Stevens Creek Reservoir Temperature, Turbidity, and Dissolved Oxygen Data Report 2020-2021

Valley Water

Clean Water • Healthy Environment • Flood Protection

Environmental Planning

Unit 248

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Background

Valley Water owns and operates Stevens Creek Reservoir (Cupertino, CA). Stevens Creek Reservoir is a monomictic, mesotrophic surface water reservoir with a storage capacity of 3,138 acre-feet. Profundal water is released from Stevens Creek Reservoir to Stevens Creek through a bottom-release penstock outlet. Stevens Creek supports the federally threatened Central California Coast (CCC) steelhead (*Oncorhynchus mykiss*) Distinct Population Segment and is designated critical habitat from the creek's confluence with the San Francisco Bay to Stevens Creek Reservoir (70 FR 52570, September 2005). Maintaining suitable conditions for steelhead downstream of Stevens Creek Reservoir is of high importance to Valley Water.

Stevens Creek Reservoir is listed on the State's 303(d) list of impaired water bodies for mercury in fish. Since 2015, Valley Water has operated a line-diffuser hypolimnetic oxygenation system (HOS) in the reservoir during thermal stratification (approximately April – October) to prevent anoxic outlet releases, improve downstream water quality, and reduce methylmercury production and bioaccumulation in the reservoir. The HOS at Stevens Creek Reservoir generates nearly pure oxygen from the atmosphere that is injected to the bottom of the reservoir in the vicinity of the dam via fine bubbles released along diffuser lines. Though the HOS has increased dissolved oxygen (DO) concentrations in outlet releases from Stevens Creek Reservoir, Valley Water also observed increases in outlet temperature and turbidity during operation compared to non-operation (Seelos et al.,2017; Seelos et al., 2021). Statistical analysis of data collected in previous years suggested that HOS may influence temperature and turbidity in reservoir releases, but the magnitude of these effects remained unclear.

From June 2020 to May 2021 Valley Water monitored temperature, turbidity, and DO in Stevens Creek Reservoir inflow and outflows including upstream of the reservoir, in the reservoir outlet structure, and downstream of the reservoir. The purpose of this sampling design was to isolate the effects of the HOS on water quality. Data collection was initially planned to continue into the next season of HOS operation; however, the HOS was not operated in 2021 due to very low water levels. The results reported here reflect dissolved oxygen, temperature, and turbidity during a below-normal water year (reservoir capacity of 53% on 6/1/2020) with and without HOS operation.

Study Goal

This study was designed to observe DO, temperature, and turbidity of Stevens Creek Reservoir outlet releases with and without the HOS.

Study questions include:

1. How do observed DO, temperature, and turbidity change between the inlet and outlet?
2. Does HOS operation affect temperature and/or turbidity in outlet releases?
3. How do DO, temperature, and turbidity changes during HOS operation compare to background DO, temperature, and turbidity changes between the inflow and outlet?

4. How do observed DO, temperature, and turbidity levels compare at the reservoir outlet and 60 meters downstream of the outlet prior to, during, and after hypolimnetic HOS operation?

Methods

Staff deployed YSI EXO2 multiparameter water quality sondes for eleven months of continuous (15-minute interval) monitoring at the Stevens Creek Reservoir inlet, outlet, and 60 meters downstream of the outlet from June 2020 to May 2021 (Sites 1, 2, and 3 respectively; Figure 1).

Site 1: Stevens Creek upstream of the reservoir at Valley Water stream flow gage #5045.
Site 2: Stevens Creek Reservoir outlet works above drop structure.
Site 3: Stevens Creek approximately 60 meters downstream of the outlet works.

Though there are multiple small inflows to Stevens Creek Reservoir, Stevens Creek is the largest and most continuously flowing tributary. Parameters collected during continuous monitoring included DO (mg/L and % saturation), temperature (°C), and turbidity (NTU). Additional parameters were collected to help explain changes in turbidity and oxygen including chlorophyll and phycocyanin (turbidity and increases in biomass), and redox potential (indicator of oxidizing vs. reducing conditions).

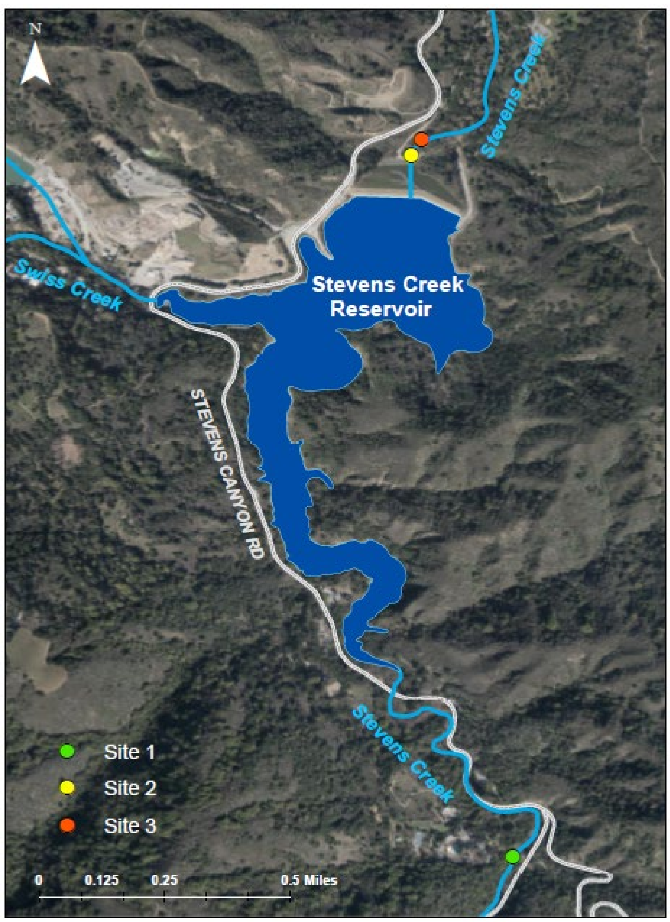

Figure 1: Sonde Deployment Locations

Deployment

Sondes were deployed at Sites 1, 2, and 3 inside protective weight-anchored metal cages, attached to wire cables to prevent movement and or theft. At Site 1, the sonde was deployed in the deepest portion of the stream below the weir structure with depths ranging from approximately 1 foot to 3 feet throughout the year. During periods of low flow at Site 1, the cage was removed to ensure the sonde remained fully submerged. At Site 2, the sonde was submerged in the dam's outlet works where water pools prior to flowing over the drop structure into the creek. At Site 3, the sonde was deployed in the center of the stream and remained fully submerged within the protective cage throughout monitoring. Nearly continuous data was collected at 15-minute intervals from June 2020 to May 2021. In addition to brief pauses in data collection for calibration and maintenance, minor equipment failures interrupted data collection twice at Site 1 and once at Site 3 as described in the table below.

Location	Missing Data Time Period
Site 1, Upstream	8/20/2020 - 8/24/2020
Site 1, Upstream	10/9/2020 - 10/27/2020
Site 3, Downstream	12/12/2020 – 12/22/2020

Schedule

Sondes were deployed for eleven months from June 4, 2020, to May 6, 2021. Thirteen-month deployments were originally planned, however due to drought conditions and the decision not to operate the HOS, monitoring was stopped early. A detailed deployment timeline including HOS status and brief system shut down periods caused by mechanical failure are described below.

Date	**Activity**
6/4/2020	Begin Sonde Data Collection
6/24/2020	Begin HOS Operation
9/8/2020 08:22- 9/10/2020 09:13	HOS Off
9/11/2021 09:02- 9/18/2021 08:01	HOS Off
10/22/2020	End HOS Operation
5/6/2021	End Sonde Data Collection

Calibration and Maintenance

During periods of data collection, EXO2 sondes were removed once per month and taken to Valley Water facilities for calibration and cleaning. These maintenance activities caused brief gaps in the dataset lasting up to 8 hours but largely prevented data inaccuracy due to sensor drift and biofouling.

High Flows

During the monitoring period, storms were mild and infrequent, so sondes were accessed but not removed during storms.

Data Storage

During each battery check or calibration, data were downloaded to a field laptop and transferred to Excel spreadsheets on Valley Water servers.

QA/QC

EXO2 sondes are equipped with SmartQC™ mechanisms that assesses individual sensor performance relative to factory-defined performance parameters. SmartQC™ alerts users when the individual sensor may be starting to drift from factory-defined limits or require adjustments or replacement. SmartQC™ was used each calibration period before re-deployment to ensure all sensors were providing reliable, consistent, and replicable data. The EXO2 sondes also have internal thermistors for quality assurance related to temperature correction. All collected data also underwent manual QA/QC checks for anomalous results and were flagged as necessary.

Results and Discussion

Water Quality Changes Between Sites

The most pronounced differences in water quality were observed between Site 1 and Site 3. Dissolved oxygen concentration was consistently higher upstream compared to the outlet and downstream sites. The outlet had lower dissolved oxygen concentrations throughout the study compared to downstream (Figure 2). This suggests that water released from the reservoir outlet is naturally reoxygenated quickly upon exiting the reservoir. Upstream turbidity was consistently lower than the outlet and downstream except during storm events (Figure 2). We believe daily temperature variation was highest at the upstream site likely due to low riparian canopy cover, shallow stream depth, and naturally variable stream flow not influenced by reservoir releases (Figure 2). During the wet season (October 1st to April 30th), and majority of the dry season (May 1st to September 30th) mean water temperatures were higher in the outlet and downstream sites than in the upstream site. However, this was not the case in June, likely due to thermal stratification that occurs in the reservoir in the dry season, which keeps bottom water relatively cool (Figure 3). Temperature did not vary greatly between the outlet and downstream sites throughout the year.

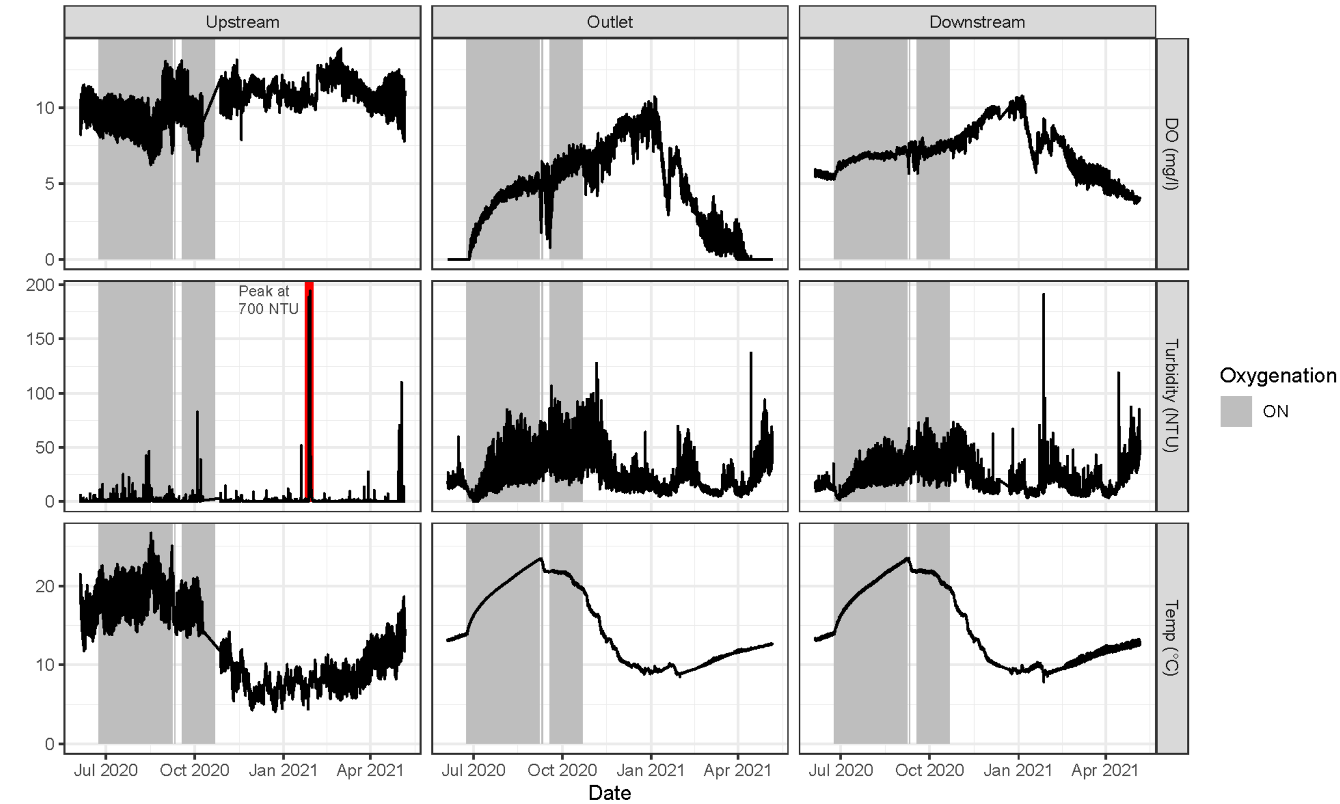

Figure 2: DO, Temperature, and Turbidity at All Sites

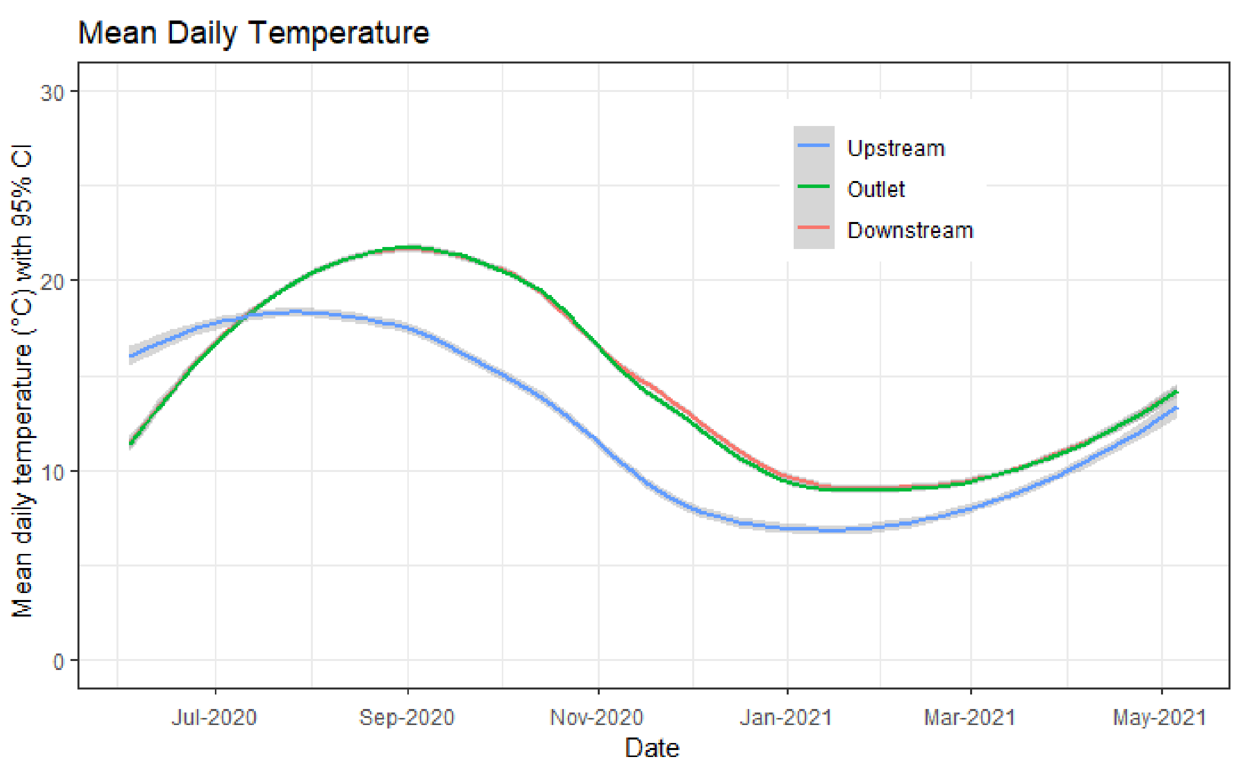

Figure 3: Mean Daily Temperature

Influence of the HOS on Water Quality

Evaluating impacts of the HOS on water quality is limited to the one-year monitoring period of this study. Changes in water quality may be attributed in part to seasonal changes rather than operation of the HOS.

During operation of the HOS, dissolved oxygen concentrations increased at the reservoir outlet relative to periods of non-operation during the dry season. Despite periods of anoxic outlet releases (when the HOS was off), anoxia was not observed downstream (Figure 2). This further supports our hypothesis that outlet water is quickly reoxygenated upon exiting the reservoir. Downstream water remained oxygenated throughout the study likely due to rapid oxygenation as water was released over the drop structure into the creek.

Temperature and turbidity increased when the HOS was turned on in June 2020. During a brief HOS shutdown period in September 2020, temperature initially declined and then stabilized (Figure 2). Turbidity was decreasing before the HOS was turned on and continued to decrease for a short time before increasing. Turbidity continued to increase slightly after the HOS was turned off. On average, turbidity was 10.14% (2.35 NTU) higher downstream and 1.12% (0.31 NTU) higher at the outlet during HOS operation than during non-operation during the dry season. Temperature was on average 30.72% (4.75°C) higher downstream and 29.24% (4.57°C) higher at the outlet during HOS operation than during non-operation during the dry season. In comparison, temperature at the upstream site (not influenced by HOS) was on average 13.98% (2.23°C) higher during the same time periods suggesting the increase may be attributed in part to seasonal differences in temperature. Temperature increases observed in outlet flows are consistent with previous studies that show HOS's can increase turbidity and temperature of bottom water in lakes and reservoirs (Niemisto et. al, 2019; Seelos et.al, 2021; Toffolon et.al, 2013).

DO, turbidity, and temperature differences among sites were compared throughout the year (Figure 4). In Figure 4, values of 0 indicate no difference in water quality between two sites. Throughout the year, DO consistently decreased from upstream to the outlet; however, during HOS operation, the difference in DO between the two sites was less extreme. In contrast, DO generally increased when moving from the outlet to downstream, and this difference was lessened when the HOS system was operating during summer and during several months in the winter. In late winter and early spring, the difference in DO between the outlet and downstream was greater.

Differences in turbidity between the outlet and upstream as well as outlet and downstream sites increased shortly after the HOS was turned on for the summer (Figure 4). There was consistently greater turbidity at the outlet than upstream throughout the year. Conversely, turbidity downstream was generally lower than at the outlet apart from during strong precipitation events. Although lower than outlet concentrations, turbidity downstream was considerably higher than turbidity upstream throughout the year (Figure 2).

Prior to oxygenation in the summer, water temperature was generally lower at the outlet than upstream; however, shortly after the HOS was turned on, outlet temperatures became greater than upstream and did not begin to trend downward until winter

(Figure 4). Temperature differences between the outlet and downstream sites did not vary greatly throughout the year, but downstream temperatures began to increase slightly relative to the outlet in late winter through spring, which may be a direct effect of lower stream flow and reduced reservoir storage experienced in 2021 compared to 2020 (Appendix A).

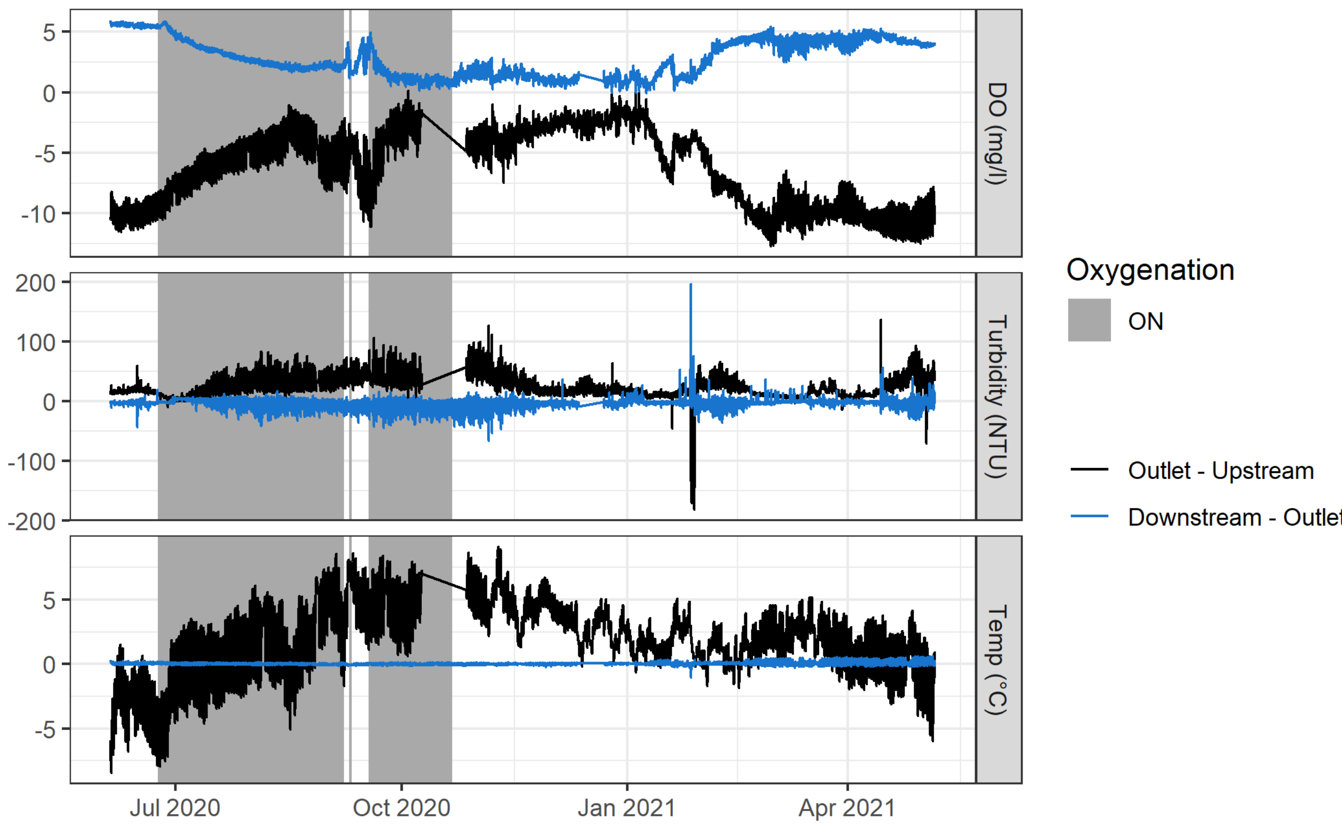

Figure 4:Difference in Water Quality from Upstream to Outlet and Outlet to Downstream

<u>Further Data Considerations</u>

The data collected as part of this monitoring study shows variability by season, location, and HOS status throughout a calendar year and demonstrates points in time when the HOS appeared to cause a change in water quality to the outlet and downstream portions of Stevens Creek. While these data are useful to provide comparison to natural stream water quality (upstream), and can further inform management of the HOS, a statistical analysis of the effect of the HOS on water quality is not feasible. Data collected at a similar frequency during a dry season when the HOS is not operated are needed to statistically analyze the HOS effects on water quality at the outlet and downstream. Natural seasonal changes in temperature can interfere in the assessment of the HOS's impact to water quality, so comparative OFF data should be collected during a full dry season period. Valley Water may consider collecting additional data during the dry season of a comparable water year when the HOS is not operated to allow for statistical comparison.

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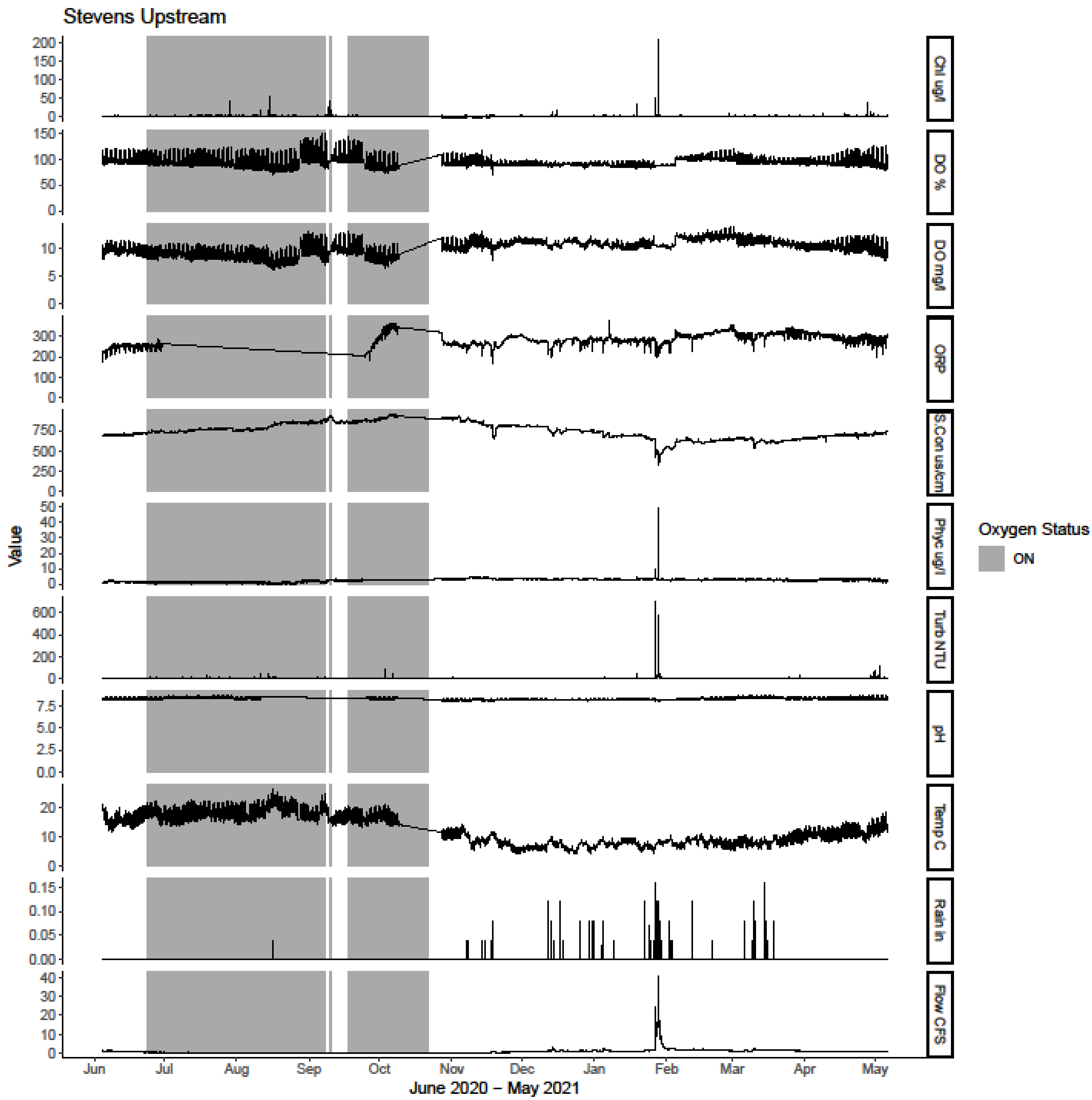
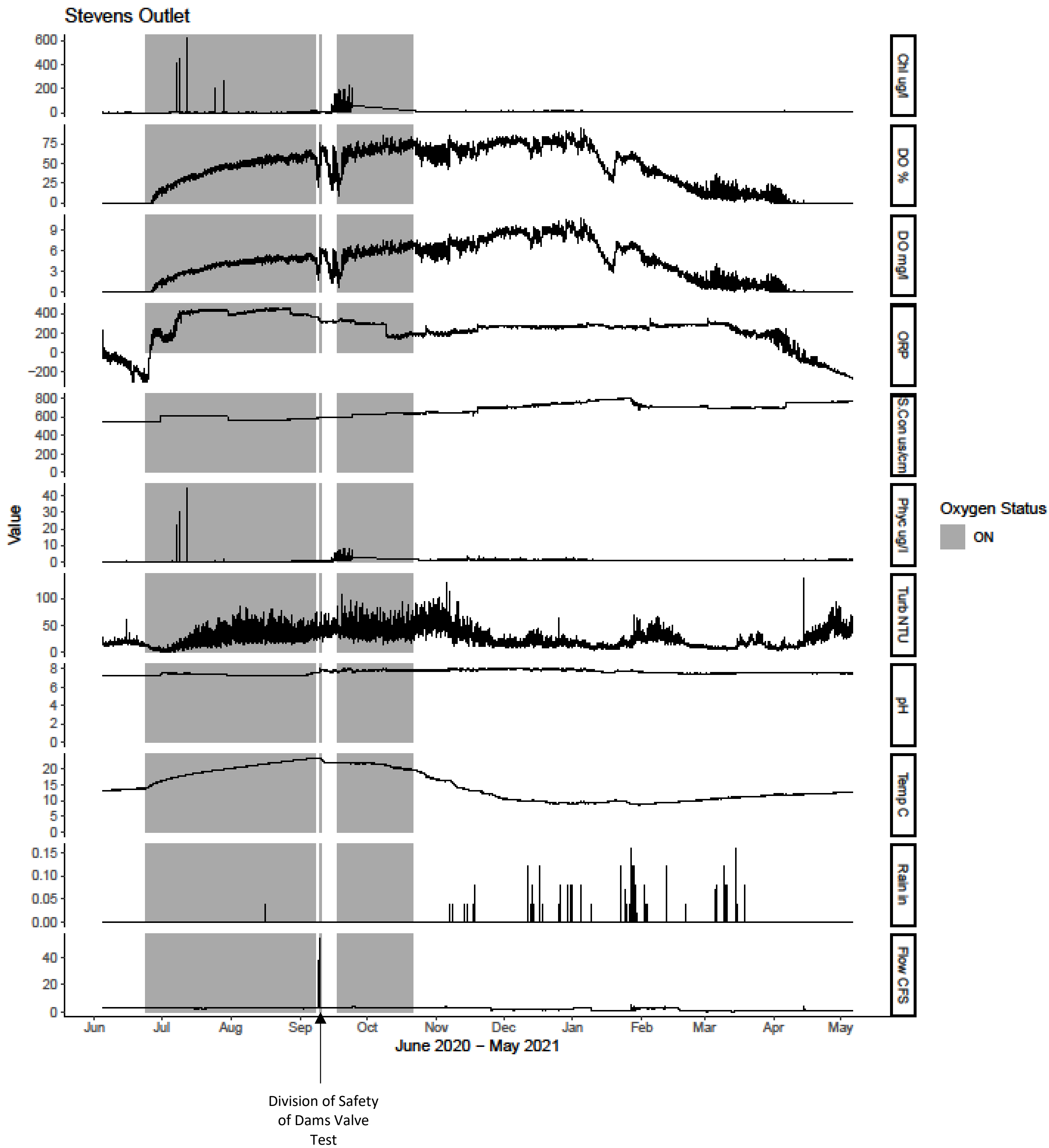
APPENDIX A:

Water Quality Summary Plots



Stevens Upstream
Value
Chl ug/l
DO %
DO mg/l
ORP
S.Con us/cm
Phyc ug/l
Turb NTU
pH
Temp C
Rain in
Flow CFS
Oxygen Status
ON
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June 2020 – May 2021


Stevens Outlet
Value
Chl ug/l
DO %
DO mg/l
ORP
S.Con us/cm
Phyc ug/l
Turb NTU
pH
Temp C
Rain in
Flow CFS
Oxygen Status
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June 2020 – May 2021
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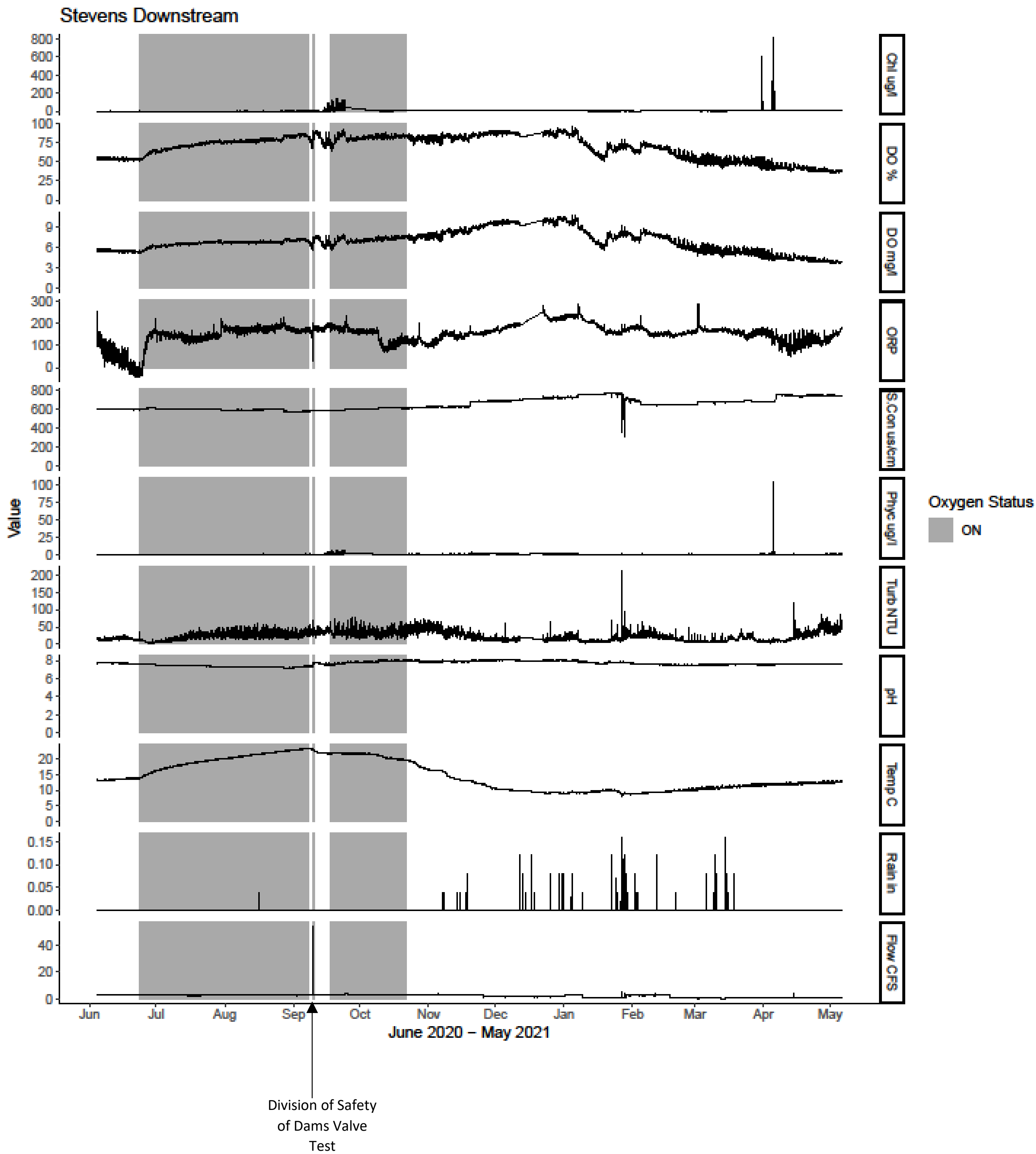
Stevens Downstream
Value
Chl ug/l
DO %
DO mg/l
ORP
S.Con us/cm
Phyc ug/l
Turb NTU
pH
Temp C
Rain in
Flow CFS
Oxygen Status
ON
Jun
Jul
Aug
Sep
Oct
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June 2020 – May 2021
Division of Safety of Dams Valve Test