KRBI samples with uncertainty factors applied [n=37, skewness of 0.13 (close to zero) and kurtosis of 2.85 (close to three standard deviations from the mean)]. The same data set without uncertainty applied was skewed left (skewness of -1.59) with a heavy tail (kurtosis of 4.68). We have also tested the differences between the upstream of the curtain vs. downstream of the curtain data sets for normality. These are similar (skewed left and/or high or low kurtosis values).<br><br>The p-values reported for the sign and Wilcoxon signed-rank tests are the one-tailed p-values, which take into account the direction of the difference and are therefore, smaller (and more likely to be "significant") than the two-tailed p-values. The draft report has been edited to clarify that the reported p-value is the one-tailed p-value. |
| 5 | page 5, ¶2 | "The Sign Test only takes into account whether the differences between the pairs are positive or negative, but not the magnitude of the differences, whereas the Wilcoxon Signed Rank Test takes into account the magnitude of the differences." | The data have been re-analyzed using the Wilcoxon Signed-Rank Test in addition to the Sign Test and the results are presented in the report. |

**Table B-1. Yurok Tribe comments on April 2020 IMIC barrier curtain presentation, from letter to Demian Ebert, Pacific Power, dated May 1, 2020, and comment resolutions.**

| Comment # | Location | Comment | Resolution |
|---|---|---|---|
| | page 5, ¶2 | "If the paired observations are numeric quantities and the differences between paired observations are random samples from a single normal distribution, then a Paired T-Test would be appropriate" | As described in response to comment 4, normality of data was examined for the differences between log boom and KRBI pairs and found to not be normally distributed for almost all data sets tested. The difference between upstream of the curtain and downstream of the curtain data sets has been evaluated and was found to not be normally distributed (skewed left and/or high or low kurtosis values). |
| 6 | Page 5, ¶1 and page 6, ¶1 | Values were estimated from the April 16, 2020 presentation figure (log boom integrated 0-8 m sample vs KRBI sample, when the curtain was not deployed, and from the productive season of July through October), and pairs analyzed with the Sign Test, non-parametric Wilcoxon test, and parametric paired t-test. The letter notes: "For the whole data set (n=40 pairs) we came up with a similar non-significant result to PacifiCorp for both the Sign Test and the Wilcoxon Signed Rank Test. However, the paired T-Test showed a p value of 0.068, not significant at $p<0.05$, but marginally significant at $0.05 \leq p<0.10$. Using a threshold chlorophyll-*a* value of 5 µg/L at the log boom station, the Sign | This data set only included data pairs from periods in which the curtain was not deployed (pre-curtain installation or curtain at its minimum deployed depth of 1.5 m). Therefore, any observed differences between this set of sample pairs would not be interpreted to be caused by the curtain, but rather would be a function of the dam. Additional statistical analyses (Wilcoxon Signed Rank test) have been applied to the full data set as well as the data set with threshold applied and the results are included in the draft report. |

**Table B-1. Yurok Tribe comments on April 2020 IMIC barrier curtain presentation, from letter to Demian Ebert, Pacific Power, dated May 1, 2020, and comment resolutions.**

| Comment # | Location | Comment | Resolution |
|---|---|---|---|
| | | test showed improved significance (p=0.052), and both the Wilcoxon and Paired T-Tests were significant at p≈0.01 (i.e., greatest indication that there are differences between the pairs). The issue of normality notwithstanding, that the non-parametric Wilcoxon test was significant at p≈0.01, and the Sign Test at p≈0.05 provides strong evidence that chlorophyll-*a* is generally higher at the log boom then it is at KRBI when the curtain is not in place, especially when algal biomass levels increase in the reservoir (i.e., > 5 µg/L). This suggests that a not all of the observed decrease in chlorophyll-*a* when the curtain is in place is necessarily due to the curtain." | |
| 7 | page 6, ¶2 | "Our comments above regarding the use of the Sign Test also apply to the comparisons of upstream/downstream of the curtain." | The threshold analyses and Wilcoxon Signed-Rank test have been added to both the upstream of the curtain vs. downstream of the curtain analyses, and the log boom vs. KRBI analyses, in the draft report (see response to item 1). |
| 8 | Page 6, ¶3 | "…it seems like it might be useful to run a test that combines the | It is important to remember that the curtain is a management tool intended to improve water quality in the Klamath River downstream of Iron Gate Dam. The point of this work |

**Table B-1. Yurok Tribe comments on April 2020 IMIC barrier curtain presentation, from letter to Demian Ebert, Pacific Power, dated May 1, 2020, and comment resolutions.**

| Comment # | Location | Comment | Resolution |
|---|---|---|---|
| | | 'high effectiveness' and 'medium/low effectiveness' periods as an overall test of curtain effectiveness that does not pre-select the data points. | is twofold: 1) To demonstrate that this tool works, and 2) to establish the conditions and/or deployment patterns that make the curtain more effective. Stable stratification is important to overall curtain effectiveness and that stratification and effectiveness rating can be clearly determined, which means that the analysis can be logically separated into periods defined by this effectiveness rating. There are very different conditions present during periods of high curtain effectiveness (e.g., stratification depth and depth of the curtain at or deeper than stratification) as compared to periods of low curtain effectiveness (e.g., no stratification or depth of the curtain shallower than stratification). These conditions in turn produce different results in the analysis as discussed in the draft report. The only data set that was combined is the curtain deployed pairs for different effectiveness ratings to support statistical analysis of the log boom vs. KRBI data set because there simply are not that many data pairs. |
| 9 | Page 6, ¶3 | "And/or perhaps there is some way to use other data sets (wind and/or continuous water temperature probes) to estimate the percent of the algal growth season when it is expected that the curtain would be 'highly effective'." | Calculation of the Wedderburn number in the report uses wind and water temperature data to understand stratification conditions, and defines when the curtain would be expected to be highly effective. The curtain is only deployed during the algal growth season, so any time a highly effective period is indicated in the report this means that: stratification exists (based on Wedderburn number) and the curtain is deployed to a depth at or below existing stratification. |
| 10 | Page 6, ¶4 | "Interestingly, the chlorophyll values upstream of the curtain tend to be much higher during periods of 'high effectiveness' and 'curtain not deployed' than periods of 'medium/low effectiveness' (Figure 3). Is that a coincidence, or is there some systematic reason for that? It | The point of the curtain is to retain cyanobacteria-laden surface waters in Iron Gate Reservoir. Normal deployment pattern waits for the bloom to develop before the curtain is lowered. In other words, the higher concentrations of chlorophyll-*a* collected during periods when the curtain was not deployed is simply evidence of this management strategy. For example, all sample pairs when the curtain was not deployed came from only 4 dates in July 2017 and July 2018. The higher concentrations (108 µg/L to 290 µg/L) within this set of samples occurred in late July (7-24-17, 7-25-17, 7-23-18), and at a samples depth of 0.5 m. Because of changing bloom conditions including higher |

**Table B-1. Yurok Tribe comments on April 2020 IMIC barrier curtain presentation, from letter to Demian Ebert, Pacific Power, dated May 1, 2020, and comment resolutions.**

| Comment # | Location | Comment | Resolution |
|---|---|---|---|
| | | would be good if the report included some speculation as to what factors might explain that phenomenon, and how it might affect results or affect how the results should be interpreted." | concentrations of cyanobacteria, the curtain was deployed to 7.6 m on 7-25-17 and to 4.6 m on 7-24-18 after the curtain not deployed samples were collected on each date. As is explained and analyzed in the report, chlorophyll-*a* concentrations upstream of the curtain tend to be much higher during periods of high curtain effectiveness because conditions exist that merit curtain use. Specifically, cyanobacterial growth season, stratification, an effective curtain depth (meaning the curtain is deployed to or deeper than stratification (i.e., depths where Wedderburn numbers greater than one, which suggests surface waters are not mixing to that depth), and a sample from a depth that is shallower than both the curtain depth and the depth of stratification.<br><br>Samples collected during periods of medium and low curtain effectiveness were: 1) collected at a depth shallower than the curtain depth, but no stratification existed (e.g., isothermal conditions, or wind broke up previously existing stratification); or 2) collected at a depth shallower than the curtain depth, but the curtain depth did not extend past the stratification depth (mixed layer depth). These conditions tend to occur earlier or later in the season (hence the June and late August and September dates), during periods of relatively higher winds, and when isothermal conditions existed which often do not coincide with large blooms. |
| 8 | page 7, ¶1 | "Some slides show a binary "Y (p<0.05" or "N (p>0.05)". In the report, please show the actual p-values rather than a binary yes/no since p-values are a measure of strength of evidence, and do not necessarily indicate a binary line of "significant" or "not significant". For example, according to the American Statistical Association 2016 | The report has been edited to include the actual p-values from all statistical tests. The text includes determinations of significance based on a threshold p-value of 0.05. |

**Table B-1. Yurok Tribe comments on April 2020 IMIC barrier curtain presentation, from letter to Demian Ebert, Pacific Power, dated May 1, 2020, and comment resolutions.**

| Comment # | Location | Comment | Resolution |
|---|---|---|---|
| | | statement on p-values, "Scientific conclusions and business or policy decisions should not be based only on whether a p-value passes a specific threshold" such as 0.05 (Wasserstein and Lazar 2016)." | |

# Appendix C
# Yurok Tribe Comments on Draft Iron Gate Curtain Intake Barrier Curtain Summary Report (Oct 2020) and PacifiCorp Responses

Comments submitted by the Yurok Tribe on November 21, 2020, to PacifiCorp regarding the Iron Gate Curtain Intake Barrier Curtain Summary Report (IMIC Draft October 2020) and PacifiCorp responses to those comments. Comments are direct quotes from the Yurok letter.

| # | Comment | Response |
|---|---|---|
| 1 | One of the draft report's most important findings is the three-year analysis of water column stability, which indicates that the curtain is likely to be more effective in July and August than September and October. The draft report's summary and conclusions do not currently summarize the key findings of the water column stability analysis, so we request that such discussion be added. | The report has been edited to reflect this observation. However, the focus of the report remains the evaluation of the effectiveness of the intake barrier curtain. |
| 2 | **Executive Summary**<br>The executive summary should mention one of the key findings of the report (Table 6-1), which is that water column stability analysis based on water temperatures indicates the curtain is likely to be more effective in July and August than September and October. | Edited the executive summary. |
| 3 | The following hypotheses are stated at several places in the document, including on page 3-1 and 3-2:<br>- "H2: Iron Gate Dam, without a curtain present, provides some downstream reduction in cyanobacteria loads by reducing the downstream movement of surface waters, which often contain high concentrations of cyanobacteria, from Iron Gate Reservoir into the Klamath River."<br>- "H3: The curtain in combination with Iron Gate Dam is effective at reducing cyanobacteria loads in downstream waters by reducing the downstream movement of surface waters, which often contain high concentrations of cyanobacteria, from Iron Gate Reservoir into the Klamath River."<br>The wording of these hypotheses should be revised to make them more clear and less prone to potential mis-interpretation. The dam does not reduce downstream movement of cyanobacteria. | PacifiCorp does not dispute the observation that Iron Gate Reservoir provides ideal habitat for the growth of algae and cyanobacteria. PacifiCorp considers the intake structure to be part of the dam and for ease of discussion in the report simply refers to Iron Gate Dam. The layout and design of the intake tower are described in detail in Section 2.1. The text in Section 3.2 was edited to clarify this. |

| # | Comment | Response |
|---|---|---|
| | The dam creates a reservoir that provides ideal habitat for cyanobacteria, but the well-designed intake tower pulls water from a range of depths, so the surface accumulations of cyanobacteria are mixed with deeper water that have lower concentrations of cyanobacteria. Suggested potential revised wording:<br>- "H2: Without a curtain present, cyanobacteria concentrations are lower in the Klamath River below Iron Gate Dam than in the top 8 meters of Iron Gate Reservoir." or "H2: Without a curtain present, the intake structure draws water from a range of depths, resulting in cyanobacteria concentrations being lower in the Klamath River below Iron Gate Dam than in the top 8 meters of Iron Gate Reservoir."<br>- "H3: With the curtain present, cyanobacteria concentrations are lower in the Klamath River below Iron Gate Dam than in the top 8 meters of Iron Gate Reservoir." or "H3: The curtain in combination with the intake results in cyanobacteria concentrations being lower in the Klamath River below Iron Gate Dam than in the top 8 meters of Iron Gate Reservoir."<br><br>The section headings "Hypothesis 2: Reductions in Downstream Loading Attributable to Iron Gate Dam Only" and "Hypothesis 3: Reductions in Downstream Loading Attributable to Iron Gate Dam plus Curtain", which appear in several places in the document, should also be re-worded. For example, maybe: "Hypothesis 2: Reductions in Downstream Loading Attributable to Iron Gate Dam Intake Tower" and "Hypothesis 3: Reductions in Downstream Loading Attributable to Iron Gate Dam Intake Tower Plus Curtain" | |
| 4 | 4.1.1 Continuous Sampling with Data Sondes<br>p. 4-2: "Sondes were cleaned, calibrated, and accumulated data downloaded at regular intervals of every 3 to 6 weeks." That | Biofouling and drift are potential issues, particularly in productive waters. In the early 2000s, probe technology was such that drift was a common issue, sometimes occurring after only a few days of |

| # | Comment | Response |
|---|---|---|
| | seems like a very long interval between cleanings in an environment as productive as the Klamath River and reservoirs, so it would be good to add sentence or two here with additional details and/or citations on the sonde methods. Were biofouling and drift assessed using a particular protocol (e.g., Wagner et al. 2006) and if so, what were the results of those assessments? | deployment. However, in more recent years (and including the 2015 onward sampling), probe technology has improved. Specifically, the YSI EXO platform that was introduced in 2012 includes wipers to remove biofouling from the sensor tips. Servicing was approximately monthly in 2015 and 2016, ranging from 3 to 6 weeks. The service interval was reduced in 2017 to present for several reasons including: reduce potential for lost data due to probe malfunction, to service the profiling sondes on the platforms upstream and downstream of the curtains (this was also to assess and maintain the profiler platforms and mechanisms as well as the sondes), and to reduce potential for biofouling. Biofouling conditions were dominated by the accumulation of filamentous algae on the profiler platform mechanisms, which interrupted the automated profiling from the platforms. Probe fouling was not a major issue in most cases (one occurrence is noted in Watercourse 2018). As such, data were reviewed for potential drift (associated with biofouling or other issues) and addressed as necessary.<br><br>The report has been edited to clarify the service interval and data review process. |
| 5 | p. 4-12 "For both tests, the one-tailed p-value was used because the direction of the difference was hypothesized for each trial." We agree with the use of the one-tailed test, however, we are confused why the hypothesized direction of the difference is not consistent among test runs. For example, in the results Table 6-8 (that is just one example, there are many others), some tests are run with the hypothesized direction being UC>DC (i.e., upstream of curtain greater than downstream of curtain) whereas some are run as DC>UC (i.e., downstream of curtain greater than upstream of curtain). Since the report's hypotheses H1, H2, and H3 are all that upstream concentrations are greater than the downstream concentrations, shouldn't all one-tailed tests be run in the same | The report has been edited to clarify that the direction of the difference was hypothesized based on the proportion of negative versus positive differences (sign test) or the magnitude of the sum of negative ranks versus the sum of positive ranks (Wilcoxon signed-rank test). Most cases were consistent with the overarching hypotheses: the data indicated that more pairs had upstream concentrations greater than downstream concentrations, or the magnitude of the sum of negative ranks was greater than the magnitude of the sum of positive ranks indicating generally greater concentrations upstream than downstream. However, as noted in the comment, there were other cases, such as after application of the uncertainty factor or for the sonde total algae as chlorophyll data, where there were actually more sample pairs with greater concentrations downstream than upstream of the curtain (Table 6-13). In these few cases, the test was run for the hypothesized direction being DC > UC to determine |

| # | Comment | Response |
|---|---|---|
| | direction (i.e., UC>DC and LB>KR, where LB is Log Boom and KR is Klamath River below Iron Gate Dam)? | if those increases in the downstream direction were significant; a one-tailed test testing if UC > DC would have resulted in p-values greater than 0.05. |
| 6 | p. 4-12: “Bias and average bias were calculated when a significant difference was identified.” This statement appears to be incorrect because the tables in the report’s results section show that bias and average bias were calculated (appropriately) for every test, not just those tests where p-values were less than 0.05 (i.e., the threshold of statistical significance). This sentence could probably just be deleted because the next sentence in the report explains what was actually done? | Deleted the sentence as suggested. |
| 7 | P 4-12: “Uncertainty factors were incorporated into the analysis to address system heterogeneity (cyanobacteria distributions are naturally patchy), sonde accuracy, and laboratory analysis uncertainty. Uncertainty factors for sonde data (Table 4-5) were determined based on the largest difference encountered between heterogeneity sites during the 2016 heterogeneity study (PacifiCorp 2017) and sonde probe accuracy. For paired sonde data where a significant difference was identified, the uncertainty factor was subtracted from the data set with larger data values and added to the data set with smaller data values, and the sign and Wilcoxon signed-rank tests were performed a second time. For paired sonde data where a significant difference was identified, the uncertainty factor was subtracted from the data set with larger data values and added to the data set with smaller data values, and the sign and Wilcoxon signed-rank tests were performed a second time. If the second test indicated no significant difference, or if the result opposed the original result (e.g., downstream of the curtain was greater than upstream of the curtain whereas the original result indicated that upstream of the curtain was greater than downstream of the curtain), then the two sets of sample pairs were assumed to be no different from each other.” | This comment raises a few points that will be addressed separately.<br><br>**Uncertainty Analysis.** The uncertainty analysis in the report is necessary to account for the heterogenous nature of the Iron Gate Reservoir and the constituents being evaluated. Without this analysis, the statistics would indicate that the curtain reduces loading downstream of Iron Gate Dam in a statistically significant fashion during periods of what are defined as low and medium effectiveness periods. While the statistical analysis may indicate this, PacifiCorp’s goal with curtain operations is to not have to post public health warnings on the Klamath River for areas downstream of Iron Gate Dam. With that as a goal, a reduction in cyanobacterial loading of some percentage, while statistically significant, was not what the objective was. Overall, PacifiCorp wanted to achieve two objectives with this study and the related analysis:<br>1. Make the most definitive statement possible about when the curtain functions.<br>2. Understand the operational and environmental requirements to achieve the highest level of function possible.<br><br>The use of the results of the heterogeneity study as an error adjustment for data collected at the observation buoy locations is an appropriate application of known system variability to data to |

| # | Comment | Response |
|---|---|---|
| | We understand that the point of the uncertainty analysis is to emphasize that all measurements have uncertainty, and that apparent differences between populations of measurements could potentially be explained by measurement errors rather than real differences. An uncertainty analysis is an interesting concept to consider, but in our opinion it receives far too much weight in the report. There is likely a more appropriate means of incorporating measurement error into these statistical tests (perhaps a Bayesian method?). However, we view the current method as inappropriate given that the current method combines probabilistic statistical tests with a non-probabilistic adjustment of data (i.e., assuming there's a 100% change that the worst-case scenario occurred). It seems odd to derive a constant adjustment *based on the uncertainty associated with individual measurements*, and then add that as a constant adjustment *to every measurement within a set (i.e., population)*, and then also subtract that from *every measurement within the other set*. What are the odds that the maximum possible difference would occur for every sample pair? A true uncertainty analysis would explicitly incorporate that probability rather than assuming it is 100%. The maximum possible difference might conceivably occur with sonde sensors where the paired measurements are actually being collected by different instruments; however, for lab samples this is not a realistic assumption because all samples are being processed on the same equipment, so *errors should be randomly distributed* among the sets being compared, *not systemic error affecting one set or other*. [emphasis in original]<br><br>If the results and interpretation of the uncertainty analysis are to remain in the report as-is, additional justification is required. This could include citations along with further analysis showing that errors are not randomly distributed among the sets being compared, but rather are systemic errors affecting one set or | capture the uncertainty in the data. It is important to consider the overall sample size when addressing uncertainty. While the heterogeneity sample size is small, the buoy data are within the range of the heterogeneity sample data. Increasing the sample size of the heterogeneity data would likely refine the distribution of that data and not result in much change in the overall differences.<br><br>**Specific Methods.** PacifiCorp agrees that uncertainty in lab-processed samples should be small; however, the uncertainty associated with the collection of that sample itself could be very large given the nature of the conditions in the reservoir. In some cases (i.e., 2016-2018 *Microcystis*, microcystin, and cyanobacteria data), 95 percent confidence intervals were provided by Bend Genetics based on laboratory replicates. Field duplicates were not generally collected, although heterogeneity study data (which collected samples from four sites at two depths upstream of the curtain over a 2-hour midday period in 2016) were available. The largest difference between heterogeneity sites was found to be similar to doubling the laboratory 95 percent confidence interval. Also, 95 percent confidence intervals were not available for all data (e.g., all chlorophyll-*a* data and 2015 genetics data), but the available doubled 95 percent confidence intervals were similar to 25 percent of the result. Therefore, 25 percent of the result or the reporting limit, whichever was greater, was used as a conservative factor to adjust for the system heterogeneity that is not captured when collecting only one sample on each side of the curtain.<br><br>**Justification.** The comment correctly notes that there was limited supporting discussion for the uncertainty analysis. PacifiCorp has expanded this section to include discussions that illustrate the sources of uncertainty, provide definitions, present standard methods for assessing uncertainty, and provide other materials to support the |

| # | Comment | Response |
|---|---|---|
| | other. Absent such an analysis the uncertainty tests should be omitted from the report.<br><br>If you insist on keeping the uncertainty tests in the report, the results of the tests would need to be interpretated [*sic*] differently. Instead of interpreting the uncertainty test as over-riding the results of the initial test, interpret it as an indicator of secondary (or even tertiary) importance. Rather than the last sentence in the excerpt above (i.e., "If the second test indicated no significant difference … then the two sets of sample pairs were assumed to be no different from each other"), a more accurate way to interpretate [*sic*] the uncertainty tests would be something like the following: "If the second test indicated no significant difference … then the two sets of sample pairs do not differ if there was a consistent worst-case scenario systematic measurement error in one set versus the other, which in reality is extremely unlikely." | inclusion of the uncertainty analysis in general and the selected method specifically.<br><br>**Interpretation.** PacifiCorp respectfully disagrees with the comment that the uncertainty analysis should receive less weight in the analysis. The focus of this entire project has been a question of how to manage the curtain to minimize public health risk downstream of Iron Gate Dam. With that goal in mind, the most conservative application of uncertainty allows more definitive statements about the function of the curtain and the conditions under which that function is achieved. |
| 8 | p. 4-13 "Total chlorophyll-*a* concentrations were used to assess the reduction associated with Iron Gate Dam on its own (i.e., without a curtain)." and p. 4-14 "To assess reduction associated with the curtain in combination with Iron Gate Dam, total chlorophyll-*a* concentrations were the primary data employed." Is there a reason why the draft barrier report evaluates Hypothesis 2 and 3 using chlorophyll-*a* rather than microcystin toxin or *Microcystis* cell density? We recognize that a lot of effort has already been put into the report, so we are not asking that additional analyses be added, just that the choices be explained. | Hypothesis 2 evaluates the function of Iron Gate Dam in reducing loading of cyanobacteria into the Klamath River downstream of the dam. To do this, it was necessary to use data in the analysis from before the curtain was installed as well as when the curtain was installed but not deployed. Hypothesis 3 essentially adds the intake barrier curtain to the analysis conducted in Hypothesis 2. Because an abundance of chlorophyll-*a* data were available for when the curtain was not installed or deployed (90 sample pairs), it was used as a surrogate for cyanobacteria (3 sample pairs) and microcystin (3 sample pairs). To be consistent, this approach was used in the analysis of Hypothesis 3.<br><br>Edited the report text for clarity. |
| 9 | p. 5-6: "At the 5-m depth, average dissolved oxygen upstream and downstream of the curtain ranged from approximately 1 mg/L to 6.5 mg/L (less than 20 to 75 percent saturation) during | Relatively low dissolved oxygen at depth is not that unusual of a condition for Iron Gate Reservoir. PacifiCorp has collected an abundance of vertical profile data (unpublished) from the data |

| # | Comment | Response |
|---|---|---|
| | the curtain deployment period (Figure 5-4, Figure 5-5).” This seems like a remarkably low *daily average* DO for a relatively shallow (5m) depth in 2017, never exceeding 4gm/L in August through September. Might be good to speculate why? Were all the algae concentrated at the surface (low wind?) and completely shading the 5m depths? Was the bloom generally more intense that year than other years? Was 5m DO that low in other years or was 2017 abnormal? Also, might be useful to compare the sonde DO to the DO measured in the manual depth profiles (i.e., Figs 5-17) to confirm that the sondes were not misbehaving. | sondes in Iron Gate Reservoir show similar patterns for all summers. The similarity between 2017 and 2018 can be seen within the curtain report. In 2018 dissolved oxygen levels in July and August ranged from a high of about 7 mg/L in early July to a low of about 2 mg/L in late August (Figure 5-27). Review of the data presented in the report indicates that dissolved oxygen profiles were similar in 2017 and 2018 (see Figures 5-17 (2017), Figure 5-40 (2018), and Figure 6-5). There is no indication in the sonde data that the instruments were malfunctioning or collecting erroneous data. As was noted previously, the water column is very stable in the summer and therefore very resistant to wind mixing. |
| 10 | The thermographs stringer plots (e.g., Figure 5-8, etc.) showing time series comparing river water temperature to water temperatures at various depths in the reservoir are a nice way of visualizing the curtain’s effect on the average depth of water being entrained into the intake tower and being released into the river. | Comment noted. |
| 11 | p. 5-21 “The sondes profiled three times per week during the morning hours of approximately 7:00 AM PDT to 11:45 AM PDT.” Can the sondes be programmed to look at diel migration of cyanobacteria? It would also be useful to have data from late afternoon and before sunrise. | It appears that the comment is asking if the sondes could profile again in the afternoon or perhaps in the middle of the night, thereby allowing the comparison of cyanobacteria data from morning and afternoon at the same depths. The profiles are achieved by a digital controller that operates the winch, which in turn raises and lowers the data sonde. Target depths are achieved by spooling line out for a specific amount of time, waiting for 15 minutes, and then spooling out more line until a maximum depth target is reached. This is not the most precise system, which is why depths at the various vertical profiles change slightly from profile to profile. At this time, the controller that operates the winch does not have the capability of managing two profiles per day.<br><br>Effectively characterizing the diel migration of cyanobacteria would require considerable fieldwork over a range of conditions to determine the influence of wind mixing, thermal stratification, time |

| # | Comment | Response |
|---|---|---|
| | | of day, and so on. This level of work was beyond the scope of this study. The curtain was designed for deployment to 10 meters because data from Moisander's (2008) diel migration study indicated that few cyanobacteria would be expected to migrate below this depth. |
| 12 | Table 6-1, showing the percent of time with Wedderburn numbers (Wn) less than 1 indicating unstable conditions for each two-week or monthly period in 2016–2018, is highly useful information and deserves more weight in the report summary and discussion. This is key information regarding which months the curtain is expected to be most useful. | The executive summary of the report has been edited to convey this information. Equally important from a curtain operation perspective is the information in Table 6-2, which shows the percent of time mixing occurs to depth; this allows the targeted deployment of the curtain with some understanding that deeper deployments are necessary in September and October to achieve the same results. |
| 13 | p. 6-38: "The sign and Wilcoxon signed-rank test results indicated that Iron Gate Dam alone does not significantly reduce chlorophyll-a concentrations in the river downstream of the dam during periods that the curtain was not present and/or not deployed, after an uncertainty factor has been applied to address system heterogeneity and laboratory analysis uncertainty (Table 6-18 and Table 6-19)." As noted in our comments above on *4.3.1.4 Uncertainty Factors*, we disagree with the application and interpretation of the uncertainty analysis. Primary conclusions should be based on the main tests, not the uncertainty-adjusted tests. In addition, for context, this section (and/or elsewhere in the report), should provide a citation to Genzoli and Kann (2017) showing lower *Microcystis* and microcystin concentrations in the river versus at the reservoir log boom. | See response to comment 7. |
| 14 | 7.4 Analysis and Discussion<br>This section should mention one of the key findings of the report (Table 6-1), which is that water column stability analysis based on water temperatures indicates the curtain is likely to be more effective in July and August than September and October. It would also be good to compare this with the seasonality of cyanobacteria blooms. Bloom timing varies somewhat from year to year, but September is the typical peak (i.e. see Figures 15 and | Edited discussion. |

| # | Comment | Response |
|---|---|---|
| | 16 in Genzoli and Kann 2017, or slide 14 in Genzoli and Kann 2019). | |
| 15 | p. 7-3 “Data from all years were employed in these analyses to integrate inter- and intra-annual variability over multiple years in order to assess overall curtain performance under a range of conditions.” There definitely were a range of conditions over the years evaluated, but is there an easy way to quantify how representative the curtain years are to the whole range of years? Since curtain deployment, have there been any years with intense cyanobacterial blooms other than 2017, or are there still not much data for curtain performance under intense bloom conditions? | The relative magnitude of bloom conditions in any given year does not directly affect the curtain’s effectiveness. Because the curtain relies on the shallow stratification of the near-surface waters to be effective, the bloom conditions are not material to the discussion. Although not discussed in this document, bloom conditions in 2020 were relatively intense when compared to some of the more recent years and the curtain performed well until the reservoir mixed in the fall, destratifying the reservoir, mixing surface waters to depths below the curtain, and allowing their release into the Klamath River. |
| 16 | p. 7-3 “The results of analysis of sonde data for temperature, chlorophyll, and phycocyanin were less clear.” Any speculation as to why the sonde data for chlorophyll and phycocyanin show different patterns than the lab sample data for chlorophyll-a, *Microcystis*, and microcystin? Could it have something to do with diel migration of cyanobacteria (some of the sonde data are based on daily averages, rather than instantaneous)? | It is likely that the answer to this question is related to the precision of the probes on the data sonde and their ability to consistently measure the resource present when compared to a physical sample analyzed in a laboratory setting. The data sonde data have to be averaged to be useable since the instantaneous data simply have too much variability to accurately represent conditions and provide any meaningful information in a statistical analysis.<br><br>Sonde data were averaged in two ways based on depths: Averages were calculated for the late morning period (8:00 AM to 11:30 AM) at depths of 5 and 10 meters and for 24-hour periods at the surface (because that is where the sondes were ‘parked’ when not profiling).<br><br>Edits were made to the report to remove the references to temperature in this discussion because temperature did clearly demonstrate a reduction from upstream to downstream of the curtain.<br><br>See the response to comment 11 for a brief discussion of diel migration of cyanobacteria as related to the analysis in this study. |

| # | Comment | Response |
|---|---|---|
| 17 | As noted in comments above regarding the Hypotheses in Section 3, the wording “Reduction in Downstream Loading Attributable to Iron Gate Dam” is somewhat misleading. The dam creates habitat for cyanobacteria. It is the dam’s intake structure that mixes surface accumulations of cyanobacteria with deeper waters, reducing the amount of cyanobacteria discharged downstream relatively to what would be discharged if the intake structure drew purely surface waters. | See response to comment 3. |
| 18 | p. 7-3 “Comparing conditions at the log boom in Iron Gate Reservoir and the Klamath River downstream of Iron Gate Dam without a curtain yielded no statistically significant (p>0.05) reduction in chlorophyll-a for the sample sets analyzed when considering uncertainty in the data sets, although average bias demonstrated some reduction may occur.” As noted in our comments above on *4.3.1.4 Uncertainty Factors*, we disagree with the application and interpretation of the uncertainty analysis. Primary conclusions should be based on the main tests, not the uncertainty-adjusted tests. | See response to comment 7. |
| 19 | As noted in comments above regarding the Hypotheses in Section 3, the wording “Reduction in Downstream Loading Attributable to Combined Curtain and Iron Gate Dam” is somewhat misleading. The dam creates habitat for cyanobacteria. It is the dam’s intake structure that mixes surface accumulations of cyanobacteria with deeper waters, reducing the amount of cyanobacteria discharged downstream relatively to what would be discharged if the intake structure drew purely surface waters. | See response to comment 3. |
| 20 | 7.5 Recommendations<br>Why are the temperature stringers not included in the recommendations for future monitoring? They allow continuous calculation of the Wedderburn number (Wn) water column stability which can be used to predict the performance of the curtain. The vertical profilers do not have as good of temporal | Data from the thermograph strings are only available after someone has gone to the site, retrieved the strings, and downloaded and processed the data. The data sondes are connected to the PacifiCorp data and communications network and allow remote access to the data. This in turn allows for almost real-time calculations of *Wn*.<br>It is worth noting that the data sondes do provide enough data to determine where the epilimnetic thermocline is and make decisions |

| # | Comment | Response |
|---|---|---|
| | resolution and are not as reliable, right? Or have the sonde profile reliability issues been resolved? | on how deep to deploy the curtain; however, those data are limited to the time of the profile (i.e., morning). |
| 21 | p. 7-4 "Develop a metric to quantify cyanobacteria reductions to assist resource managers in operating the curtain during summer and early fall periods." The meaning of this is unclear. Should this be "method", not "metric"? | Method is correct. However, on further review PacifiCorp determined that this recommendation was unlikely to generate any useful information and has removed it entirely from the report. |
| 22 | p. B-3 "It is unclear if similar results should be expected from the different data set and analysis in Genzoli and Kann (2017) [*Microcystis* and microcystin used in Genzoli and Kann (2017) versus chlorophyll-*a* used in the barrier report]. The barrier report does not present an analysis of log boom vs KRBI microcystin toxin or *Microcystis* cell density but rather compares chlorophyll-a data between these two sites. Chlorophyll-a is often a good indicator of algae biomass concentrations." Is there a reason why the draft barrier report evaluates Hypothesis 2 and 3 using chlorophyll-*a* rather than microcystin toxin or *Microcystis* cell density? We recognize that a lot of effort has already been put into the draft report, so we are not asking that additional analyses be added, just that the choices be explained. | One of the reasons to use chlorophyll-*a* instead of microcystin data is that there are substantial data available over the years for chlorophyll-*a*, but there are not enough microcystin reservoir and river data pairs to perform statistical tests and to draw meaningful conclusions. When looking at paired data for the log boom and Klamath River downstream of Iron Gate Dam, there are 99 chlorophyll-*a* sample pairs between 2009 and 2019 (90 of which were used in the report analysis) compared to 3 for microcystin or cyanobacteria for that same period of time (when the curtain was not installed or deployed). The report has been edited in Section 4.3.2 to clarify this reasoning.<br><br>See response to comment 8. |