Browns Pond Dam Temperature Monitoring Project
Bakersfield, Vermont
July – October 2021

Abstract

The Browns Pond Dam Temperature Monitoring Project undertaken by the Franklin County Natural Resources Conservation District (the District) in consultation with Just Water Consulting aimed to document the changes in stream temperatures upstream and downstream of the Browns Pond Dam within The Branch in Bakersfield, Vermont over the 2021 field season.

This project was completed within the larger context of on-going discussions with the Town of Bakersfield and the private dam owner to determine the current state of the dam and the potential for future removal, if found to be in the best interest of all parties. At a larger scale, this project was undertaken in the context of FERC relicensing projects for hydroelectric dams on the Missisquoi River where stakeholders sought to support water quality efforts throughout the larger watershed.

On July 19, 2021, two temperature loggers were installed in The Branch outside of the influence of the impoundment of Browns Pond Dam – one upstream, one downstream of the dam. The loggers recorded temperature readings every 15 minutes. Both loggers were removed on October 12, 2021. This project aimed to document in-stream changes upstream and downstream of the dam and impoundment.

Results show that downstream temperatures were higher than upstream temperatures throughout 88% of the monitoring study.

The average temperature increase throughout the entire monitoring period from upstream to downstream was 1.1 °C. However, there were a number of time periods where the downstream temperatures were actually colder than upstream temperatures; this is thought to possibly be a result of the volatility of upstream reach temperatures compared to downstream reach temperatures with the diurnal cycle of the sun, however the data does not definitively support that hypothesis and additional monitoring work will be needed in the 2022 season. It is our goal to place additional temperature loggers within the impoundment of the Browns Pond Dam to analyze possible thermal stratification within the pond and provide context for temperatures recorded throughout the stream system.

This monitoring project provides an opportunity to inform the dam owner, Town of Bakersfield, and conservation organizations in the area about water temperatures in The Branch around the Browns Pond Dam.

Background

The Browns Pond Dam is a cyclopean concrete structure that is 82 feet long with a maximum height of 22 ft. located on The Branch in Bakersfield, VT (see Figure 1). The Branch is a tributary to the Tyler Branch which is a tributary to the Missisquoi River. The dam is jurisdictional in size, meaning it impounds more than 500,000 cubic feet of sediment and water. The drainage area of The Branch at the point of the dam is 7.38 square miles and the associated impoundment is 9 acres. The Vermont Dam Safety Program inspected the dam in 1998 and 1999 after a low-flow outlet in the lower section of the dam abruptly failed and subsequently drained the entire pond in 36 hours (Agency of Natural Resources, 2000). At the time, the Dam Safety Program described the dam as being in poor condition and recommended that the owner hire a Professional Engineer to investigate the dam further and consider removal if repairs were not made. To the District's knowledge, these recommendations have not been followed as of October 2021. Records from the Dam Safety Program do indicate that the low-flow outlet was plugged with wooden boards by concerned town members following the failure, even though repairs or modifications to dams require a permit from the State. The report further states: "This dam is tentatively classified as a Class 2 (a significant hazard) structure. The dam may be a low hazard (Class 3) structure because much of its storage capacity appears to have silted in".

Figure 1. Browns Pond Dam viewed looking upstream from the Browns Pond Road bridge over The Branch. Photo taken 5/27/20 by Brodie Haenke.

The Browns Pond Dam was identified for removal in a 2017 report by The Nature Conservancy where it was noted that removal of the dam would reconnect 17 river miles for aquatic organism habitat. Wild brook trout rely on regular seasonal movements to maintain viable populations (Letcher et al. 2007 as cited in VTFWD 2017) which can be greatly affected by the presence of dams and culverts (VTFWD 2017). Barriers to movement can isolate populations, impact genetic diversity and increase the risk of extirpation (Letcher et al. 2007, Whitely et al. 2013 as cited in VTFWD 2017)

In addition to blocking fish passage and altering wildlife habitat, some dams can cause water temperatures to increase in the impoundment, making the downstream reach less hospitable for cold-water species like brook trout. Brook trout is a native Vermont species and has experienced significant declines across its historic range due to habitat degradation and fragmentation, elevated water temperatures, genetic introgression and the expansion of non-native species (EBTJV, Hudy et al. 2008 as cited in VTFWD 2017).

Stream temperature has a profound effect on the distribution and abundance of aquatic populations (Poole and Berman 2001, DeWeber and Wagner 2014, Hitt et al. 2015 as cited in VTFWD 2017). Global climate change predictions suggest further losses of brook trout populations throughout their range due to increases in temperature and flood frequency (Wenger et al. 2011 as cited in VTFWD 2017). In Vermont, Kratzer and Warren (2013 as cited in VTFWD 2017) found brook trout abundance to be negatively correlated with the duration of temperatures exceeding 20 ^{o}C (68 ^{o}F). Maximizing cold water in smaller tributary streams is also extremely important for moderating temperatures and providing thermal refuges in the larger streams, rivers, and lake which they feed (Baird and Kruger 2003 as cited in VTFWD 2017).

The damming of streams often promotes increased temperatures as the wider, slower impoundment is exposed to increased solar radiation and heating (VTFWD 2017). Maxted et al. (2008 as cited in VTFWD 2017) and Lessard and Hayes (2003 as cited in VTFWD 2017) reported degraded aquatic habitat from increased temperatures and reduced dissolved oxygen resulting in significant impacts to macroinvertebrate communities and cold-water fish populations. Lessard and Hayes (2003 as cited in VTFWD 2017) concluded that increased temperatures were maintained 2-3 km below small dams and resulted in shifts in macroinvertebrate communities, increased fish species richness and reductions in brook trout, brown trout, and slimy sculpin densities. Increases in water temperature also decrease dissolved oxygen concentration and in turn, influences the mobilization of nutrients and metals (USGS, 2021).

This project aims to determine changes in in-stream temperature between upstream of the Browns Pond Dam and impoundment to below the dam. The District installed one logger upstream of the impoundment and one downstream of the dam which recorded temperatures between July and October 2021. The goal was to determine if the temperatures of the waters upstream of the dam differ from those downstream of the dam.

Project Location

The Browns Pond Dam is located in Browns Pond in Bakersfield, VT (see Figure 2). The Branch flows through the dam's impoundment and over the dam, eventually emptying into the Tyler Branch, which feeds the Missisquoi River. The pond's elevation is 636 ft (WGS84 EGM96 Geoid).

Figure 2: Map showing the Browns Pond Dam in the Browns Pond in Bakersfield, VT (44.8098656, -72.7904215). The dam is labeled with a yellow diamond. The Branch flows through the dam to meet with the Tyler Branch.

Browns Pond is an impoundment along Vermont Route 108. There is a small one-lane bridge that crosses The Branch immediately downstream of the dam. Concrete lines the river right side of the channel downstream of the dam presumably to prevent undercutting of VT-108. The Branch flows south to north in the location of Browns Pond.

Methods

Becky Tharp of Just Water Consulting assisted the District in identifying the most suitable tools for the job, the best location for data collection, timing, and data analysis support. The District and Just Water Consulting installed two HOBO Water Temp Pro v2 loggers from ONSET. The loggers have a precision sensor for ±0.2 °C accuracy, measuring temperatures up to 50 °C in water.

The two loggers were installed outside of the influence of the dam and impoundment, see Figure 3. The Upstream Logger was installed approximately 50 feet upstream of the box culvert that runs underneath Vermont Route 108. The Downstream Logger was installed approximately 400 feet downstream of the dam in the main channel past the overhead bridge for Browns Pond Road.

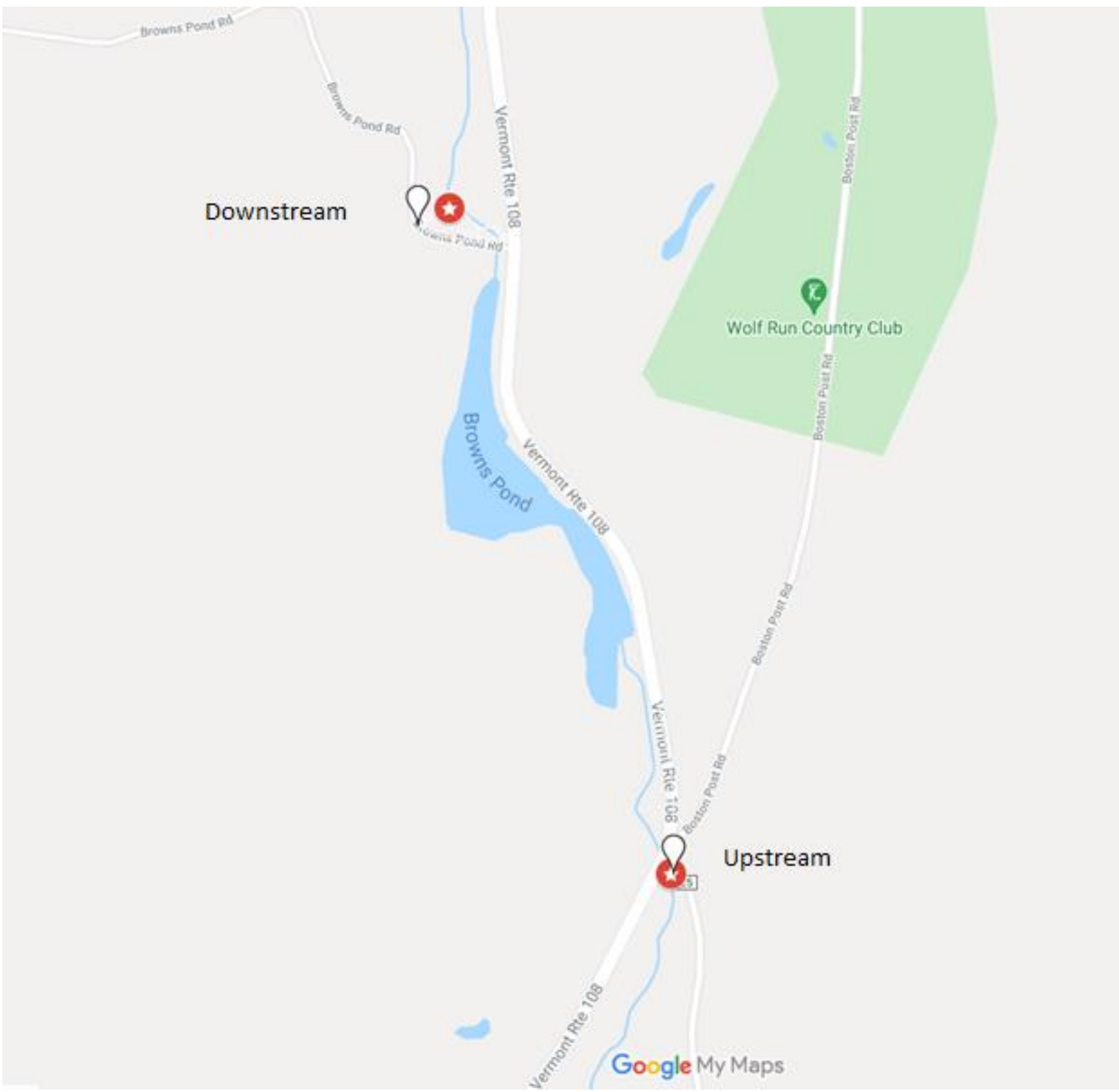

Figure 3. Map showing locations of Upstream and Downstream Loggers

Geographic Coordinates of Loggers:

Upstream:	44.804690635458364, -72.78752346279259
Downstream:	44.812910859296984, -72.79125047659011

The loggers were installed inside of perforated PVC tube cases to secure the loggers from damage within the stream. The Upstream Logger and PVC system was secured to a tree overhanging the channel with a support rebar rod to keep the logger in place throughout the season, see Figure 4. The logger was installed close to the channel bed to ensure submersion in the water even during periods of low flow. The Downstream Logger and PVC system was tied closely to a large rock in the channel downstream of the dam in efforts to keep the logger fully submerged, see Figure 5.

Figure 4. Upstream Logger inside PVC case installed in stream attached to overhanging tree branch. Photo taken 7/19/21.

Figure 5. Downstream Logger inside PVC case installed in channel downstream of Browns Pond Dam. Photo taken 7/19/21.

The loggers were retrieved from their in-stream positions on October 12, 2021. Data was downloaded from the loggers on October 25, 2021 with the assistance of Becky Tharp from Just Water Consulting using HOBOware Pro software and a Waterproof Shuttle from ONSET.

Temperature data collected and analyzed was from the period between July 19th, 2021 at 12:00 pm through October 12th, 2021 at 12:00 pm; across 92 days. Observations were recorded at the same time by both loggers in 15-minute intervals. 8161 temperature observations were recorded by each logger over the nearly three months of the monitoring project.

Results

The results of this temperature monitoring study found that for 88% of the time that the loggers were collecting temperature data, the downstream temperatures were higher than upstream temperatures, see Figures 6, 7, 8. 11% of the time, the Downstream Logger recorded cooler temperatures than the Upstream Logger; 1% of the time, they were equal.

During the time periods when the Downstream Logger recorded temperatures greater than the Upstream Logger temperatures, the average temperature difference was 1.4 ^{o}C; the median temperature difference was 1.3 ^{o}C. During these times, the maximum temperature difference was 5.2 ^{o}C.

During time periods when the Downstream Logger recorded temperatures lower than the Upstream temperatures, the average temperature difference was 0.7 ^{o}C; the median temperature difference was 0.5 ^{o}C. During these times, the maximum temperature difference was 2.9 ^{o}C.

Across the entire monitoring time period, the average temperature difference between the downstream and upstream loggers was 1.1 ^{o}C with the downstream logger recording the warmer temperatures generally. The median temperature difference was also 1.1 ^{o}C.

In-stream temperatures ranged from 10.6 ^{o}C to 25.4 ^{o}C at the Upstream Logger and 11.8 ^{o}C to 28.2 ^{o}C at the Downstream Logger, see Table 1 and Figure 7.

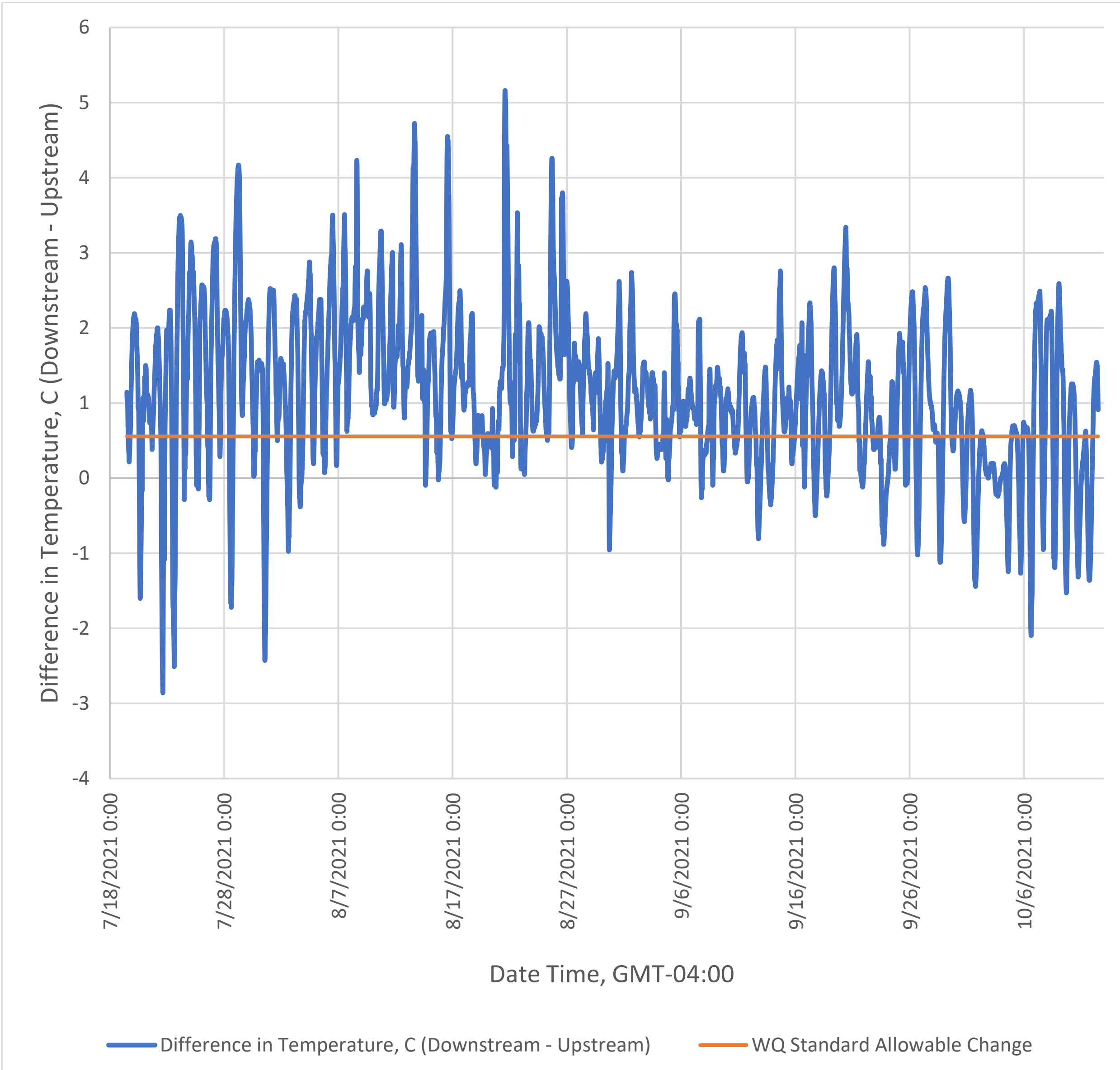

Figure 6. Difference in temperature reading (Downstream Logger – Upstream Logger reading) in °C shown in blue. Red line at 0.556 °C (1 °F) is imposed on the graph to show the total temperature allowable increase (as determined by the rolling seven-day mean of maximum daily water temperatures for the entire period from June 1 to September 30 of any year) for warm water fish habitat for class B(2) waters with an upstream ambient temperature above 60 °F due to all discharges and activities for lakes, ponds, and reservoirs as stated in the Vermont Water Quality Standards, Environmental Protection Rule Chapter 29A (State of Vermont, 2017, pp 18). A different monitoring study and analysis would need to be performed to evaluate whether or not the Browns Pond impoundment and dam were indeed creating a situation that was in exceedance of this Vermont Water Quality Standards; the line shown here is simply for illustrative purposes.

Table 1. Key Temperature Statistics for Upstream, Downstream, and the Difference between Loggers across the Entire Monitoring Time Period

Metric	Upstream	Downstream	Difference (Downstream – Upstream)
Maximum Temperature (°C)	25.4	28.2	2.7
Minimum Temperature (°C)	10.6	11.8	1.1
Average Temperature (°C)	18.0	19.2	1.1
Median Temperature (°C)	18.0	19.0	1.05

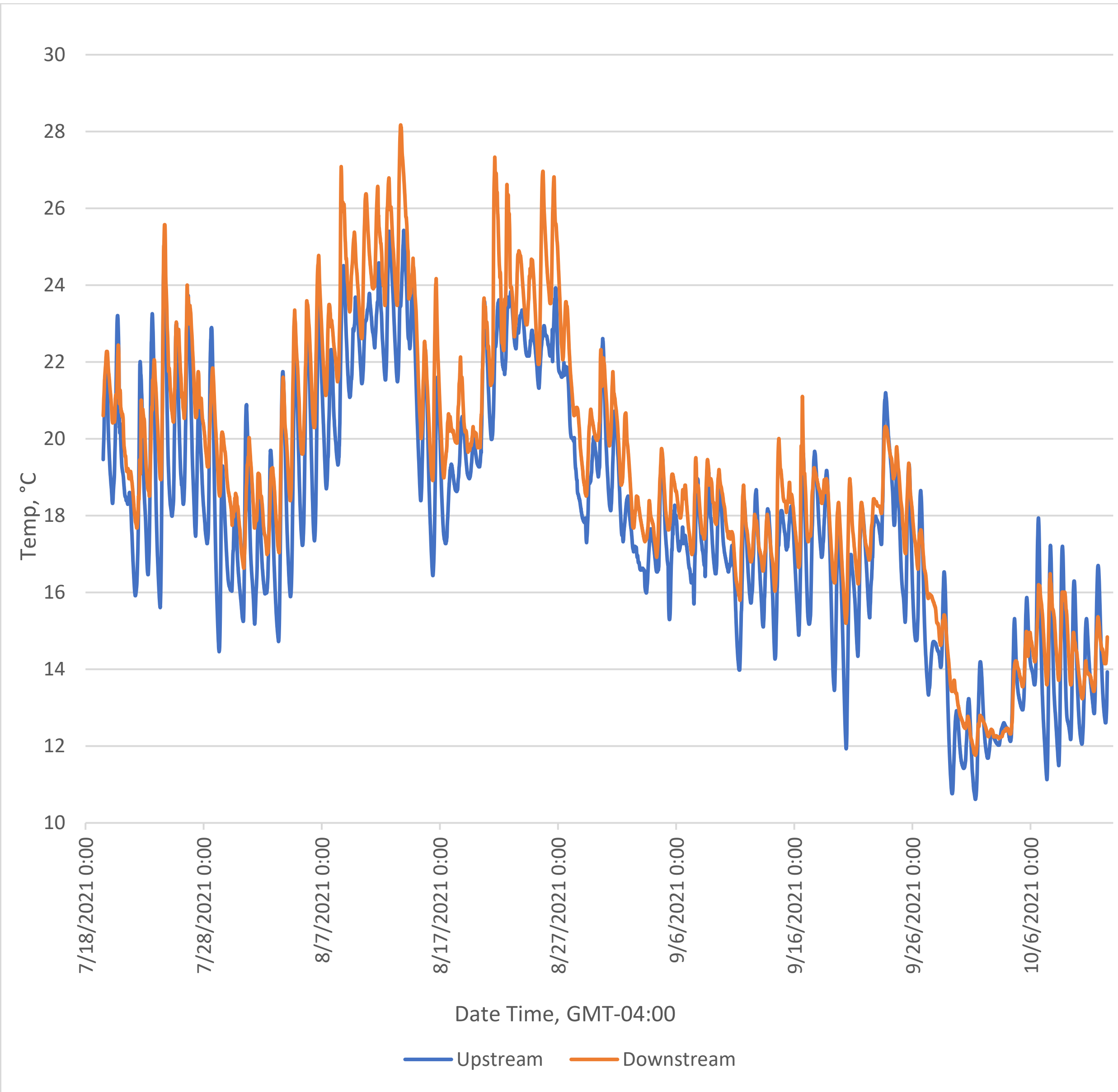

Figure 7. Water temperatures recorded by the Upstream Logger and Downstream Logger over time

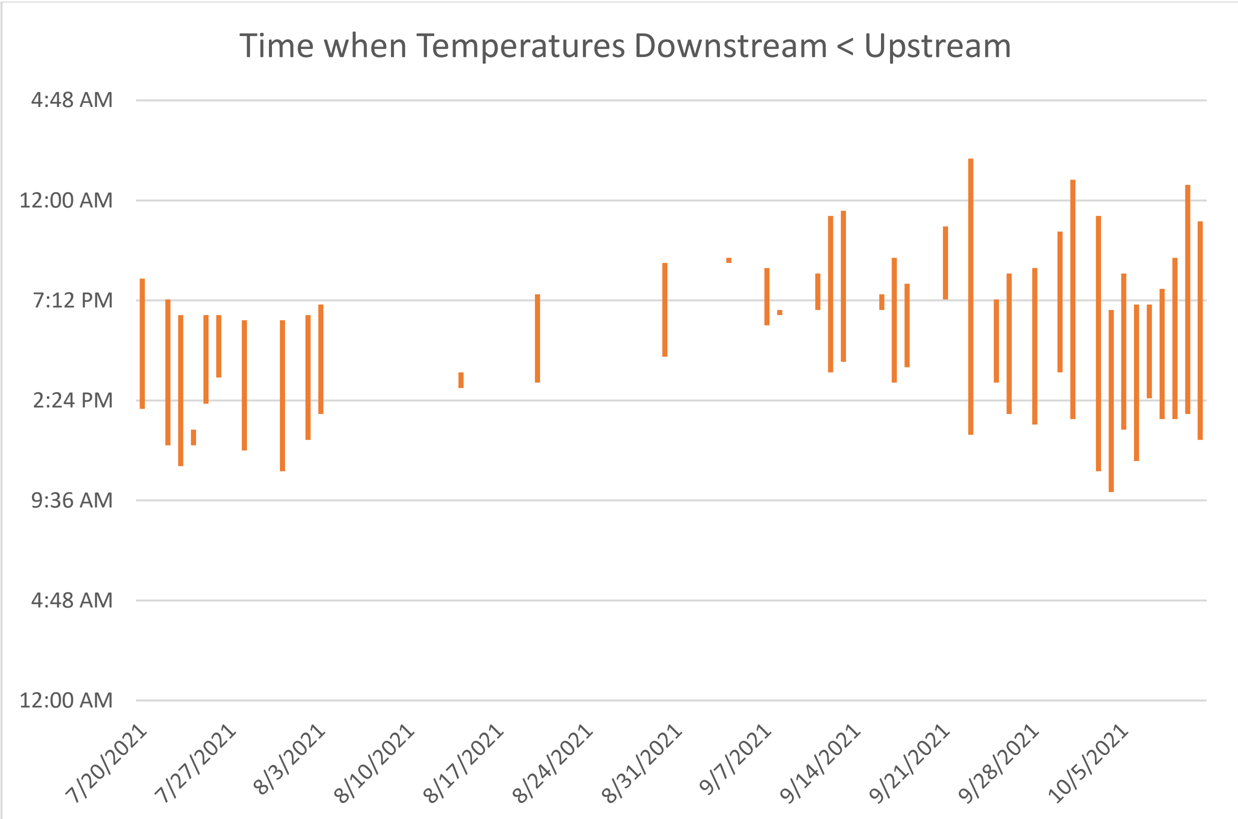

Figure 8. Periods of time shown when the Downstream Logger recorded temperatures cooler than the Upstream Logger.

Discussion

The results of this temperature monitoring project showed that, for the period of the study, in-stream temperatures were generally higher downstream of the Browns Pond Dam and impoundment than they were upstream.

However, there were many notable instances where the temperatures recorded downstream of the dam were lower than those upstream. These instances typically began in the mid to late morning hours and lasted into the afternoon or very early morning of the next day; an average length of 5.6 hours, see Figure 8. This may suggest that the diurnal cycle of solar radiation did play a role in this pattern, especially since the Upstream Logger had less overhead vegetative cover than the Downstream Logger. Additionally, sections of streams upstream of impoundments typically indicate greater volatility in temperature as a result of diurnal cycling whereas the impoundment and downstream temperatures are more stable due to the thermal mass of the impounded water as a factor in controlling temp.

This pattern of colder temperatures downstream that may be influenced by diurnal cycles does not hold true for every day of the study, only occurring on 39 days out of 92 total, so perhaps there are additional variables to be considered. There does not appear to be a correlation with air temperatures, precipitation, recorded cloud cover, or wind speed based on historic weather information reviewed from Weather Underground Station “Burlington International Airport Station” which may not have captured microclimate conditions at the monitoring site in Bakersfield, approximately 30 miles away (Weather Underground). Based on these findings, the District may choose to place the temperature loggers in different locations to reduce the impact of overhead cover and solar radiation in future monitoring studies.

It is also possible that the box culvert immediately downstream of the Upstream Logger could have been creating its own unexpected impoundment, perhaps slowing water around the Upstream Logger and allowing for the temperature of that reach to increase. There was not similar infrastructure near the Downstream Logger.

Additionally, the loggers were positioned at different depths within the reaches and the stream cross sections at the logger locations were quite dissimilar, with the downstream reach being very shallow and wide (logger was placed in one channel in a valley with multiple channels across a floodplain) compared to the upstream channel location which was deeper and narrower.

These variables may have influenced temperature recordings in the loggers throughout the duration of this study including time periods when the temperatures downstream were higher than the temperatures upstream, as previously anticipated. Continuous monitoring within the impoundment in the future and improved logger location choice may provide additional context and insight into these patterns.

Additionally, further data collection, monitoring, and study would need to be performed to determine if the Browns Pond Dam and impoundment were creating conditions that would lead to the exceedance of allowable temperature increases for this stream based on the Vermont Water Quality Standards, Environmental Protection Rule Chapter 29A (State of Vermont, 2017). This information cannot be gained from this particular 2021 monitoring effort because of the confounding variables stated above, and because the loggers were not collecting data in the stream for the required monitoring period of June 1 to September 30 to determine relevant metrics.

Conclusion

This study found that the temperatures recorded downstream of the Browns Pond Dam were generally higher than those recorded upstream by an overall average of 1.1 °C, with notable exceptions where the opposite trend was found.

The Upstream Logger recorded 2218 temperature readings above 20 °C (27%), whereas the Downstream Logger recorded 3145 temperature readings above 20 °C (39%), see Figure 7. As previously stated, in Vermont, Kratzer and Warren (2013) found brook trout abundance to be negatively correlated with the duration of temperatures exceeding 20 °C (68 °F) (VTFWD 2017). The downstream reach trends towards warmer water, making it less hospitable for certain aquatic habitat, particularly for Vermont's native brook trout and other cold-water fishes. However, the warmer temperatures can also make for more suitable habitat for other aquatic species that prefer warm water. In general, aquatic habitat assessments and restoration projects seek to maximize the "good" conditions for the greatest number of species, rather than achieving the perfect conditions for only one species; all these factors will need to be part of future discussions about this dam and associated habitat.

Next year, we hope to investigate the driving forces behind the temperature differences upstream and downstream of the dam by including monitoring within the impoundment itself and improving our monitoring locations upstream and downstream so that they are more similar, to avoid the influence of shading and solar radiation, among other potential complicating factors. This 2021 monitoring study has provided data that will inform reconsideration of temperature logger placements upstream and downstream of the dam in an attempt to reduce the number of uncontrollable variables influencing water temperatures. In order to gain access to the Browns Pond impoundment, the District will continue to reach out to the dam owner and discuss access for the summer of 2022.

That work would involve installing three loggers at the deepest point in the impoundment in a profile. They would be positioned near the surface, the sediment water interface, and roughly the center of the water column to detect potential stratification. Through this monitoring, the District seeks to determine if the impoundment thermally stratifies during summer months, indicating the potential for other water quality challenges beyond increased temperature such as reduced dissolved oxygen and associated biogeochemical alterations.

This data will be used to inform the Browns Pond Dam owner and other dam owners of the impacts of dams and impoundments on aquatic habitat and stream temperatures with the goal of seeking partnerships to evaluate derelict dams for removal in the future.

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