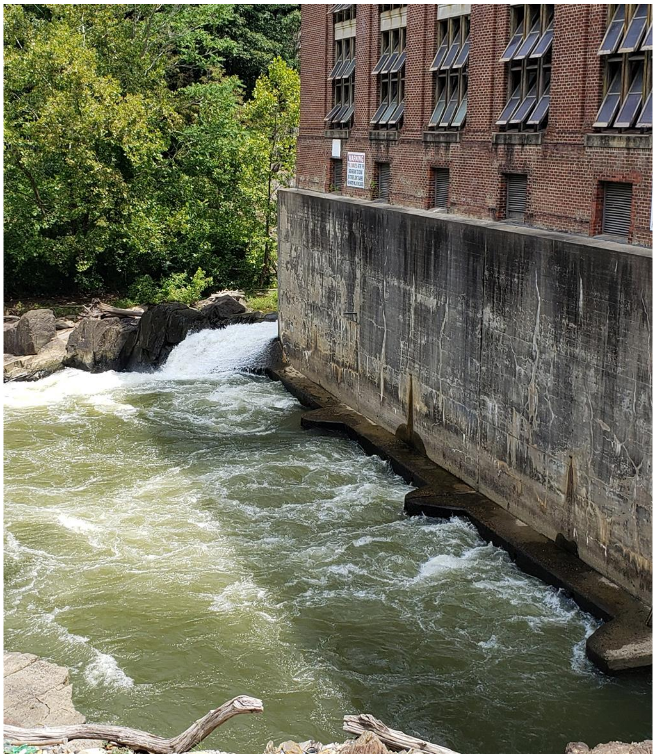

# Water Quality Study Report

Byllesby-Buck Hydroelectric Project
(FERC No. 2514)

November 17, 2021

Prepared by:

HDR

Prepared for:

Appalachian Power Company

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# Acronyms and Abbreviations

| | |
|---|---|
| °C | degrees Celsius |
| AEP | American Electric Power |
| Appalachian or Licensee | Appalachian Power Company |
| Byllesby | Byllesby Development |
| Buck | Buck Development |
| DO | dissolved oxygen |
| CFR | Code of Federal Regulations |
| CWA | Clean Water Act |
| FERC or Commission | Federal Energy Regulatory Commission |
| ft | feet/foot |
| mg/l | milligrams per liter |
| HDR | HDR Engineering, Inc. |
| Hydrolab | Hach Hydrolab® MS5 |
| ILP | Integrated Licensing Process |
| ISR | Initial Study Report |
| $mg/m^3$ | milligrams per cubic meter |
| NGVD | National Geodetic Vertical Datum of 1929 |
| NTU | Nephelometric turbidity units |
| PAD | Pre-Application Document |
| PM&E | protection, mitigation, and enhancement |
| Project | Byllesby-Buck Hydroelectric Project |
| RM | river miles |
| RSP | Revised Study Plan |
| SPD | Study Plan Determination |
| USGS | U.S. Geological Survey |
| USR | Updated Study Report |
| VAC | Virginia Administrative Code |
| VDEQ | Virginia Department of Environmental Quality |
| μS/cm | microsiemens per centimeter |

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# 1 Project Introduction and Background

Appalachian Power Company (Appalachian or Licensee), a unit of American Electric Power (AEP), is the Licensee, owner, and operator of the two-development Byllesby-Buck Hydroelectric Project (Project) (Project No. 2514), located on the upper New River in Carroll County, Virginia. The Byllesby Development (Byllesby) is located about 9 miles north of the city of Galax, and the Buck Development (Buck) is located approximately 3 river miles (RM) downstream of Byllesby and 43.5 RM upstream of Claytor Dam.

The Project is currently licensed by the Federal Energy Regulatory Commission (FERC or Commission). The Project underwent relicensing in the early 1990s, including conversion to run-of-river operations and incorporating additional protection, mitigation, and enhancement (PM&E) measures (FERC 1994). The current operating license for the Project expires on February 29, 2024. Accordingly, Appalachian is pursuing a subsequent license for the Project pursuant to the Commission's Integrated Licensing Process (ILP), as described at 18 Code of Federal Regulations (CFR) Part 5. In accordance with FERC's regulations at 18 CFR §16.9(b), the licensee must file its final application for a new license with FERC no later than February 28, 2022.

In accordance with 18 CFR §5.11 of the Commission's regulations, Appalachian developed a Revised Study Plan (RSP) for the Project that was filed with the Commission and made available to stakeholders on October 18, 2019. On November 18, 2019 FERC issued the Study Plan Determination (SPD). On December 12, 2019, Appalachian filed a clarification letter on the SPD with the Commission. On December 18, 2019, Appalachian filed a request for rehearing of the SPD. The SPD was subsequently modified by FERC by an Order on Rehearing dated February 20, 2020.

On July 27, 2020, Appalachian filed an updated ILP study schedule and a request for extension of time to file the Initial Study Report (ISR) to account for Project delays resulting from the COVID-19 pandemic. The request was approved by FERC on August 10, 2020, and the filing deadline for the ISR for the Project was extended from November 17, 2020 to January 18, 2021. Stakeholders provided written comments in response to Appalachian's filing of the ISR meeting summary, which are addressed in this Updated Study Report (USR) along with study methods and results.

In accordance with 18 CFR §5.15, Appalachian has conducted studies as provided in the RSP as subsequently approved and modified by the FERC. This report describes the methods and results of the Water Quality Study conducted in support of preparing an application for new license for the Project.

# 2 Study Goals and Objectives

Appalachian's study employs standard methodologies that are consistent with the scope and level of effort of water quality monitoring conducted at hydropower projects in the region. This study is intended to provide sufficient information to support an analysis of the potential Project-related effects on water quality. The goals and objectives of this study are to:

- Gather baseline water quality data sufficient to determine consistency of existing Project operations with applicable Virginia state water quality standards and designated uses (Virginia Administrative Code [VAC] Chapter 260).

- Provide data (temperature and dissolved oxygen [DO] concentration) to determine the presence and extent, if any, of thermal or DO stratification in the Byllesby and Buck impoundments.
- Provide data to support a Virginia Water Protection permit application (Clean Water Act [CWA] Section 401 Certification).
- Provide information to support the evaluation of whether additional or modified PM&E measures may be appropriate for the protection of water quality at the Project's developments.

# 3 Study Area

The study area for the Water Quality Study is shown on Figure 3-1 and includes the reservoirs, bypass reaches, and tailraces downstream of Byllesby and Buck dams. Water quality data was collected at all five Buck monitoring locations and one Byllesby monitoring location (tailrace) for approximately two months in 2020, and at all six Byllesby monitoring locations for approximately three and a half months in 2021.

- **Byllesby Development**
  - One location in the upstream extent of the Byllesby reservoir
  - Three locations in the Byllesby forebay (near surface, mid-depth, and near bottom)
  - One location in the tailrace
  - One location in the Byllesby bypass reach
- **Buck Development**
  - Two locations in the forebay (near surface and near bottom)
  - One location in the tailrace
  - Two locations in the bypass reach (upstream and downstream)

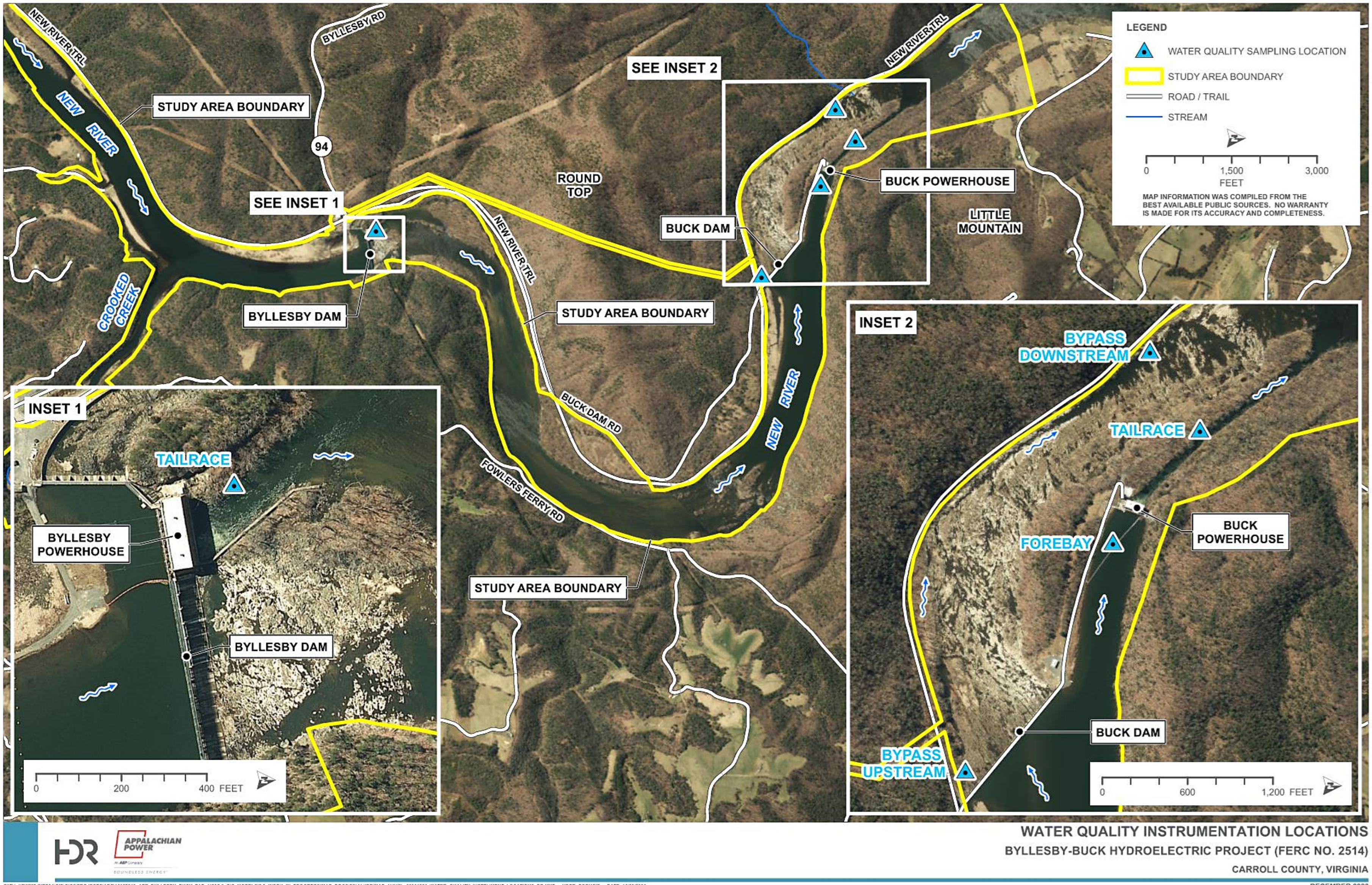


**Figure 3-1. Byllesby-Buck Water Quality Study Locations**

# 4 Background and Existing Information

## 4.1 Applicable Water Standards

Existing relevant and reasonably available information regarding water quality in the Project vicinity was presented in Section 5.3 of the Pre-Application Document (PAD) (Appalachian 2019). The PAD included historical water quality data collected by the U.S. Geological Survey (USGS) and the Virginia Department of Environmental Quality (VDEQ) (discussed in Section 4.2). The data presented in the PAD indicates that temperatures and DO concentrations did not differ between impoundments and tailraces during collection efforts, and no evidence of thermal stratification was observed in either impoundment. Data from the historical studies also demonstrated that the Project waters meet the state water quality standards, including temperature maximums and DO minimums.

The VDEQ is responsible for carrying out the mandates of the State Water Control Law as well as meeting federal obligations under the CWA (VDEQ 2017). Waters in the New River Basin are classified in 9VAC25-260-540. The New River in the vicinity of the Project is designated as Class IV (Mountainous Zone) (Table 4-1). Numerical criteria for DO, pH, and maximum water temperature for these waters are identified in 9VAC25-260-50 and are summarized in Table 4-2. In accordance with 9VAC25-260-50, these water quality criteria do not apply when flows are below the lowest 7-day average flow expected to occur once every 10 years (i.e., the 7Q10 flow).

**Table 4-1. Classification of Project Area Waters – New River**

| Section | Class | Special Standards | Section Description |
|---|---|---|---|
| 2 | IV | v, NEW-5 | New River and its tributaries, unless otherwise designated in this chapter, from the Montgomery-Giles County line upstream to the Virginia-North Carolina state line. |
| 2l | IV | PWS | New River and its tributaries inclusive of the Wythe County Water Department's Austinville intake near the Route 636 bridge, and the Wythe County Water Department's Ivanhoe intake on Powder Mill Branch just upstream of the Wythe-Carroll County line to points 5 miles above the intakes. |

v – The maximum temperature of the New River and its tributaries (except trout waters) from the Montgomery-Giles County line upstream to the Virginia-North Carolina state line shall be 29 degrees Celsius (°C) (9VAC25-260-310).

NEW – nutrient-enriched waters; only includes New River and its tributaries, except Peak Creek above Interstate 81, from Claytor Dam upstream to Big Reed Island Creek (Claytor Lake) as per 9VAC25-260-350.

PWS – public water supply.

**Table 4-2. Numeric Water Quality Criteria for Class IV Waters**

| Parameter | Standard |
|---|---|
| **Minimum DO** | 4.0 milligram per liter (mg/l) |
| **Daily Average DO** | 5.0 mg/L |
| **pH** | 6.0 – 9.0 |
| **Maximum water temperature** | 29°C* |

*The maximum temperature of the New River and its tributaries (except trout waters) from the Montgomery-Giles County line upstream to the Virginia-North Carolina state line shall be 29°C (9VAC25-260-310).

Multiple segments of the New River are listed as impaired for aquatic life or recreation uses due to *E. coli* concentrations. However, the source of *E. coli* is not associated with the Project and it is expected that continued operation of the Project will have no effect on *E. coli* concentrations in the New River.

## 4.2 Existing Water Quality Data

Water quality data have been collected approximately 3.0 RM downstream of the Buck Dam at the U.S. Geological Survey (USGS) 03165500 New River at Ivanhoe, VA. Due to the proximity of this monitoring location to the Project, the water quality data is expected to be indicative of the characteristics of Project outflows. Daily mean water temperature and specific conductance data were collected from March 2007 to September 2008; daily mean water temperatures ranged from 0.3°C in to 28.9°C and were below the maximum state criterion. Daily mean specific conductance ranged from 55 microsiemens per centimeter (µS/cm) to 108 µS/cm.

The VDEQ has also collected water quality data approximately 2 RM downstream of Buck Dam at Site 9-NEW127.49. Water temperature, DO, pH, and specific conductivity data were collected at a depth of approximately 0.3 meters from 1992 to 2017. Water temperatures ranged from 0.0 to 28.7°C and were below established state criterion. DO concentrations ranged from 5.3 mg/l to 14.8 mg/l and were well above the minimum state criterion. The pH ranged from 5.9 to 8.9 and were also within the state criteria range, except for a single day in December 1999. Specific conductivity ranged from 20 to 80 µS/cm.

On August 29, 2019, a site visit was conducted by HDR Engineering, Inc. (HDR) on behalf of Appalachian to collect water quality data and evaluate field logistics associated with potential water quality monitoring locations for the Byllesby and Buck developments. During the site visit, a calibrated multiparameter water quality data sonde was used to collect depth profiles in each development's forebay and discrete measurements were taken in each development's tailrace. Streamflow during the site visit was approximately 1,500 cubic feet per second (cfs) measured at USGS gage 03165500, which is typical of average flow conditions in August at this location. During the site visit, the Byllesby forebay elevation[1] was in the normal operating range,[2] however, the Buck forebay elevation was approximately 9 feet (ft) lower than the normal operating range[3] to facilitate construction activities associated with installation of the new Obermeyer gates.

All water quality measurements during the site visit were within applicable Virginia state water quality standards. As Figure 4-1 and Figure 4-2 indicate, the depth profiles in each forebay did not show any significant difference in water quality from top to bottom or laterally. The tailrace measurements were reflective of the water quality in each forebay.

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[1] Elevations in this report are referenced to National Geodetic Vertical Datum of 1929 (NGVD)

[2] Normal operating range for the Byllesby impoundment is between 2,078.2 – 2,079.2 ft NGVD.

[3] Normal operating range for the Buck impoundment is between 2,002.4 – 2,003.4 ft NGVD. During the August 29, 2019 water quality sampling site visit, the forebay elevation was approximately 1994 ft NGVD; or approximately 9 ft below the normal operating range.

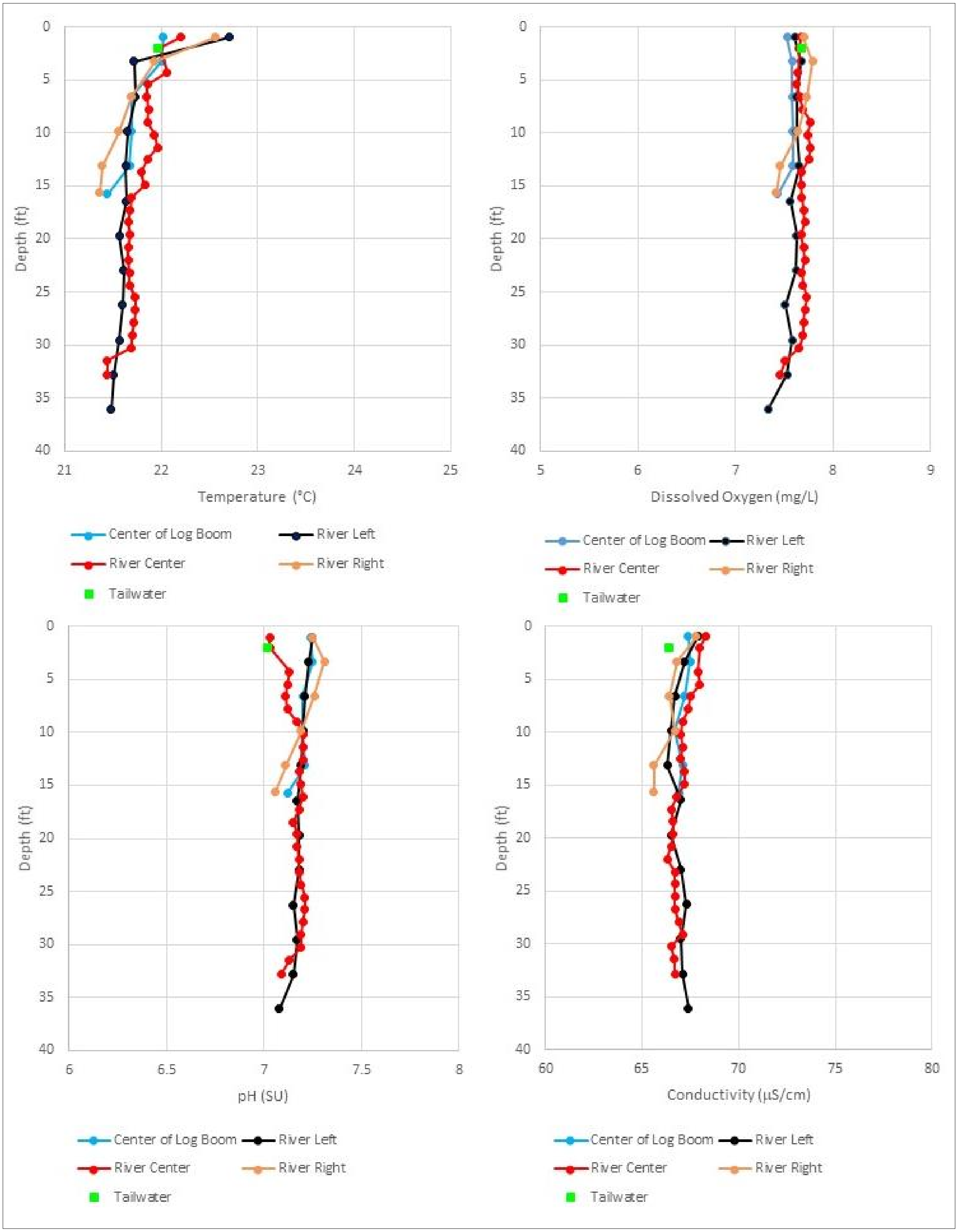


**Figure 4-1. Water Quality Parameters for Byllesby (August 29, 2019)**

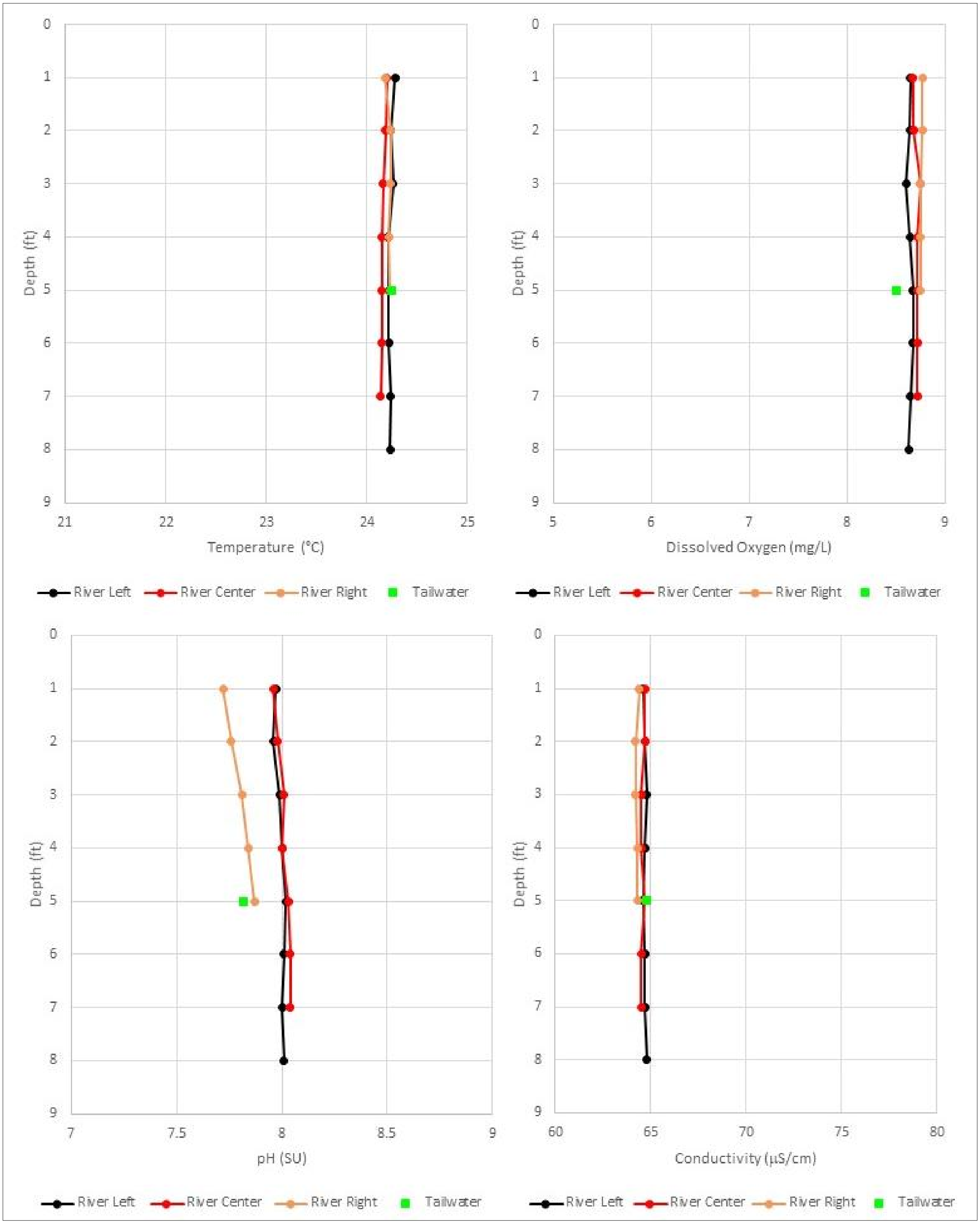


**Figure 4-2. Water Quality Parameters for Buck (August 29, 2019)**

# 5 Methodology

## 5.1 Byllesby Data Collection

Initial deployment of water quality instrumentation at the Project was scheduled for the week of August 17, 2020, however, due to high flow conditions and continuous flow release at the dam through the damaged flashboard section throughout the latter part of 2020, the only water quality instrumentation deployed at Byllesby was at the tailrace location. HDR deployed the remaining water quality instruments (i.e., DO and water temperature sondes) at Byllesby on June 15 – 16, 2021. The water quality monitor that was deployed in the tailrace in August 2020 was removed at the end of the 2020 study period and then reinstalled at the same location for the 2021 data collection effort. The locations of the water quality instrumentation are shown on Figure 3-1. The equipment recorded data at 15-minute intervals. Data were downloaded from instrumentation at Byllesby approximately every 2 to 3 weeks[4] until September 28, 2021, at which time the data collection instruments were removed.

The depth of the Byllesby forebay water quality monitoring location is approximately 27 ft. The RSP specified a monitoring location near the surface and bottom of the forebay (approximately 3 ft from the surface and bottom, respectively). Appalachian also deployed a water quality data sonde at approximately mid-depth to help determine the extent of any thermal and/or DO stratification in the forebay area.

Field staff downloaded data from sondes at each monitoring location using a data shuttle or directly to a laptop computer. Sondes were regularly cleaned and checked for operation, calibration, and battery life, and adjusted as necessary based on manufacturer's specifications. The cable, housing, and other installation materials were visually inspected for damage and repaired or replaced as necessary.

During the initial deployment and subsequent download events, discrete multi-parameter water quality measurements of temperature, DO concentration, pH, and specific conductivity were collected at each monitoring location using a Hach Hydrolab® MS5 (Hydrolab). For the upstream, tailrace, and bypass reach monitoring locations, discrete water quality data were collected at one location within the water column at a depth similar to the sondes. Profile data at the Byllesby forebay monitoring location were collected at 2.0-ft intervals near the surface and 1.0-ft intervals near the bottom of the reservoir[5] using the Hydrolab to document temperature and DO stratification at the time of the data sonde downloads.

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[4] The mid-August 2021 water quality download event was postponed due to a planned reservoir drawdown event to repair a section of broken flashboards. Immediately after the reservoir returned to normal pool elevation, Tropical Storm Fred resulted in a large rainfall runoff event that further delayed the equipment download event to late August.

[5] During the initial water quality equipment deployment on June 15, 2021 and first download event on June 28, 2021, a faulty data cable prevented vertical profile measurements below a depth of 14 ft.

## 5.2 Buck Data Collection

Water quality instruments (i.e., DO and water temperature sondes) were deployed at Buck at all five planned monitoring locations the week of August 17, 2020. The locations of the water quality instrumentation are shown on Figure 3-1. The equipment recorded data at 15-minute intervals.

Based on the August 29, 2019 site visit described in Section 4.2, the depth of the Buck forebay near the center of the intake channel is approximately 17 ft.[6] As a result, the upper and lower data sondes were placed at approximately 3 ft and 14 ft below the surface, respectively.

Data were downloaded from instrumentation at Buck during the field efforts from September 8 - 10, 2020, and at Byllesby (tailrace only) and Buck from October 7 – 8, 2020, after which time data collection instruments were removed per the schedule in the RSP. Field staff downloaded data from sondes at each monitoring location using a data shuttle or directly to a laptop computer. Sondes were regularly cleaned and checked for operation, calibration, and battery life, and adjusted as necessary based on manufacturer's specifications. The cable, housing, and other installation materials were visually inspected for damage and repaired or replaced as necessary.

During the initial deployment and subsequent download events, discrete multi-parameter water quality measurements of temperature, DO concentration, pH, and specific conductivity were collected at each monitoring location using a Hydrolab. For the tailrace and bypass reach monitoring locations, Hydrolab water quality data were collected at one location within the water column at a depth similar to the sondes. Profile data were collected at 1.0-ft intervals[7] at the Buck forebay monitoring location using the Hydrolab to document temperature and DO stratification at the time of the data sonde downloads.

## 5.3 Data Analysis and Processing

Upon completion of the field data collection effort, data was checked for errors and omissions. Data that more closely matched the discrete measurement readings made in the field during download events were preferentially reported and analyzed for each monitoring location.

Real-time flow data (15-minute) was obtained from the USGS New River at Ivanhoe, VA Gage (USGS 03165500), which is approximately 3.0 RM downstream of the Buck powerhouse and includes the combined flows from the powerhouse and bypass reach. Flows have been recorded since January 1996 at the USGS New River at Ivanhoe, VA gage and corresponding stage from August 2020 to present.

[6] During the August 29, 2019 water quality sampling site visit, the Buck pool level was at approximately 1994 ft NGVD; or approximately 9 ft below the normal operating range of 2002.4 – 2003.4 ft NGVD (the impoundment was drawn down to facilitate construction activities at the spillway). At the time of the site visit, the depth measured near the center of the intake channel was approximately 8 ft. Therefore, at normal pool levels, the depth at the same location will be approximately 17 ft (i.e., 8 ft + 9 ft).

[7] During the August 17, 2020 water quality sampling event, profile data were collected at 2-ft intervals; a 1-ft interval was used during subsequent water quality sampling events.

## 5.4 Equipment Calibration and Quality Assurance

Prior to the first deployment, Onset HOBO® Model U26 DO/Temperature Loggers were initialized with a new DO sensor cap and calibrated. The Hydrolab multi-parameter water quality sonde was lab calibrated by the manufacturer. Prior to each instantaneous sample collection, the Hydrolab was checked against a suite of standards. A Hydrolab® Surveyor 4a is the handheld display that connects to the Hydrolab sonde for attended monitoring applications and was sent to the manufacturer for calibration prior to the field deployment. The water quality sensor specifications as specified by the manufacturer are presented in Table 5-1.

**Table 5-1. Water Quality Sensor Specifications**

| Water Quality Sensor Accuracy | | |
|---|---|---|
| **Sensor** | Hydrolab® MS5[2] | Onset HOBO® Model U26[3] |
| **Temperature** | +/- 0.1°C | +/- 0.2°C |
| **DO**[1] | +/- 0.1 mg/l for 0 – 8 mg/l;<br>+/- 0.2 mg/l for greater than 8 mg/l | +/- 0.2 mg/L for 0 – 8 mg/l;<br>+/- 0.5 mg/L for greater than 8 mg/l |
| **Specific conductivity** | +/- 0.5 % of reading;<br>+/- 0.001 millisiemens/centimeter | N/A |
| **pH** | +/- 0.2 units | N/A |

Note:
[1] = Hach LDO® - Luminescent Dissolved Oxygen sensor or Onset RDO ® - Rugged Dissolved Oxygen. Both use light to optically measure DO.
[2.] Specifications for the Hydrolab® MS5: https://s.campbellsci.com/documents/ca/product-brochures/series_5_br.pdf
[3.] Specifications for the Onset HOBO® Model U26: https://www.onsetcomp.com/products/data-loggers/u26-001/

# 6 Study Results

## 6.1 Byllesby Water Quality Results

### 6.1.1 Water Temperature

Figure 1-1 (Attachment 1) provides continuous and discrete water temperature data at the upstream end of the Byllesby reservoir. The highest water temperatures occurred during the last week of July 2021 and peaked between 29–30 ºC during the afternoon hours that week. Diurnal temperature variation during the water quality study period ranged from approximately 2–4 ºC. Discrete measurements at all Byllesby water quality monitoring locations are provided in Attachment 3.

Figure 1-2 (Attachment 1) provides continuous and discrete water temperature data at the Byllesby tailrace location in 2020. Water temperatures measured in the 21–26ºC range for the first three weeks of the study. In mid-September 2020, the average temperature decreased over a one-week period by approximately 7ºC. Figure 1-3 (Attachment 1) provides continuous and discrete water temperature data at the forebay and tailrace monitoring locations at Byllesby for 2021. Water temperatures at both of these locations were similar to those recorded at the upstream end of the Byllesby reservoir. As described in Section 5.1, continuous water temperature data was collected at three elevations at the Byllesby forebay monitoring location (near surface, mid-depth, and near bottom). Water temperature differences between the surface and bottom forebay locations typically varied between 0–2ºC indicating minimal thermal stratification in the forebay, which is reflective of run-of-river operations. Tailrace water temperatures were generally similar to the forebay surface monitoring location, but with less daily fluctuation.

Figure 1-4 (Attachment 1) provides continuous and discrete water temperature data at the Byllesby bypass reach monitoring location. Bypass reach water temperature magnitude and daily fluctuation was very similar to that at the Byllesby upstream reservoir monitoring location.

Air temperature data is also included in Figures 1-1 through 1-4 (Attachment 1) to help put into context the larger daily air temperature fluctuations compared to the daily water temperature fluctuations.

Water temperature vertical profile data for the Byllesby forebay are presented in Figure 5-1 (Attachment 5). While water temperature varied seasonally, there was little (i.e., <2.0ºC) to no thermal stratification at the forebay monitoring location.

### 6.1.2 Dissolved Oxygen

Figure 1-5 (Attachment 1) provides continuous and discrete DO concentration data at the Byllesby upstream monitoring location. All measurements were greater than the 5.0 mg/l daily average DO standard with daily fluctuations in the 1.0–2.5 mg/l range. DO concentrations were in the 6.0–9.0 mg/l range through the July–August 2021 period and then generally increased through September as water temperatures decreased[8]. Note at the beginning of the water quality study period in 2021, the upstream monitoring location was in a pool with very slow-moving water which resulted in significant biofouling of the DO sensors. The sampling equipment was subsequently relocated during the July 14, 2021 download event to an area just upstream of the original location with slightly higher velocities, which greatly reduced biofouling affects.

Figure 1-6 (Attachment 1) provides continuous and discrete DO concentration data at the Byllesby forebay monitoring locations. All measurements were greater than the 5.0 mg/l daily average DO standard with the exception of several days when DO concentrations measured at the forebay bottom monitoring location dipped below 5.0 mg/l. During these periods, thermal and DO stratification was present in the forebay, therefore, the surface DO concentration was used for comparison to the state water quality standards (all of which were above the 5.0 mg/l daily average DO standard). Differences in DO concentrations between the upper and lower forebay monitoring locations typically ranged from 0–1.0 mg/l indicating minor stratification in the forebay area during the summer months. See data tables in Attachment 3 for discrete sampling results in the Byllesby forebay.

A planned reservoir drawdown occurred from August 6 – 13, 2021 to repair a section of broken flashboards at the Byllesby spillway. During this period, the reservoir was drawn down approximately 8 ft (see Figure 1-6 in Attachment 1) which impacted the results from the forebay middle and bottom monitoring locations as the DO sensors were likely resting on the bottom of the reservoir. Data points were removed from Figure 1-6 during the reservoir drawdown period.

[8] Generally, there is an inverse relationship between DO concentrations and water temperature. Colder water temperatures have a higher capacity for DO concentrations and vice versa.

Figure 1-7 and Figure 1-8 in Attachment 1 provide continuous and discrete DO concentration data at the Byllesby tailrace monitoring location for 2020 and 2021, respectively. All measurements were greater than the 5.0 mg/l daily average DO standard with daily fluctuations in the 0.5–1.5 mg/l range. DO concentrations generally increased over the course of the study period as water temperatures decreased[9].

A data gap between August 8, 2021 and August 25, 2021 resulted from a combination of the planned maintenance drawdown event (August 6 – 13, 2021) which was immediately followed by a large rainfall runoff event as the remnants from Tropical Storm Fred moved through the area (see Figure 1-9 in Attachment 1). These two back-to-back events delayed the routine download trip to August 25, 2021. By this time, the DO sensors had experienced significant biofouling resulting in data that was not usable. Based on water temperature data (which decreased during the rainfall runoff period, see Figure 1-3), it is expected that DO in the tailrace would have remained above the 5.0 mg/l daily average DO standard.

Figure 1-10 in Attachment 1 provides continuous and discrete DO concentration data at the bypass reach monitoring location. All measurements were greater than the 5.0 mg/l daily average DO standard with daily fluctuations ranging from 1.0 mg/l up to 4.0 mg/l as temperatures cooled toward the end of September. Like the Byllesby tailrace monitoring location, the same data gap occurred at the bypass reach monitoring location (for the same reasons described above). Similar to the tailrace monitoring location, it is expected that DO concentrations in the bypass reach would have remained above the 5.0 mg/l daily average DO standard due to cooler water temperatures and higher flows in the bypass reach during the Tropical Storm Fred rainfall runoff event (Figure 1-9, Attachment 1).

DO vertical profile data is presented in Figure 5-1 of Attachment 5 for the Byllesby forebay monitoring location and similar to the water temperature profile data, there was minor indication of stratification of DO concentrations at this location.

### 6.1.3 pH

Vertical pH profile data are presented on Figure 5-2 of Attachment 5 for the Byllesby forebay monitoring location. While there was some variability between sampling events, the overall pH range was between 6.8 and 8.9. Four of the sampling events indicated little to no stratification between the reservoir surface and bottom measurements; all closely grouped around a pH of 7.0. The other three sampling events indicated a higher pH range with some degree of stratification.

Discrete pH measurements at each monitoring location during the initial instrument deployment and subsequent download events were between 6.9 and 8.9; these values meet state water quality standards for Class IV waters (see Table 4-2). The only pH value outside this range was a discrete measurement of 9.2 at the upstream monitoring location during the last download event on September 28, 2021 (see data tables in Attachment 3 for discrete sampling results).

[9] Generally, there is an inverse relationship between DO concentrations and water temperature. Colder water temperatures have a higher capacity for DO concentrations and vice versa.

### 6.1.4 Specific Conductivity

Specific conductivity vertical profile data is presented in Figure 5-3 of Attachment 5 for the Byllesby forebay monitoring location. Specific conductivity at this monitoring location varied each sampling event, but concentrations were typically the same from reservoir surface to bottom and ranged from 58–69 µS/cm over seven sampling events during the study period. Discrete measurements of specific conductivity for all monitoring locations ranged from 55–69 µS/cm (see data tables in Attachment 3 for discrete sampling results). These results are consistent with specific conductivity measurements during the August 29, 2019 site visit, the 2020 water quality monitoring results at Buck (see Section 6.2.4), and the results of other nearby historic studies and data collection efforts (NWQMC 2020; Stantec 2016) indicating a long-term, relatively consistent range of conductivity in the Project area.

### 6.1.5 Chlorophyl A

Chlorophyll a grab samples were collected at the Byllesby and Buck forebay surface monitoring locations on July 14, September 9[10], and September 29, 2021 and analyzed at the certified laboratory Pace Analytical Services in Ormond Beach, Florida. All sample results were “non-detect” indicating chlorophyll a concentrations in the samples were less than 5.0 milligrams per cubic meter ($mg/m^3$).

### 6.1.6 Turbidity

Turbidity grab samples were collected at the Byllesby and Buck forebay surface monitoring locations on July 14, August 25, and September 29, 2021 and analyzed at Pace Analytical Services. Turbidity concentrations were 16.9, 6.1, and 1.0 Nephelometric turbidity units (NTU) on these three sampling dates, respectively.

Appalachian also performed a more intensive turbidity study to evaluate the potential impact that Project operations, in particular drag rake operations, may have on turbidity concentrations in the Project tailraces. The study was conducted in two phases under relatively low flow conditions during late-September and mid-October 2021. The first phase consisted of a one-week deployment of five Hydrolab data sondes equipped with turbidity sensors installed at each of the locations listed below (which coincide with the continuous monitoring locations shown on Figure 3-1).

- One location in the upstream extent of the Byllesby reservoir (to characterize background turbidity levels)
- One location in the Byllesby forebay (approximate mid-depth)
- One location in the Byllesby tailrace below the powerhouse
- One location in the Buck forebay (approximate mid-depth)
- One location in the Buck tailrace below the powerhouse

[10] A chlorophyll a sampling event was conducted on August 25, 2021. However, due to a delay in shipping, the grab sample arrived at the off-site laboratory after the maximum allowable hold period and as a result, was not analyzed. A second grab sample was subsequently collected on September 9, 2021 which resulted in two chlorophyll a sampling events in September 2021.

The data sondes were deployed from September 28 through October 5, 2021 and set to record turbidity concentrations at 5-minute intervals. Appalachian operated the generating units and drag rakes at each Project under a normal operating regime. Due to the relatively low Project inflows which carried little debris, the drag rakes were set to operate just once per day during the morning hours (i.e., from 7–10 am) during the field collection effort. Results from this one-week deployment are provided in Figure 8-1 (Attachment 8). Only the Byllesby upstream data sonde and Buck tailrace data sonde operated continuously during the one-week deployment; the other three data sondes ceased operating within hours of their deployment.

Results indicate that during periods of low Project inflows, turbidity entering the Byllesby reservoir is correspondingly low, typically < 3.0 NTU. Turbidity concentrations in the Buck tailrace during the one-week study were also low and ranged from approximately 3.0–6.0 NTU[11].

Due to the turbidity sensor failures and low frequency of drag rake operations during the one-week study period, a second phase was added to the original study to collect turbidity data at the Buck forebay and tailrace monitoring locations[12] over a one-day period on October 14, 2021. During this second phase, generation at the Buck Development was held relatively steady and the drag rakes were operated approximately every 30 minutes throughout the sampling period. This resulted in 15 discrete drag rake operating events. Figure 8-2 (Attachment 8) provides continuous turbidity concentration data at the Buck forebay and tailrace monitoring locations on October 14, 2021. Turbidity values in the tailrace were slightly higher than in the forebay, but low overall (ranging from approximately 5–12 NTU). Drag rake operations are also provided on this figure and there is no discernable effect on turbidity concentrations in the tailrace immediately following drag rake operations. A discrete measurement of turbidity concentrations at the Byllesby upstream monitoring location yielded a range of 4–6 NTU which represents turbidity concentrations of Project inflows during this second phase sampling event.

## 6.2 Buck Water Quality Results

### 6.2.1 Water Temperature

Figure 2-1 in Attachment 2 provides continuous and discrete water temperature data at the forebay and tailrace locations at Buck. Water temperatures at both of these locations were similar to those recorded at the Byllesby tailrace. The Buck forebay and tailrace monitoring locations were within 0.5ºC of each other for most of the study period, which is reflective of run-of-river operations. Discrete measurements at all Buck water quality monitoring locations are provided in Attachment 4.

Figure 2-2 in (Attachment 2) provides continuous and discrete water temperature data at the Buck bypass reach monitoring locations. Daily temperature fluctuations at the downstream monitoring

[11] The turbidity sensors use infrared wavelength to measure turbidity concentrations in the water column. The daily NTU cycling effect shown on Figure 8-1 (Attachment 8) at the Byllesby upstream and Buck tailrace monitoring locations is likely due to sunlight interference with the turbidity sensors (which is inherent in continuous in-situ sampling). Baseline turbidity concentrations would be during nighttime hours when sunlight interference is minimized.

[12] During the second phase of the turbidity study, Byllesby was in a planned maintenance outage to repair the intake structure trash racks. As a result, the Byllesby drag rakes were not operating and Project inflows were routed through the spillway structure instead of the powerhouse.

location were approximately twice that observed at the upstream monitoring location. While both monitoring locations are in relatively small pools, the upstream location is shaded more hours of the day compared to the downstream location, thus daily temperature cycles at the upper location are lower in magnitude.

Air temperature data is also included on Figures 2-1 and 2-2 (Attachment 2) to help put into context the larger daily air temperature fluctuations compared to the daily water temperature fluctuations.

Water temperature vertical profile data for the Buck forebay is presented on Figure 6-1 in Attachment 6. While water temperature varied seasonally, there was little (i.e., <0.7ºC) to no thermal stratification at the forebay monitoring location.

### 6.2.2 Dissolved Oxygen

Figure 2-3 (Attachment 2) provides continuous and discrete DO concentration data at the Buck forebay and tailrace monitoring locations. All measurements were greater than the 5.0 mg/l daily average DO standard. Daily fluctuations in DO concentrations were less than 1.0 mg/l during the study except for September 4–11 when the daily fluctuation increased to the 1.0–2.0 mg/l range at the forebay monitoring locations[13]. Similar to water temperature, there is little (i.e., typically < 1.0 mg/l) to no difference in DO concentrations between the forebay surface and bottom locations; indicating little to no stratification of DO concentrations throughout the forebay water column. DO concentrations in the tailrace were generally higher (by up to 1.0 mg/l) compared to the forebay monitoring locations. This suggests that unit generation and the trash sluice gate operation increase aeration into the tailrace. Tailrace concentrations typically fluctuated approximately 0.25 mg/l between day and night. Discrete measurements at all Buck water quality monitoring locations are provided in Attachment 3.

Figure 2-4 in Attachment 2 provides continuous and discrete DO concentration data at the bypass reach upstream and downstream monitoring locations. The overall trend in DO concentrations was similar between the two bypass reach monitoring locations. All measurements were greater than the 5.0 mg/l daily average DO standard with daily fluctuations of up to 1.0 mg/l for the upstream location and up to 3.0 mg/l at the downstream location. DO concentrations are influenced by water temperatures and as described in Section 6.1, the upstream monitoring location is shaded more hours of the day (compared to the downstream monitoring location), thus the daily fluctuation in DO concentrations is reduced at the upstream location relative to the downstream location.

DO vertical profile data is presented in Figure 6-1 of Attachment 6 for the Buck forebay monitoring location and similar to the water temperature profile data, there was no stratification of DO concentrations at this location.

### 6.2.3 pH

Vertical pH profile data are presented on Figure 6-2 of Attachment 6 for the Buck forebay monitoring location. The variation in pH was very small (between 7.3 and 7.7) and there was little to no

[13] Flows recorded at the Ivanhoe USGS flow gaging station from September 4 – 11, 2020 were relatively low and stable (compared to the weeks preceding and following) which likely contributed to slightly increased fluctuations in DO concentrations during this period. Flows recorded at the Ivanhoe USGS flow gaging station are shown on Figure 7-1 and 7-2 of Attachment 7.

stratification between the reservoir surface and bottom measurements. Discrete pH measurements at each monitoring location during the initial instrument deployment and two download events were between 7.2 and 8.9; these values meet state water quality standards for Class IV waters (see Table 4-2). Eleven of the fifteen readings were within the vertical profile range (7.3 and 7.7).

### 6.2.4 Specific Conductivity

Specific conductivity vertical profile data is presented in Figure 6-3 of Attachment 6 for the Buck forebay monitoring location. Specific conductivity at this monitoring location varied each sampling event, but concentrations were typically the same from reservoir surface to bottom and ranged from 53 – 61 µS/cm over three sampling events during the study period (see Figure 3-3). Discrete measurements of specific conductivity for all monitoring locations ranged from 52 – 62 µS/cm (see Table 2-1 of Attachment 2 for discrete sampling results). These results are consistent with specific conductivity measurements during the August 29, 2019 site visit and the results of other nearby historic studies and data collection efforts (NWQMC 2020; Stantec 2016) indicating a long-term, relatively consistent range of conductivity in the Project area.

### 6.2.5 Chlorophyl A

Chlorophyll a grab samples were collected at the Buck forebay surface monitoring location on July 14, September 9[14] and September 29, 2021 and analyzed at Pace Analytical Services. All sample results were "non-detect", indicating the chlorophyll a concentrations were less than 5.0 $mg/m^3$.

### 6.2.6 Turbidity

Turbidity grab samples were collected at the Buck forebay surface monitoring location on July 14, August 25 and September 29, 2021 and analyzed at Pace Analytical Services. Turbidity concentrations were 8.0, 4.3, and 1.5 NTU on these three sampling dates, respectively. Please refer to 6.1.6 for a detailed description of the turbidity study and methods.

# 7 Summary and Discussion

## 7.1 Effects of Station Operations on Water Quality

During the 2020 water quality study period (from August 17 to October 8, 2020), there were no station outages or flashboard failures at the Byllesby or Buck developments that would have impacted the water quality results.

During the 2021 water quality study period (from June 15 to September 28, 2021), a broken section of flashboards at the Byllesby spillway resulted in a spill of approximately 88 cfs into the bypass reach from the beginning of the study period until August 13, 2021 when the repair work was completed. During this period, the Byllesby reservoir was drawn down approximately 8 ft from

[14] A chlorophyll a sampling event was conducted on August 25, 2021. However, due to a delay in shipping, the grab sample arrived at the off-site laboratory after the maximum allowable hold period and as a result, was not analyzed. A second grab sample was subsequently collected on September 9, 2021 which resulted in two chlorophyll a sampling events in September 2021.

August 6 – 13, 2021 to support the repair work. There were no other station outages at the Byllesby development that would have impacted the water quality results.

Project inflows and precipitation data during the 2020 and 2021 water quality study periods are provided in Figures 7-1 and 7-2 (Attachment 7).

## 7.2 Consistency with Applicable Virginia State Water Quality Standards

Continuous and discrete water quality data collected during the 2020 study period met Virginia Class IV (New River) water quality standards for temperature (<29ºC), DO (>4.0 mg/l instantaneous minimum; >5.0 mg/l daily average), and pH (range 6.0 – 9.0) at all monitoring locations during the study period.

Continuous and discrete water quality data collected during the 2021 study period met the Virginia Class IV standards described above with the exception of water temperature. New River water temperature flowing into the Byllesby reservoir exceeded 29ºC on an instantaneous basis approximately 12 days between late-July and late-August. Similarly, instantaneous water temperature exceeded 29ºC at the forebay surface monitoring location and bypass reach monitoring location on approximately 8 days during the study period, respectively. During each of these events, the maximum instantaneous water temperature recorded was less than 30ºC and the daily average water temperature was less than 29ºC. Water temperatures recorded in the Byllesby tailrace were all less than 29ºC.

## 7.3 Temperature and Dissolved Oxygen Stratification in the Byllesby-Buck Impoundments

Continuous and discrete water quality data collected during the August 29, 2019 site visit (at Byllesby and Buck), 2020 study period (at Buck [and one location at Byllesby]), and 2021 study period (at Byllesby) indicated little to no thermal or DO stratification at the forebay monitoring locations. Water temperatures typically varied less than 0.5ºC from reservoir surface to bottom at Buck and less than 2.0ºC at Byllesby. DO concentrations typically varied less than 1.0 mg/l from reservoir surface to bottom at both developments. While the data sondes were not deployed until August 17, 2020 at Buck, water temperature and DO concentrations were typical of warmer summer conditions[15].

## 7.4 Need for Protection, Mitigation, and Enhancement Measures to Protect Water Quality

Water quality data collected during 2019–2021 at the Byllesby and Buck forebay areas, tailraces, and bypass reaches are consistent with applicable Virginia state water quality standards for

[15] Figure 7-3 of Attachment 7 provides a comparison of air temperature data at Fries and Ivanhoe, Virginia beginning approximately one month prior to (i.e., mid-July 2020) the water quality data sonde installation in mid-August 2020. Meteorological conditions in mid-August 2020 were similar to the prior month supporting the conclusion that water temperature and DO concentrations were typical of warmer summer conditions.

temperature, DO, and pH for Class IV (New River) surface waters with the exception of infrequent instantaneous surface water temperatures at the Byllesby upstream, forebay surface, and bypass reach monitoring locations as described in Section 7.1. And, while Byllesby forebay surface water temperatures tailrace water temperatures occasionally exceeded 29ºC, the maximum was 29.5ºC, and the Byllesby tailrace water temperatures remained below 29ºC. While there is no state standard for specific conductivity, concentrations less than 500 µS/cm are generally considered to be suitable for aquatic species in southern Appalachian streams (USEPA 2020).

Chlorophyll a grab samples collected at the Byllesby and Buck forebay monitoring locations all resulted in “non detect” readings indicating the chlorophyll a concentrations were less than 5.0 $mg/m^3$.

Maximum turbidity concentrations based on the grab sample data were 16.9 NTU and 8.0 NTU at the Byllesby and Buck forebay monitoring locations, respectively. The continuous turbidity monitoring study also yielded relatively low overall turbidity concentrations (typically < 12.0 NTU) and there were no discernible effects (i.e., increases in turbidity) resulting from station operations and maintenance activities such as routine intake structure drag rake operations.

Based on the results of this water quality study, and in consideration of results of other historic studies and data collection efforts, during the new license term Appalachian proposes to continue the existing run-of-river operating mode for the Project for the protection of water quality and other resources, and there is no need for additional PM&E measures to protect water quality at the Project.

## 7.5 Additional Future Water Quality Data Needs

Water quality data collected during 2019 – 2021 were consistent between years and with Virginia Class IV surface water criteria for water temperature, DO concentrations, and pH with the exception of infrequent instantaneous surface water temperatures as described in Section 7.1. As a result, additional future water quality data collection is not warranted based on a nexus to Project operations.

# 8 Variances from FERC-Approved Study Plan

The RSP included installation of two water quality data sondes at the Byllesby forebay monitoring location, one near the surface of the forebay and the other near the bottom. During installation, the depth of the forebay monitoring location was approximately 27 ft. Since one of the study objectives was to determine the extent (if any) of thermal and DO stratification in the Byllesby reservoir, Appalachian installed a third water quality data sonde at mid-depth to supplement data collected at the near surface and near bottom monitoring locations.

The Water Quality Study was otherwise conducted in accordance with the RSP, with approved schedule modifications as previously communicated to FERC and relicensing stakeholders and minor gaps in data collection due to field conditions or equipment malfunction beyond the control of Appalachian or HDR and typical for a data collection effort of this scale in a large river environment.

# 9 Germane Correspondence and Consultation

As required by the RSP, on September 22, 2021, Appalachian sent an email to state and federal agencies (VDEQ, Virginia Department of Wildlife Resources, and U.S. Fish and Wildlife Service) describing the one-week turbidity study planned to assess potential impacts that Project operations, in particular drake rake operations, have on turbidity concentration in the tailrace of the Project. A copy of this communication was included in the consultation documentation filed as part of the Draft License Application on October 1, 2021.

# 10 References

Appalachian Power Company (Appalachian). 2019. Pre-Application Document. Byllesby-Buck Hydroelectric Project. January 2019.

National Water Quality Monitoring Council (NWQMC). 2020. Water Quality Portal. Accessed January 2021. [URL]: https://www.waterqualitydata.us/portal/#countrycode=US&statecode=US%3A51&countycode=US%3A51%3A035&siteid=21VASWCB-9-NEW128.97&mimeType=csv.

Stantec Consulting Services Inc. (Stantec). 2016. Final Report: Claytor Hydroelectric Project FERC No. 739 Mussel Survey. Prepared for Appalachian Power Company. June 17, 2016.

U.S. Environmental Protection Agency (USEPA). 2020. National Rivers and Streams Assessment 2013-2014: A Collaborative Survey. December 2020. EPA 841-R-19-001. Washington, DC. Accessed January 2021. [URL]: https://www.epa.gov/national-aquatic-resource-surveys/nrsa.

Virginia Department of Environmental Quality (VDEQ). 2017. Water Program. Accessed September 2017. [URL]: https://www.deq.virginia.gov/water/water-quality/-fsiteid-1.

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# Attachment 1

## Attachment 1 – Byllesby Continuous Temperature and Dissolved Oxygen Plots

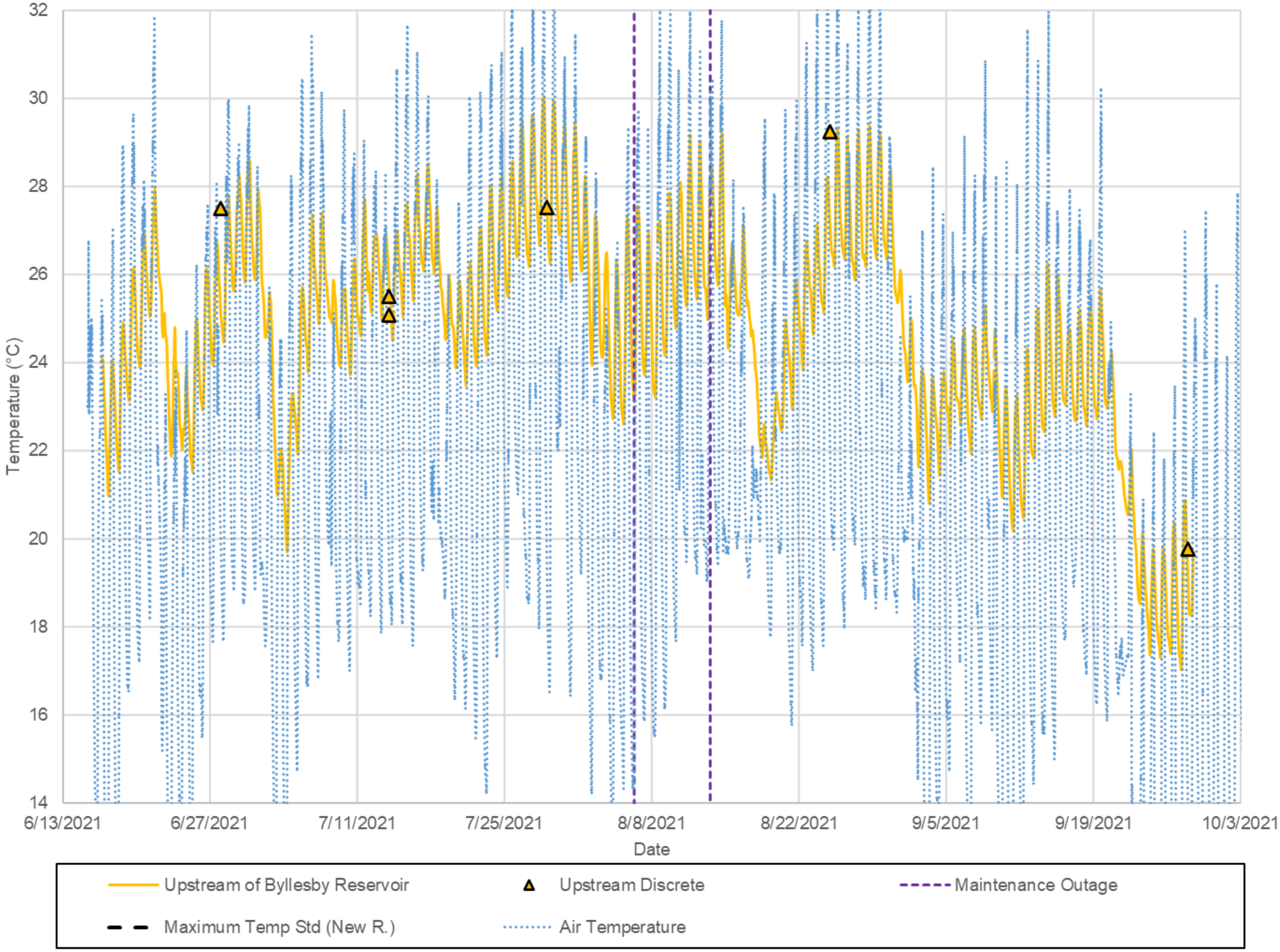


**Figure 1-1. Temperature Upstream of Byllesby Reservoir**

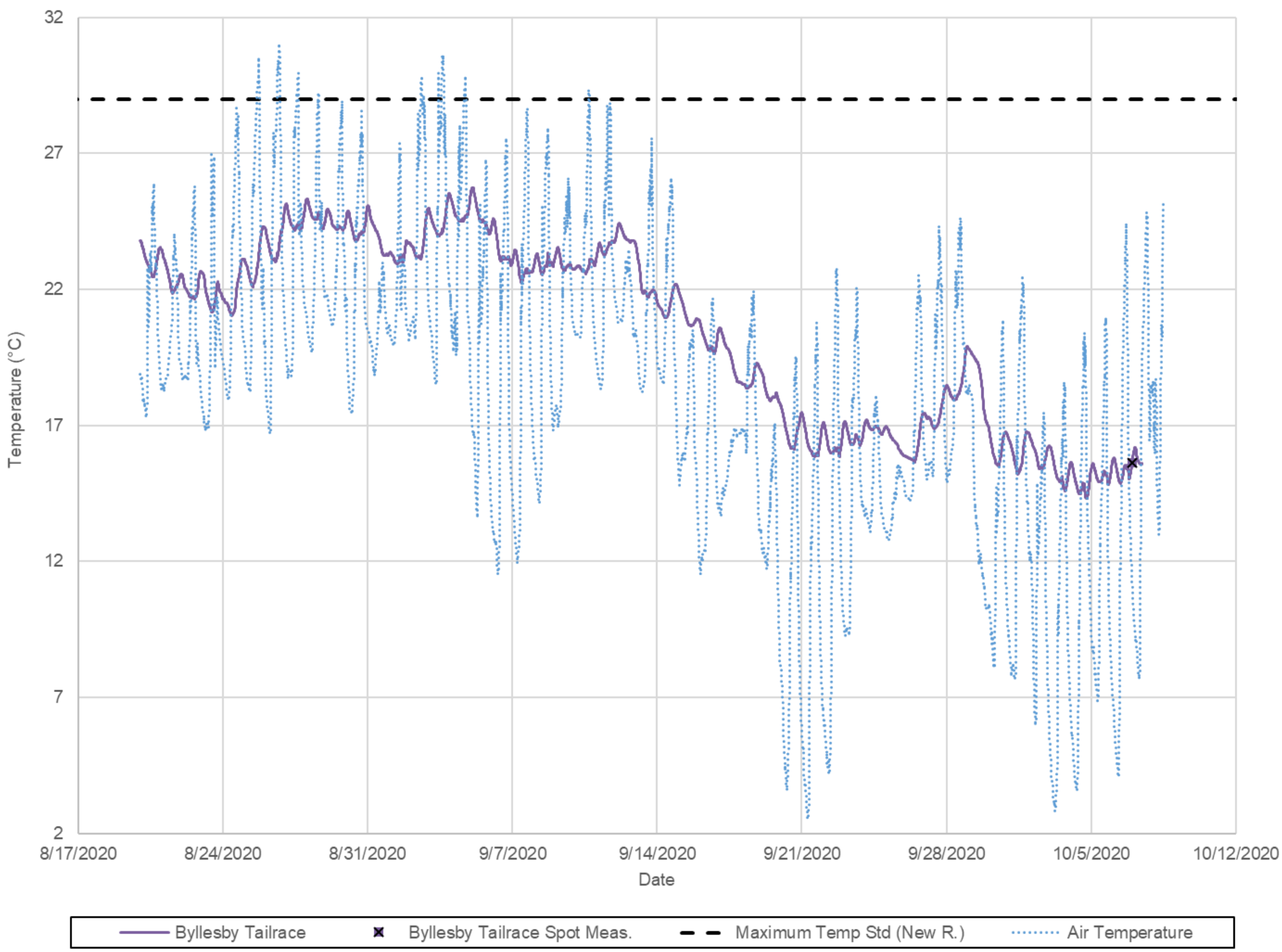


**Figure 1-2. Continuous and Discrete Temperature Measurements in the Byllesby Tailrace (2020)**

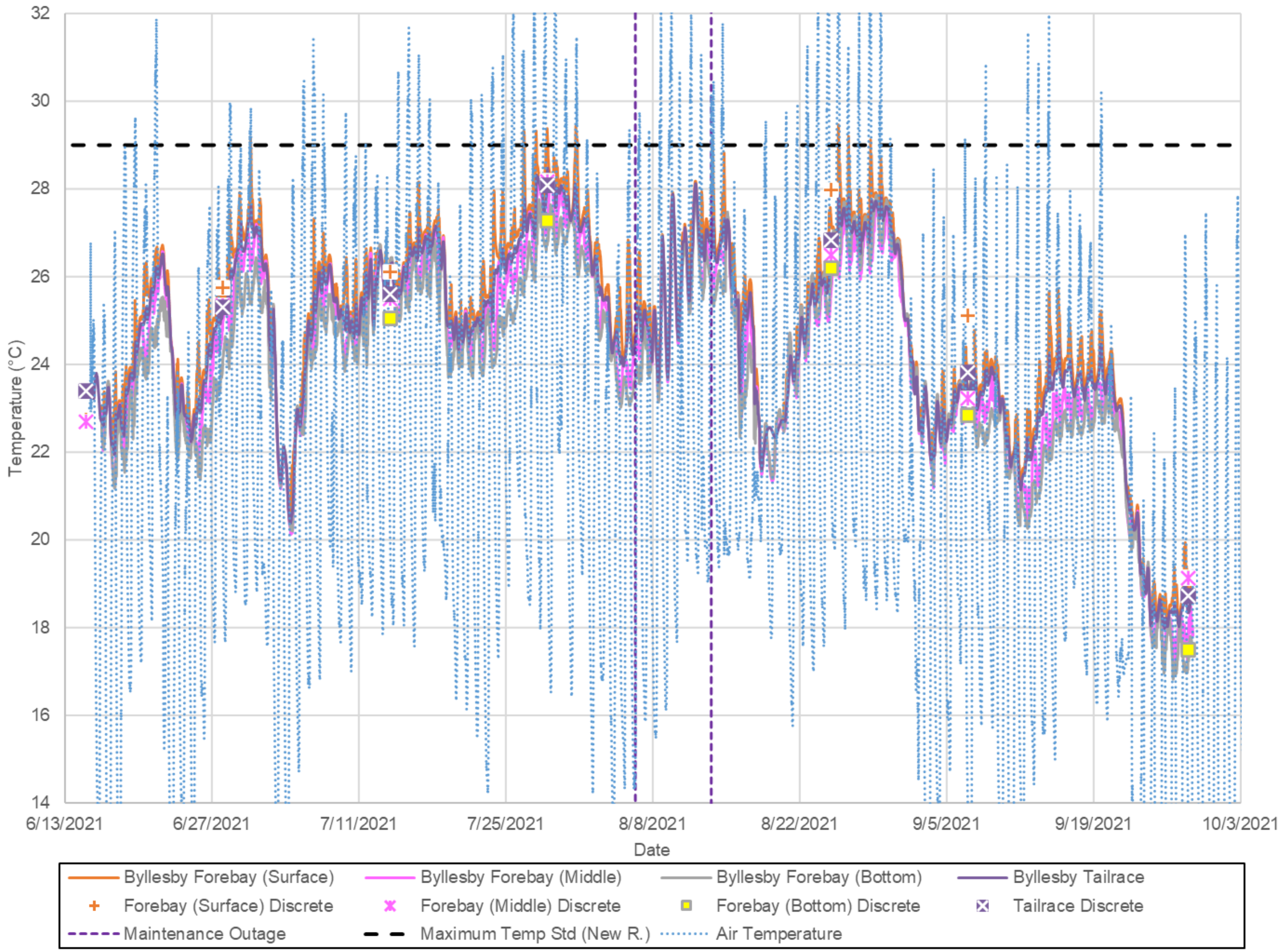


**Figure 1-3. Temperature in the Byllesby Forebay and Tailrace (2021)**

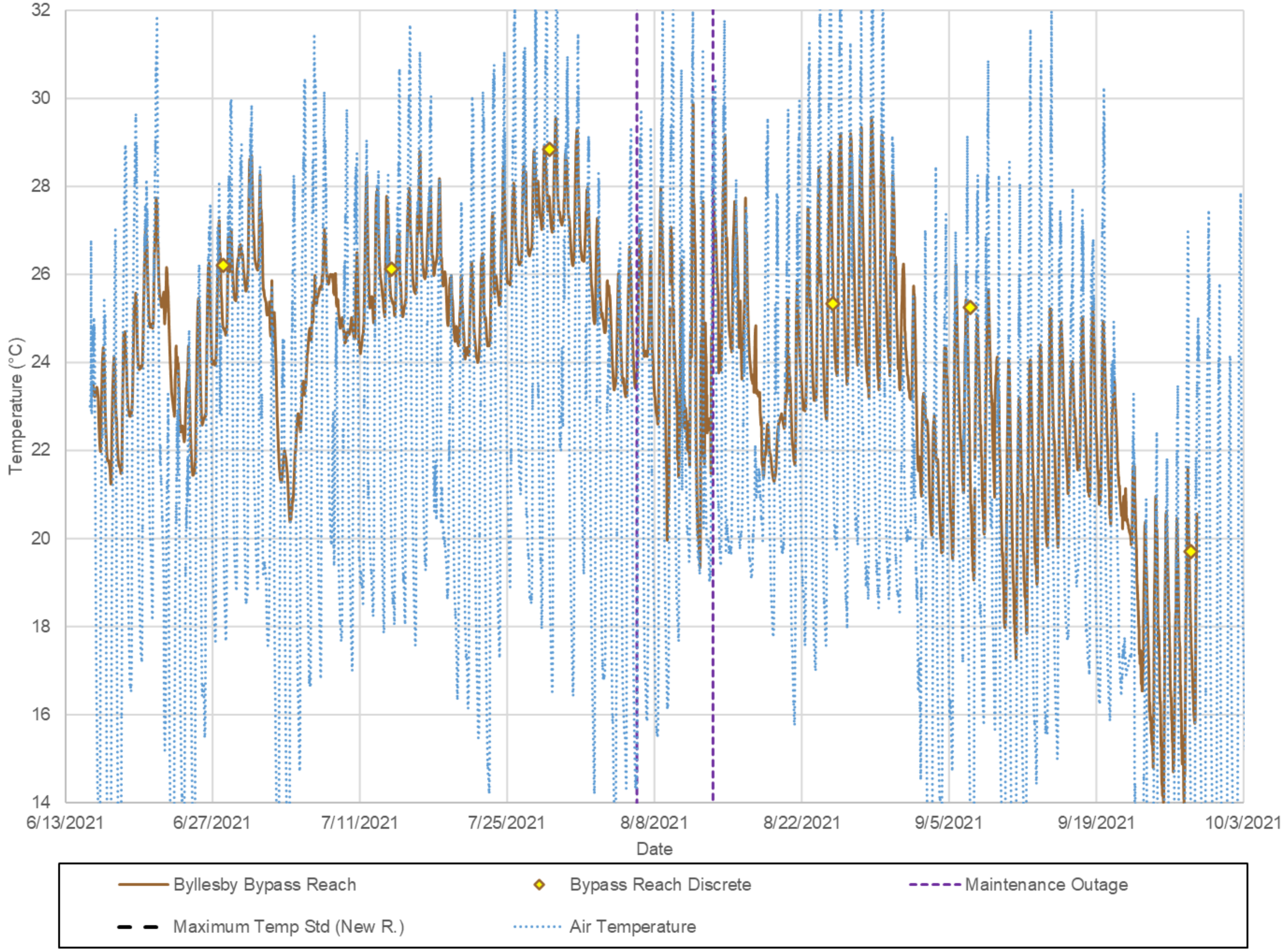


**Figure 1-4. Temperature in the Byllesby Bypass Reach**

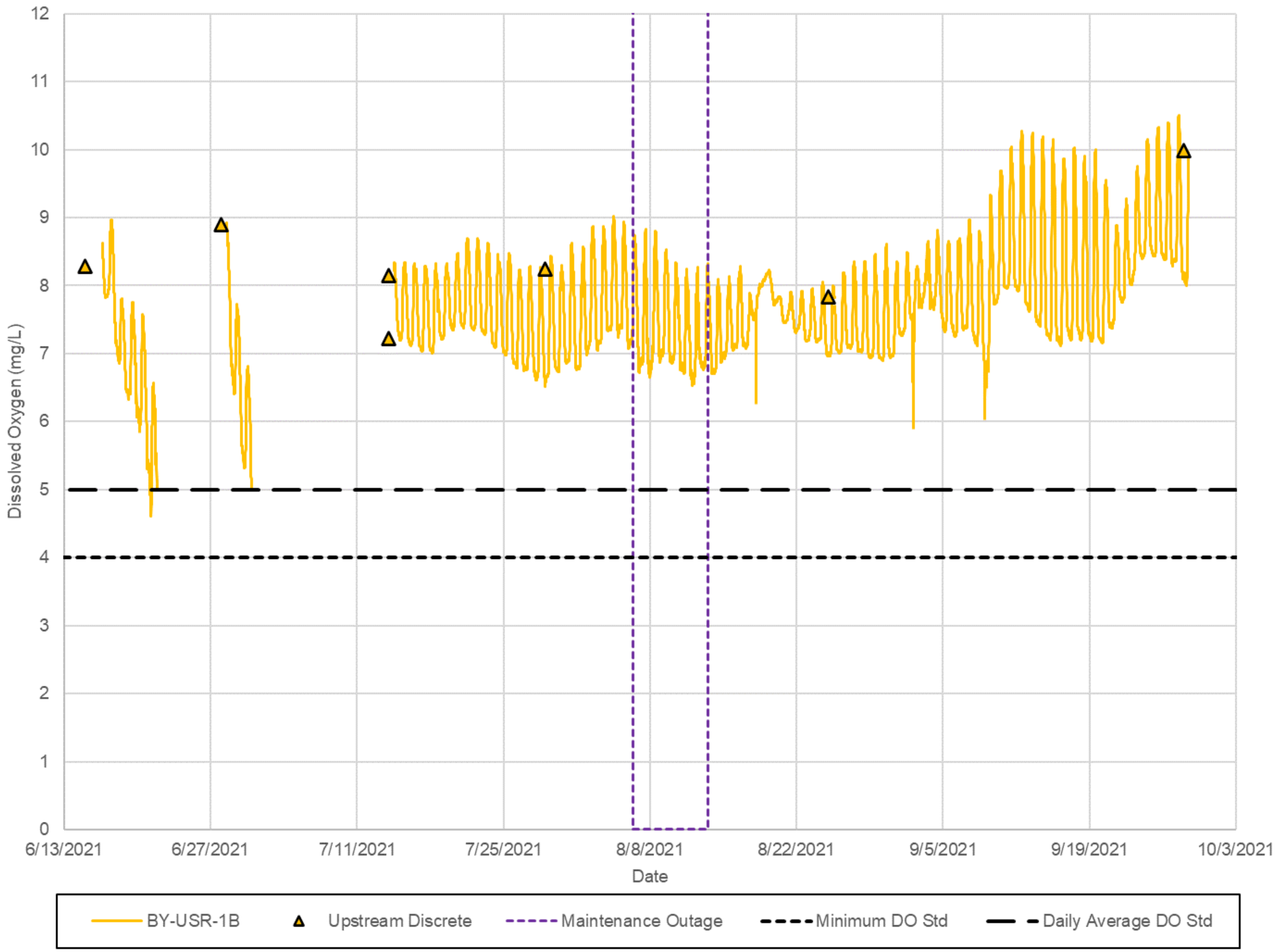


**Figure 1-5. Dissolved Oxygen in the Byllesby Upstream Reach**

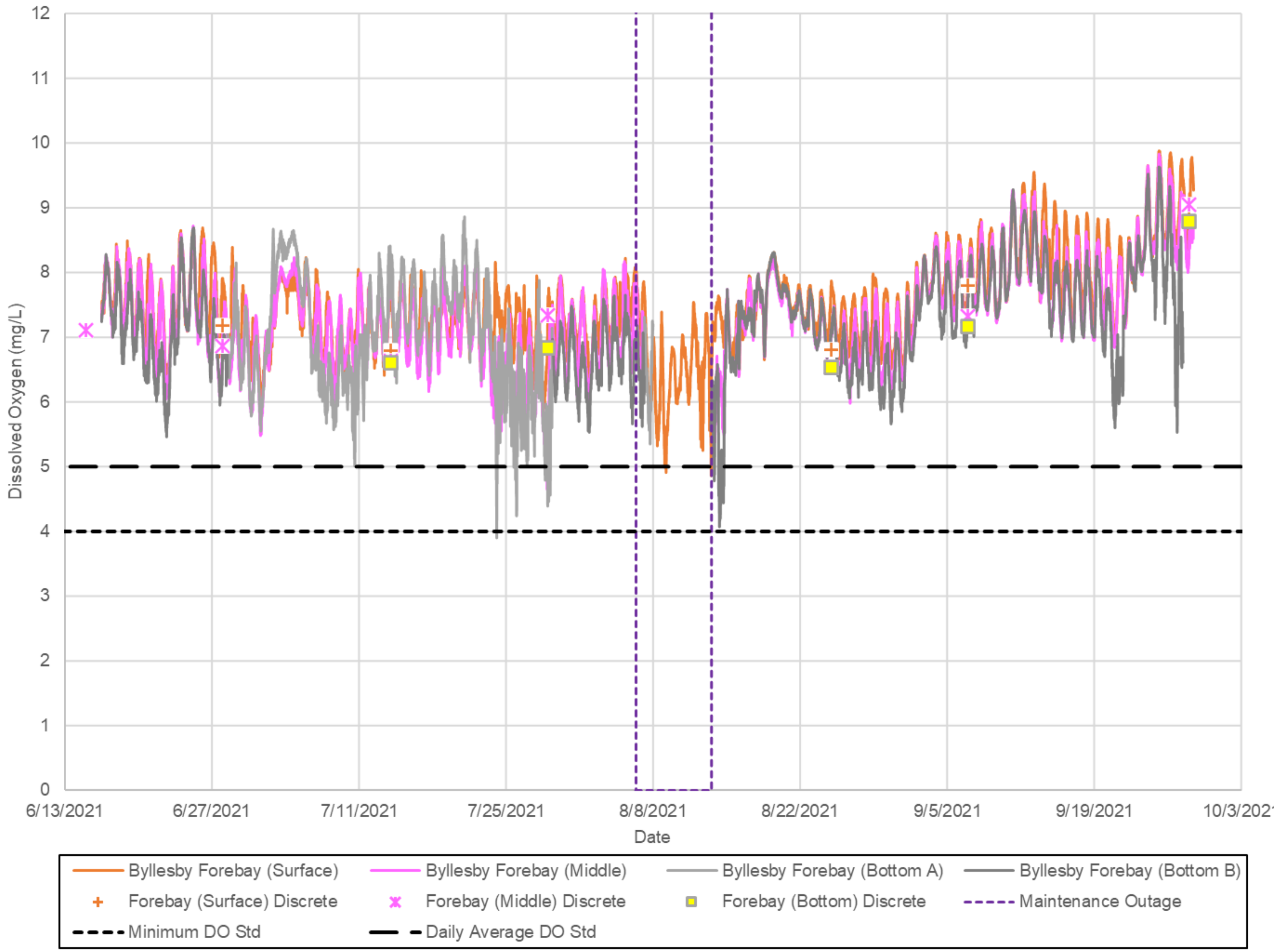


**Figure 1-6. Dissolved Oxygen in the Byllesby Forebay**

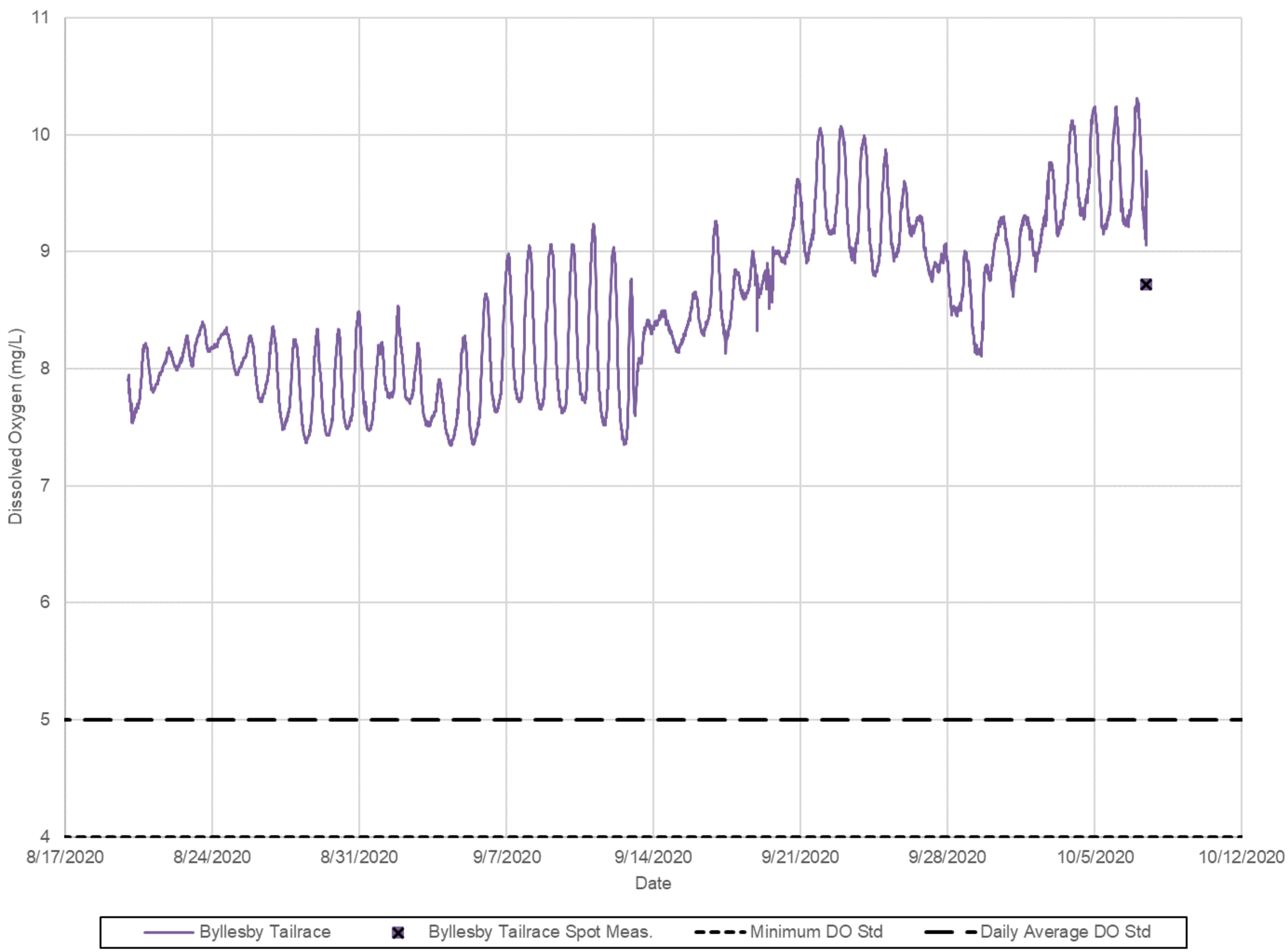


**Figure 1-7. Continuous and Discrete Dissolved Oxygen Concentrations in the Byllesby Tailrace (2020)**

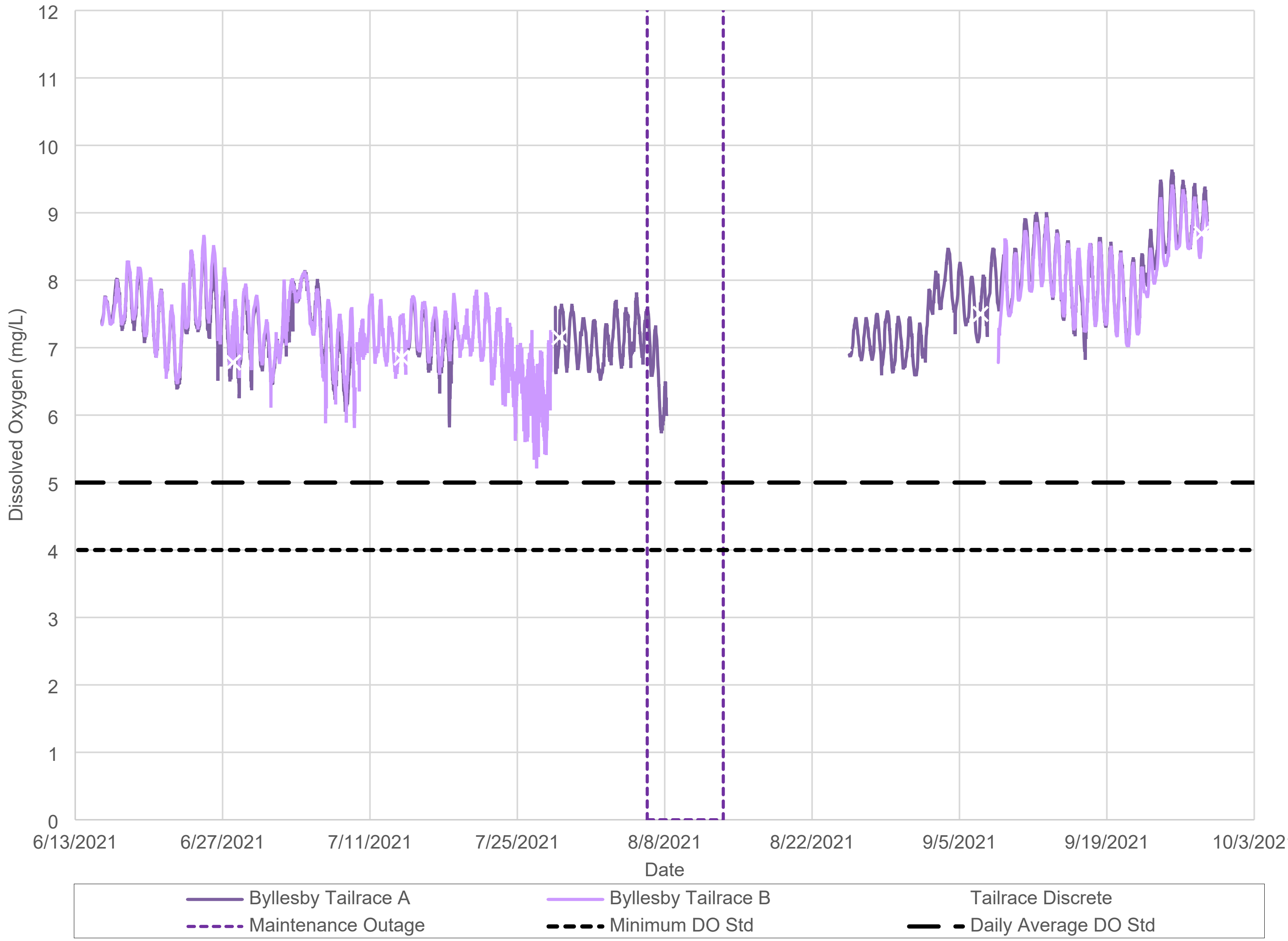


**Figure 1-8. Dissolved Oxygen in the Byllesby Tailrace (2021)**

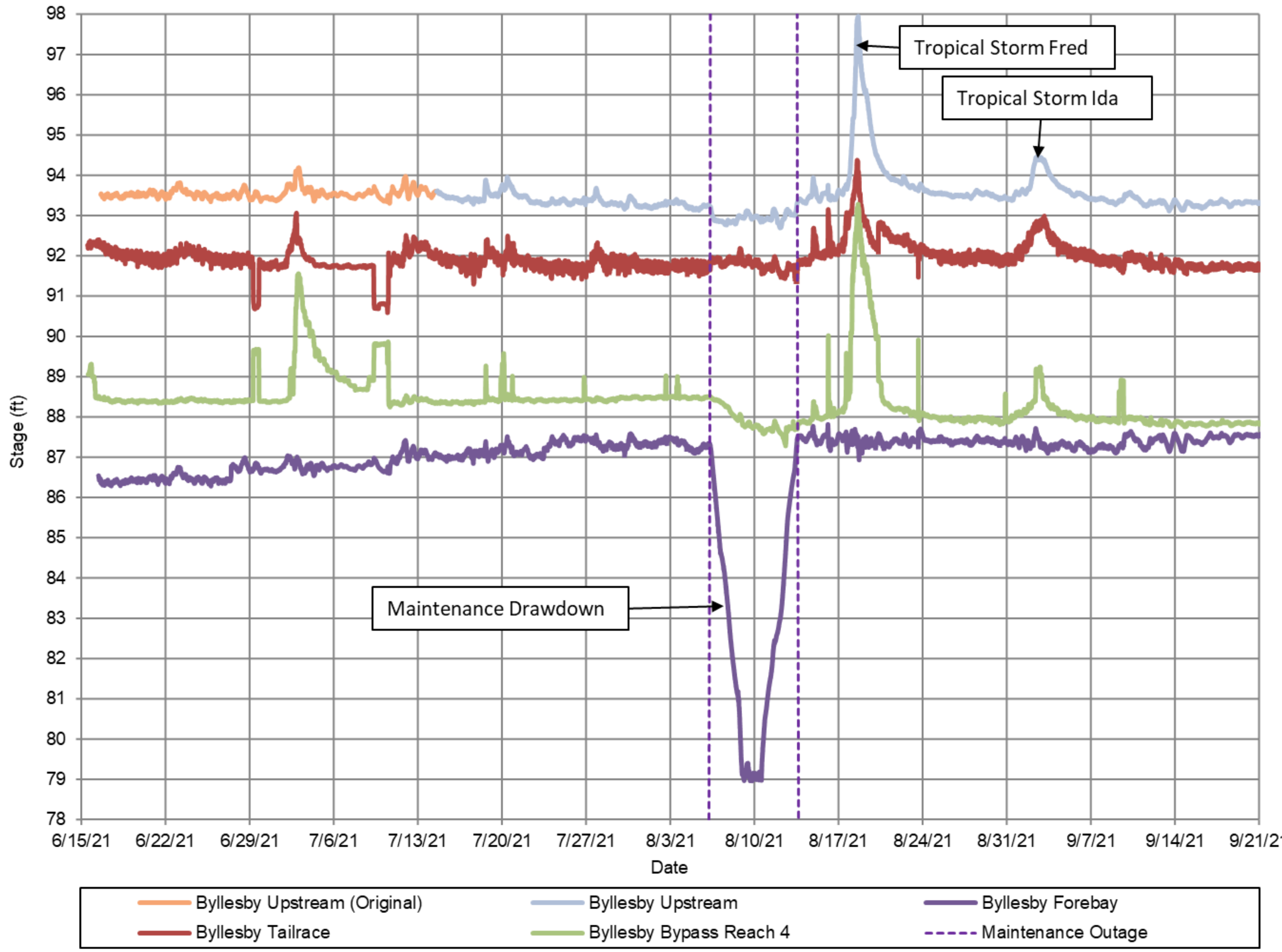


**Figure 1-9. Water Level Elevations (Level Logger Data)**

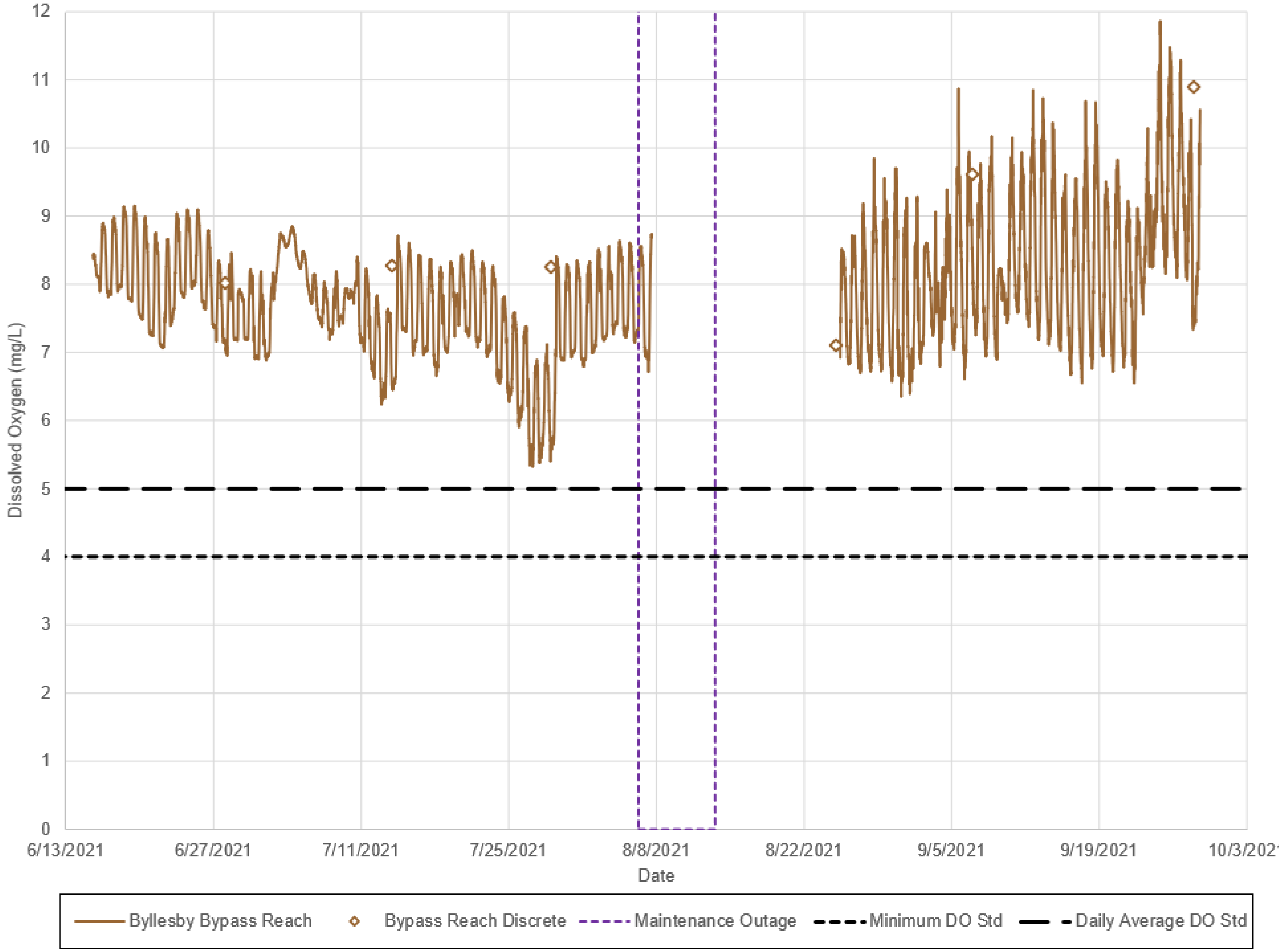


**Figure 1-9. Dissolved Oxygen in the Byllesby Bypass Reach**

# Attachment 2

## Attachment 2 – Buck Continuous Temperature and Dissolved Oxygen Plots

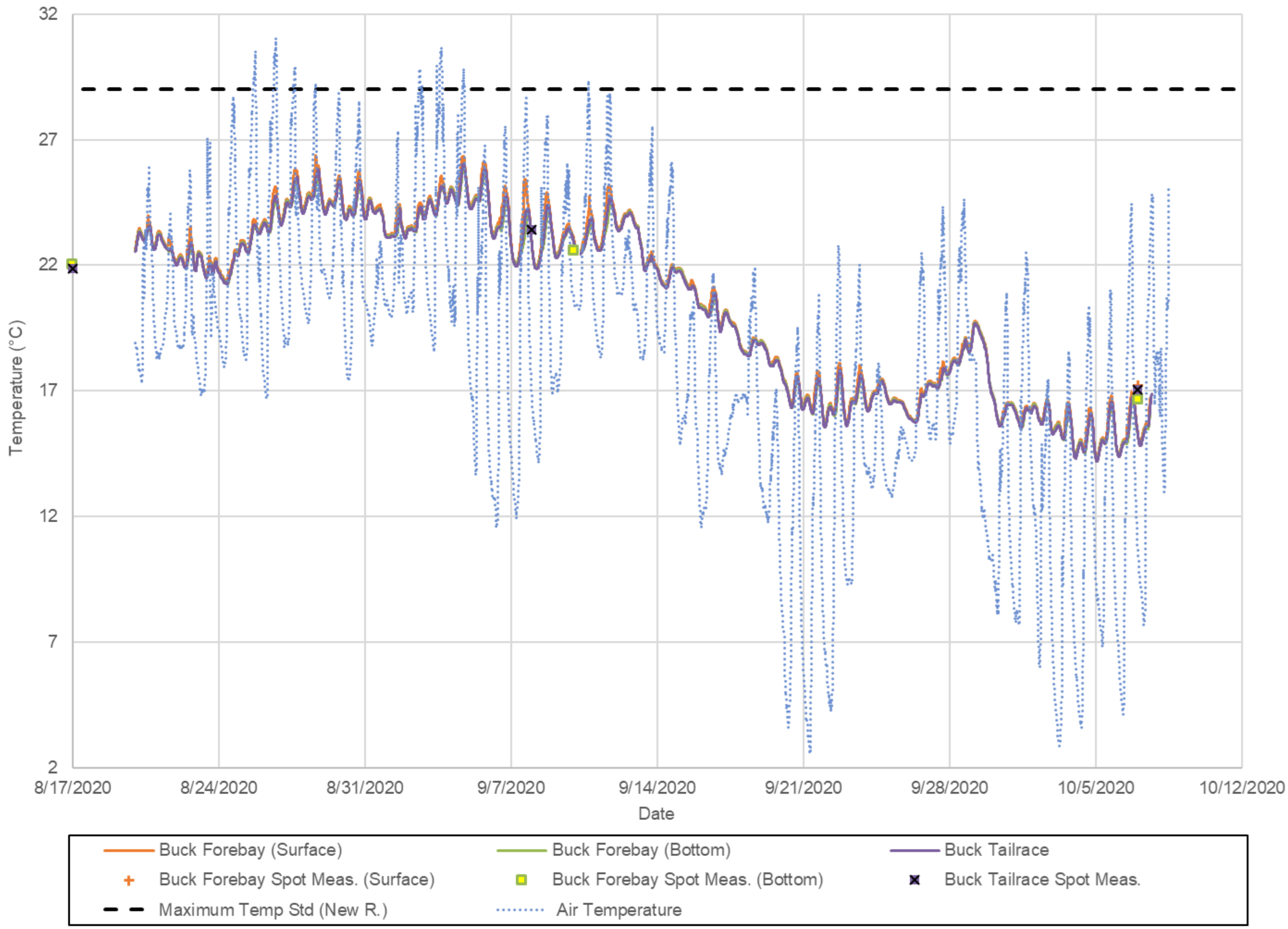


**Figure 2-1. Continuous and Discrete Temperature Measurements at Buck Forebay and Tailrace Water Quality Monitoring Locations**

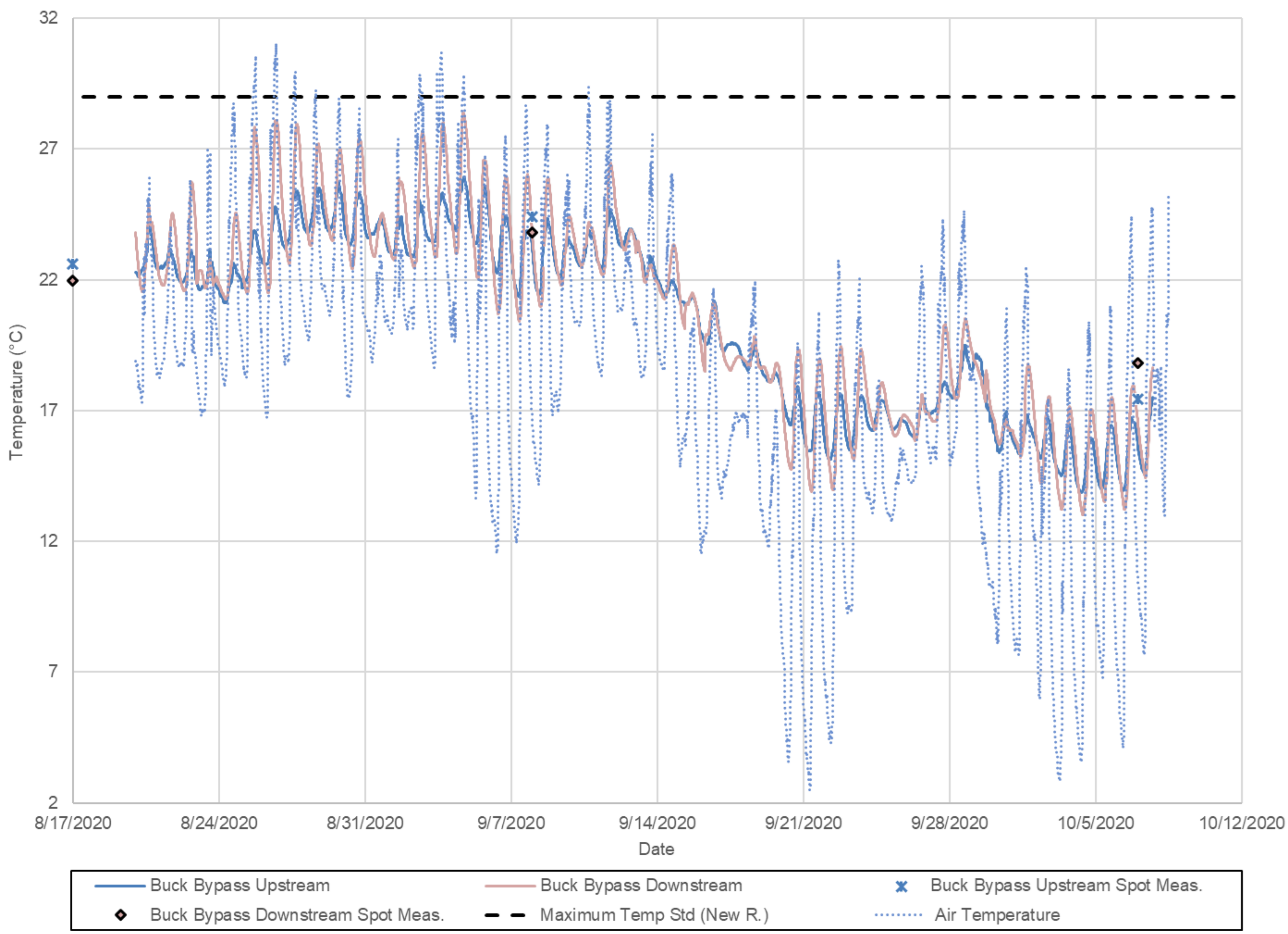


**Figure 2-2. Continuous and Discrete Temperature Measurements at Buck Bypass Reach Water Quality Monitoring Locations**

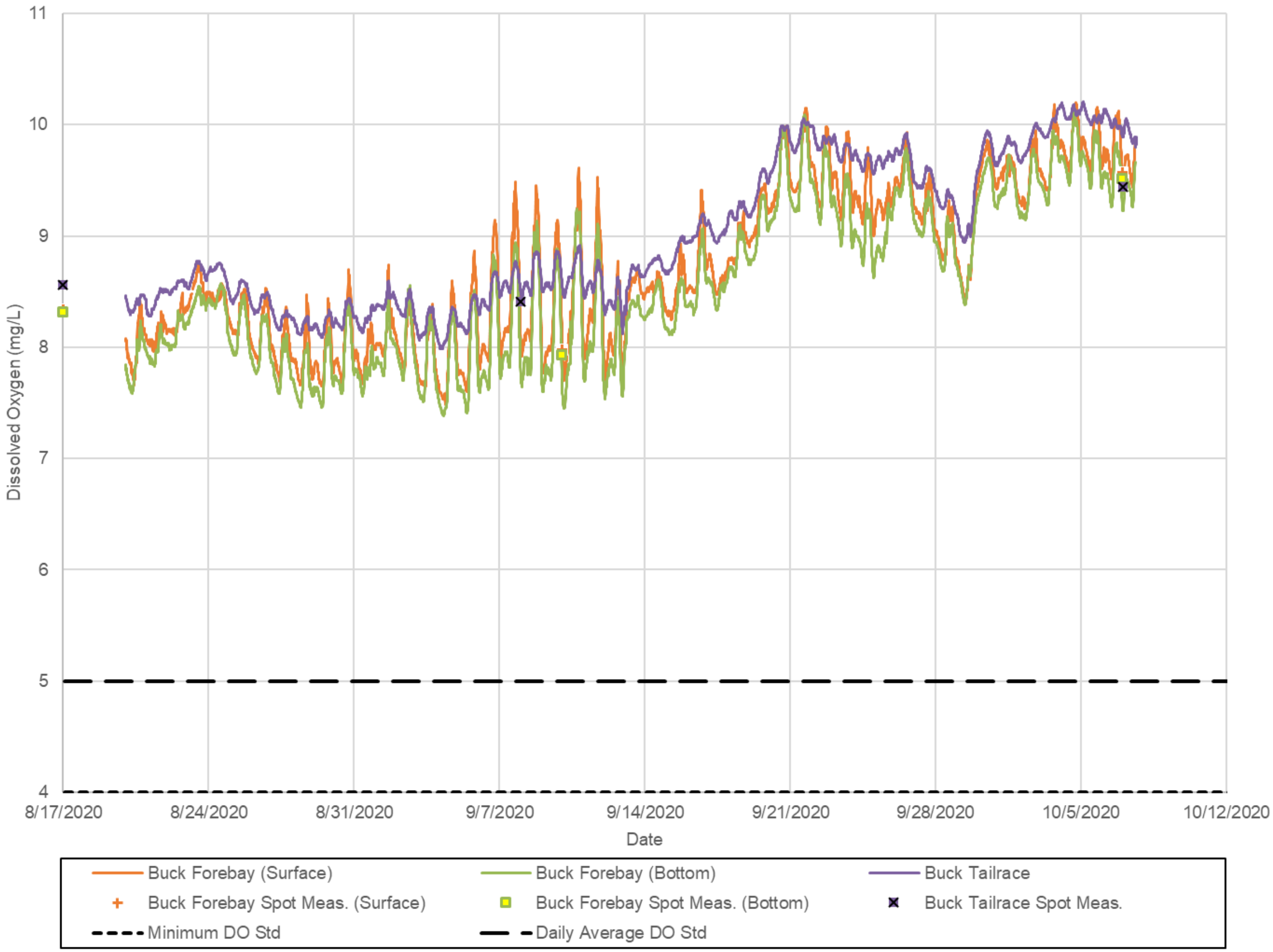


**Figure 2-3. Continuous and Discrete Dissolved Oxygen Concentrations at Buck Forebay and Tailrace Water Quality Monitoring Locations**

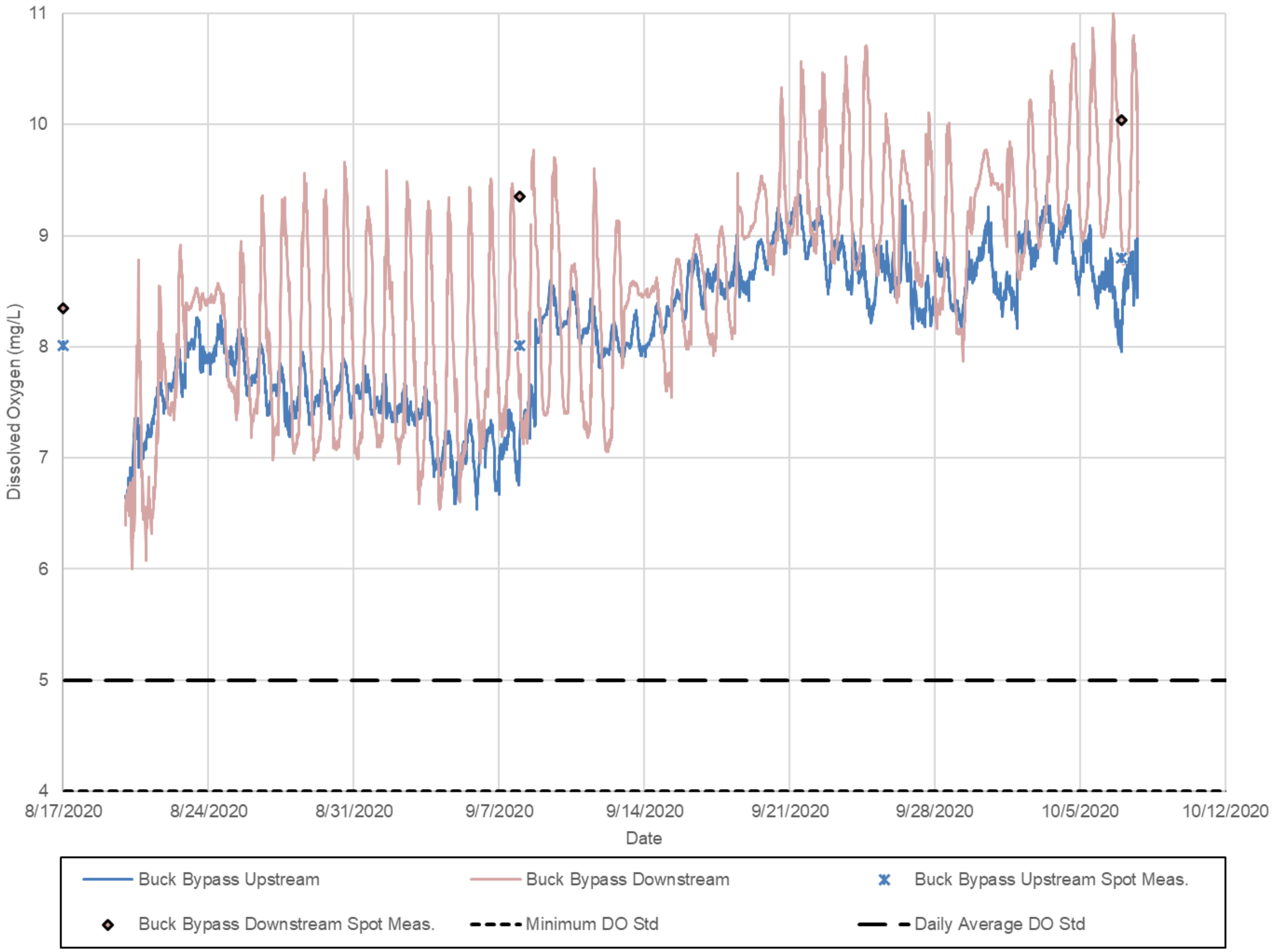


**Figure 2-4. Continuous and Discrete Dissolved Oxygen Concentrations at Buck Bypass Reach Water Quality Monitoring Locations**

# Attachment 3

Attachment 3 – Byllesby Discrete Measurement Tables

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## Table 3-1. Discrete Measurements at Byllesby Quality Monitoring Locations (2021)

| Location | Date | Temperature (°C) | Dissolved Oxygen (mg/l) | pH (Standard Units) | Specific Conductance (µS/cm) |
|---|---|---|---|---|---|
| Upstream of Reservoir | 6/15/2021 | 24.2 | 8.3 | 7.6 | 62 |
| | 6/28/2021 | 27.5 | 8.9 | 8.6 | 64 |
| | 7/14/2021 | 25.1 | 7.2 | 7.6 | 55 |
| | 7/14/2021 | 25.5 | 8.2 | 7.9 | 56 |
| | 7/29/2021 | 27.5 | 8.3 | 8.5 | 62 |
| | 8/25/2021 | 29.3 | 7.8 | 8.5 | 65 |
| | 9/28/2021 | 19.8 | 10.0 | 9.2 | 67 |
| Forebay (Surface) | 6/15/2021 | 22.7 | 7.1 | 7.1 | 62 |
| | 6/28/2021 | 25.7 | 7.2 | 8.7 | 66 |
| | 7/14/2021 | 26.1 | 6.8 | 7.0 | 59 |
| | 7/29/2021 | 28.2 | 7.3 | 8.4 | 68 |
| | 8/25/2021 | 28.0 | 6.8 | 7.2 | 66 |
| | 9/7/2021 | 25.1 | 7.8 | 7.3 | 65 |
| | 9/28/2021 | 19.2 | 9.0 | 8.9 | 69 |
| Forebay (Middle) | 6/15/2021 | 22.7 | 7.1 | 7.1 | 62 |
| | 6/28/2021 | 25.3 | 6.9 | 8.5 | 66 |
| | 7/14/2021 | 25.5 | 6.6 | 6.9 | 59 |
| | 7/29/2021 | 28.1 | 7.3 | 8.4 | 67 |
| | 8/25/2021 | 26.5 | 6.5 | 7.0 | 66 |
| | 9/7/2021 | 23.2 | 7.3 | 7.2 | 64 |
| | 9/28/2021 | 19.1 | 9.1 | 8.9 | 69 |
| Forebay (Bottom) | 7/14/2021 | 25.0 | 6.6 | 6.9 | 59 |
| | 7/29/2021 | 27.3 | 6.8 | 7.4 | 64 |
| | 8/25/2021 | 26.2 | 6.5 | 7.0 | 65 |
| | 9/7/2021 | 22.9 | 7.2 | 7.1 | 64 |
| | 9/28/2021 | 17.5 | 8.8 | 7.7 | 64 |
| Tailrace | 6/15/2021 | 23.4 | 7.1 | 6.9 | 60 |
| | 6/28/2021 | 25.3 | 6.8 | 7.0 | 66 |
| | 7/14/2021 | 25.6 | 6.9 | 7.1 | 62 |
| | 7/29/2021 | 28.1 | 7.2 | 7.8 | 67 |
| | 8/25/2021 | 26.8 | 6.9 | 7.2 | 65 |
| | 9/7/2021 | 23.8 | 7.5 | 7.3 | 65 |
| | 9/28/2021 | 18.7 | 8.7 | 8.8 | 68 |
| Bypass Reach | 6/15/2021 | 23.5 | 8.1 | 7.3 | 60 |
| | 6/28/2021 | 26.2 | 8.0 | 7.9 | 66 |
| | 7/14/2021 | 26.1 | 8.3 | 7.8 | 61 |
| | 7/29/2021 | 28.8 | 8.3 | 8.6 | 67 |

| Location | Date | Temperature (°C) | Dissolved Oxygen (mg/l) | pH (Standard Units) | Specific Conductance (µS/cm) |
|---|---|---|---|---|---|
| | 8/25/2021 | 25.3 | 7.1 | 7.0 | 65 |
| | 9/7/2021 | 25.3 | 9.6 | 8.4 | 64 |
| | 9/28/2021 | 19.7 | 10.9 | 8.9 | 67 |

## Table 3-2. Discrete Measurements at Byllesby Quality Monitoring Location (2020)

| Location | Date | Temperature (°C) | Dissolved Oxygen (mg/l) | pH (Standard Units) | Specific Conductance (µS/cm) |
|---|---|---|---|---|---|
| Tailrace | 10/7/2020 | 15.64 | 8.72 | 7.13 | 60.9 |

## Table 3-3. Byllesby Forebay Temperature Profile Data

| | Temperature (°C) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Depth** | **6/15/2021** | **6/28/2021** | **7/14/2021** | **7/29/2021** | **8/25/2021** | **9/7/2021** | **9/28/2021** |
| 1 | -- | -- | 26.1 | 28.2 | 28.0 | 25.1 | 19.2 |
| 2 | 22.7 | 25.7 | -- | -- | -- | -- | -- |
| 3 | -- | -- | 26.0 | 28.2 | 27.0 | 25.0 | 19.1 |
| 4 | 22.8 | 25.3 | -- | -- | -- | -- | -- |
| 5 | -- | -- | 25.6 | 28.2 | 27.1 | 24.3 | 19.1 |
| 6 | 22.9 | 25.3 | -- | -- | -- | -- | -- |
| 7 | -- | -- | 25.6 | 28.2 | 26.8 | 24.4 | 19.1 |
| 8 | 22.8 | 25.2 | -- | -- | -- | -- | -- |
| 9 | -- | -- | 25.7 | 28.2 | 26.9 | 23.4 | 19.1 |
| 10 | 22.7 | 25.0 | -- | -- | -- | -- | -- |
| 11 | -- | -- | 25.4 | 28.2 | 26.6 | 23.5 | 19.1 |
| 12 | 22.7 | 25.3 | -- | -- | -- | -- | -- |
| 13 | -- | -- | 25.5 | 28.2 | 26.5 | 23.2 | 19.1 |
| 14 | -- | 25.2 | -- | -- | -- | -- | -- |
| 15 | -- | -- | 25.5 | 28.2 | 26.6 | 23.0 | 19.1 |
| 17 | -- | -- | 25.2 | 28.1 | 26.5 | 22.9 | 18.6 |
| 19 | -- | -- | 25.2 | 28.0 | 26.5 | 22.8 | 17.7 |
| 21 | -- | -- | 25.2 | 27.8 | 26.3 | 22.8 | 17.6 |
| 23 | -- | -- | 25.1 | 27.5 | 26.3 | 22.8 | 17.5 |
| 25 | -- | -- | 25.0 | 27.3 | 26.2 | 22.9 | 17.5 |
| 26 | -- | -- | -- | 27.3 | -- | -- | -- |
| 27 | -- | -- | 25.1 | 27.3 | 26.0 | 22.8 | -- |

## Table 3-4. Byllesby Forebay Dissolved Oxygen Profile Data

| | Dissolved Oxygen (mg/l) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Depth** | **6/15/2021** | **6/28/2021** | **7/14/2021** | **7/29/2021** | **8/25/2021** | **9/7/2021** | **9/28/2021** |
| 1 | -- | -- | 6.8 | 7.3 | 6.8 | 7.8 | 9.0 |
| 2 | 7.1 | 7.2 | -- | -- | -- | -- | -- |
| 3 | -- | -- | 6.8 | 7.4 | 6.7 | 7.7 | 9.0 |
| 4 | 7.1 | 7.1 | -- | -- | -- | -- | -- |
| 5 | -- | -- | 6.7 | 7.4 | 6.8 | 7.5 | 9.0 |
| 6 | 7.0 | 7.0 | -- | -- | -- | -- | -- |
| 7 | -- | -- | 6.7 | 7.3 | 6.8 | 7.4 | 9.0 |
| 8 | 7.1 | 6.9 | -- | -- | -- | -- | -- |
| 9 | -- | -- | 6.7 | 7.3 | 6.7 | 7.4 | 9.1 |
| 10 | 7.1 | 6.8 | -- | -- | -- | -- | -- |
| 11 | -- | -- | 6.7 | 7.4 | 6.6 | 7.4 | 9.0 |
| 12 | 7.1 | 6.9 | -- | -- | -- | -- | -- |
| 13 | -- | -- | 6.6 | 7.3 | 6.5 | 7.3 | 9.1 |
| 14 | -- | 7.0 | -- | -- | -- | -- | -- |
| 15 | -- | -- | 6.7 | 7.3 | 6.7 | 7.3 | 9.1 |
| 17 | -- | -- | 6.7 | 7.4 | 6.7 | 7.3 | 9.0 |
| 19 | -- | -- | 6.6 | 7.2 | 6.7 | 7.3 | 8.7 |
| 21 | -- | -- | 6.6 | 7.0 | 6.6 | 7.3 | 8.8 |
| 23 | -- | -- | 6.6 | 6.9 | 6.6 | 7.2 | 8.8 |
| 25 | -- | -- | 6.6 | 6.8 | 6.5 | 7.2 | 8.8 |
| 26 | -- | -- | -- | 6.8 | -- | -- | -- |
| 27 | -- | -- | 6.6 | 6.8 | 6.5 | 7.2 | -- |

## Table 3-5. Byllesby Forebay pH Profile Data

| | pH (Standard Units) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Depth** | **6/15/2021** | **6/28/2021** | **7/14/2021** | **7/29/2021** | **8/25/2021** | **9/7/2021** | **9/28/2021** |
| 1 | -- | -- | 7.0 | 8.4 | 7.2 | 7.3 | 8.9 |
| 2 | 7.1 | 8.7 | -- | -- | -- | -- | -- |
| 3 | -- | -- | 6.9 | 8.4 | 7.2 | 7.3 | 8.8 |
| 4 | 7.1 | 8.6 | -- | -- | -- | -- | -- |
| 5 | -- | -- | 6.9 | 8.4 | 7.1 | 7.3 | 8.9 |
| 6 | 7.1 | 8.5 | -- | -- | -- | -- | -- |
| 7 | -- | -- | 6.9 | 8.4 | 7.1 | 7.2 | 8.9 |
| 8 | 7.1 | 8.5 | -- | -- | -- | -- | -- |
| 9 | -- | -- | 6.9 | 8.4 | 7.1 | 7.2 | 8.9 |
| 10 | 7.1 | 8.4 | -- | -- | -- | -- | -- |
| 11 | -- | -- | 6.9 | 8.4 | 7.1 | 7.2 | 8.9 |
| 12 | 7.1 | 8.5 | -- | -- | -- | -- | -- |
| 13 | -- | -- | 6.9 | 8.4 | 7.0 | 7.2 | 8.9 |
| 14 | -- | 8.6 | -- | -- | -- | -- | -- |
| 15 | -- | -- | 6.9 | 8.3 | 7.1 | 7.1 | 8.8 |
| 17 | -- | -- | 6.9 | 8.3 | 7.1 | 7.1 | 8.4 |
| 19 | -- | -- | 6.9 | 8.0 | 7.1 | 7.1 | 7.8 |
| 21 | -- | -- | 6.9 | 7.6 | 7.1 | 7.1 | 7.7 |
| 23 | -- | -- | 6.9 | 7.5 | 7.0 | 7.1 | 7.8 |
| 25 | -- | -- | 6.9 | 7.4 | 7.0 | 7.1 | 7.7 |
| 26 | -- | -- | -- | 7.3 | -- | -- | -- |
| 27 | -- | -- | 6.9 | 7.3 | 7.0 | 7.1 | -- |

## Table 3-6. Byllesby Forebay Specific Conductivity Profile Data

| | Specific Conductance (µS/cm) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Depth** | **6/15/2021** | **6/28/2021** | **7/14/2021** | **7/29/2021** | **8/25/2021** | **9/7/2021** | **9/28/2021** |
| 1 | -- | -- | 59 | 68 | 66 | 65 | 69 |
| 2 | 62 | 66 | -- | -- | -- | -- | -- |
| 3 | -- | -- | 59 | 68 | 65 | 65 | 69 |
| 4 | 62 | 66 | -- | -- | -- | -- | -- |
| 5 | -- | -- | 58 | 68 | 65 | 65 | 69 |
| 6 | 62 | 66 | -- | -- | -- | -- | -- |
| 7 | -- | -- | 59 | 67 | 65 | 65 | 69 |
| 8 | 62 | 66 | -- | -- | -- | -- | -- |
| 9 | -- | -- | 58 | 67 | 65 | 65 | 69 |
| 10 | 62 | 66 | -- | -- | -- | -- | -- |
| 11 | -- | -- | 59 | 68 | 65 | 64 | 69 |
| 12 | 62 | 66 | -- | -- | -- | -- | -- |
| 13 | -- | -- | 59 | 67 | 66 | 64 | 69 |
| 14 | -- | 66 | -- | -- | -- | -- | -- |
| 15 | -- | -- | 58 | 67 | 65 | 64 | 68 |
| 17 | -- | -- | 59 | 67 | 65 | 64 | 67 |
| 19 | -- | -- | 58 | 67 | 65 | 64 | 65 |
| 21 | -- | -- | 59 | 66 | 65 | 64 | 65 |
| 23 | -- | -- | 59 | 65 | 65 | 64 | 64 |
| 25 | -- | -- | 59 | 64 | 65 | 64 | 64 |
| 26 | -- | -- | -- | 64 | -- | -- | -- |
| 27 | -- | -- | 59 | 64 | 64 | 64 | -- |

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# Attachment 4

## Attachment 4 – Buck Discrete Measurement Tables

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## Table 4-1. Discrete Measurements at Buck Quality Monitoring Locations

| Location | Date | Temperature (°C) | Dissolved Oxygen (mg/l) | pH (Standard Units) | Specific Conductance (μS/cm) |
|---|---|---|---|---|---|
| Forebay (Surface) | 8/17/2020 | 22.1 | 8.3 | 7.3 | 53 |
| | 9/10/2020 | 22.6 | 8.0 | 7.7 | 61 |
| | 10/7/2020 | 17.2 | 9.6 | 7.7 | 61 |
| Forebay (Bottom) | 8/17/2020 | 22.0 | 8.3 | 7.3 | 53 |
| | 9/10/2020 | 22.6 | 7.9 | 7.6 | 61 |
| | 10/7/2020 | 16.7 | 9.5 | 7.6 | 61 |
| Tailrace | 8/17/2020 | 21.9 | 8.6 | 7.3 | 52 |
| | 9/8/2020 | 23.4 | 8.4 | 8.3 | 61 |
| | 10/7/2020 | 17.0 | 9.4 | 7.6 | 60 |
| Bypass Reach Upstream | 8/17/2020 | 22.6 | 8.0 | 7.2 | 57 |
| | 9/8/2020 | 24.4 | 8.0 | 7.3 | 62 |
| | 10/7/2020 | 17.4 | 8.8 | 7.6 | 61 |
| Bypass Reach Downstream | 8/17/2020 | 22.0 | 8.4 | 7.2 | 51 |
| | 9/8/2020 | 23.8 | 9.4 | 8.2 | 62 |
| | 10/7/2020 | 18.8 | 10.0 | 8.9 | 59 |

## Table 4-2. Buck Forebay Profile Data

| | Temperature (°C) | | | Dissolved Oxygen (mg/l) | | | pH (Standard Units) | | | Specific Conductance (µS/cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Depth** | **8/17/2020** | **9/10/2020** | **10/7/2020** | **8/17/2020** | **9/10/2020** | **10/7/2020** | **8/17/2020** | **9/10/2020** | **10/7/2020** | **8/17/2020** | **9/10/2020** | **10/7/2020** |
| 1 | -- | 22.6 | 17.3 | -- | 8.0 | 9.6 | -- | 7.6 | 7.7 | -- | 61 | 61 |
| 2 | 22.1 | 22.6 | 17.2 | 8.3 | 8.0 | 9.6 | 7.3 | 7.7 | 7.7 | 53 | 61 | 61 |
| 3 | -- | 22.6 | 17.1 | -- | 8.0 | 9.6 | -- | 7.7 | 7.7 | -- | 61 | 61 |
| 4 | 22.0 | 22.6 | 17.1 | 8.3 | 8.0 | 9.6 | 7.3 | 7.7 | 7.7 | 53 | 61 | 61 |
| 5 | -- | 22.6 | 16.9 | -- | 8.0 | 9.5 | -- | 7.6 | 7.7 | -- | 61 | 61 |
| 6 | 22.0 | 22.6 | 17.0 | 8.3 | 8.0 | 9.6 | 7.3 | 7.7 | 7.7 | 53 | 61 | 61 |
| 7 | -- | 22.6 | 16.9 | -- | 8.0 | 9.6 | -- | 7.6 | 7.7 | -- | 61 | 61 |
| 8 | 22.0 | 22.6 | 16.7 | 8.3 | 8.0 | 9.6 | 7.3 | 7.6 | 7.7 | 53 | 61 | 61 |
| 9 | -- | 22.6 | 16.7 | -- | 8.0 | 9.5 | -- | 7.6 | 7.7 | -- | 61 | 61 |
| 10 | 22.0 | 22.6 | 16.7 | 8.3 | 7.9 | 9.5 | 7.3 | 7.6 | 7.6 | 53 | 61 | 61 |
| 11 | -- | 22.6 | 16.6 | -- | 8.0 | 9.6 | -- | 7.6 | 7.6 | -- | 61 | 60 |
| 12 | -- | 22.6 | 16.6 | -- | 7.9 | 9.5 | -- | 7.5 | 7.6 | -- | 61 | 61 |
| 13 | -- | 22.6 | 16.6 | -- | 7.9 | 9.5 | -- | 7.5 | 7.6 | -- | 61 | 60 |
| 13.5 | -- | -- | 16.6 | -- | -- | 9.5 | -- | | 7.6 | -- | -- | 61 |
| 14 | -- | 22.6 | -- | -- | 7.9 | -- | -- | 7.5 | -- | -- | 61 | -- |
| 15 | -- | 22.6 | -- | -- | 7.9 | -- | -- | 7.5 | -- | -- | 61 | -- |
| 15.5 | -- | 22.6 | -- | -- | 7.9 | -- | -- | 7.5 | -- | -- | 61 | -- |

# Attachment 5

Attachment 5 – Byllesby Water Quality Vertical Profile Figures

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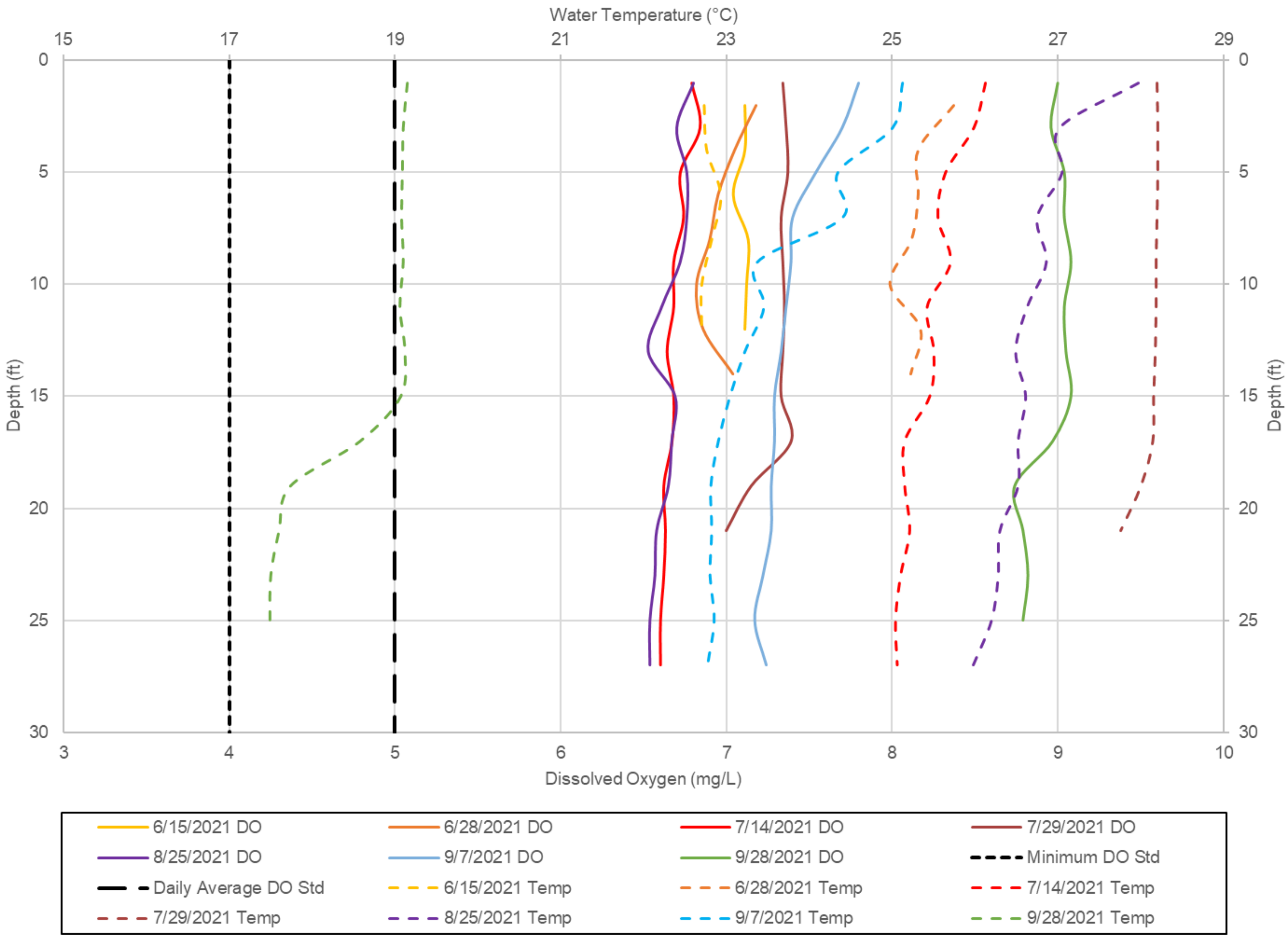


**Figure 5-1. Forebay Vertical Profile —Temperature and Dissolved Oxygen Concentration**

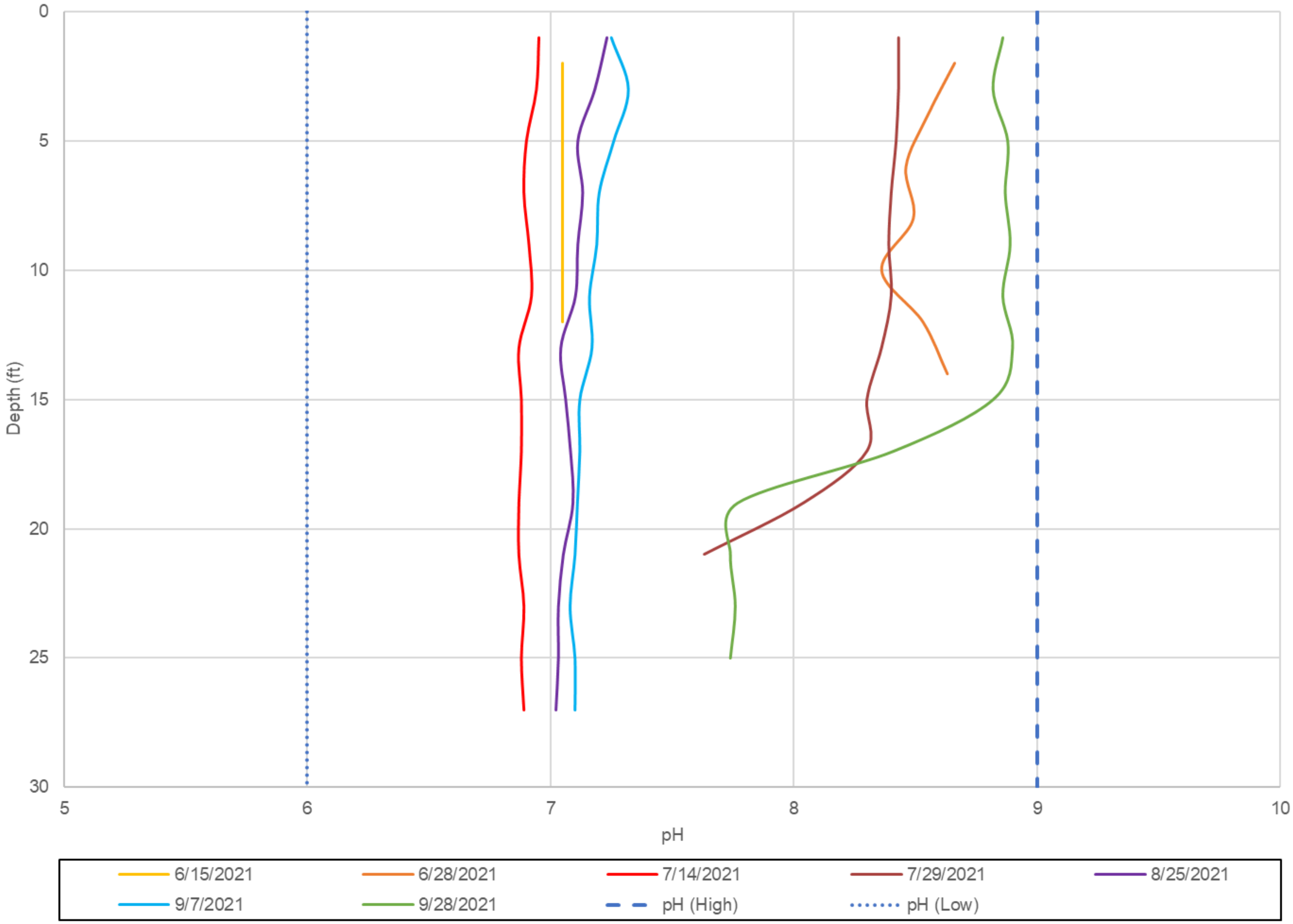


**Figure 5-2. Forebay Vertical Profile —pH Profile**

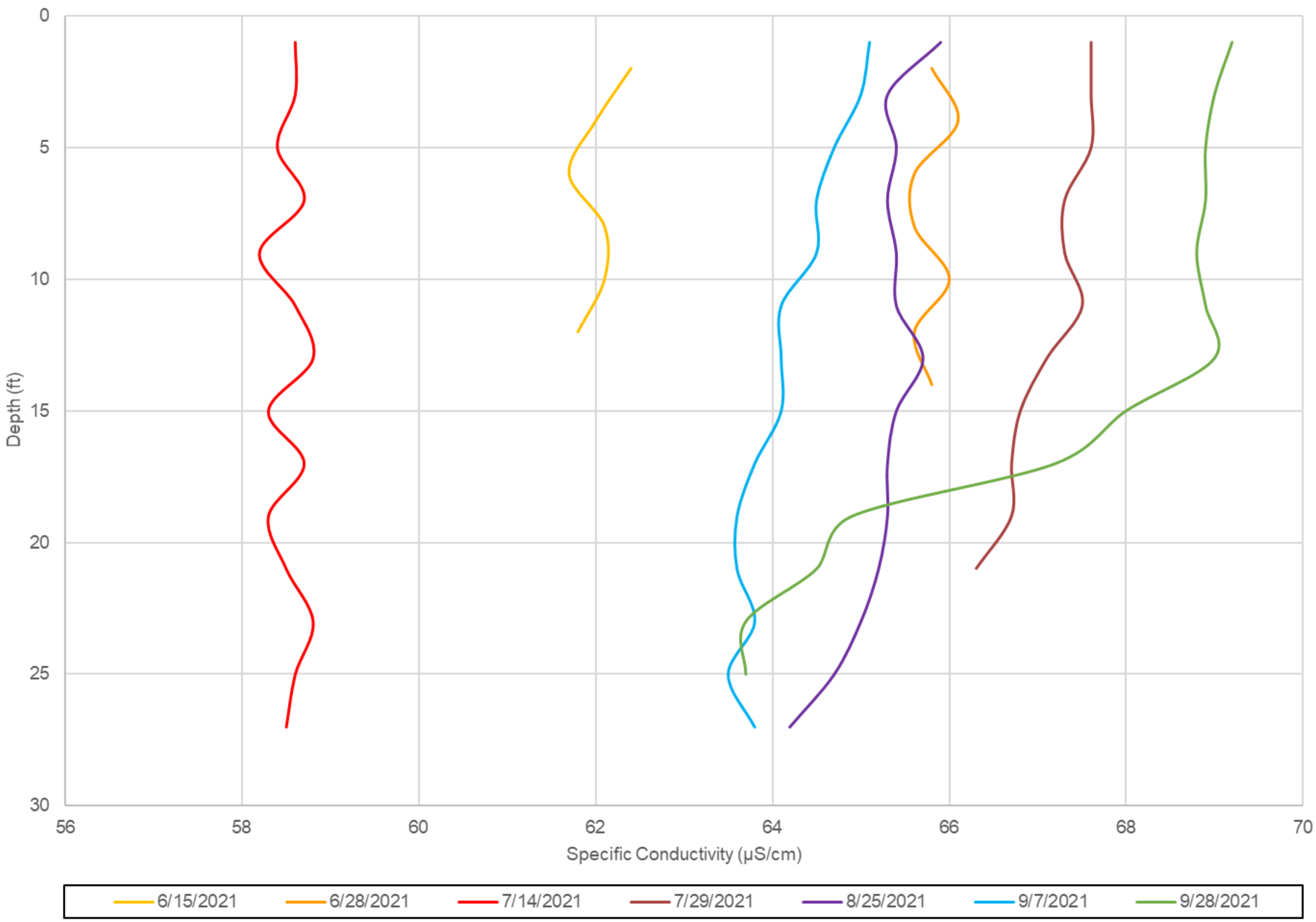


**Figure 5-3. Forebay Vertical Profile —Specific Conductivity Profile**

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# Attachment 6

## Attachment 6 – Buck Water Quality Vertical Profile Figures

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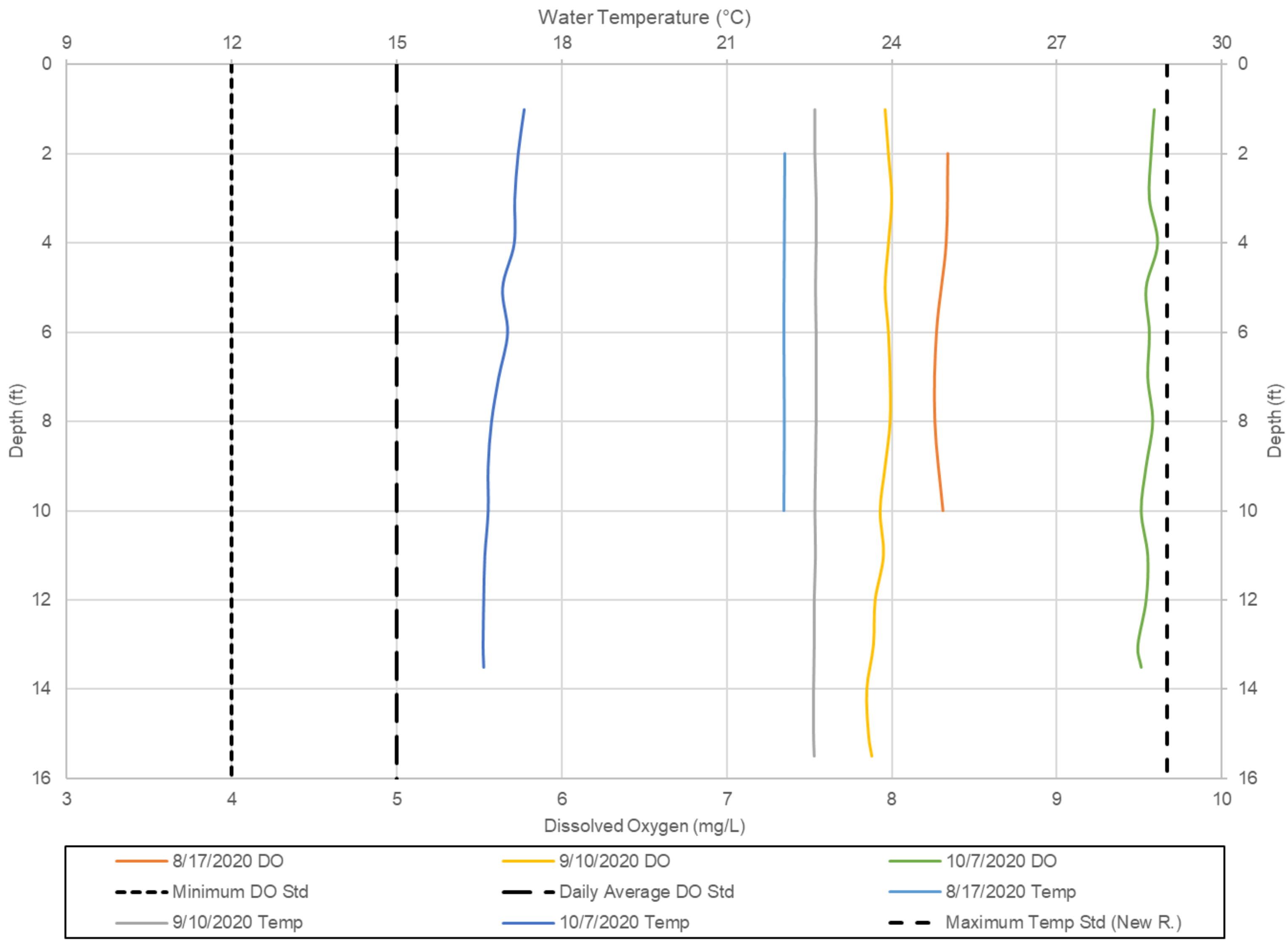


**Figure 6-1. Forebay Vertical Profile —Temperature and Dissolved Oxygen Concentration**

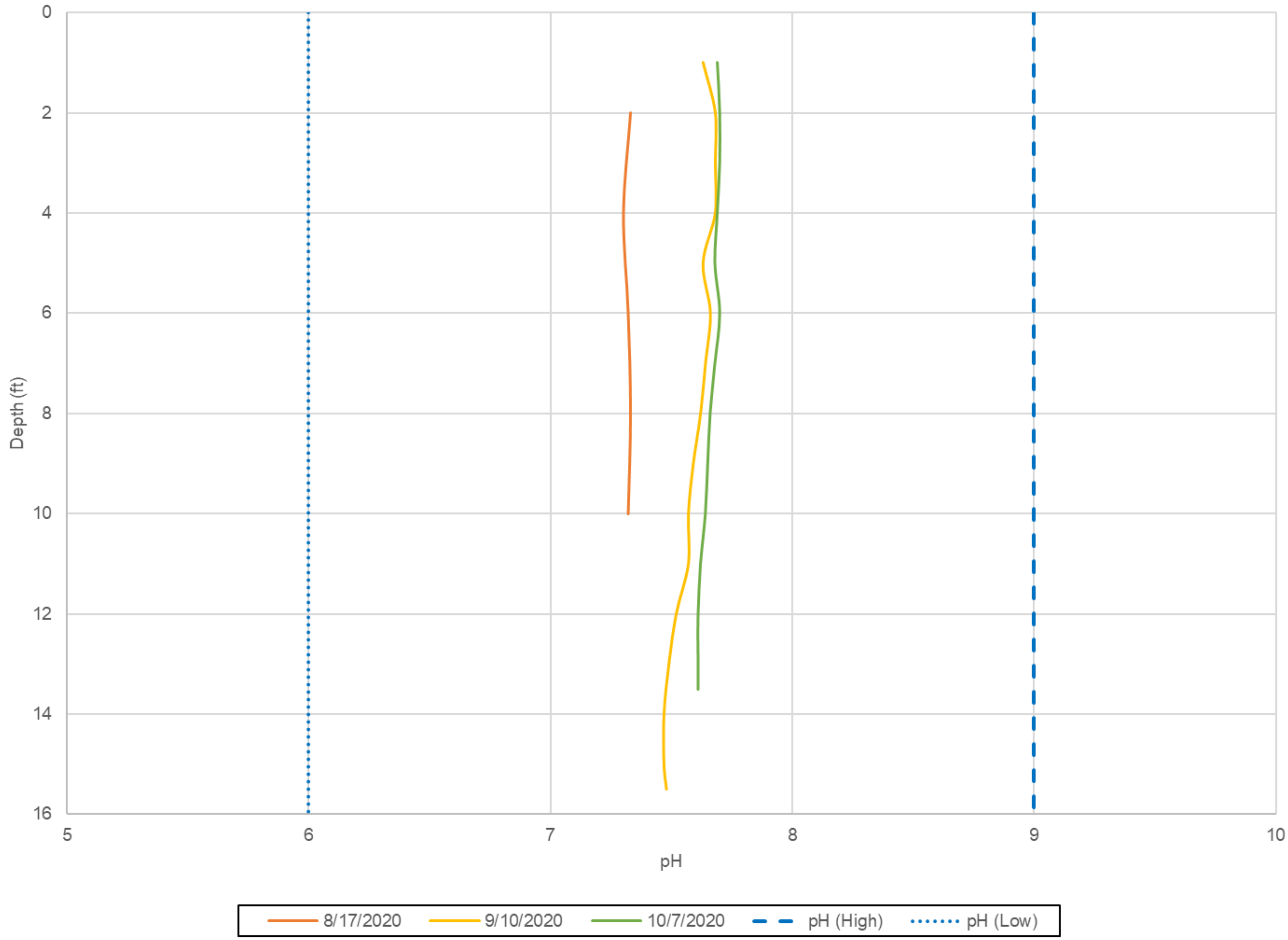


**Figure 6-2. Forebay Vertical Profile — pH**

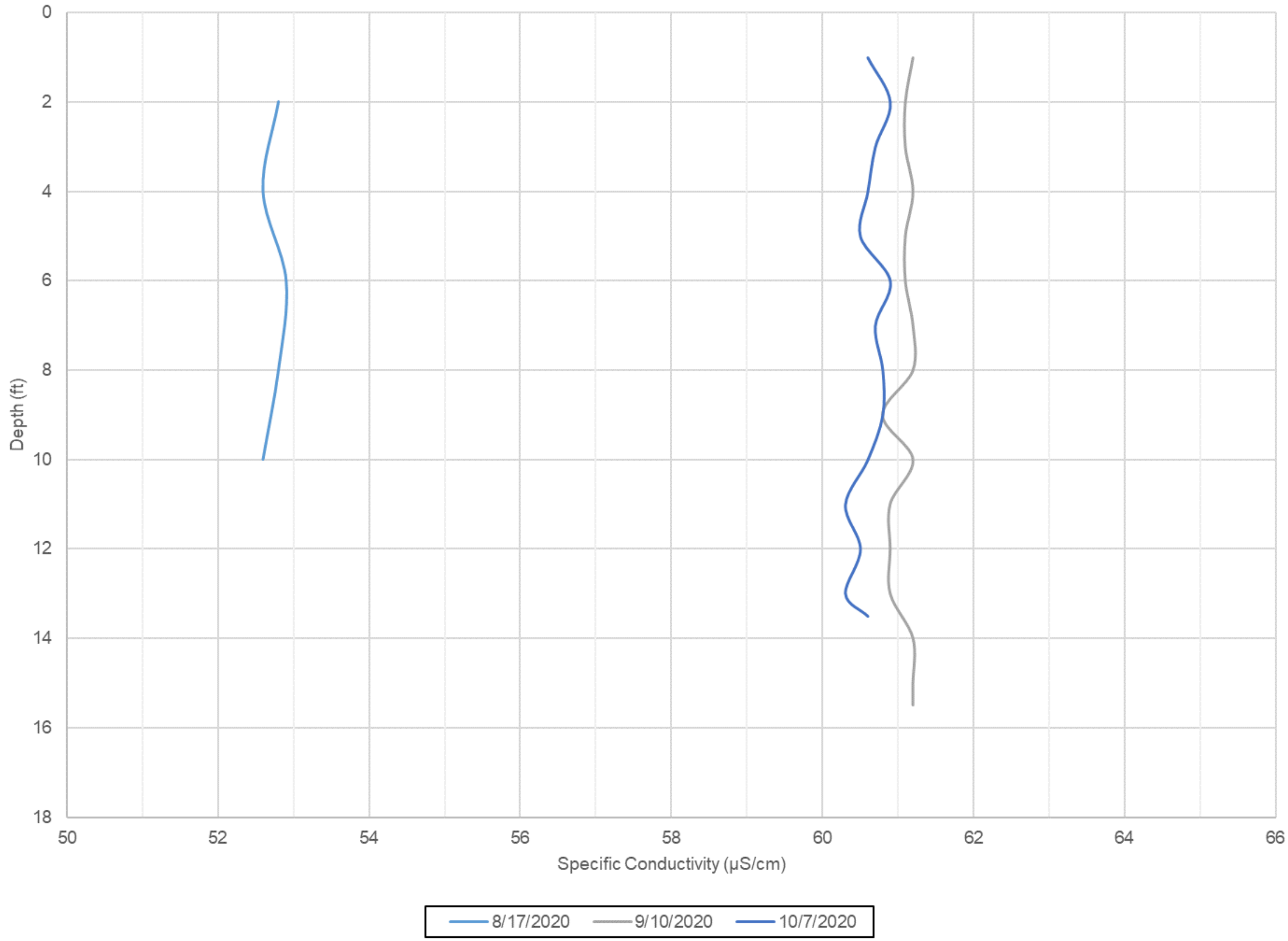


**Figure 6-3. Forebay Vertical Profile — Specific Conductance**

# Attachment 7

## Attachment 7 – New River Flow and Meteorological Data

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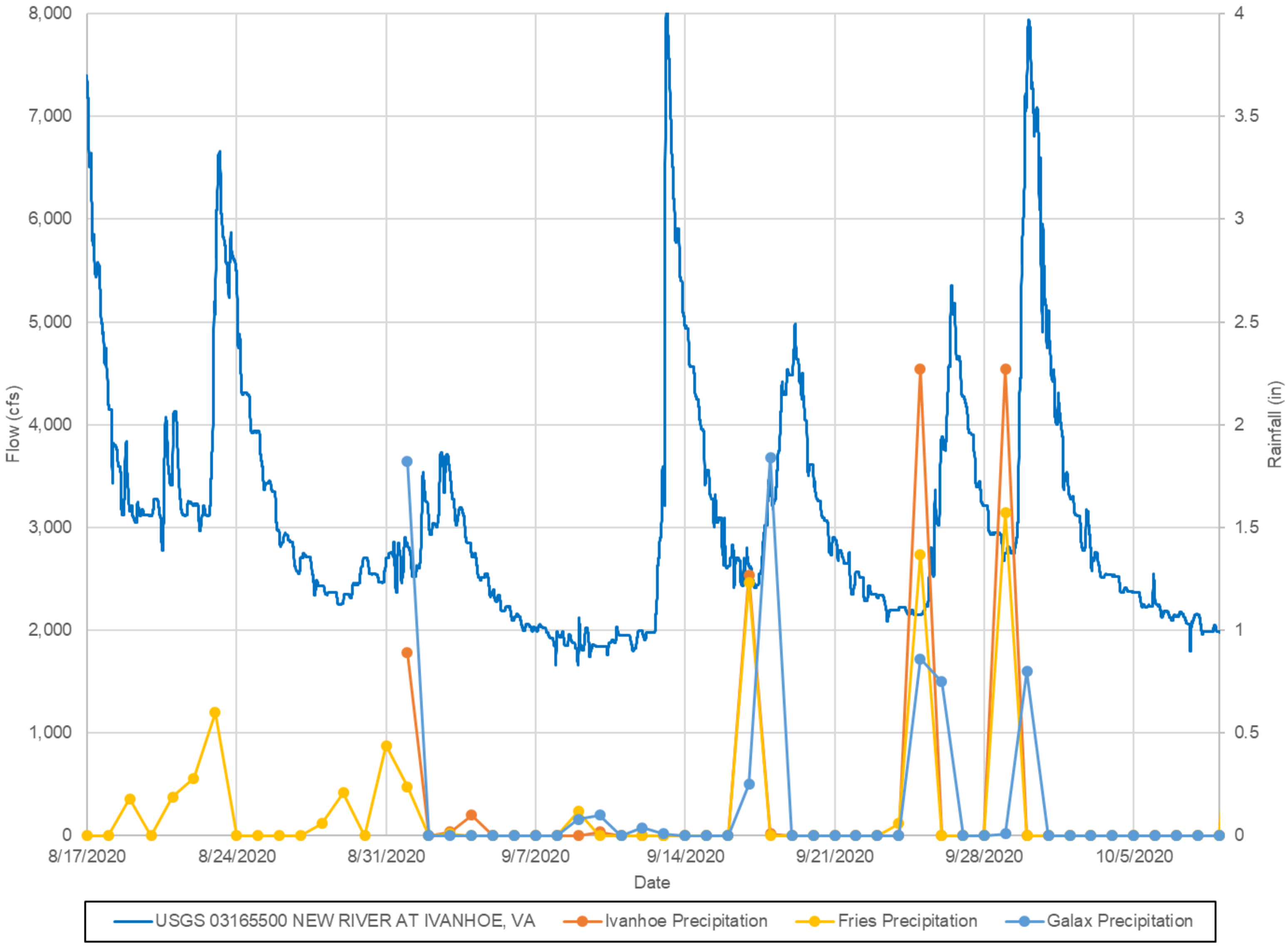


**Figure 7-1. New River Flow (USGS 03165500) and Precipitation at Ivanhoe, Fries, and Galax, Virginia (2020)**

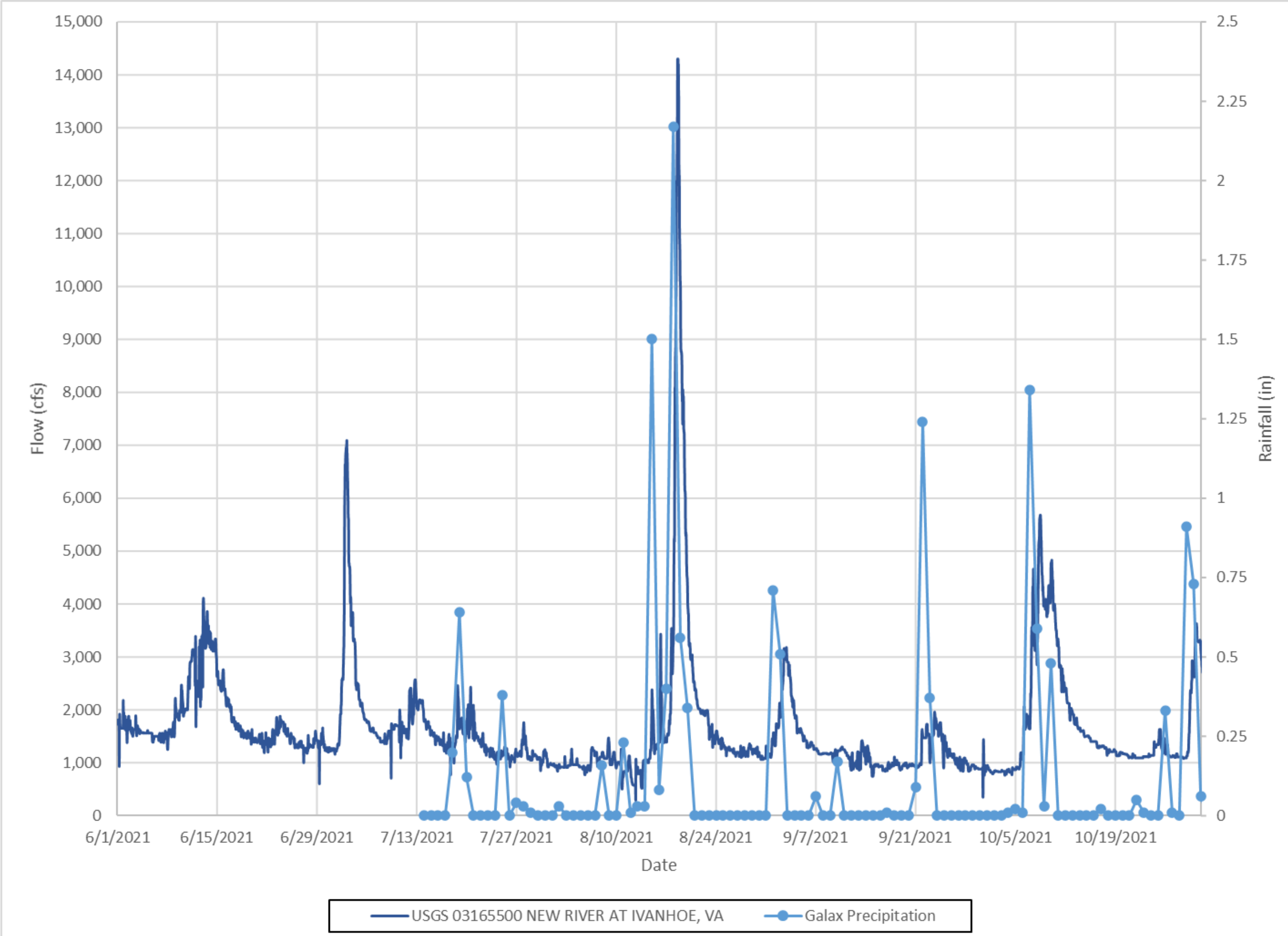


**Figure 7-2. New River Flow (USGS 03165500) and Precipitation at Galax, Virginia (2021)**

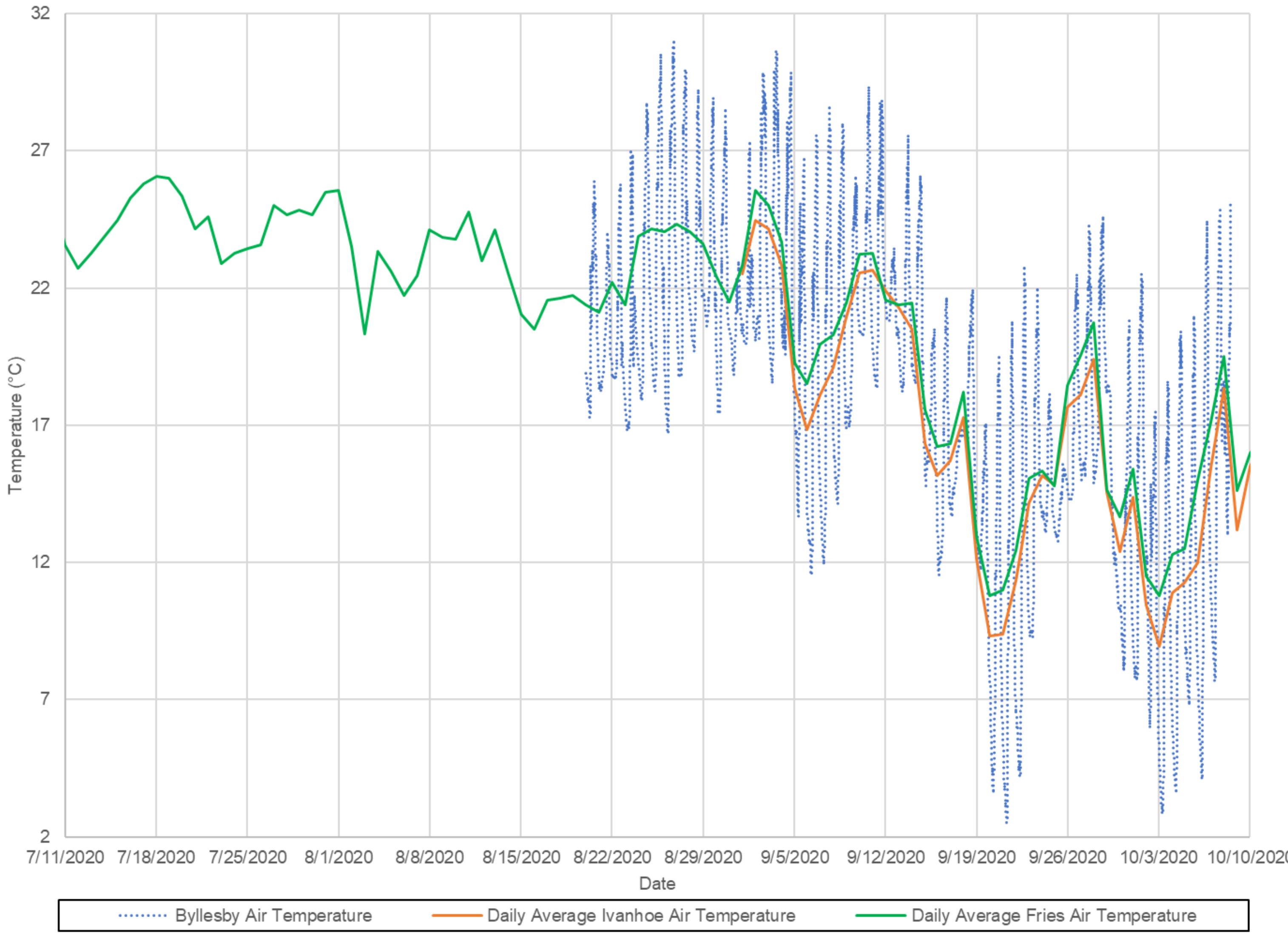


**Figure 7-3. Air Temperature Comparison between Ivanhoe and Fries, Virginia**

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# Attachment 8

## Attachment 8 – Turbidity Data

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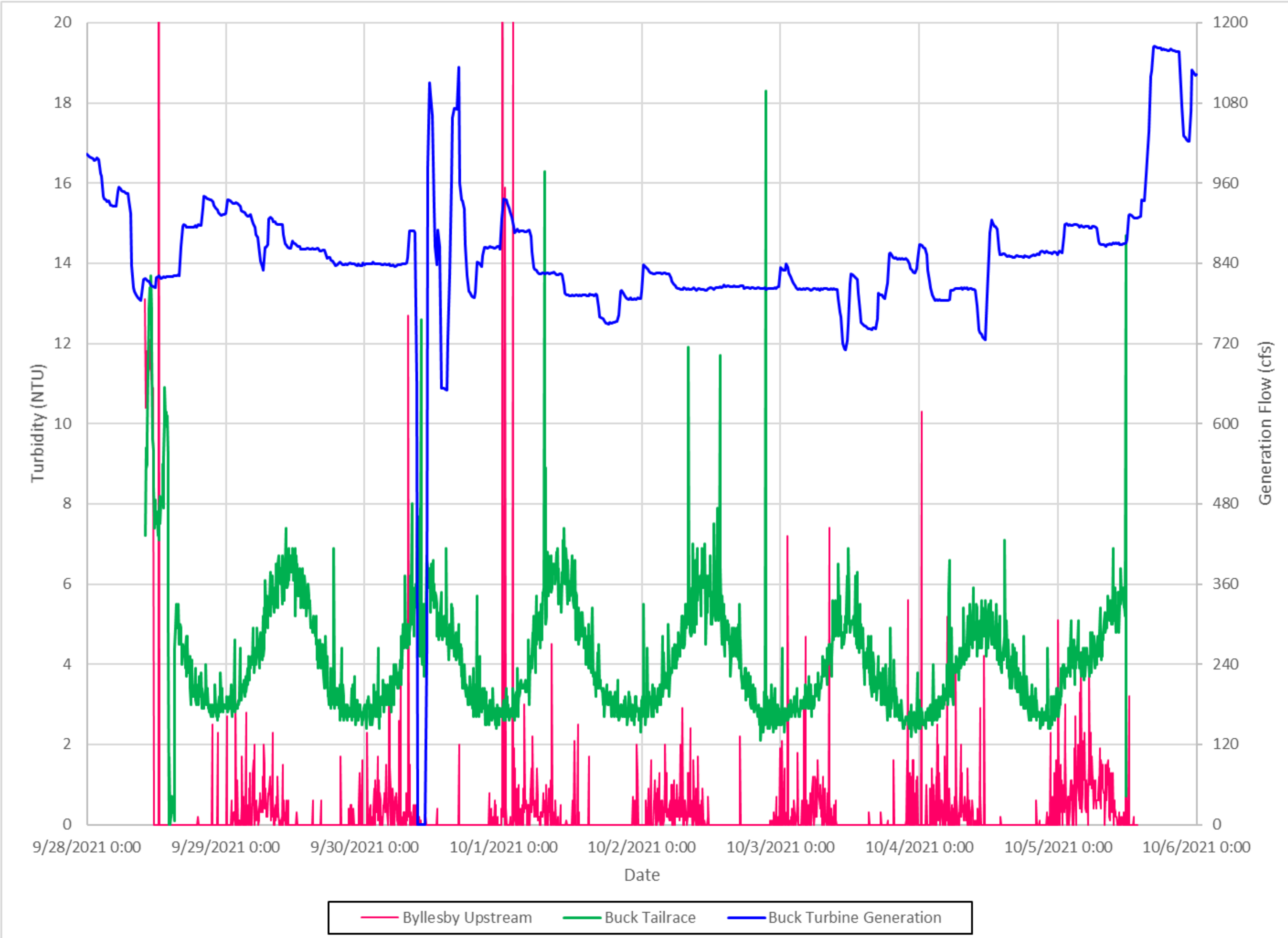


**Figure 8-1. Turbidity and Buck Generation, September 29 – October 5, 2021**

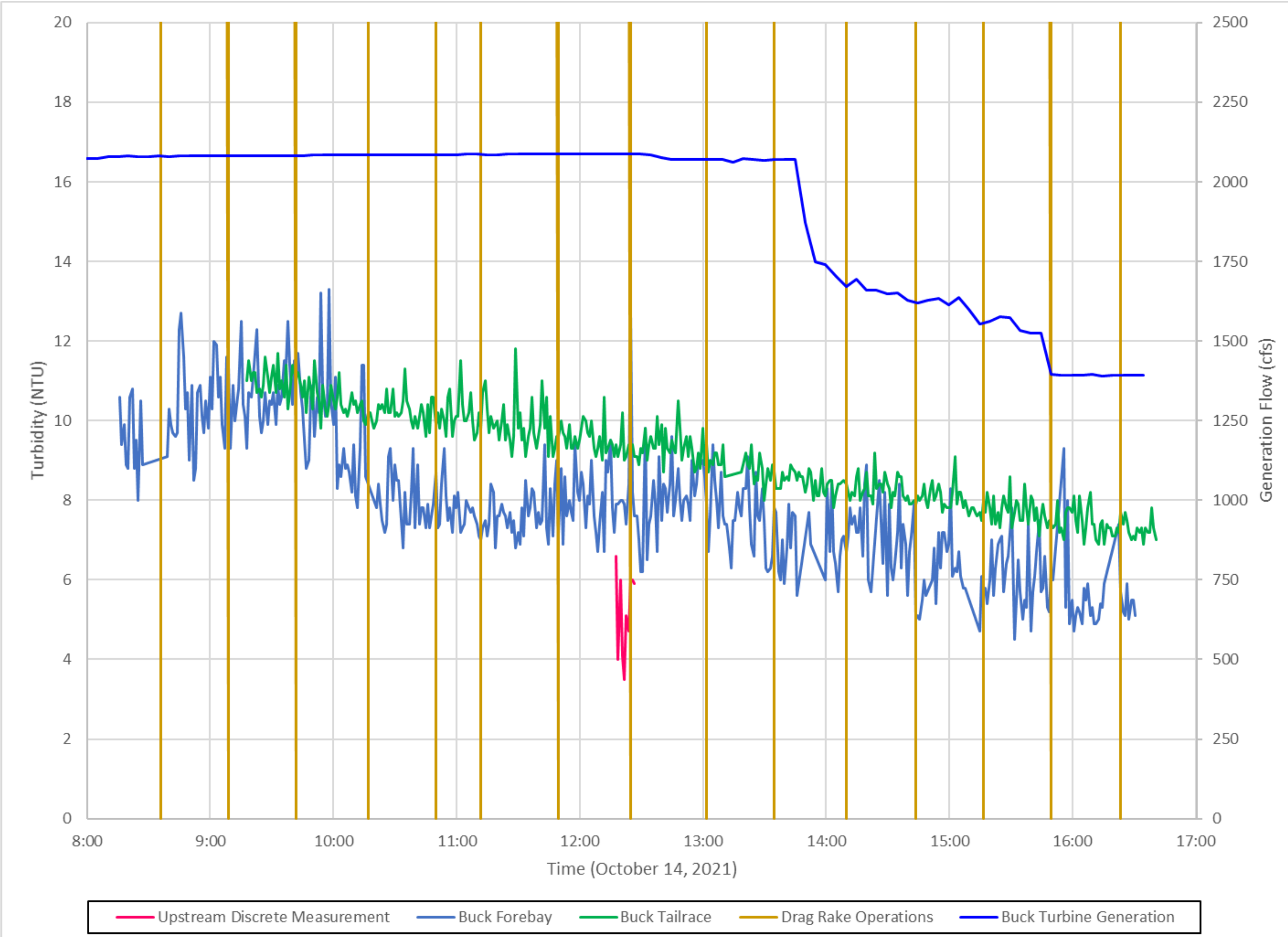


**Figure 8-2. Turbidity and Buck Generation and Drag Rake Operations, October 14, 2021**