BEAR RIVER HYDROELECTRIC PROJECT FERC NO. 20.

SODA SPINNING RESERVE TEMPERATURE TECHNICAL REPORT

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1.0 BACKGROUND

The Bear River Hydroelectric Project (Project), owned and operated by PacifiCorp, consists of three distinct developments constructed between 1909 and 1927 and has a gross generating capacity of 77 megawatts. PacifiCorp along with interested parties developed a Settlement Agreement as part of the previous relicensing process; FERC granted PacifiCorp a 30-year license on December 22, 2003, for the continued operation of the Project.

The Project developments include:

(1) The Soda Development (Soda) – is the uppermost development on the Bear River and consists of a 103-foot concrete gravity dam, a powerhouse containing two vertical Francis turbines each rated at 7 MW, and a combined maximum discharge of 2,624 cfs;

(2) The Grace Development (Grace) – consists of a 51-foot timber crib dam, 26,000 foot-long, 11-foot diameter flowline, powerhouse containing three vertical Francis turbines each rated at 11 MW, and a combined maximum discharge of 960 cfs;

(3) The Oneida Development (Oneida) – is the lowermost developments and consists of a 111-foot earthen dam, a powerhouse containing three vertical Francis turbines each rated at 10 MW, and a combined maximum discharge of 3,290 cfs.

Article 412 (iii) of the FERC license, grants the Project the utilization of spinning reserve capacity from the developments. The spinning reserve generation from Soda has never been utilized. However, under changing conditions in their operation, market, and regulatory setting PacifiCorp has utilized spinning reserve capacity at Oneida in recent years. Further changes in these conditions have necessitated PacifiCorp to plan and implement the spinning reserve capacity at Soda. Spinning reserve can be defined as the unloaded generation that is synchronized and ready to serve additional demand; in most cases spinning reserve power is used in emergency situations.

On July 20, 2017, PacifiCorp convened a work session with Bear River Project Environmental Coordinating Committee (ECC) members and PacifiCorp consultants, Cirrus Ecological Solutions (Cirrus) and RedFISH Environmental (RedFISH), to discuss the implementation of spinning reserve capacity at Soda. One of the major aquatic concerns identified was the potential impact of high-temperature releases from Soda Dam on fish habitat in the Grace bypass reach (i.e., from the dam downstream through Black Canyon to the Grace power plant). Implications for a state sensitive fish species in the project area, Bonneville cutthroat trout (BCT; *Oncorhynchus clarki utah*), were of principal interest.

Continued ECC discussions about the potential impacts on BCT led to the recommendation of a temperature study with two objectives: to evaluate existing river conditions and to assess effects of experimental releases from Soda. The spatial scope of the study includes the Bear River from the base of Soda Dam to Cottonwood Creek, located at the upper end of Oneida (Figure 1), referred to in this report as the study reach.

The study was divided into three tasks:

- Task I: Longitudinal temperature study in the study reach.
- Task II: Experimental spinning reserve assessment in the Grace bypass reach.
- Task III: BCT temperature tolerance literature analysis.

This report describes the methods and results of the completed study.

2.0 METHODS

To address both objectives, 25 Onset Hobo temperature sensors were installed at various locations throughout the study reach (Figure 1, Table 1). The installation of sensors was completed May 30–June 6,

2018. Eleven sensors were removed October 21, 2018, in Black Canyon, and the remaining sensors were removed June 10, 2019. Sensor specifications are listed below.

Onset Hobo MX2201:

- Range: -20° to 70°C (-4° to 158°F) in air -20° to 50°C (-4° to 122°F) in water
- Accuracy: ±0.5°C from -20° to 70°C (-4° to 158°F)
- Resolution: 0.04°C (0.072°F)
- Drift: <0.1°C (0.18°F) per year
- Response Time: 17 minutes typical to 90 percent in air moving 1 m/s (3.3 ft/s), unmounted 7 minutes typical to 90 percent in stirred water, unmounted

Temperature sensors were placed in custom PVC housings to protect them from damage during high flow events. Each sensor was attached to a boulder using 316 bright stainless rope and a bronze cable ferrule or waterproof epoxy. Sensors were set to record at 15-minute intervals and run continuously for a 1-year period, ending in June 2019.

2.1 Task I: Longitudinal Temperature Study

The objective of this task was to place sensors at strategic locations and continuously monitor temperature for a period of 12 months at 15-minute intervals. The longitudinal assessment was intended to identify heating or cooling effects from spring inflow, water diversions causing reduced flows, and the general effect of heat transfer with distance along the study reach. This temporal assessment addressed seasonal temperature variations throughout the study reach, which could exceed the daily average temperature standard of 19°C for cold water habitats. Ambient temperature data were downloaded from an Idaho Department of Transportation weather station 8 miles north of Black Canyon.

The study reach comprises the Dam Complex Geographic Management Unit (GMU) and Gentile Valley GMU. The Dam Complex GMU is a single reach. The Gentile Valley GMU was split into three reaches with boundaries defined by Project features such as dams and diversions, and geomorphic features. The resulting four reaches (Figure 2) are:

1. Last Chance reach (Soda Dam to Grace Dam)
2. Upper and middle bypass reach (Grace Dam to upper spring complex in the bypass reach)
3. Lower bypass reach (upper spring complex to Grace powerplant)
4. Gentile Valley reach (Grace powerplant to Cottonwood Canyon)

Last Chance Reach

This reach is approximately 6-miles from the base of Soda Dam downstream to Grace Dam (Figure 2). The Last Chance diversion dam and canal are located 3.7 miles downstream of Soda and form a small forebay. The Grace forebay is approximately 1.5 miles long and considerably lowers the velocity of the river creating a small reservoir. This section of river is characterized by long runs of laminar flow and short stretches of turbulent riffle habitats.

Three temperature sensors were installed in this reach: BR01 (Soda Dam), BR02 (Last Chance), and Grace forebay (Figures 2 and 3). The Grace forebay sensor was installed on July 25, 2018, for the spin release and remained in place for the duration of the study. The BR01 sensor malfunctioned July 29 and was replaced July 31. The BR02 sensor malfunctioned beginning in February, possibly as a result of highly reduced flows or ice. The sensor continued to operate but exhibited a large diel variation and did not accurately reflect water temperature. These data were removed from the analysis.

Upper and Middle Bypass Reach

This reach is approximately 4.6 miles long, starting at the base of Grace Dam and extending downstream to a spring complex near the Black Canyon Trout Farm. The upper reach is approximately 0.9-miles in length and characterized as shallow, low-velocity run habitat. The middle reach begins approximately 0.75 miles upstream of Turner Bridge and is the beginning of Black Canyon. The canyon is bound by cliff and steep boulder scree. The middle reach is very high gradient dropping 85-90 feet/mile on average. The majority of the habitat is highly turbulent and characterized as riffles, chutes, and rapids with intermittent pool and run habitats.

Two sensors were installed in this reach, BR03 and BR04 (Figure 2 and 4). Data from two long-term monitoring stations operated by Idaho Department of Environmental Quality were also used to characterize longitudinal and temporal changes in the river. The lower end of the middle reach is located above the spring complex. Two sensors (BR03 and BR04) were placed to describe conditions 4.6 miles below Grace Dam. Sensor BR03 is located on the main river channel, and BR04 is located in a small secondary channel on river right. It was hypothesized that temperature in the secondary channel was lower than at the main river channel because of potential groundwater exchange from springs located above the sensor location.

Sensors BR03 and BR04 were removed October 21, 2018. Data at these sites were similar to BR07 and BR11 (located immediately downstream during the spin release) and were not analyzed for the longitudinal study.

Lower Bypass Reach

This reach begins at the spring inflow near Black Canyon Trout Farm and ends at the outflow of the Grace powerplant. The reach is approximately 2 miles in length and has a gradient similar to the middle section, with the upper 0.7-miles described as braided with two distinct channels formed by a series of narrow islands. Habitat is a series of pools, runs, and riffles, creating areas of very turbulent flow, followed by deeps pools of laminar flow. The lower 1.3 miles is a single channel, medium gradient with riffles and runs.

Fifteen sensors (BR05-BR19) were installed in the Lower Bypass reach (Figures 5-8). A number of springs enter the river through this section: two large springs at the top of the reach, one in the middle below the islands, and a small spring near the fishermen's bridge. Spring inflow is estimated at approximately 30 cfs.

Seven temperature sensors were installed in the area around the two large upper springs (Figure 5). Sensor BR05 was located on river right in a small secondary channel approximately 250 feet downstream of BR04. Sensor BR06 captured spring inflow at the immediate interface with the river. Sensor BR07 was located on the main river channel. Sensor BR08 was located just below the second spring inflow. Sensor BR10 was located middle river at the tip of the first island below the springs to capture mixing. Sensor BR11 was located near BR10 farther river left. Sensor BR12 was located downstream of BR10 on river right to capture spring water flow along the secondary channel.

Temperature sensors BR13, BR14, and BR15 were placed in a section where the river is split into two channels (Figure 6). Sensor BR13 was installed near the upper end of the island complex in the middle of the river, where water feeding the left channel flows back into the right channel. This sensor was placed to determine if water continues to mix with spring water cooling the sensor at BR10. Sensors BR14 on river right and BR15 on river left were located mid-island to compare temperatures in both channels and determine if cooler water continues to flow along the right side of the river.

Temperature sensors BR16, BR17, BR18, and BR19 were located upstream 0.6 miles from the fishermen's bridge (Figure 7). Sensor BR16 was located on river right 150 feet below the spring discharge near the lower raceways at the Trout Farm. Sensor BR17 was anchored mid-channel. Sensor BR18 was located downstream on river left. Sensor BR19 was located a quarter mile downstream on river right, and sensor BR09 (Figure 8) was located mid-channel at the fishermen's bridge. BR09 was installed to provide researchers the opportunity to compare historical data collected during white-water boater flows to spin release flows in the future.

Nine of the 15 sensors were removed on October 21, 2018, for the longitudinal study to eliminate redundancy within the reach. Sensors removed include BR05, BR06, BR07, BR08, BR13, BR15, BR16, BR18, and BR19.

Gentile Valley Reach

The Gentile Valley reach begins at the Grace powerplant and continues downstream to Cottonwood Creek at the upper end of Oneida Reservoir, the bottom of the study reach. The reach is 23 miles long and transitions from riffle and run habitat near the Grace powerplant to highly sinuous, low-velocity habitat in Gentile Valley. The bottom end of the reach near Cottonwood is influenced by Oneida Reservoir elevations and deposition of fine sediment.

Six temperature sensors were installed in this reach: BR20 at the old Cove Dam site, BR21 at the Cove powerplant, BR22 at the old Cheese Factory Bridge, BR23 at the Centennial Bridge, BR24 at the Thatcher Bridge, and BR25 at the lower Highway 34 bridge near Cottonwood (Figure 1). Sensor BR21 failed in August 2018, so data from this sensor were not included in the analysis.

2.2 Task II: Experimental Spinning Reserve Assessment

The objective of this task is to simulate a spinning reserve release through Grace bypass reach during the summer months, monitor water temperature, and evaluate the thermal changes in the river. The flow through the bypass reach, calculated to match the probable maximum flow during a spin call at Soda Dam, was 1,200 cfs, reflecting the peak discharge at Soda, irrigation demand above Grace Dam, and flow through the Grace Development.

On July 25, 2018, investigators installed three additional Hobo MX2201 temperature sensors in sections of the Grace bypass reach to provide additional data during the event in the upper sections of the bypass reach. Settings in temperature sensors installed in late May from Soda Dam to the Grace powerplant were changed to record 1-minute intervals and filtered to a 5-minute average to provide a higher resolution of temperature dynamics as water passed through the bypass reach. Site names, coordinates, and reach names for each sensor are found in Table 1. Experimental flows were released from Soda Dam on July 26, 2018, and lasted for 4 hours before being curtailed.

The sensor at the Grace forebay was placed near the spill gates of Grace Dam, at a depth of approximately 8 feet (Figure 3). The Highway 34 sensor was located approximately 0.15 miles downstream of Grace Dam. This sensor was added to determine if the low-level outflow of Grace Dam lowered river temperatures. The Turner Bridge sensor was located approximately 1.5 miles downstream of Grace Dam and approximately 0.75-miles downstream from the top of the middle section of the bypass reach (Figure 4).

2.3 Task III: BCT Temperature Tolerance Literature Analysis

The objective of Task III is to compile readily available data on the thermal requirements of BCT, compare results of the experimental flow analysis to these thermal requirements, and assess potential effects of spinning reserve releases on resident BCT. This analysis is not intended to determine quantitative estimates of project mortality since insufficient information is available to undertake that task, but rather to provide a qualitative assessment of relative risk to target species using information from the spinning reserve experiment and published literature.

3.0 RESULTS

3.1 TASK I: LONGITUDINAL TEMPERATURE STUDY

Ambient Temperature

Ambient temperature data were collected from an Idaho Department of Transportation weather station (site ITDC3) located on Highway 30 in the Gem Valley. The site is approximately 5 miles from Black Canyon. Ambient temperature in the Gem Valley ranged from a maximum of 95.0°F in August to a low of -12.1°F in February. The average monthly temperature ranged from 18.7°F to 69.6°F during the study (Table 2). Average daily, maximum, and minimum temperatures are found in Appendix A.

Flow

Daily average flows from Soda and Grace dams from June 1, 2018, to June 10, 2019, were used to describe the flow conditions in the project area. Flows below Soda Dam generally follow a seasonal hydrograph with high spring flows tapering to winter base flow conditions. Higher summer releases for irrigation extend the high flow conditions before decreasing to natural conditions in early October (Figure 9). Average daily flows briefly peaked above 1,800 cfs in June and July and remained above 1,000 cfs until mid-September before decreasing. Flows declined below 300 cfs in mid-October and remained reduced until March as lower basin runoff began.

Flows below Grace Dam remained consistent throughout the study period. Intermittent releases into the bypass do occur occasionally for forced outages, mitigation (boater flows), experiments (spin release), and excess water during spring runoff. Average daily flows varied during the study from approximately 75–100 cfs. Twenty-nine days were observed when average daily flows exceeded 200 cfs. Peak discharge occurred in the bypass reach during the spin release's forced outage on July 28, reaching a daily average over 900 cfs.

Last Chance Reach

Data collection was completed on June 10, 2019. Daily average water temperature graphs and a summary table are provided in Appendix B. Little difference in seasonal temperature was observed between BR01, BR02, and Grace forebay. Average winter temperatures at BR01 were slightly higher than at BR02 as flows decrease during the winter months and distance from Soda Dam increases (Figure 10). Minimum temperatures observed in February ranged from 0.3°C to 2.2°C at BR02 and BR01, respectively. The highest temperatures were observed in July and ranged from 22.8°C at BR01 to 23.9°C at BR02 (Table 3).

Lower Bypass Reach

Five temperature loggers were analyzed in the bypass reach for the entire study period. Site BR10 receives some temperature influence from spring inflows, having an average monthly temperature range from 20.4°C to 2.4°C peaking in July with a minimum in January (Table 3, Figure 11). The maximum temperature recorded at this site was 24.5°C with a minimum temperature of 0.2°C, in July and February respectively.

Near the uppermost area with spring inflow, BR11 recorded the highest and lowest temperatures in the spring complex area. Comparing temperatures to BR2 upstream in the Last Chance reach, the temperature was similar, slightly cooler during the summer and winter months, but representative of the majority of the bypass reach upstream to Grace Dam. The average temperature ranged from 21.0°C in July to 0.8°C in January at BR11 (Table 3, Figure 11). Temperatures peaked in July with a maximum of 25.0°C and the lowest temperature of -0.1°C in January (Table 3).

BR12 exhibited spring influence on river temperature with the maximum recorded in July (23.6°C) and the minimum recorded in January and March (1.8°C; Table 3). In January, average monthly temperatures at

BR12 were 2.8°C warmer than BR11 and 1.2°C warmer than BR10. The average seasonal temperature range at BR12 was 19.8°C to 3.6°C, in July and January respectively.

The monthly average temperatures at BR17 and BR09 were nearly identical, similar to BR10 (Figure11), ranging from 19.5°C to 2.6°C at BR09 and 19.3°C to 2.8°C at BR17. BR09 was 0.2°C warmer in July and cooler in January. The maximum temperatures recorded in July at BR17 and BR09 were 23.0°C, and the minimums were 1.2°C and 0.6°C, respectively.

Gentile Valley Reach

Maximum temperatures across the sites in Gentile Valley had July peaks ranging from 25.2°C to 23.2°C at BR24 and BR22, respectively (Table 3, Figure 12). July maximum at BR20 (23.9°C) was slightly warmer than BR22 with a 0.7°C difference; BR23, and BR25 peaked at 25.1°C and 23.9°C.

Average monthly temperature among the sites was similar during higher flow conditions in the spring, summer, and fall. July average temperatures remained below 22.0°C at all sites with BR22 being approximately 1.0°C cooler than both upstream and downstream sites (Table 3).

Winter low flow conditions create a divergence in monthly average temperature (Figure 12). The minimum temperature recorded at BR20 was 0.0°C in January and February with an average January temperature of 1.5°C. BR22 maintained a much warmer average low during February, with a temperature of 4.8°C, a difference of 3.3°C. The minimum temperature at BR22 was 2.7°C in January and February. Temperatures at BR23, BR24, and BR25 had similar average January averages of 2.5°C, 1.9°C, and 0.9°C, respectively. The lowest temperature recorded occurred at BR23 with -0.2°C in January and February. BR24 had a slightly warmer low in February at 0.8°C, and BR 25 recorded lows in January, February, and March of -0.1°C.

3.2 Task II: Experimental Spinning Reserve Assessment

Flow

The spinning reserve experiment was initiated on July 26, 2018. River flows were ramped from 1,364 cfs to 2,390 cfs, with an estimated flow through the radial gates on Soda Dam of 1,040 cfs. The full flow of 2,390 cfs was carried through the upper section of the river to Last Chance, where continued depletions of 340 cfs occurred at Last Chance Canal for irrigation demands. Flows into the Grace forebay were estimated at 2,050 cfs for approximately 2 hours. The additional water allowed the Grace powerplant to slowly ramp down while increasing flows in the bypass reach.

Prior to the spinning reserve experiment, base flows in the bypass reach were stable at 87 cfs; during the experiment, flows increased to a high flow of 1,288 cfs for 4 hours before ramping back to normal operations (Figure 13). As flows decreased in the bypass reach and normal operations resumed, the Grace powerplant experienced a “forced outage” due to a breakage in the penstock requiring the plant to ramp down, go offline, and divert water into the bypass reach to meet irrigation demands. Flows in the bypass reach remained above 1,000 cfs until July 29, 2018, when the Grace plant resumed operations.

Last Chance Reach

Water temperature below Soda at BR01 can be characterized as homogenous, indicating that water in the reservoir is mixed throughout the water column. From July 25-29, during the experiment and over a broad range of flows, temperature varied little, with a maximum temperature of 22.1°C and a minimum of 21.4°C (Figure 14, Table 4). No effects on temperature were observed during the simulated spinning release.

The BR02 sensor is located immediately below the Last Chance powerplant in riffle habitat. Temperatures observed over the study period indicated a slight diel cycle with a max temperature of 23.4°C (Table 4). Minimum temperatures observed were slightly lower than releases at Soda. No changes in river temperature were observed as flows varied throughout the study.

Upper and Middle Bypass Reach

Water temperature at Highway 34 is on average 0.6°C cooler than at Grace forebay, suggesting that there is a slight temperature variation in the water column. The diel curve is very similar to the Grace forebay, and no noticeable effect in temperature was observed during the experiment. The maximum temperature recorded at the Highway 34 sensor during the release occurred on July 26, peaking at 23.1°C (Table 5).

Turner Bridge is the first site where a typical, Western-river, large diel temperature pattern is evident. Peak diel temperature range under normal flow conditions is approximately 6.1°C, with a maximum daily temperature of 26.3°C, recorded the day prior to the experiment, and a minimum of 20.2°C the morning of the experiment (Figure 15, Table 5). These were the highest temperatures recorded from Soda Dam to Grace powerplant.

The Turner Bridge sensor location was the first site downstream from Soda Dam where a noticeable effect from the 4-hour spinning reserve experiment was observed. Peak temperature during the experiment was 23.9°C (Table 5). At the onset of increased flows, temperature became unstable with a short spike then slight decreases before climbing again. The second spike in temperature occurred as flows decreased to normal conditions as the experiment ended (Figure 15).

Although flows were elevated in the bypass reach during the forced outage, maximum temperature at Turner Bridge remained similar to releases at Soda. Slight diel patterns were observed, with cooler daytime peak temperatures on July 27 and 28 (22.5°C, 22.3°C). The minimum temperatures remained similar (Table 5).

Temperatures recorded at BR03 and BR04 were identical; there was no divergence in temperature between the sites throughout a diel cycle (Figure 15). Temperature at the lower end of the middle section was considerably cooler than at Turner Bridge. Prior to the experiment, daily maximum and minimum temperatures recorded were 23.5°C and 18.5°C, respectively (Table 5). Temperatures recorded during the experiment peaked at 23.3°C, just as flows began to increase as a result of the forced outage. However, they were slightly below the previous day under normal conditions. The following days, during the forced outage, maximum daily temperatures were about 22.2°C and 22.4°C, approximately 1.0°C lower than under normal flow conditions. Similar to upstream sites, daily minimum temperatures were elevated at 20.9°C and 20.7°C the following days (Table 5). It should be noted that minimum temperature was considerably lower after flows receded than prior to the experiment (17.7°C).

Lower Bypass Reach

Spring-water inflow at the BR06 location was the coldest recorded, ranging from a low of 14.2°C to a maximum of 17.4°C on July 25 (Table 6). The experimental release inundated the site, and temperature increased similar to other sites in the area (Figure 16). Even though the site measured 100 percent of the spring inflow, temperature during the experiment and high-water event were not substantially reduced (22.4°C) when compared to upstream sites. Temperature remained elevated during high flows.

Conditions at BR05 are cooler than many sites near the spring inflow (Figure 17). The maximum and minimum temperatures recorded were 20.7°C and 17.4°C prior to the experiment (Table 6), 2.8°C and 1.3°C cooler than BR04, respectively.

The BR05 sensor location was the first site where an increase in maximum daily temperature was observed during the flow experiment. Maximum temperature increased from 20.7°C to 22.6°C, a 1.9°C increase from the previous day. As high-water conditions persisted, maximum daily temperatures remained at approximately 22°C until flows returned to normal (Table 6).

Sensors BR07 and BR11 recorded nearly identical temperature ranges, similar to upstream sites indicating the main channel and far river left are not influenced by cold water inflows (Figure 17). BR07 and BR11 recorded maximum daily temperatures prior to the experiment of 23.5°C and 23.7°C, respectively, and approximately the same minimum temperature 19.0°C (Table 6). During the flow experiment, maximum temperature at BR07 (23.3°C) and BR11 (22.8°C) were similar or slightly cooler than existing conditions. Temperatures for BR07 followed the same pattern as upstream sites during high flows. A temperature divergence at BR11 was observed after the forced outage; maximum temperature was lower and minimum temperature higher, creating a narrow temperature diel cycle (Figure 17).

Water temperatures recorded by the BR08 sensor were among the lowest across all river sites. This sensor was located just below the second spring inflow. Maximum daily temperature prior to the experiment was 20.4°C and minimum temperature was 16.3°C (Table 6). As flows from the experiment increased, temperature increased similar to other sites. Maximum temperature recorded during the experiment was 22.1°C, on average approximately 1.0°C cooler than water on the left bank and upstream sites at BR03 and BR07 sensor locations. This trend continued as flows remained high for the forced outage the following days. Temperature quickly returned to normal as conditions changed with decreasing flow (Figure 17). Minimum temperature during the forced outage was 19.8°C, and 3.5°C higher than conditions on July 25.

The BR10 and BR12 sensor locations can be described as a temperature mixing zone for the area around the springs. BR10 was located at the tip of the first island, splitting the river into two channels, and BR12 was located along the right bank on river right (Figure 5). Under normal operating conditions, maximum daily temperature prior to the experiment was measured at 22.8°C at BR10 and 22.2°C at BR12 (Table 6). During the flow experiment and forced outage, temperature followed a similar pattern as surrounding sites. Maximum temperatures recorded during the experiment were slightly higher than the previous day – a 0.2°C increase. A thermal gradient across the river was observed in the springs area and large pool habitat where river right is cooler than river left.

Temperature sensors BR13, BR14, and BR15 had similar maximum daily temperatures the day prior to the experiment, 22.6°C, 22.5°C, 22.8°C, respectively (Table 7). Maximum daily temperature at BR13 was slightly cooler (0.2°C) than BR10 suggesting some continual mixing occurs. During the experiment, temperatures rose slightly to 23.2, 23.1°C, and 23.3°C, respectively, and followed a similar pattern at all three sites (Table 7, Figure 18). As high flows continued, temperatures remained similar to maximum temperatures measured prior to the experiment. Differences between the right and left channel were measured at these sites, suggesting the river is thoroughly mixed at a quarter mile below spring inflow into the lower bypass reach.

Temperature data from the cluster of sensors BR16, BR17, BR18, BR19, and BR09 in the lower reach suggest there is a thermal gradient across the river channel. Sensors BR16 and BR19, both located on river right, had lower maximum daily temperatures (Table 8). Temperatures at the midchannel sensors BR17 and BR09 were slightly higher, and BR18 on river left recorded the warmest water temperatures of any sensor in this reach during the experiment (Figure 19). The spring discharge cools river right (2.2°C) from upstream sensors BR14 and BR15 in the split channel area downstream to BR16. Sensors BR16, BR17, BR18, and BR19 recorded maximum daily temperatures the day prior to the experiment of 20.3°C, 21.3°C, 22.0°C, and 20.7°C, respectively (Table 8). Cool water from the spring inflow flows along the relatively narrow channel (45-foot average) maintaining the thermal gradient in highly turbulent riffles.

During the experiment, temperatures increased similarly to all upstream sites. Maximum temperature on the right side of the channel increased 1.9°C (22.2°C) at BR16 and 1.7 °C (22.4°C) at BR19, then began to decrease slowly as high flows continued (Table 8). Temperatures recorded at BR17 and BR18 were slightly warmer during the experiment and increased 1.3°C (22.6°C) and 0.9°C (22.9°C), respectively. During the forced outage, river right maintained slightly cooler daily maximum and minimum temperatures and returned to normal conditions as flows were reduced.

Sensor BR09 recorded similar maximum temperatures to BR17 mid-channel prior to the experiment, although slightly warmer with a 0.5°C (21.8°C) difference and similar maximum temperatures during the experiment (0.1°C difference; Table 8, Figure 19). These data suggest the river does not warm up as rapidly as the area near the upper springs. Peak temperatures during the experiment at BR09 (22.7°C) were similar to upstream sites and continued to follow a similar diel cycle throughout the experiment and forced outage.

The temperature differential from July 25 (the day prior to the experiment) and the effect on maximum daily temperature during the experiment (July 26), the forced outage (July 27−28), and the return to normal conditions (July 30) is summarized in Table 9. Throughout the upper river, from Soda Dam to Grace Dam temperature was not affected by flow variation. In the bypass reach from Grace Dam to the Upper Spring Complex, maximum daily temperatures measured at sensors BR07 and BR11 were reduced during the experiment. The greatest reduction in temperature was observed at Turner Bridge during the forced outage (-4.0°C). The largest temperature increase in the river was observed just below the lower spring complex (which includes discharge from the Black Canyon Trout Farm lower raceway) at BR16 having a 2.0°C increase in temperature. BR05 above the spring inflow recorded an increase of 1.9°C as a result of the higher flows. Overall the lower canyon (excluding BR06, BR07, and BR11) had a general maximum daily temperature increase of 1.1°C as a result of the experiment.

Although this study was focused on the maximum daily temperature to illustrate changes that may occur during a summertime spinning reserve release, and address potential effects of temperature variation on BCT in the project area, changes that occur over time with daily average temperatures are also important in terms of fish behavior. The daily average temperatures at Soda Dam (BR01) were 22.0°C on July 25, 21.9°C on July 26, and trending lower during the forced outage (Table 10). Sites from Soda Dam to Grace Dam had the highest temperature averages peaking in Grace forebay at 22.5°C the day of the experiment. The only site to have average temperature above 22.0°C in the bypass reach was Highway 34 bridge the day of the experiment (22.3°C). The river begins to cool as water travels down the bypass reach. At Turner Bridge, the peak average temperature (21.9°C) was slightly cooler than sites up river the day of the experiment.

An average daily temperature increase was observed throughout much of the lower bypass reach. For example, BR08 and BR16 (sensors measuring lowest temperature) recorded a 1.0°C temperature increase to 19.2°C and 19.5°C, respectively (Table 10). A slight increase of less than half a degree was recorded at other sites as a result of the experiment (e.g., BR14 0.4°C and BR15 0.2°C). Overall, daily average temperatures remained below 22.0°C across all monitoring sites in the bypass reach during the experiment, including sites above the spring complex with the exception of Highway 34. All sites from BR03 downstream to the fishermen's bridge averaged 20.3°C the day of the experiment, a 0.5°C increase from temperatures recorded on July 25th. Flow as a result of the forced outage continued to increase average daily temperatures at all sites in the bypass reach up to 21.3°C on July 27 and 28, before normal operation resumed.

3.3. TASK III: BCT TEMPERATURE TOLERANCE LITERATURE ANALYSIS

Fish Community

Fish species known to occur in the study reach include, in addition to BCT, rainbow trout (*O. mykiss)*, Utah sucker (*C. arden)s*, mottled sculpin (*Cottus baird)i*, speckled dace (*Rhynichthys osculus)*, longnose dace (*R. cataractae)*, redside shiner (*Richardsonius balteatu)s*, smallmouth bass (*Micropterus dolomieu)*, and common carp (*Cyprinus carpio)* (Oasis 2008). Other species that have been observed in the Bear River and may occur in the project area include brown trout (*Salmo trutta)*, walleye (*Sander viterus)*, and yellow perch (*Perca flavescents)* (Hillyard and Keeley 2012). All of these species are native except rainbow trout, brown trout, walleye, yellow perch, smallmouth bass, and common carp. Hybridization of BCT with rainbow trout has been observed in the past through genetic testing, and some hybrid fish may be present in the project area (Campbell et al. 2006; ECC undated).

Bonneville Cutthroat Trout

Biology and Life History

BCT is one of 14 subspecies of cutthroat trout recognized as native to interior portions of western North America (Behnke 1992). Fish may be found in a variety of different environments ranging from small headwater streams to rivers and streams at lower elevations to lakes or reservoirs. Individuals feed primarily on aquatic invertebrates and terrestrial insects during their lives (May et al. 1978) but may consume small fish if they attain sufficient size (Lentsch et al. 2000). Growth is largely a function of temperature and site productivity.

Maturity is reached generally by age 2 for males and age 3 for females. BCT in Birch Creek, a small stream in southcentral Utah, became mature in their second year upon reaching about 134 mm total length (TL) as males and 147 mm TL as females (May et al. 1978), although maturity can occur at a larger size at localities where growth is more rapid. Spawning occurs in late spring when temperatures range from about 4-10°C (May et al. 1978) and chiefly during May and June, although elevation, temperature, and life history strategy can influence the exact timing (USFWS 2001).

Larval emergence occurs typically during mid to late summer. Precise timing depends largely on when spawning occurs and stream temperatures. Larvae are poor swimmers and migrate or drift downstream, settling into lower velocity habitats along stream margins. As fish grow, they soon occupy more mid-channel habitats (Nielson and Lentsch 1988).

BCT exhibit four distinct life history adaptations: lacustrine (spawning/rearing occurs in lakes); adfluvial (adults live in lakes, spawn in lake tributaries); fluvial (migration between mainstem river and tributary); and resident (adults remain in stream, no migration). Past studies indicate that a population can exhibit more than one life history strategy, such as a stream population including both fluvial and resident components (Colyer et al. 2005; Randall 2012).

Habitat fragmentation caused by the construction of diversions and other human activities has caused many populations of fluvial BCT and other native cutthroat to decline or disappear. As a result, there are relatively few remaining fluvial BCT populations available for scientific study. One such study examined movement of radio-tagged adults in the Thomas Fork of the Bear River in Idaho and Wyoming in relation to a diversion structure. Home ranges were more extensive above the structure than below it; however, the researchers noted attempts to ascend the structure in the spring. Substantial portions (>50 percent) of both upstream and downstream groups were mobile (>1 km movement) with median home ranges of about 2 km even during the fall and winter periods, contrary to the relatively sedentary behavior that was expected initially. During spring, some fish had moved as far as 86 km into tributaries of the Thomas Fork, presumably for spawning (Colyer et al. 2005). Related work documented post-spawning movements of similar magnitude in the spring of up to 82 km, but fish remained relatively sedentary in the summer when movements did not exceed 0.5 km. They also reported that 23 percent of the radio-tagged fish eventually became entrained in an irrigation diversion (Schrank and Rahel 2004).

Stream resident populations appear to move far less than fluvial populations, particularly during fall and winter (Hilderbrand and Kershner 2000).

Conservation Status

BCT were present historically throughout the Bonneville Basin, which was covered by Lake Bonneville during the Pleistocene Epoch up to about 30,000 years ago. The lake encompassed parts of Idaho, Wyoming, Nevada, and Utah. After the lake retreated, cutthroat populations became restricted to headwater streams and lakes. Numbers have dwindled in recent years due to various human activities, raising concerns among resource agencies regarding its future prospects (Lentsch et al. 1997).

BCT are not listed as a Sensitive Species by Idaho Fish and Game (IDFG) but are listed as a Tier I Sensitive Species by the Utah Division of Wildlife Resources. They have also been afforded Sensitive Species status by the US Forest Service (USFS) Intermountain Region and the US Bureau of Land Management. In 1992 and 1998, they were unsuccessfully petitioned for listing under the Endangered Species Act (ESA) (Lentsch et al. 2000). Most recently, on September 9, 2008, the US Fish and Wildlife Service (USFWS) again concluded there was insufficient cause to list it as either threatened or endangered under the ESA (Federal Register 2008).

Continuing threats include: (1) water development projects affecting timing, magnitude, and duration of stream flows; (2) degraded aquatic habitat and water quality; (3) riparian habitat loss; (4) interruption of migratory corridors by manmade barriers; and (5) competition with, predation by, and hybridization with nonnative fishes (Lentsch et al. 2000). Potential impacts on upstream and downstream movement of BCT is a principal concern of agencies.

In addition, natural factors such as drought and fire have also been shown to impact BCT through vegetation community change, water quality impacts, and other mechanisms (Hepworth et al. 1997; White and Rahel 2008). Frequency and severity of these events may be exacerbated by ongoing, human-induced global warming, which could further threaten coldwater species like BCT well into the future (Williams et al. 2007; Haak et al. 2010).

To protect BCT from further decline and foster recovery, the State of Idaho developed a BCT Conservation Management Plan (Tuescher and Capsuro 2007). To facilitate BCT management efforts in Idaho, its known range was separated into six Geographic Management Units (GMUs) extending from the Wyoming State line, the eastern limit of the BCT distribution in Idaho, to the Malad River Basin, to the Utah border. The Bear River Project boundaries are located within four GMUs which include the following; Nounan Valley, Dam Complex, Gentile Valley, and Riverdale GMUs. The Bear River Project dams delineate boundaries for three of the four units. As noted previously, the focus of this temperature study falls specifically within the Dam Complex and Gentile Valley GMUs starting at Soda Dam and ending at the head of Oneida.

Conservation actions outlined in the BCT Management Plan to guide sustainability efforts in Idaho include: (1) surveys to document population status; (2) genetic analysis to determine purity; (3) reconnecting, protecting, and enhancing important habitats; (4) nonnative fish control; (5) reintroduction via broodstock augmentation; and (6) continued monitoring (Tuescher and Capsuro 2007). All of these activities have been undertaken in Idaho and ongoing efforts are part of these management goals.

Project Area Studies

As part of the Settlement Agreement and License Article 403, PacifiCorp was required to develop a Comprehensive BCT Restoration Plan in collaboration with ECC partners. PacifiCorp and the ECC have conducted research and improvement projects since issuance of the new license, with the ultimate goal of expanding BCT populations in the Bear River to historic ranges. This collaborative plan, initiated by PacifiCorp and ECC members in 2004, focused on several key areas including 1) documenting BCT genetics, restoration areas and barriers for survival probability, 2) defining adult movement patterns and migratory ranges because of its relevance to population viability and persistence, and 3) establishing a brood stock program to augment populations and reintroduction to extirpated tributaries.

Beginning in 1998, IDFG and USFS began collecting fin clips throughout the Bear River Basin in Idaho and Wyoming. Collection concluded in 2005 with approximately 1,200 samples collected from 44 streams and tributaries, generally meeting the goal of obtaining 30 samples from each waterway. The primary objectives included assessing intraspecific and interspecific hybridization and introgression in cutthroat trout within the Bear River drainage, and assessing DNA diversity and distribution in cutthroat trout throughout the drainage (Campbell et al. 2006). The study concluded that BCT in the Bear River drainage are a distinct population from Southern BCT found in Utah and remnant numbers in the Malad GMU. BCT in the Bear River exhibit characteristics similar to Yellowstone cutthroat, but only three tributaries showed evidence of hatchery-reared genetic markers found in Henrys Lake, Yellowstone Lake, and Jackson National Fish Hatchery, leading investigators to conclude nonnative cutthroat are not well adapted to desert conditions of the Bear River drainage. In order to foster the sustainability of the BCT population, agencies need to identify and preserve core populations of BCT within the Bear River drainage.

Telemetry studies were initiated in 2005, with mitigation funding from PacifiCorp and IDFG, to better understand seasonal movement patterns of fluvial BCT in the Bear River. These initial studies focused on the Pegram and Nounan GMUs (above the study reach) and were used as a basis for creating the Comprehensive BCT Restoration Plan. Additional telemetry studies were conducted 2012-14 in the Gentile

Valley Complex GMU to monitor whitewater boater flows (WWBF), a license condition providing recreational opportunities. This study involved implanting 108 transponders in BCT to track movements through the Grace bypass reach to determine if high flushing flows (minimum of 700 cfs) would displace BCT in the canyon. Between April and May of 2013-14, eight WWBF events occurred where fish tracking noted three fish (<3 percent) were displaced as a result of the high flows (ECC, no date).

For a subsequent study in the bypass reach conducted from 2012-14, researchers installed passive integrated transponder arrays (PIT tag) to track downward stream movement of BCT and assess the potential effects from WWBF. Results were similar to the telemetry studies, where a low number of BCT were displaced as a result of high flushing flows. During the study researchers noted a large percentage (65 percent) of the PIT tagged fish moved downstream prior to the WWBF events.

BCT Thermal Tolerance Literature

Temperature has long been acknowledged as a key factor influencing distribution, behavior, and physiology of fish (Johnstone and Rahel 2003). Elements within a temperature profile (maximum, daily average, and seasonal variability) provide important cues to aquatic organisms and signal growth, hibernation, and reproduction (Poole et al. 2004).

A myriad of factors influence temperature including solar radiation, shading, ambient surface temperature, streamflow, groundwater exchange, and basin morphology. Under the Clean Water Act, regulators attempted to generate temperature criteria to sustain self-supporting populations of fishes. However, throughout the West, conventional water quality standards are often poorly suited in describing in-stream conditions that fulfill or meet criteria and management goals (Poole et. al 2004). A number of states have undertaken efforts to rewrite temperature criteria for salmonids in order to address the range of conditions in areas a species inhabits (WA Department of Ecology 2002; NDEP 2016; Todd et al. 2008).

Many studies have attempted to quantify the thermal limits of fish by either constant or continually increasing temperature (Fry 1967). Constant thermal exposure in a controlled setting has allowed researchers to determine the upper incipient lethal temperature (LT50), described as the temperature lethal to 50 percent of the test population over a period of time. The LT50 has been widely studied for salmonids. A broad range of temperatures have been established, with the LT50 ranging from 23.9°C-29.9°C for a number of salmonids (Meeham 1991). This may provide researchers the upper tolerance of a species, but the ecological practicality is unknown because streams usually have a diurnal cycle varying in magnitude.

Wagner et al. (2001) compared four stocks of BCT in critical thermal maximum (CTM) and 96-hour tolerance tests at extreme temperatures. Bear Lake, southern Bonneville, Snake River (fine spotted), and Electric Lake stocks were used to compare inherent differences among strains of cutthroat. During the CTM test, using two acclimating temperatures, 13.6°C and 18°C, stocks of fish were randomly selected and placed in 3-L tanks. Temperature was increased rapidly at 0.2°C per minute until first signs of loss of equilibrium and the onset of spasms, when tests were concluded. For fish acclimated at higher temperatures, CTM was significantly higher than for fish acclimated at lower temperatures. Bear Lake and Snake River cutthroat had equilibrium loss at 27.9°C and 28.2°C, and the onset of spasms at 28.6°C and 28.6°C, respectively, in 13.6°C acclimating water. When fish were acclimated to 18°C, Bear Lake and Snake River cutthroat had tolerances at 29.7 and 29.4°C during the onset of equilibrium loss and spasms at 30.0 and 29.6°C, respectively. No significant difference was noted among the four stocks of cutthroat.

During the tolerance tests fish were acclimated at the same two temperatures (13.6 and 18.0°C). Fish acclimated to 13.6°C were tested in 23-24°C water. Bear Lake and Snake River cutthroat in 24°C water experienced a 100 percent mortality rate, significantly higher than southern BCT (13 percent). Fish subjected to an acclimating temperature of 18°C experienced a 100 percent mortality rate for Snake River and Bear Lake cutthroat when temperatures were increased to 24.5°C, while southern BCT had a 75 percent mortality rate. The LT50 for Snake River cutthroat was calculated at 23.5°C and Bear Lake was 23.9°C.

Johnstone and Rahel (2003) undertook a comprehensive effort to evaluate the thermal tolerances of BCT. They first conducted an upper incipent lethal limit test to determine the LT50 over the course of a 7-day constant exposure period. Next, they examined the survival of BCT by fluctuating temperature daily attempting to mimic conditions observed in Western rivers and streams. To begin the temperature tolerance trial and determine the LT50, fish were held at a constant 18°C for a period of 2-3 weeks to acclimate, before increasing to test temperatures. Test temperatures from 19°C to 26°C (19, 22, 24, 25, 25.5, 26, replication at 22 and 24) were used in the experiment. No fish survived over 25°C, and mortality began at hour 11 for fish at 25.5°C and hour 14 for fish at 26°C. The LT50 over the course of the 7-day trial was calculated at 24.2°C with a 95 percent confidence range of 23.9-24.6°C.

Following the constant temperature trial, researchers began the fluctuating temperature trial to mimic a natural system. Fish were placed in a tank at 10°C and gradually increased temperature by 2°C daily to the target temperature of cycling 10-20°C for a 7-day period, identified as the moderate cycle. After seven days, temperature was increased 2°C until the target fluctuation was 16-26°C and held for a 7-day period, this was identified as the extreme cycle. Following a 7-day period at the extreme cycle, the temperature was raised 1°C per day until all the fish died. No fish died during the moderate and extreme cycling temperature; mortality began with cycling temperatures 18-28°C, and 100 percent mortality was observed at 19-29°C.

Schrank et al. (2003) conducted field sampling to evaluate the thermal criteria for BCT derived in laboratory settings from Johnstone and Rahel (2003). The study took place in the Thomas Fork basin in Coal Creek, a tributary to the Bear River. Thermal conditions were measured at three sites using temperature loggers throughout the study period when fish were tracked. Handheld thermometers were used to validate conditions. To determine movements of fish the following methods were implemented: (1) population estimates to determine emigration in response to warming temperatures; (2) radio telemetry to track fish from June to September; (3) visible implants (VI tag) to identify fish at sites sampled multiple times; and (4) two-way weir to detect emigration of fish during periods of high water temperature.

Thermal conditions observed in Coal Creek during the 2-year study show two sites exceeding the laboratory established LT50 of 24.2°C. In 2000, upper Coal Creek exceeded the LT50 for 5-weeks, with a maximum daily temperature of 27.1°C, and middle Coal Creek for 2-weeks with a maximum daily temperature of 26°C. Field measurements were identical to the logger temperatures, validating the functional accuracy of loggers.

Population estimates were conducted three times in 1999 and again in 2000 during June, July, and August to estimate abundance and to determine if fish emigrated from the area due to increasing temperature. In 1999, populations in upper and middle Coal Creek remained similar throughout the summer months. However, estimates during 2000 suggest a substantial increase in population in July and August, even though temperatures exceeded the LT50 for a 5-week period.

Six fish implanted with telemetry tags remained within ±200 m of the tagging location throughout the summer of 1999. Fish were located every other day, and temperature was measured within meters of the fish's location and validated by fish body temperatures in two fish recorded by the transmitter. Correlation between thermometer and telemetry tag was significant (r^2=0.97) and suggested that fish were not seeking cold water habitats but inhabiting warm-water conditions.

In 2000, fish were implanted with VI tags. During population estimates, tags were identified, further verifying fish were staying within the same reach. Weir data showed no evidence that fish emigrated from the tributaries during the summer. Based on the other methods, it is clear that mortality was not occurring with increased populations in the reaches, e.g. none of the fish implanted with radio transmitters died over the 2 months, and VI tags were documented in recaptures with temperatures increasing throughout the summer.

Hillyard and Keeley (2012) conducted a temperature suitability study for BCT in the Pegram (extending into Wyoming) and Nounan Valley GMUs of the Bear River to identify habitat availability and determine if BCT selectively seek cool-water habitats during extreme summer temperatures. This study compared fixed temperature loggers and weekly meter-accurate floating temperature surveys to temperature-sensitive telemetry tags.

Thirty-four temperature loggers were placed systematically in the two reaches, recording at 30-minute intervals, approximately 5 km apart. Floating surveys were conducted weekly, including seven surveys in each reach from July 15 – October 6. These data were used to characterize habitat conditions and calculate average weekly mean temperature.

A total of 84 BCT (32 Nounan Valley, 52 Pegram GMUs) were tagged with temperature-sensitive transmitters and tracked June-November 2006. A total of 1,186 tracking locations were recorded, with an average of 14 detections per fish. Average weekly mean temperature from transmitters was used to determine temperatures used by BCT.

During July, river temperatures approached or exceeded the LT50 of 24.2°C. One BCT in the Pegram GMU was observed in habitat exceeding the LT50. Overall, 98 percent of the fish moved to habitat cooler than the average daily temperature during this period.

Linear regression analysis of the relationship between average weekly river temperature and temperature use by BCT was employed to compare the frequency of use. As river temperature increased, habitat selection increased proportionally in the Nounan reach. In the Pegram reach, as temperature increased BCT were less selective until temperature increased above 22-23°C.

Comparing the distribution of temperatures used by BCT (July 15-August) and the distribution of river temperature from thermal imagery data collected in 2006 indicated that 63 percent of the BCT within the Nounan GMU utilized habitat with temperatures <22.0°C, and 98 percent used habitats with temperatures < 24.2°C. Within the Pegram GMU, 59 percent of BCT used habitats <22.0°C, and 97 percent used habitats < 24.2 °C.

4.0 DISCUSSION

4.1 LONGITUDINAL TEMPERATURE STUDY

The Bear River is a highly regulated river with impoundments for water storage and diversions for irrigation use that drastically alter the natural hydrograph. This has created sections of the river with limited flow in summer and areas of high flow to transfer water to irrigators or to produce electricity. These factors can drastically alter temperature in segments of the river.

Average temperature variations within the Last Chance reach were very similar and followed seasonal ambient temperature changes. BR01 and BR02 maintained very similar average temperatures during the spring, summer, and fall months. Average July temperature at BR01 and BR02 was 21.5°C.

As ambient temperature and flow decreased in late fall, site BR02 began to cool and deviate from temperatures at BR01. These low winter flows created the highest difference in average temperature and occurred in February, with BR01 and BR02 reaching lows of 2.2°C and 0.3°C, respectively. The large thermal mass of water in Alexander Reservoir suppressed peak temperatures in the summer and buffered lows in the winter at BR01.

Average temperatures observed in the bypass reach were nearly identical during fall and spring. Temperatures began to diverge with increasing ambient temperature. Spring inflow in the lower bypass reach resulted in cooler average summer temperatures than water released from Grace Dam. Sites BR10, BR11, BR12 illustrated the effect of spring inflow, with average July temperatures of 20.4°C, 21.0°C, and 19.8°C, respectively. BR12 exhibited more influence from spring inflow and was substantially cooler than BR11 across the river. BR10 experienced intermediate temperatures between the two sites.

As ambient temperatures decreased in the valley, water from Grace Dam cooled and temperature patterns at BR12, BR11, and BR10 inverted. Where spring inflow warmed Bear River water, BR12 on average during the winter months was almost 3.0°C warmer than BR11. This inverse relationship was observed throughout the winter months at BR09 and BR17 downstream and remained similar to temperatures observed at BR10. Continued spring inflow at the lower springs appeared to help maintain warmer winter average temperatures. BR09 and BR17 tended to be almost 2.0°C warmer than BR11.

Temperatures at five sites in Gentile Valley followed similar seasonal trends with temperatures in the summer gradually increasing and peaking in July. The highest maximum temperature at BR24 reached 25.2°C, similar to upstream sites above the spring complex. BR20, BR23, BR24, and BR25 all had similar July average temperatures with a range of 21.1°C to 21.8°C. BR22 had a notably lower July average of 20.3°C, consistent with temperatures observed in the lower bypass reach.

As summer irrigation releases declined, water temperatures among the sites began to diverge. January temperatures at BR25 maintained the coldest average of the Gentile Valley sites, and were similar to BR20, ranging from 0.9°C to 1.5°C, respectively. BR23 and BR24 were slightly warmer having January averages of 2.5°C and 1.9°C, respectively. January lows were similar to those recorded in the bypass reach. The BR22 is the notable exception having an average January temperature of 4.9°C and February of 4.8°C. This was substantially warmer than any site observed in the study area.

For short periods of time, all sites monitored during the study period exceeded the IDEQ daily average temperature standard of 19°C. June 3, 2018, was the first day the river rose above 19°C at BR24 (Appendix B). On July 8, 2018, all sites in the study reach exceeded 19°C daily average and continued to do so until July 28. The last day the river exceeded 19°C was August 21 at sites BR01, BR02, and BR20.

4.2 EXPERIMENTAL SPINNING RESERVE ASSESSMENT

During the summer months, observed releases at Soda Dam had little diel temperature variation. This suggests that there are periods of time when the reservoir has a thoroughly mixed water column, and releases create a diminished diel temperature pattern below the dam. This was observed at sensor BR01, with 1,040 cfs spilling near surface water through the radial gates and the remainder passing through the turbines during the spinning reserve experiment. No temperature change was observed as a result of the increased flow during the spinning reserve experiment at this site.

Temperature in the Last Chance reach had similar minimum and maximum values with a limited diel pattern. Temperature variance at BR01 was <0.5°C throughout the range of flows during the experiment and <0.6°C for the entire period (July 25-30). Temperature at BR02 was similar to BR01, but the formation of a narrow diel pattern could be observed with a range of <2.0°C. Temperature in the Grace forebay exhibited a similar pattern to BR02 at Last Chance.

Minimum base flow conditions in the Grace bypass reach were 87 cfs during the study period, with the reach gaining flow from the springs. During the spinning reserve experiment, flows were increased to 1,245 cfs to simulate a typical spin call for emergency power. The experiment lasted for 4 hours. Temperatures below Grace Dam, through the upper and middle reaches, exhibited higher maximum values compared to downstream sites. Temperatures at Highway 34 were very similar to the Grace forebay. Substantial heating occurred over a short distance, where measured temperatures were in excess of the LT50 for BCT at Turner Bridge (26.3°C). This was the only site in the bypass reach to exceed the LT50.

During the experiment, maximum daily temperatures were reduced substantially at Turner Bridge and maintained lower maximum temperatures during the forced outage on July 27 and 28. As flow in the bypass reach returned to normal, daily maximum temperature at Turner Bridge began to exceed the LT50. Maximum daily temperature at BR03 and BR04 were substantially cooler (3.0 °C) than at Turner Bridge.

There may be some groundwater exchange, and the turbulent nature of the middle reach may allow air temperature conditions at night to have a cooling effect on the river.

Daily maximum temperature varied throughout the upper spring inflow area. Water temperature at river right (BR05 and BR08) was substantially lower (3.1°C) than the far-left bank (BR11) as a result of spring water inflow. Spring water mixes rapidly with upstream flows. The distance between BR08 and BR10 is 130 feet, with a corresponding temperature difference of 2.4°C. Similarly, temperature difference at BR12 and BR08 (located 250 feet apart), is 1.8°C. During the experiment, temperature increased at sites along river right (BR05 and BR08), while temperature on the far left and middle channel remained similar. Maximum temperatures were relatively unchanged at BR07, BR10, BR11, and BR12.

During the forced outage on July 27−28, flows remained above 1,000 cfs in the bypass reach. Maximum daily temperature across all sites around the upper spring complex remained similar with a variance of <1.0°C for the 2-day period. While maximum daily temperatures did not change substantially, minimum daily temperatures increased to 19.4–20.8°C across all sites within the upper spring complex on July 27. This increase in minimum temperature corresponds to a 3.5°C increase at BR08.

Within the lower bypass reach, the river splits for some distance where temperature sensors BR13−BR15 were installed to measure differences between the main and secondary channels. No temperature variation was observed between the two channels. Temperatures across the three sites were similar, with a maximum daily temperature of 22.5°C for BR14 and BR15 on July 25. During the experiment, average temperatures increased 0.7°C for July 26 across all three sites on July 26. Minimum temperatures were similar for all sites during the forced outage. Maximum daily temperatures for July 27−28 were similar to July 25 or slightly lower. However, the three sites followed a similar pattern of elevated minimum temperatures during the high sustained flows, with minimum daily temperatures >20.0°C for the two outage days. As flows returned to normal, minimum temperatures also returned to lower levels.

Within the lower spring complex (BR16-BR19), the channel is narrow and highly turbulent, and it was hypothesized that water would mix rapidly with spring inflows. However, a temperature gradient of 1.7°C was recorded between BR16, BR17, and BR18. Temperature at BR19 suggested that cool spring water is carried along the river right due to similar temperatures observed at BR16 (Figure 7). On July 25, maximum daily temperatures ranged between 20.7°C and 22.0°C across the four sites and remained similar to measurements at BR09. During the experiment, temperature increased 1.9°C to 22.0°C at BR16, the highest increase within the lower spring complex. The smallest increase was 0.9°C at BR18. As elevated flows continued during the forced outage, temperatures remained elevated, ranging 21.6–22.4°C among the lower sites. Minimum temperatures were also elevated during the outage and ranged 19.8–20.8°C at all lower spring complex sites (Table 6).

Overall temperatures within the lower spring complex appeared to be colder under a variety of conditions compared to upstream areas in the lower bypass reach, with the exception of a small area directly influenced by the upper springs. The upper spring area is very small, and water temperature rapidly increased with increased spin flows. This pattern was also observed with the analysis of seasonal temperature variation across sites (Figures 16 and 17).

4.3 BCT Temperature Tolerance Literature Analysis

Like most riverine fishes, BCT exhibit life history and biological characteristics that render them vulnerable to manmade and biological barriers. Some Western states have created conservation plans to better manage river systems and provide protections specific for native fishes, such as the BCT. In many instances regulatory agencies and industry have worked together to promote the expansion of native fishes to historic ranges, with funding for studies, habitat enhancement, and rearing programs to augment populations.

Several states have conducted research to examine the specific thermal tolerances for native fishes because water-quality criteria for river systems and cold-water requirements for fishes are not clearly defined by species. In many instances, river systems cannot meet regulatory standards. The current argument is to integrate natural or existing river conditions into management strategies for native fish conservation (Poole et al. 2004). As an example, all but three temperature sensor sites installed in the Bear River meet the current water quality criteria to protect beneficial uses and aquatic life.

For a half century, researchers have studied the thermal tolerances of fish to determine upper lethal thresholds. The methods to develop the upper incipient lethal threshold or LT50 have mainly focused on acclimating fish to a particular temperature, then raising the temperature at a specific rate to the upper limit where 50 percent mortality occurs. More recent studies have focused on cycling temperature to mimic a natural river system where fish are exposed to a range of temperatures.

Some studies have focused on both methods for finding the upper temperature tolerance for BCT. Wagner et al. (2001), found that when cutthroat trout were acclimated to a higher temperature of 18.0°C, the LT50 was greatly increased. BCT were subjected to temperature as high as 29.7°C before the onset of spasms and ultimately morality occurred. Johnstone and Rahel (2003) conducted both static temperature and cycling temperature studies on BCT, calculating a LT50 of 24.2°C. This is similar to Wagner et al. (2001), who estimated the LT50 for BCT from Bear Lake at 23.9°C. When BCT were held in water with a cycling temperature, tolerances were much greater. BCT cycled between 16°C and 26°C for 7 days had no mortality. Mortality began at cycling temperatures of 18°C and 28°C, with a 100 percent mortality above 29°C.

Shrank et al. (2003) studied BCT and temperature in Coal Creek, a tributary in the Thomas Fork Basin. This study found that BCT did not actively seek cooler water even though daily maximum temperatures exceeded 26.0°C for a 2-week period. Hillyard and Keeley (2012) also observed one BCT in the Bear River inhabiting temperature exceeding the LT50. However, the majority of fish tracked preferred cooler water and became selective when temperature exceeded a weekly maximum of 22°C-23°C. In general, the LT50 for BCT reported in the literature is higher than temperatures observed across the study reach during the spin experiment.

4.4 CONCLUSIONS

The longitudinal temperature assessment covered the entire reach, from Soda Dam to Oneida Reservoir, monitoring temperatures for a 1-year period. This spatial and temporal coverage helped provide context for the experimental spinning reserve assessment results summarized below. Comparing the results of this assessment to the thermal tolerances of BCT from literature indicates the following conclusions:

1. Within the study area, no temperatures were recorded that could be considered a lethal thermal barrier to BCT. For a period of approximately 6 weeks during July and August, temperatures throughout the study area could become stressful to BCT. Temperatures do not climb to lethal thresholds derived from laboratory studies; they fall within the range of tolerable temperatures noted in other monitoring studies on BCT.

2. The Last Chance reach has a muted thermal range as a result of releases from Soda Dam. While temperatures for most of the year were suitable, elevated summer temperatures could prove stressful and potentially lethal because daily minimums remained elevated. These higher nighttime temperatures may not provide the needed recovery for BCT to tolerate the higher daily peak temperatures.

3. The bypass reach had the most diverse range of temperature conditions in the study area under existing operations. The area beginning at the spring complex and extending downstream to the Grace powerplant provided the opportunity for BCT to thermally regulate during the summertime peak temperatures. Conversely, spring inflow elevates minimum winter temperatures and may provide better overwinter survival of juvenile trout.

4. Gentile Valley reach is the longest reach within the study area and exhibited some of the highest summer peaks and lowest winter temperatures. However, the area downstream of the Grace powerplant, where spring water flows into the Bear River above BR22, may provide the most suitable fish habitat during the low flow winter months. The BR22 site consistently maintained summer temperatures lower than any other site in Gentile Valley, and resident populations of BCT could be supported based on thermal requirements.

The experimental spinning reserve assessment involved more intensive temperature monitoring in the Grace bypass reach during releases from Soda Dam simulating a spin call. Comparing the results of this assessment to thermal tolerances of BCT from literature suggests the following conclusions:

1. Water temperatures measured in the Last Chance reach could be considered the upper limit of suitable habitat, and at times be stressful to BCT based on literature values. Temperatures did not climb to lethal thresholds derived from laboratory studies conducted on BCT and fall within the range of tolerable temperatures from other studies monitoring BCT. Varying discharge from Soda Dam had no effect on temperature during the experimental release.
2. Water temperature measured in the upper and middle Grace bypass reaches could be considered stressful and at times become lethal to BCT. In the area around Turner Bridge, temperatures exceeded 26.0°C before the experimental release. This was exacerbated by the small temperature diel; temperatures may not be reduced enough to provide a recovery period from exposure to high temperature. However, during the experiment and forced outage, temperatures were reduced from highs above reported LT50 thresholds for BCT to a much lower level, potentially mitigating lethal temperature effects. Habitat around Turner Bridge would become more survivable for periods when flows were elevated.
3. The lowermost section of the middle bypass reach was much cooler than Turner Bridge. However, daily maximum temperatures could be stressful, reaching near-lethal limits during daytime maximums. The turbulent water in this reach may reduce nighttime minimum temperatures low enough to allow for fish recovery. The experiment and forced outage slightly reduced maximum temperature, but minimum temperature remained elevated, and habitat in the middle reach could be stressful to BCT under continuous high flow during periods of high-water temperature.
4. The lower bypass reach exhibited a complex thermal regime, with spring inflow cooling short sections of the river. The vast majority of habitat was suitable for BCT based on literature values, with a few areas that potentially could become stressful under high temperature conditions. Measured temperatures in this reach did not exceed the LT50 during the experiment. Minimum daily temperature was low enough for BCT to recover throughout the reach when temperatures became stressful in warmer areas. During the experiment and forced outage, maximum daily temperature increased to stressful levels of 22.0–23.0°C but did not reach lethal levels at any site. Minimum temperatures increased and could become stressful to BCT if high flows were sustained for a long period of time during warm months.

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TABLES

Table 1. Bear River temperature loggers installed for the spinning reserve experiment and temporal study from Soda Dam to Cottonwood.					
Site Name	**Northing**	**Easting**	**Description**	**Reach**	**Collection Time**
BR01	4721677	442680	Soda Dam	Last Chance	5/30/18-6/10/19
BR02	4716917	442108	Last chance	Last Chance	5/30/18-6/10/19
BR03	4712561	434470	Black Canyon abv springs main channel island side	Middle Bypass	5/31/18-10/21/18
BR04	4712579	434457	Black Canyon abv springs side channel	Middle Bypass	5/31/18-10/21/18
BR05	4712517	434415	Black Canyon abv springs side channel	Lower Bypass	5/31/18-10/21/18
BR06	4712482	434407	Black Canyon @ spring (river right)	Lower Bypass	5/31/18-10/21/18
BR07	4712490	434433	Black Canyon (middle river)	Lower Bypass	5/31/18-10/21/18
BR08	4712386	434416	Black Canyon below springs (river right)	Lower Bypass	5/31/18-10/21/18
BR09	4710436	434362	Fisherman Bridge (middle river)	Lower Bypass	5/30/18-6/10/19
BR10	4712367	434451	Black Canyon top of island (middle river)	Lower Bypass	5/31/18-6/10/19
BR11	4712374	434466	Black Canyon left main channel (middle river)	Lower Bypass	5/31/18-6/10/19
BR12	4712316	434451	Black Canyon right channel (river right)	Lower Bypass	5/31/18-6/10/19
BR13	4712286	434487	Black Canyon left main channel (middle river)	Lower Bypass	5/31/18-10/21/18
BR14	4712061	434607	Black Canyon right main channel (river left)	Lower Bypass	5/31/18-6/10/19
BR15	4712081	434638	Black Canyon left secondary channel (river right)	Lower Bypass	5/31/18-10/21/18
BR16[1]	4711420	434466	Black Canyon main channel below islands and springs (river right)	Lower Bypass	5/31/18-08/28/18
BR17	4711351	434452	Black Canyon main channel (middle river)	Lower Bypass	5/31/18-6/10/19
BR18	4711273	434450	Black Canyon main channel (river left)	Lower Bypass	5/31/18-10/21/18
BR19	4711193	434427	Black Canyon main channel (river right)	Lower Bypass	5/31/18-10/21/18
BR20	4709176	434662	Cove Dam Site (river left)	Mainstem	5/30/18-6/10/19
BR21[1]	4707201	434724	Cove Powerplant (river left)	Mainstem	5/30/18-8/03/18
BR22	4705040	434934	Cheese Plant Bridge (river left)	Mainstem	5/31/18-6/10/19
BR23	4701257	436576	Centennial Bridge (river left)	Mainstem	5/31/18-6/10/19
BR24	4695343	439695	Thatcher Bridge (river left)	Mainstem	5/31/18-6/10/19
BR25	4688566	441275	Highway 34 Bridge (river right)	Mainstem	5/30/18-6/10/19
Grace Dam	4715265	440231	Grace Dam Forebay	Last Chance	7/25/18-6/10/19
Hwy 34	4715095	440060	Hwy 34 Bridge at Grace (river left)	Upper Bypass	7/25/18-7/31/18
Turner Bridge	4714069	438385	Turner Bridge (river left)	Middle Bypass	7/25/18-7/31/18

[1] Indicates sensor failure.

Table 2. Average Monthly Ambient temperature in the Gem Valley.													
	Jun	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun[1]**
Avg	59.9	69.6	64.2	58.0	43.3	29.6	19.9	18.7	22.6	26.0	42.0	48.7	50.8
Max	88.9	93.2	95.0	84.6	75.6	52.3	41.5	38.3	41.0	51.1	66.2	74.3	66.2
Min	28.9	37.0	34.0	23.5	16.3	5.2	-10.8	-8.9	-12.1	-2.0	21.7	23.2	43.7
[1] June 2019 represents the first 10 days of temperature data.													

Table 3. Monthly temperature summary.															
			Jun	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
	BR01	**Avg**	18.3	21.5	19.5	15.4	9.4	4.7	3.3	2.9	2.7	3.1	6.4	11.2	15.9
		Max	20.8	**22.8**	21.7	17.3	12.9	8.2	3.8	3.2	3.2	3.9	12.1	13.7	17.4
		Min	15.7	19.0	15.8	12.4	7.3	3.3	2.9	2.6	**2.2**	2.3	2.6	8.8	13.5
	BR02	**Avg**	18.4	21.5	19.5	15.4	9.2	3.7	1.8	1.4	1.4	3.3	6.5	11.3	15.9
		Max	21.5	**23.9**	22.4	18.5	14.3	7.9	3.0	3.0	3.1	5.7	13.1	14.1	18.4
		Min	15.2	18.7	15.5	11.8	6.2	1.6	0.5	**0.3**	**0.3**	0.4	2.7	8.2	13.1
	BR10	**Avg**	17.7	20.4	18.3	14.7	9.9	5.6	3.2	2.4	2.6	4.8	8.5	11.9	15.7
		Max	22.2	**24.5**	23.2	18.7	14.5	8.9	5.8	5.3	5.8	8.8	14.7	17.2	20.3
		Min	12.5	14.8	13.1	10.3	6.1	1.4	0.4	0.3	**0.2**	0.3	3.7	7.8	11.4
	BR11	**Avg**	18.1	21.0	18.7	14.8	9.1	3.6	1.3	0.8	1.2	3.4	7.4	11.3	15.4
		Max	22.7	**25.0**	23.4	18.6	14.6	7.9	3.5	2.8	3.5	6.8	13.2	14.9	18.0
		Min	12.6	15.2	13.7	9.9	4.5	0.6	0.0	**-0.1**	0.0	0.3	4.0	8.6	12.9
	BR12	**Avg**	17.0	19.8	17.7	14.3	10.0	5.9	4.2	3.6	3.8	5.4	8.7	11.8	15.1
		Max	21.4	**23.6**	22.3	17.9	14.2	9.1	5.8	5.3	5.5	8.2	13.6	15.7	18.7
		Min	12.4	14.6	12.8	10.5	6.6	3.9	1.8	**1.8**	1.9	**1.8**	4.5	8.3	11.9
	BR09	**Avg**	16.9	19.5	17.2	14.1	9.6	5.2	3.1	2.6	2.8	4.8	8.5	11.7	15.2
		Max	20.8	**23.0**	21.2	17.6	14.6	9.4	5.2	5.1	5.4	9.2	14.2	17.0	19.5
		Min	12.1	13.9	12.4	9.9	5.8	2.3	1.0	**0.6**	0.9	1.8	3.9	7.2	11.0
	BR17	**Avg**	16.8	19.3	17.2	14.1	9.7	5.3	3.3	2.8	2.9	4.9	8.4	11.7	15.1
		Max	20.3	**23.0**	21.0	17.2	14.3	9.1	5.2	5.1	5.5	8.8	13.7	16.1	18.5
		Min	12.1	14.1	12.5	10.0	6.0	2.4	1.7	1.4	**1.2**	1.5	3.9	7.6	11.8
	BR20	**Avg**	18.5	21.7	19.7	15.6	9.6	4.2	2.0	1.5	1.6	3.8	6.9	11.6	16.0
		Max	21.4	**23.9**	22.2	17.9	14.4	8.1	3.5	3.3	4.0	6.4	13.3	15.9	17.7
		Min	16.3	18.7	16.0	12.0	6.1	2.1	0.1	**0.0**	**0.0**	2.1	3.6	8.4	13.3
	BR22	**Avg**	17.6	20.3	18.5	14.5	10.2	6.6	5.2	4.9	4.8	6.4	8.1	11.7	15.5
		Max	21.9	**23.2**	21.8	18.1	15.5	10.8	7.1	6.6	7.2	9.1	15.2	17.3	19.1
		Min	13.7	16.6	14.4	9.5	6.7	4.3	3.0	2.7	**2.7**	3.7	4.7	7.9	12.7
	BR23	**Avg**	18.6	21.1	19.0	15.1	9.9	5.1	2.9	2.5	2.9	5.5	8.1	12.1	16.0
		Max	23.8	**25.1**	23.3	20.3	17.4	10.3	6.5	7.5	8.8	13.5	16.3	19.4	21.7
		Min	13.4	16.7	14.3	8.2	3.9	1.3	-0.1	-0.2	-0.2	**-0.1**	3.8	7.0	12.6
	BR24	**Avg**	19.0	21.6	19.3	15.3	10.1	4.8	2.5	1.9	2.5	5.5	8.6	12.6	16.5

Table 3. Monthly temperature summary.															
			Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
		Max	22.7	**25.2**	23.2	19.6	15.1	8.6	5.0	4.3	5.1	9.3	15.7	18.3	21.5
		Min	14.2	16.9	14.2	11.2	5.6	2.3	0.3	0.6	**0.8**	2.3	4.1	7.3	12.2
		Avg	19.0	21.8	19.4	15.3	9.9	4.2	1.7	0.9	1.9	5.8	7.8		
	BR25	Max	20.1	23.9	**24.3**	22.9	18.2	16.6	9.3	4.5	4.4	6.5	11.7	11.5	
		Min	16.4	14.1	18.2	15.1	9.9	4.1	1.0	**-0.1**	**-0.1**	**-0.1**	1.6	5.1	

Table 4. Range of maximum and minimum temperature at sites within the Soda to Grace forebay reach.

	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul
BR01	22.0-21.8	22.1-21.6	21.9-21.7	21.9-21.4	21.6-21.4	
BR02	23.3-21.7	23.4-21.5	22.8-21.3	22.8-21.2	22.7-21.1	22.7-20.8
Grace Forebay	23.4	23.6-21.4	23.2-21.2	22.7-21.2	22.7-20.9	22.7-20.7

Table 5. Range of maximum and minimum temperature at sites in the upper and middle bypass reach.

	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul
Hwy34	22.9	23.1-21.4	23.0-21.2	22.5-21.2	22.5-20.8	22.4-20.7
Turner Bridge	26.3	23.9-20.2	22.5-21.2	22.3-21.0	24.9-19.2	25.4-19.2
BR03	23.5-18.7	23.3-18.5	22.2-20.9	22.4-20.7	23.2-17.7	23.6-17.7
BR04	23.5-18.7	23.3-18.5	22.1-20.9	22.4-20.7	23.1-17.8	23.6-17.7

Table 6. Range of maximum and minimum temperature in the lower bypass reach near the upper spring complex.

	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul
BR05	20.7-17.4	22.6-17.2	21.9-20.0	22.2-19.0	20.8-16.5	21.1-16.5
BR06	17.4-14.2	22.4-14.1	21.7-19.4	22.1-17.1	16.7-13.7	16.4-13.9
BR07	23.5-18.8	23.3-18.5	22.2-20.9	22.5-20.7	23.2-17.8	23.6-17.7
BR08	20.4-16.3	22.1-16.1	21.4-19.8	21.6-19.7	19.7-16.0	19.9-15.8
BR10	22.8-18.3	23.1-18.1	22.1-20.8	22.4-20.6	22.9-17.4	23.3-17.4
BR11	23.7-19.0	22.8-18.6	22.0-20.8	21.7-20.9	21.9-19.3	22.2-19.0
BR12	22.2-17.6	22.4-17.3	21.8-20.4	22.1-20.3	22.0-16.7	22.4-16.7

Table 7. Maximum and minimum temperature in the lower bypass reach in the island complex.						
	25-Jul	**26-Jul**	**27-Jul**	**28-Jul**	**29-Jul**	**30-Jul**
BR13	22.6-18.4	23.2-18.1	22.1-20.9	22.4-20.6	22.3-17.7	22.6-17.3
BR14	22.5-18.2	23.1-17.9	22.1-20.8	22.4-20.6	22.1-17.3	22.4-17.1
BR15	22.8-18.5	23.3-18.2	22.2-20.9	22.6-20.7	22.4-17.5	22.7-17.4

Table 8. Range of maximum and minimum temperatures in the lower bypass reach near the lower spring complex.						
	25-Jul	**26-Jul**	**27-Jul**	**28-Jul**	**29-Jul**	**30-Jul**
BR16	20.3-16.7	22.2-16.5	21.6-20.0	21.9-19.8	19.8-16.0	20.0-15.9
BR17	21.3-17.3	22.6-17.0	21.9-20.6	22.3-20.3	20.7-16.5	20.9-16.3
BR18	22.0-17.8	22.9-17.5	21.6-20.8			
BR19	20.7-17.1	22.4-16.6	21.8-20.3	22.1-20.2	20.4-16.3	20.6-16.2
BR09	21.8-17.5	22.7-17.0	22.1-20.6	22.4-20.3	21.1-16.5	21.3-16.4

Table 9. Maximum daily temperature differential from July 25 compared to the maximum daily temperature for spinning reserve release (July 26), forced outage (July 27-28), and normal operations (July 29-30).					
	26-Jul	**27-Jul**	**28-Jul**	**29-Jul**	**30-Jul**
BR01	0.2	0.0	-0.1	-0.3	
BR02	0.1	-0.5	-0.5	-0.6	-0.6
Grace Forebay	0.3	-0.2	-0.7	-0.7	-0.7
Hwy34	0.2	0.1	-0.4	-0.4	-0.5
Turner Bridge	-2.4	-3.8	-4.0	-1.4	-0.9
BR03	-0.2	-1.3	-1.1	-0.3	0.1
BR04	-0.2	-1.3	-1.0	-0.3	0.1
BR05	1.9	1.2	1.5	0.1	0.4
BR06	5.1	4.3	4.7	-0.6	-0.9
BR07	-0.2	-1.3	-1.0	-0.3	0.1
BR08	1.7	1.0	1.3	-0.7	-0.5
BR09	1.0	0.3	0.7	-0.7	-0.4
BR10	0.3	-0.7	-0.4	0.1	0.5
BR11	-0.9	-1.7	-2.0	-1.8	-1.5
BR12	0.1	-0.5	-0.1	-0.2	0.2
BR13	0.6	-0.5	-0.2	-0.3	0.0

Table 9. Maximum daily temperature differential from July 25 compared to the maximum daily temperature for spinning reserve release (July 26), forced outage (July 27-28), and normal operations (July 29-30).					
	26-Jul	**27-Jul**	**28-Jul**	**29-Jul**	**30-Jul**
BR14	0.6	-0.4	-0.1	-0.4	-0.1
BR15	0.5	-0.6	-0.2	-0.4	-0.1
BR16	2.0	1.3	1.7	-0.4	-0.2
BR17	1.3	0.6	0.9	-0.6	-0.5
BR18	0.9	-0.4			
BR19	1.7	1.1	1.4	-0.3	-0.1

Table 10. Average daily temperature for sites in the Study Area; July 25 baseline conditions, July 26 spinning reserve experiment, July 27-28 forced outage, July 29-30 normal operations and return to baseline conditions.						
	25-Jul	**26-Jul**	**27-Jul**	**28-Jul**	**29-Jul**	**30-Jul**
BR01	22	21.9	21.8	21.6	21.5	20.9
BR02	22.1	22.2	21.9	21.8	21.6	21.5
BR03	21.1	21.1	21.7	21.6	20.5	20.6
BR04	21.1	21.1	21.6	21.6	20.5	20.6
BR05	19.1	19.8	21.1	21.3	18.8	19.0
BR06	15.1	17.7	20.8	21.0	15.0	15.1
BR07	21.1	21.2	21.7	21.6	20.5	20.6
BR08	18.2	19.2	20.7	20.7	17.9	17.9
BR09	19.9	20.2	21.3	21.4	19.1	19.0
BR10	20.6	20.8	21.5	21.5	20.2	20.4
BR11	21.4	21.1	21.3	21.3	20.6	20.7
BR12	19.9	20.2	21.1	21.2	19.4	19.6
BR13	20.5	20.9	21.6	21.6	20.0	20.0
BR14	20.4	20.8	21.6	21.5	19.9	19.9
BR15	20.8	21.0	21.7	21.7	20.2	20.2
BR16	18.5	19.5	20.8	20.9	18.2	18.2
BR17	19.3	20.1	21.2	21.3	18.9	18.8
BR18	19.9	20.5	21.1			
BR19	18.9	19.8	21.0	21.1	18.7	18.6
Grace Forebay		22.5	22.0	21.9	21.9	21.7
Hwy34		22.3	21.9	21.9	21.8	21.6

Table 10. Average daily temperature for sites in the Study Area; July 25 baseline conditions, July 26 spinning reserve experiment, July 27-28 forced outage, July 29-30 normal operations and return to baseline conditions.

	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul
Turner Bridge		21.8	21.9	21.8	21.7	21.8

- Temperature for July 25 was extracted from 15-minute data.
- Grace forebay, Hwy 34, Turner Bridge have insufficient data to calculate an average temperature for July 25.

<u>FIGURES</u>

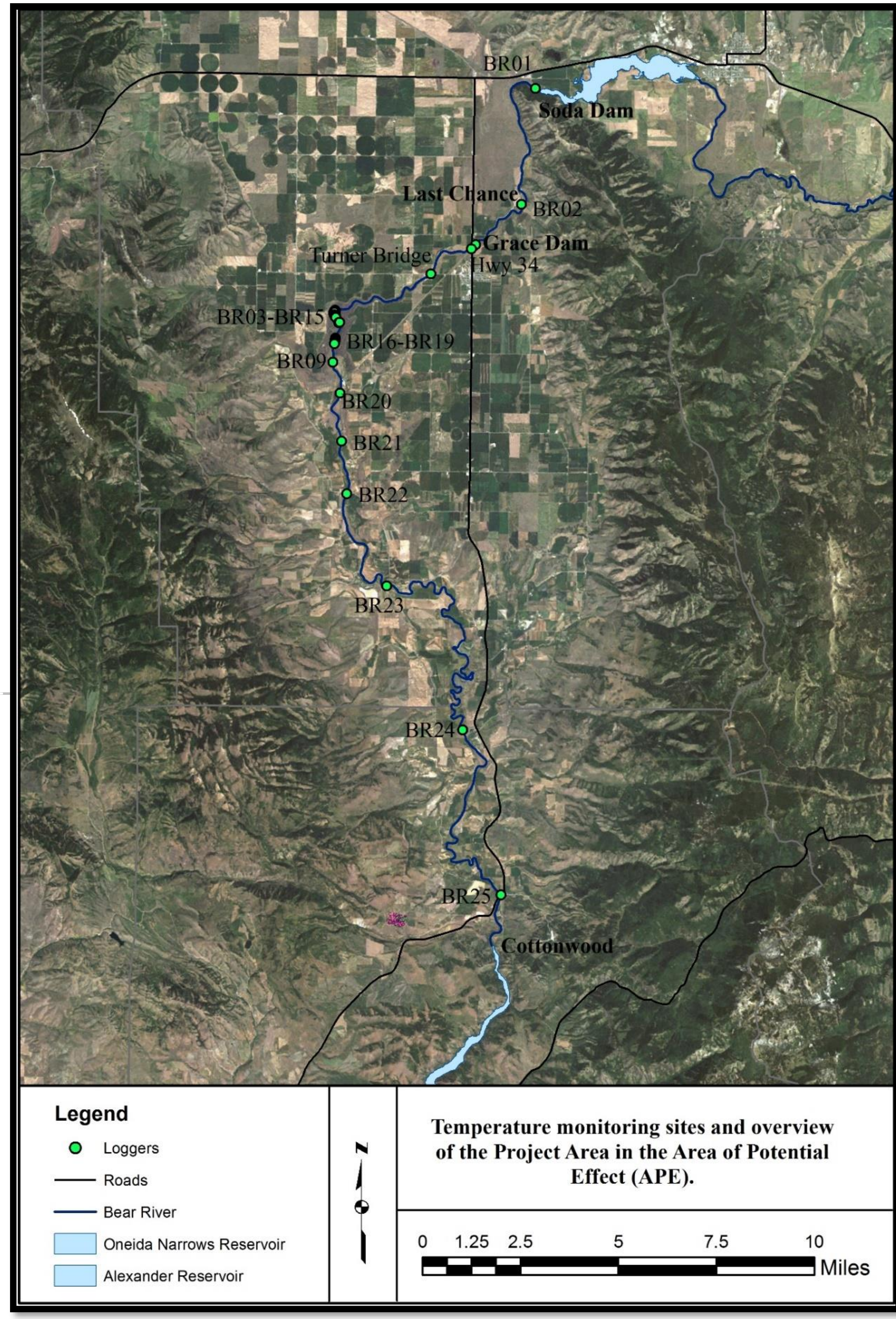


Figure 1. Location of temperature loggers throughout the study reach.

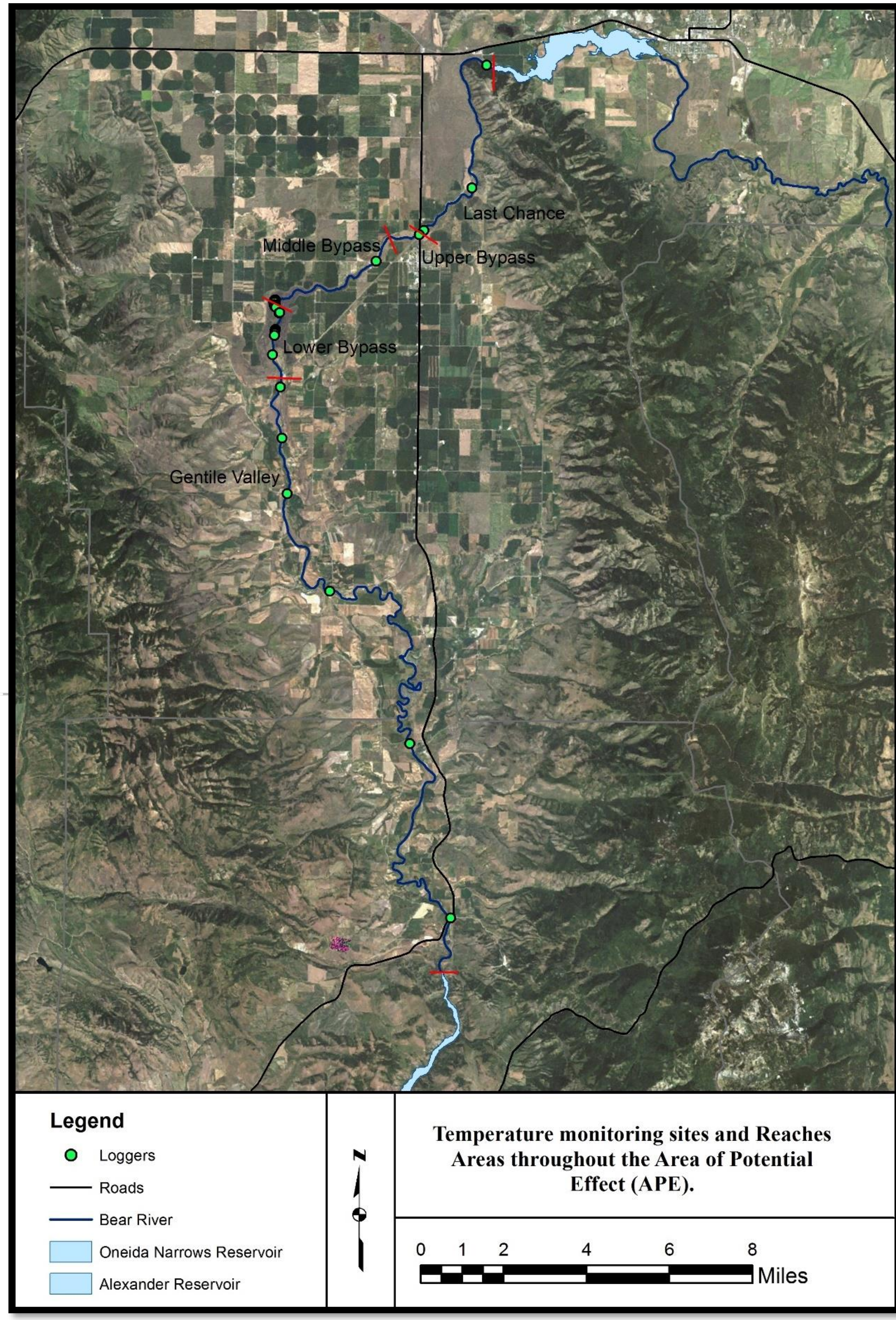


Figure 2. Reach breaks used to describe conditions at various locations throughout the study reach.

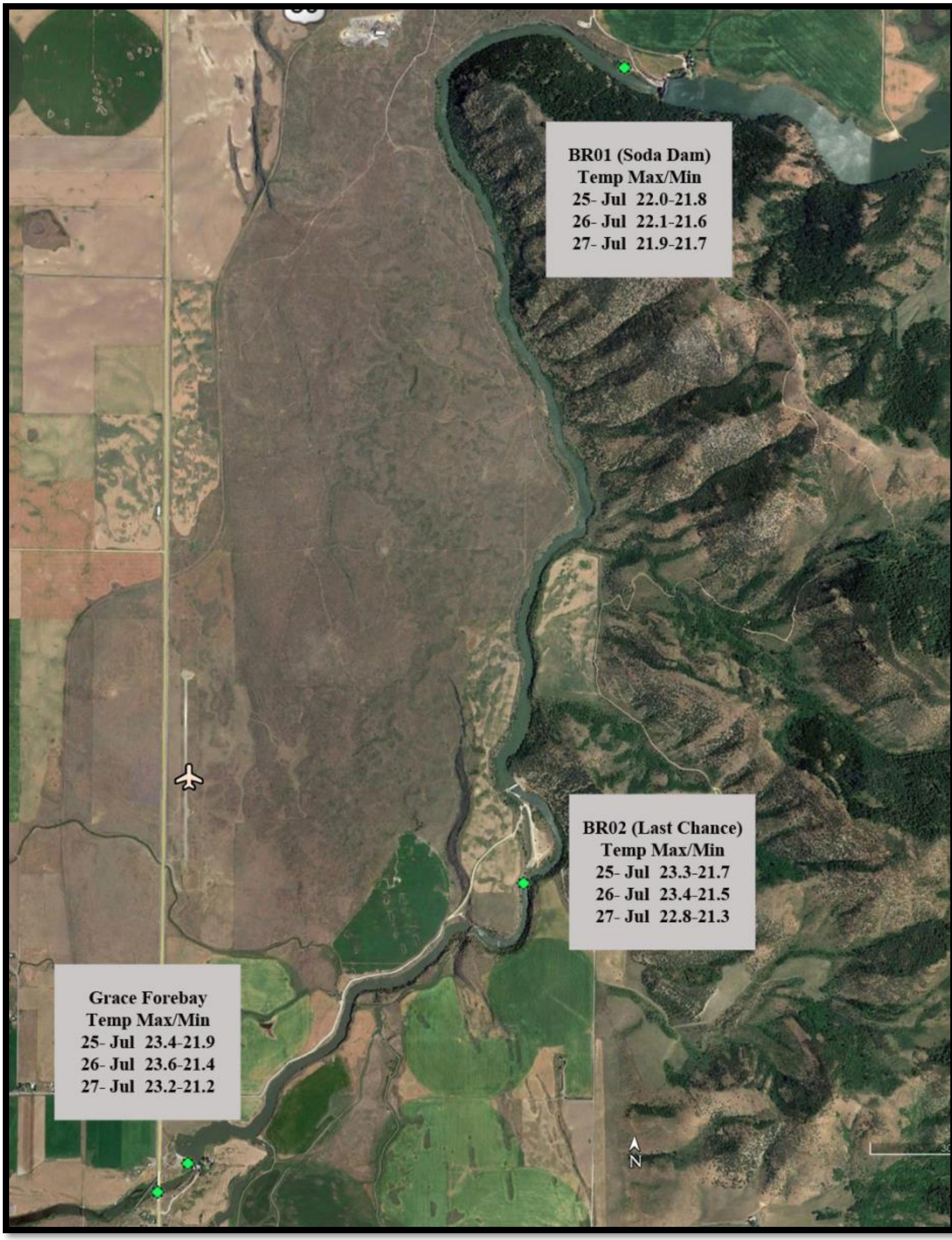


Figure 3. Location of temperature loggers in the Last Chance reach; maximum and minimum temperature at each site for existing conditions (July 25), spinning reserve experiment (July 26), and forced outage (July 27).

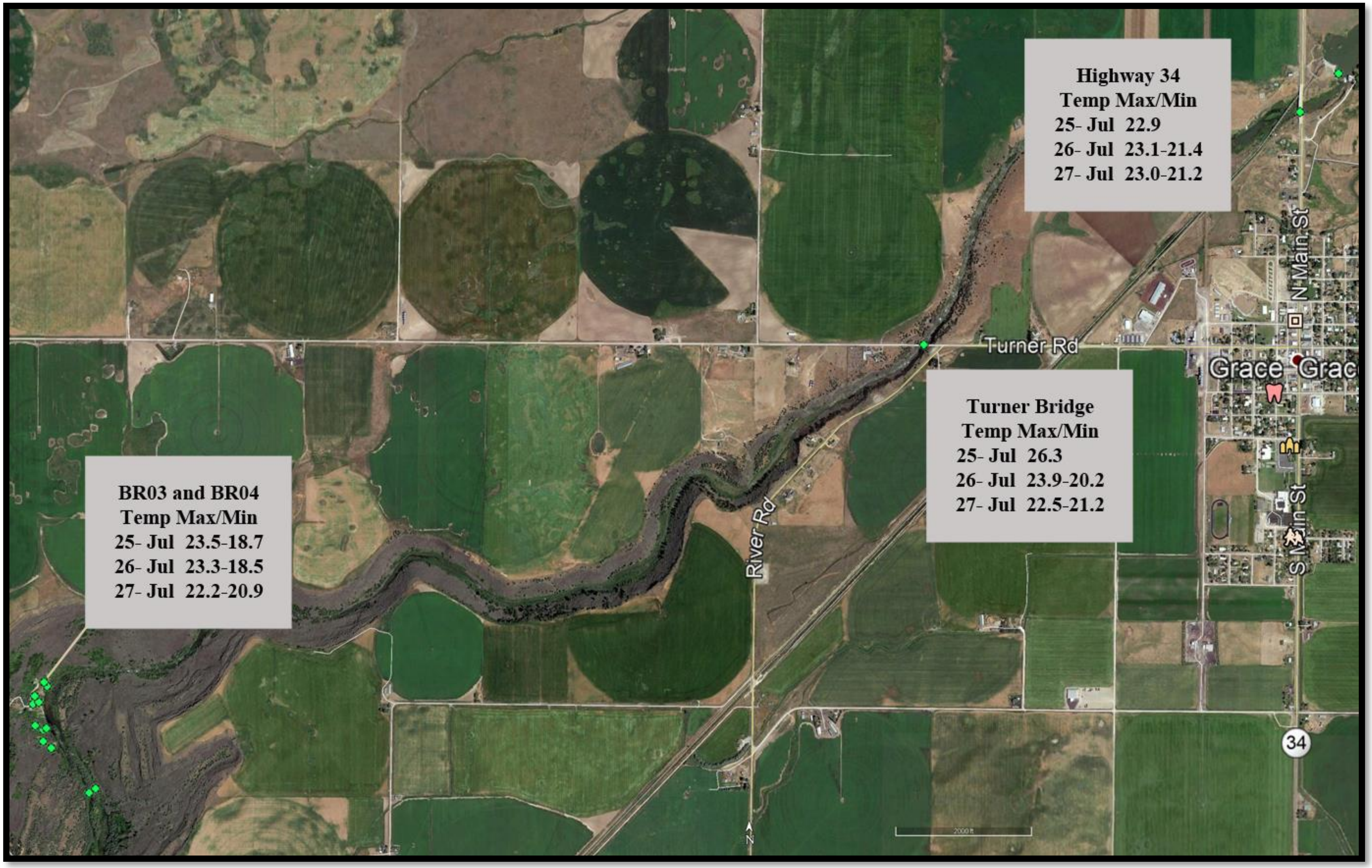


Figure 4. Location of temperature loggers in the Upper and Middle Bypass reach; maximum and minimum temperature at each site for existing conditions (July 25), spinning reserve experiment (July 26), and forced outage (July 27).

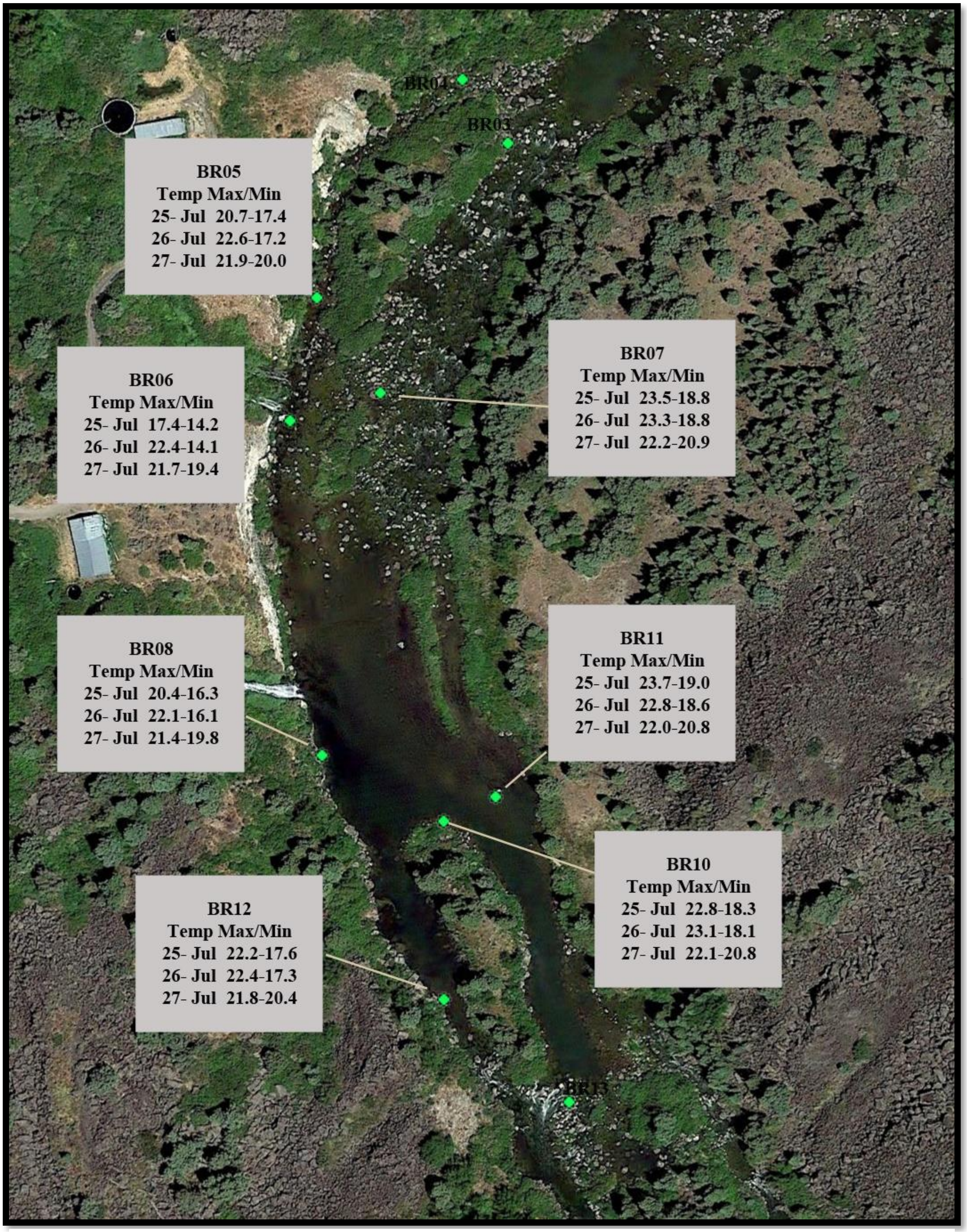


Figure 5. Location of temperature loggers in the lower bypass reach in the upper spring complex; Maximum and Minimum temperature at each site for existing conditions (July 25), spinning reserve experiment (July 26), and forced outage (July 27).

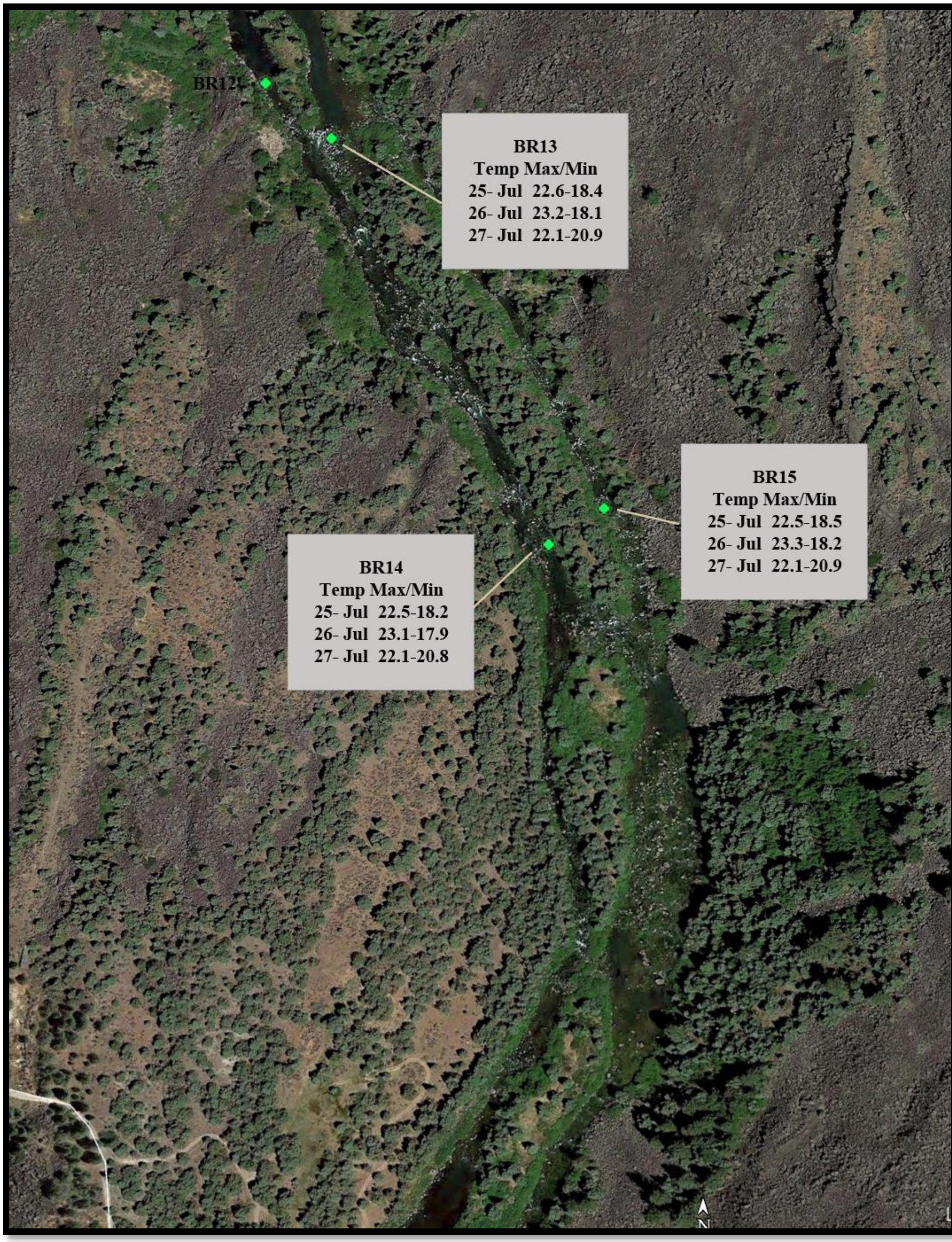


Figure 6. Location of temperature loggers in the island complex in the lower bypass reach; maximum and minimum temperature at each site for existing conditions (July 25), spinning reserve experiment (July 26), and forced outage (July 27).

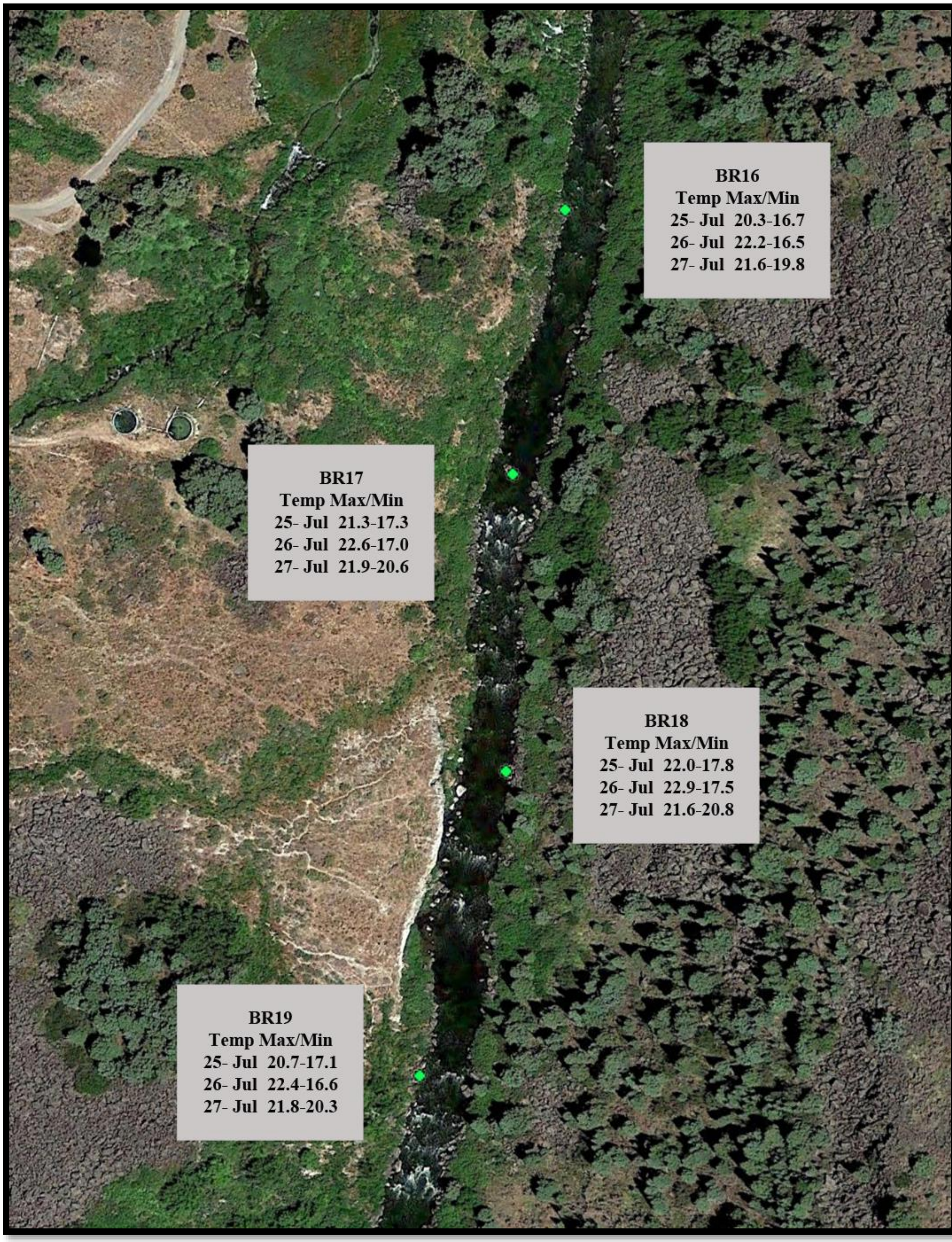


Figure 7. Location of temperature loggers in the lower spring complex in the lower bypass reach; maximum and minimum temperature at each site for existing conditions (July 25), spinning reserve experiment (July 26), and forced outage (July 27).

Figure 8. Location of temperature logger at BR09 (Fishermen Bridge) in the lower bypass reach; maximum and minimum temperature at each site for existing conditions (July 25), spinning reserve experiment (July 26), and forced outage (July 27).

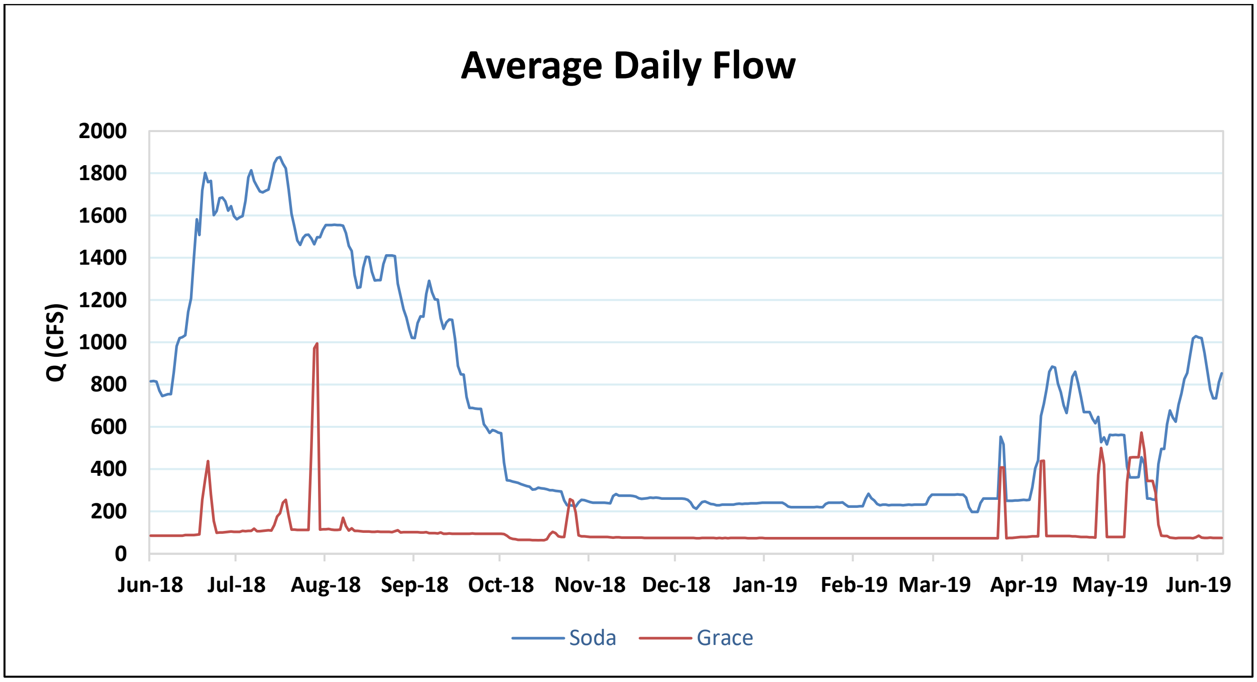


Figure 9. Average daily flows from Grace and Soda Dams during the study period.

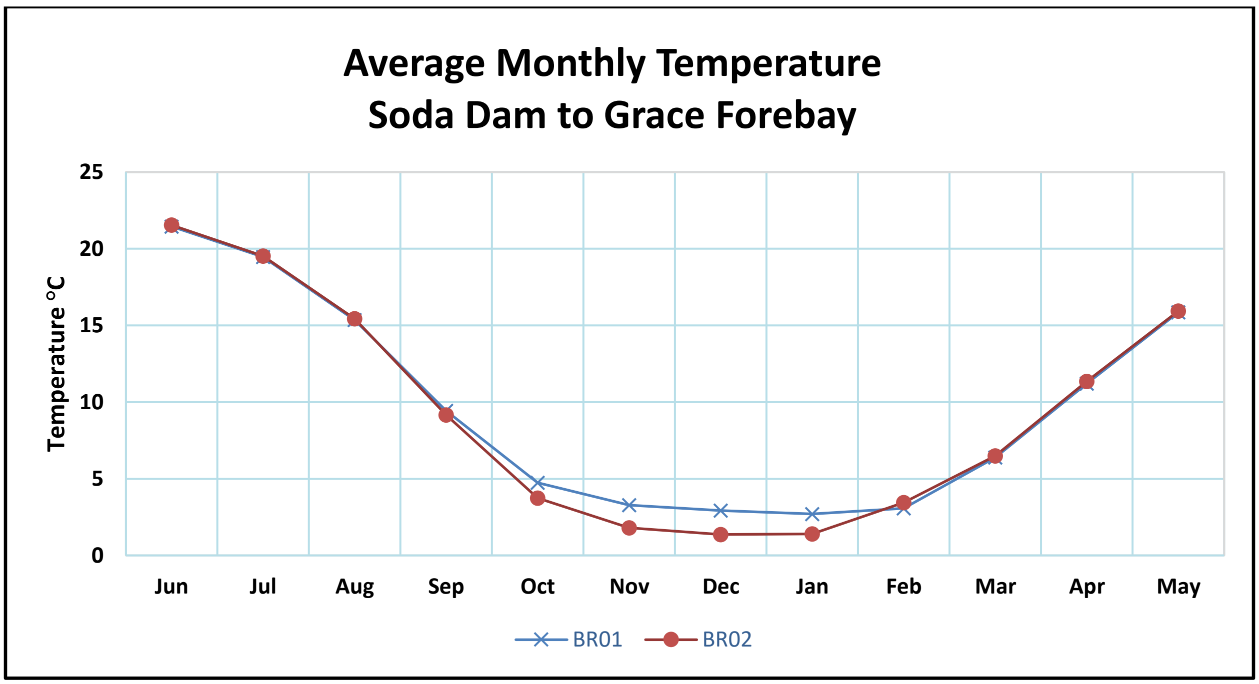


Figure 10. Average monthly temperature in the Last Chance reach.

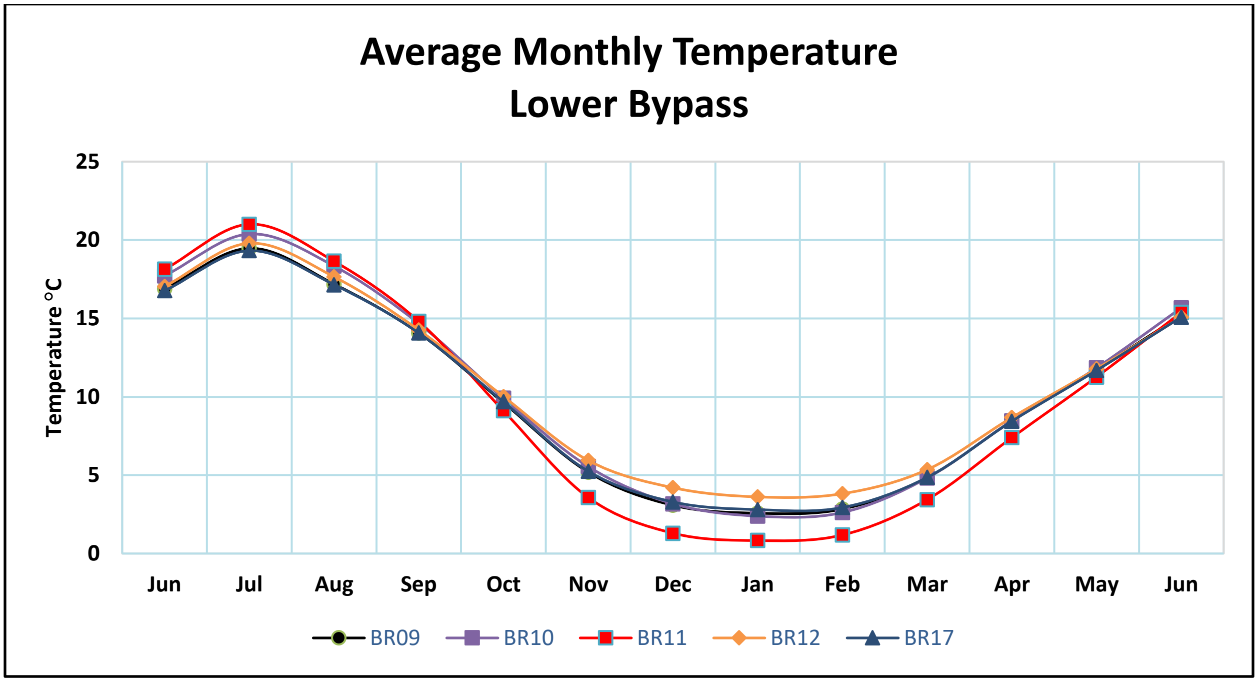


Figure 11. Average monthly temperature in the lower bypass reach.

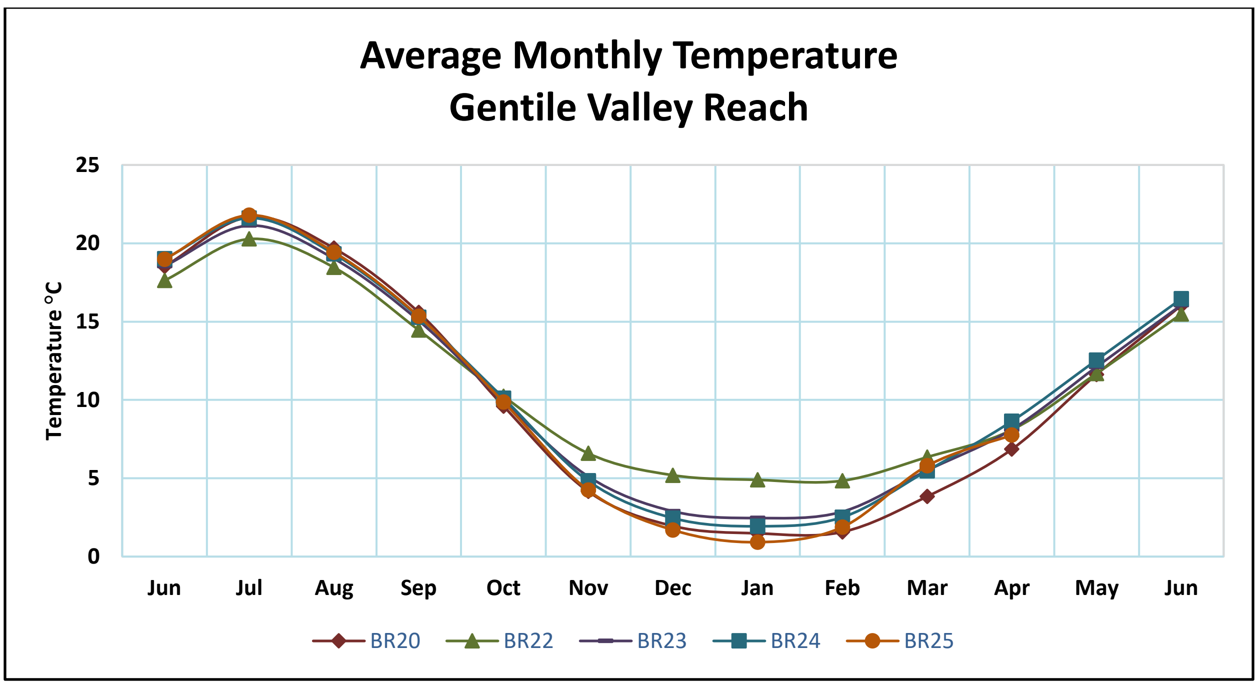


Figure 12. Average Monthly temperature in the Gentile Valley reach.

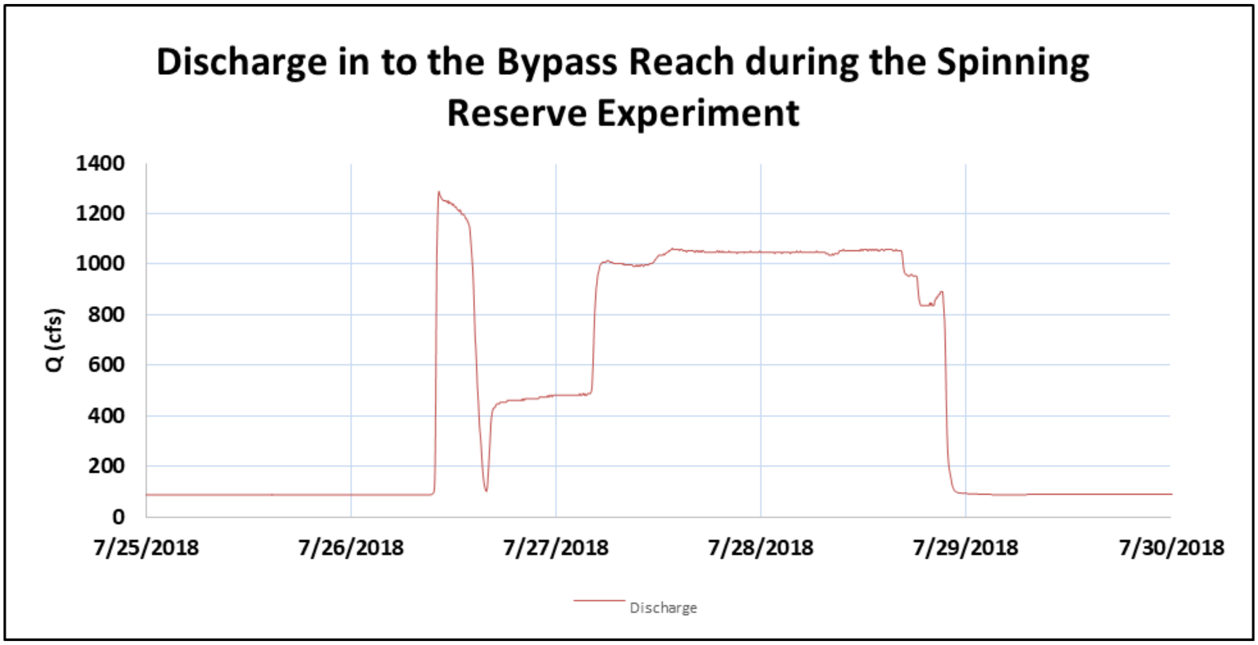


Figure 13. Discharge into the bypass reach from Grace Dam July 25-30.

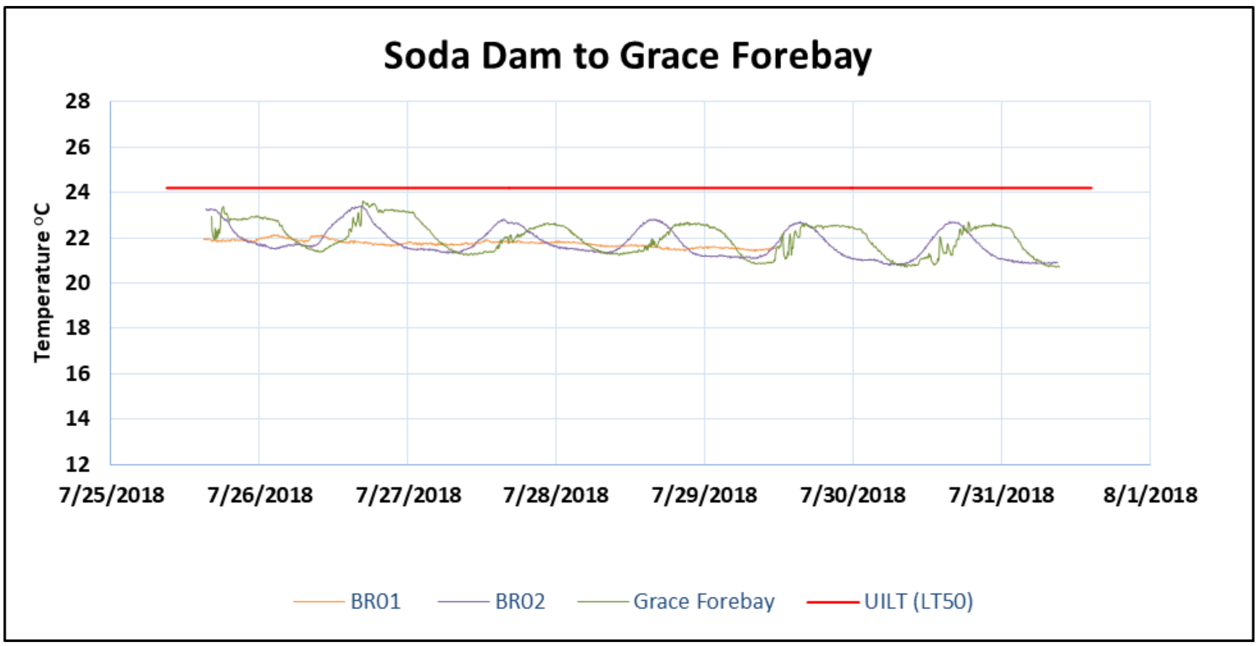


Figure 14. Temperature data from July 25-30 for sites within the Last Chance reach. Upper incipient lethal limit (LT50) derived from Johnstone and Rahel 2003.

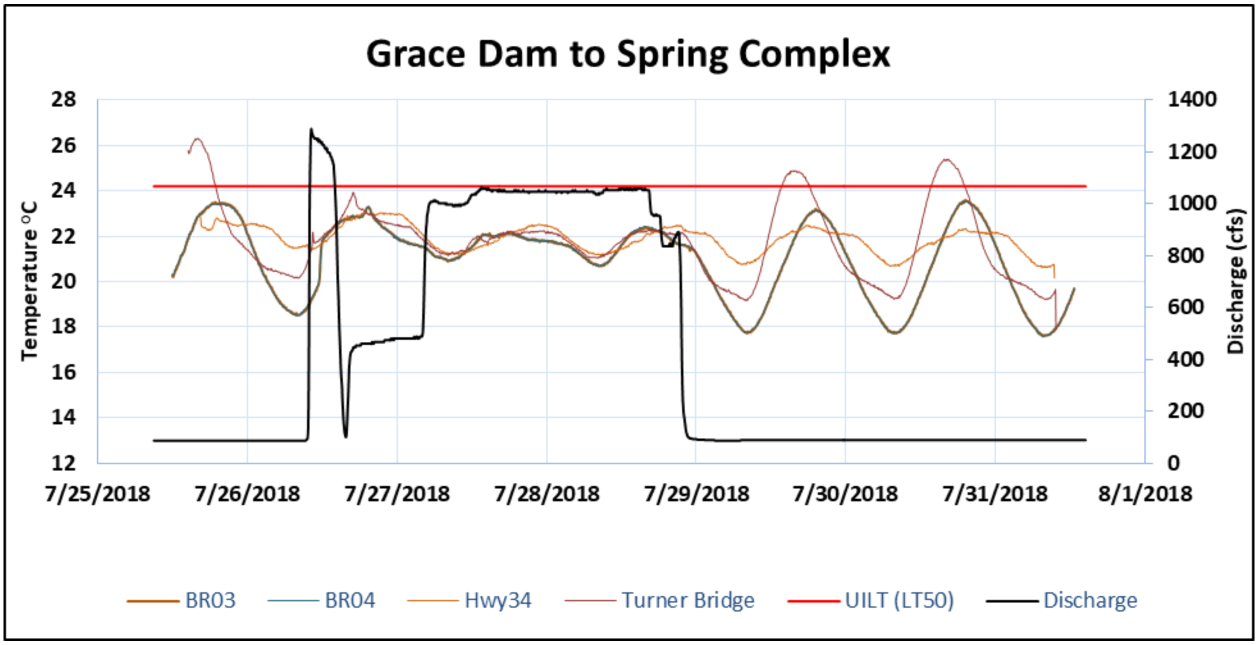


Figure 15. Temperature data from July 25-30 for sites within the upper and middle bypass reach. Note that BR03 is covered by BR04 due to similar temperatures (see Table 3). Upper incipient lethal limit (LT50) derived from Johnstone and Rahel 2003. Discharge into the Bypass reach, data from Grace Dam Gauge for the study period.

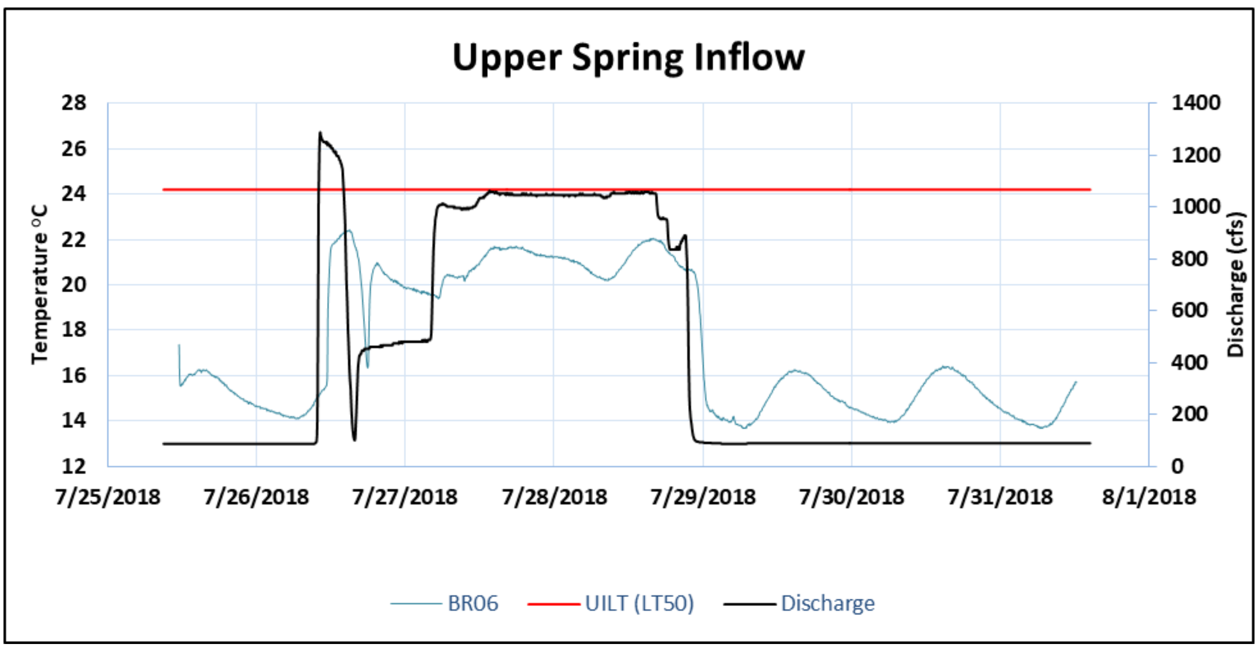


Figure 16. Temperature data from July 25-30 for the inflow from the upper spring within the lower bypass reach. Upper incipient lethal limit (LT50) derived from Johnstone and Rahel 2003. Discharge into the bypass reach, data from Grace Dam gauge for the study period.

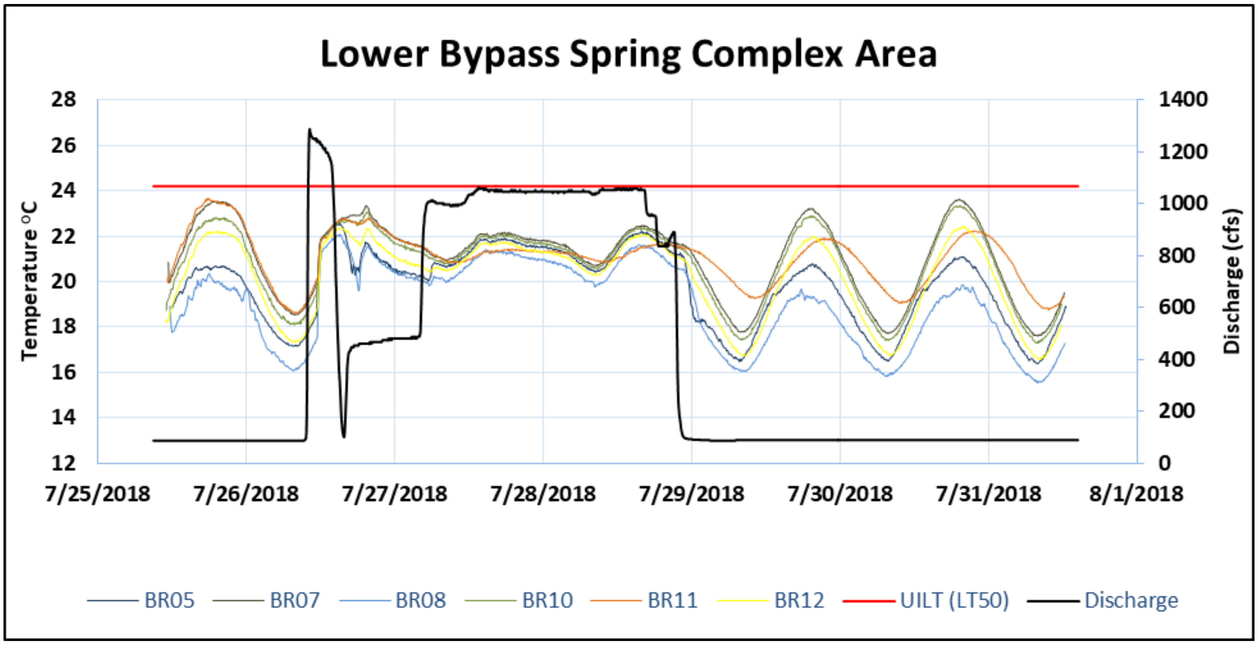


Figure 17. Temperature data from July 25-30 for sites within the lower bypass reach at the upper spring complex. Upper incipient lethal limit (LT50) derived from Johnstone and Rahel 2003. Discharge into the bypass reach, data from Grace Dam gauge for the study period.

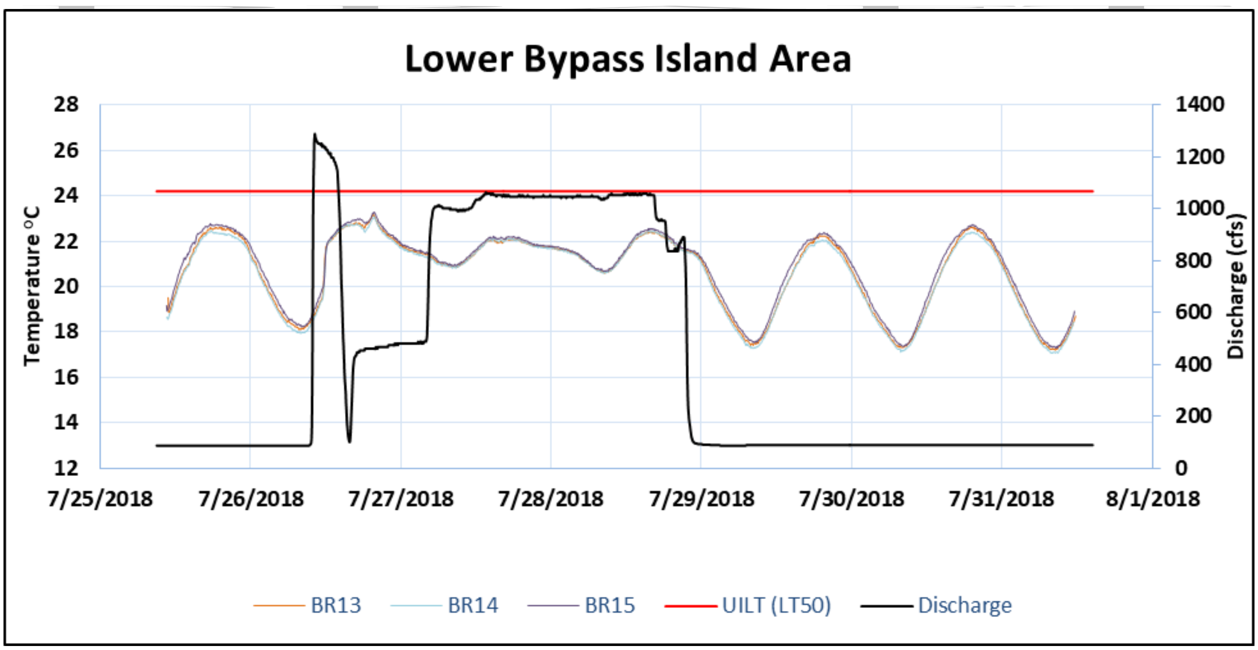


Figure 18. Temperature data from July 25-30 for sites within the lower bypass reach in the island area. Upper incipient lethal limit (LT50) derived from Johnstone and Rahel 2003. Discharge into the Bypass reach, data from Grace Dam gauge for the study period.

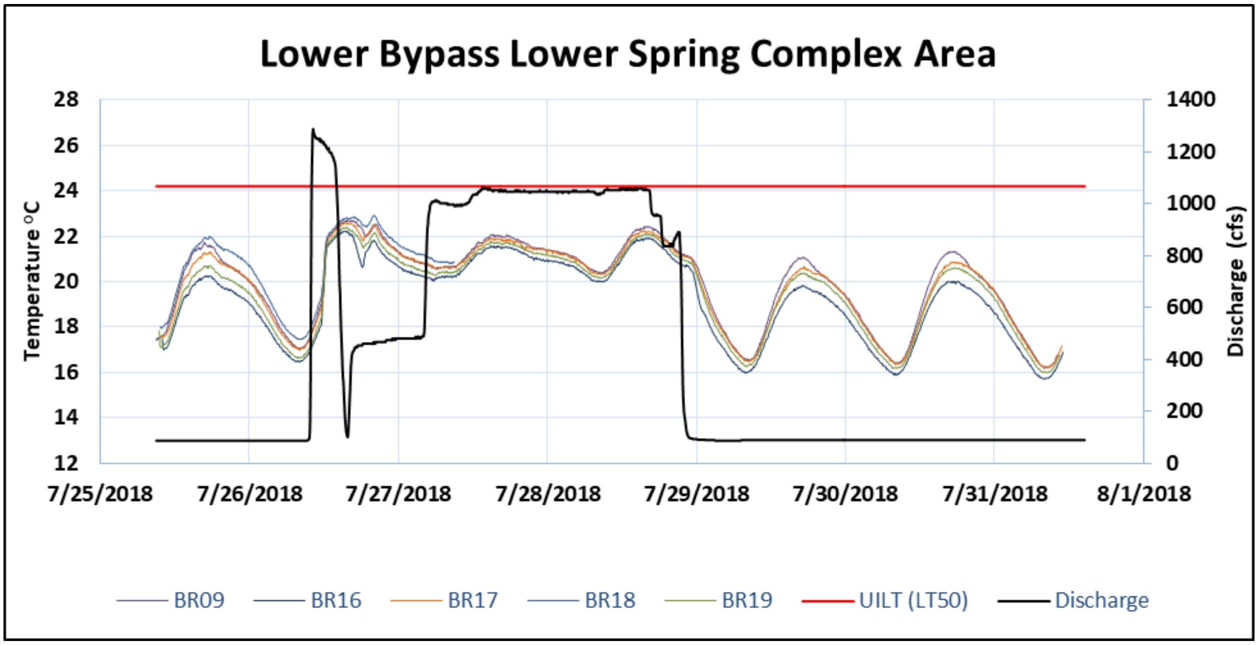
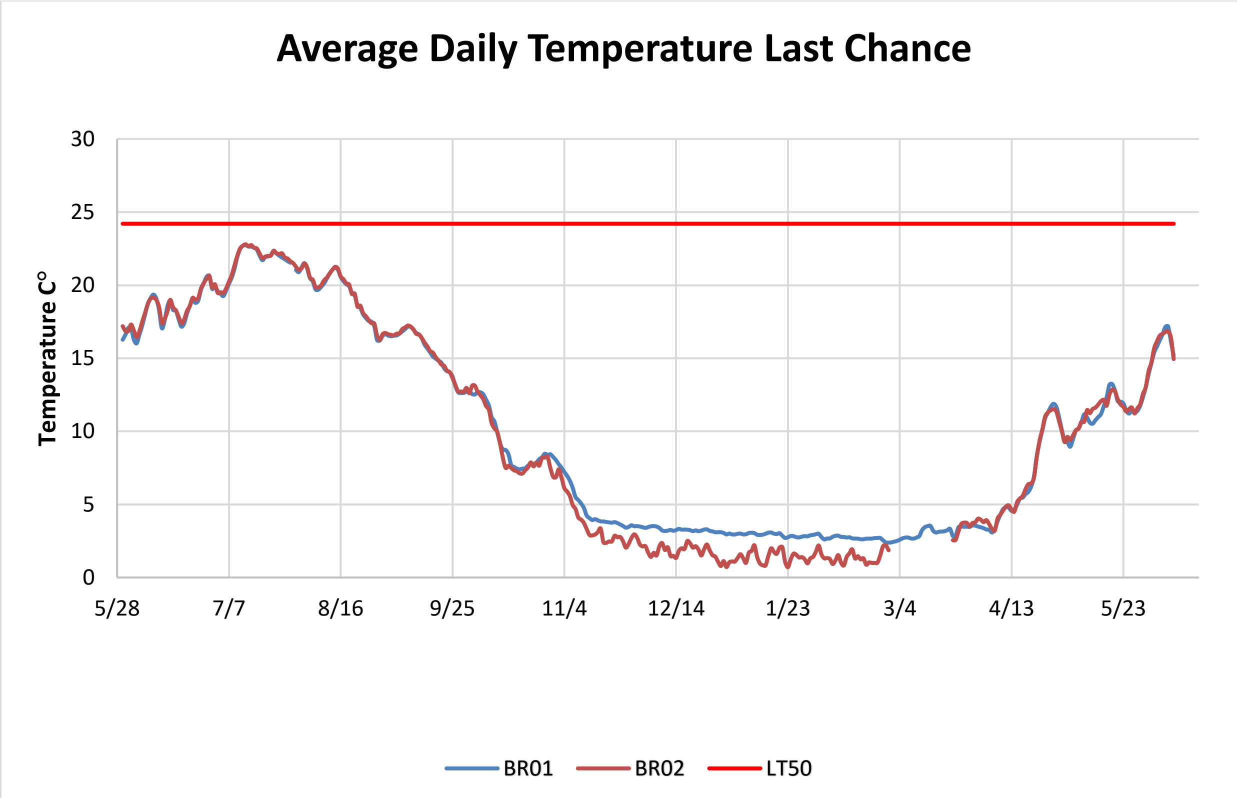
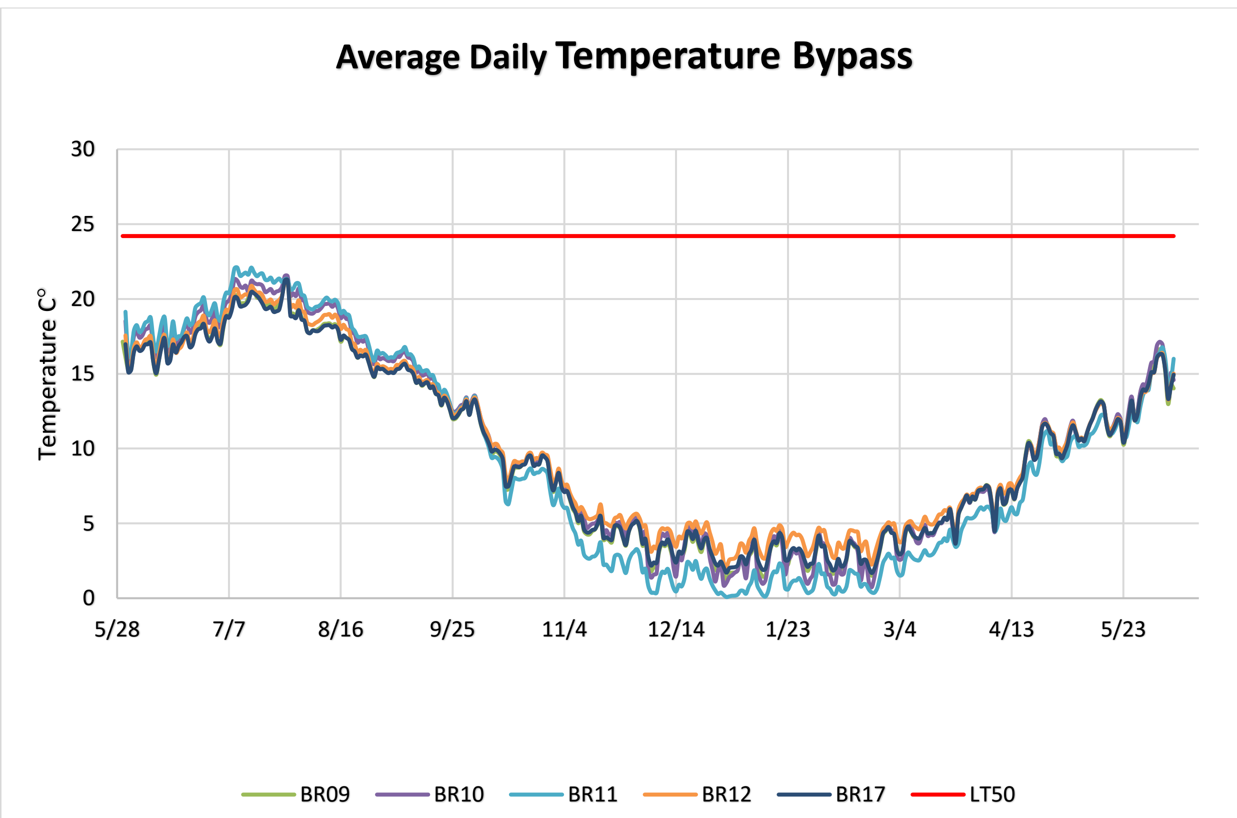


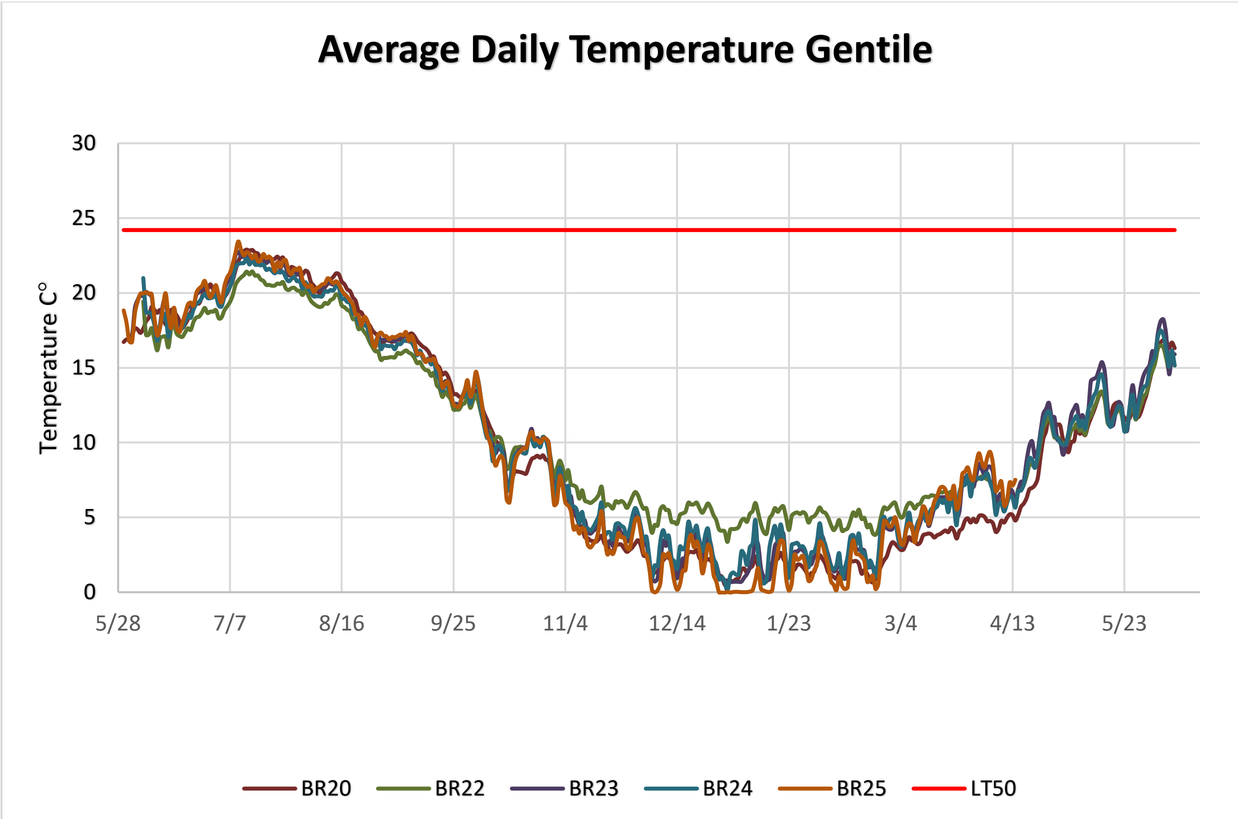
Figure 19. Temperature data from July 25-30 for sites within the lower bypass reach at the lower spring complex and Fishermen Bridge. Upper incipient lethal limit (LT50) derived from Johnstone and Rahel 2003. Discharge into the Bypass reach, data from Grace Dam gauge for the study period.

APPENDIX A

DAILY WATER TEMPERATURE DATA


Average Daily Temperature Last Chance
30
25
20
15
10
5
0
Temperature C°
5/28
7/7
8/16
9/25
11/4
12/14
1/23
3/4
4/13
5/23
BR01
BR02
LT50


Average Daily Temperature Bypass
30
25
20
15
10
5
0
Temperature C°
5/28
7/7
8/16
9/25
11/4
12/14
1/23
3/4
4/13
5/23
BR09
BR10
BR11
BR12
BR17
LT50



Average daily temperature for sites used in the longitudinal study. Red text indicates temperatures exceeding the daily average IDEQ standard of 19°C. Bold numbers highlight the spinning reserve experiment and forced outage.

	BR01	BR02	BR09	BR10	BR11	BR12	BR17	BR20	BR22	BR23	BR24	BR25
1-Jun	17.1	16.9	15.2	15.8	16.1	15.2	15.1	16.9			17.1	16.8
2-Jun	17.1	17.3	15.3	16.2	16.5	15.5	15.2	17.2			17.2	16.7
3-Jun	16.3	16.9	16.5	17.5	17.9	16.8	16.4	17.6			19.0	18.6
4-Jun	16.0	16.4	17.0	17.8	18.3	17.1	16.8	17.6			19.5	19.4
5-Jun	16.6	16.9	16.7	17.4	17.8	16.7	16.5	17.3			19.9	19.9
6-Jun	17.2	17.5	16.8	17.5	18.0	16.9	16.6	17.6	19.4	21.0	19.8	20.0
7-Jun	18.0	18.1	17.2	17.9	18.4	17.3	16.9	18.1	17.2	18.7	20.1	20.0
8-Jun	18.7	18.7	17.2	18.0	18.5	17.3	17.0	18.4	17.2	18.7	19.9	19.9
9-Jun	19.1	19.1	17.2	18.2	18.8	17.5	17.1	19.1	17.6	18.5	19.8	19.9
10-Jun	19.4	19.1	15.7	16.7	17.2	16.1	15.7	18.9	16.9	17.9	18.2	18.3
11-Jun	19.1	19.0	14.9	16.1	16.5	15.4	15.0	18.7	16.2	16.8	17.1	17.2
12-Jun	18.3	18.5	16.0	17.0	17.5	16.3	15.9	18.9	17.0	17.9	17.9	17.7
13-Jun	17.1	17.4	17.0	17.9	18.4	17.2	16.9	18.4	17.1	18.2	19.2	19.0

Average daily temperature for sites used in the longitudinal study. Red text indicates temperatures exceeding the daily average IDEQ standard of 19°C. Bold numbers highlight the spinning reserve experiment and forced outage.

	BR01	BR02	BR09	BR10	BR11	BR12	BR17	BR20	BR22	BR23	BR24	BR25
14-Jun	17.6	17.7	17.6	18.3	18.8	17.6	17.4	17.9	17.1	18.6	19.7	20.0
15-Jun	18.5	18.2	15.8	16.5	16.9	15.9	15.7	18.0	16.4	17.0	18.0	18.5
16-Jun	18.9	19.0	16.0	16.8	17.1	16.1	15.9	18.9	17.6	18.2	18.1	17.7
17-Jun	18.3	18.5	17.1	18.0	18.5	17.3	17.0	18.7	17.8	18.6	19.0	19.0
18-Jun	18.3	18.3	16.5	17.0	17.3	16.4	16.4	18.5	17.3	17.7	17.9	17.7
19-Jun	17.7	17.8	16.9	17.4	17.5	16.6	16.9	18.1	17.1	17.6	17.7	17.4
20-Jun	17.2	17.4	17.2	17.4	17.5	16.8	17.1	17.7	17.1	17.6	18.0	18.0
21-Jun	17.4	17.7	17.6	18.0	18.2	17.3	17.5	17.9	17.4	18.1	18.6	18.6
22-Jun	18.1	18.2	17.7	18.4	18.7	17.8	17.5	18.3	17.6	18.6	19.1	19.2
23-Jun	18.6	18.6	17.0	17.7	18.2	17.1	16.8	18.7	17.5	18.3	19.1	19.4
24-Jun	19.0	19.1	17.0	18.0	18.4	17.3	16.9	19.1	18.1	18.9	19.1	19.2
25-Jun	18.8	19.0	17.7	18.8	19.4	18.1	17.6	19.3	18.4	19.3	19.9	20.0
26-Jun	18.9	19.1	18.0	19.1	19.6	18.4	18.0	19.3	18.4	19.4	20.0	20.3
27-Jun	19.7	19.8	18.4	19.2	19.7	18.5	18.0	19.7	18.7	19.7	20.2	20.5
28-Jun	20.1	20.1	18.5	19.6	20.1	18.9	18.3	20.3	19.0	19.9	20.6	20.8
29-Jun	20.6	20.4	17.7	18.6	19.2	18.0	17.5	20.3	18.7	19.7	20.0	20.2
30-Jun	20.6	20.6	17.3	18.4	18.9	17.8	17.1	20.6	18.8	19.6	19.9	19.7
1-Jul	19.8	19.8	17.6	18.7	19.3	18.1	17.5	20.2	18.7	19.7	20.1	20.1
2-Jul	19.9	20.1	18.2	19.2	19.7	18.6	18.0	20.2	18.9	19.8	20.3	20.5
3-Jul	19.6	19.5	17.2	18.2	18.8	17.7	17.2	19.8	18.3	19.2	19.6	19.8
4-Jul	19.4	19.5	16.9	18.1	18.6	17.5	17.0	19.6	18.4	19.1	19.4	19.4
5-Jul	19.3	19.5	18.0	19.2	19.8	18.7	18.1	19.7	18.8	19.7	20.3	20.4
6-Jul	19.6	19.8	18.9	19.7	20.4	19.3	18.8	20.0	19.1	20.1	20.7	21.0
7-Jul	20.1	20.2	18.8	19.9	20.4	19.2	18.7	20.4	19.4	20.4	21.0	21.3
8-Jul	20.5	20.7	19.4	20.3	21.0	19.8	19.2	20.8	19.8	20.9	21.5	21.9
9-Jul	21.1	21.4	20.2	21.3	22.0	20.6	20.1	21.5	20.5	21.7	22.5	22.7
10-Jul	21.9	22.0	20.2	21.2	22.1	20.6	20.1	22.1	20.8	21.9	22.8	23.4
11-Jul	22.5	22.5	19.7	20.8	21.5	20.1	19.5	22.5	21.0	22.0	22.5	22.9
12-Jul	22.7	22.7	19.7	20.7	21.6	20.2	19.5	22.8	21.2	22.0	22.4	22.5
13-Jul	22.7	22.8	19.7	20.9	21.8	20.3	19.6	22.9	21.4	22.3	22.7	22.7
14-Jul	22.6	22.7	20.1	20.5	21.6	20.3	19.9	22.8	21.2	21.9	22.4	22.6

Average daily temperature for sites used in the longitudinal study. Red text indicates temperatures exceeding the daily average IDEQ standard of 19°C. Bold numbers highlight the spinning reserve experiment and forced outage.

	BR01	BR02	BR09	BR10	BR11	BR12	BR17	BR20	BR22	BR23	BR24	BR25
15-Jul	22.6	22.7	20.6	21.2	22.1	20.9	20.5	22.9	21.4	22.2	22.4	22.3
16-Jul	22.6	22.6	20.6	21.1	21.8	20.6	20.4	22.7	21.2	21.9	22.4	22.5
17-Jul	22.4	22.5	20.1	21.0	21.5	20.4	20.2	22.6	21.2	21.9	22.1	22.1
18-Jul	22.0	22.2	20.1	21.0	21.7	20.4	20.0	22.3	20.9	21.8	22.1	22.2
19-Jul	21.7	21.8	20.0	20.9	21.7	20.2	19.7	22.1	20.8	21.9	22.5	22.6
20-Jul	21.9	22.0	19.6	20.5	21.3	19.8	19.3	22.0	20.5	21.5	22.0	22.3
21-Jul	22.0	22.0	19.6	20.5	21.3	19.8	19.4	22.1	20.5	21.6	22.2	22.4
22-Jul	22.1	22.0	19.7	20.7	21.4	20.0	19.5	22.2	20.5	21.5	22.0	22.2
23-Jul	22.3	22.3	19.4	20.4	21.1	19.6	19.1	22.3	20.5	21.3	21.6	21.5
24-Jul	22.2	22.2	19.4	20.5	21.2	19.8	19.2	22.4	20.6	21.4	22.0	22.0
25-Jul	22.0	22.1	19.9	20.6	21.4	19.9	19.3	22.2	20.6	21.4	21.6	21.7
26-Jul	**21.9**	**22.2**	**20.2**	**20.8**	**21.1**	**20.2**	**20.1**	**22.4**	**20.7**	**21.4**	**22.1**	**22.1**
27-Jul	**21.8**	**21.9**	**21.3**	**21.5**	**21.3**	**21.1**	**21.2**	**21.8**	**20.3**	**21.0**	**21.7**	**22.2**
28-Jul	**21.6**	**21.8**	**21.4**	**21.5**	**21.3**	**21.2**	**21.3**	**21.5**	**20.2**	**20.8**	**21.2**	**21.5**
29-Jul	21.5	21.6	19.1	20.2	20.6	19.4	18.9	21.7	20.3	20.9	21.2	21.3
30-Jul		21.5	19.0	20.4	20.7	19.6	18.8	21.7	20.3	21.1	21.5	21.6
31-Jul	21.0	21.3	18.8	20.2	21.0	19.4	18.7	21.6	20.2	20.8	21.2	21.5
1-Aug	20.9	21.0	19.4	20.7	21.0	19.9	19.3	21.3	20.1	20.8	21.3	21.7
2-Aug	21.2	21.2	18.7	20.0	20.3	19.2	18.6	21.2	19.9	20.3	20.6	20.9
3-Aug	21.5	21.5	18.6	19.9	20.2	19.1	18.5	21.5	20.2	20.7	20.7	20.5
4-Aug	21.1	21.2	17.8	19.2	19.5	18.4	17.8	21.3	19.8	20.3	20.5	20.4
5-Aug	20.5	20.5	17.7	19.0	19.3	18.3	17.7	20.7	19.5	20.0	20.4	20.5
6-Aug	20.3	20.4	17.9	19.0	19.3	18.3	17.9	20.5	19.3	19.8	20.0	20.1
7-Aug	19.7	19.9	17.9	19.2	19.5	18.4	17.8	20.2	19.1	19.8	20.2	20.3
8-Aug	19.7	19.8	18.0	19.2	19.5	18.5	17.9	20.0	19.1	19.8	20.2	20.4
9-Aug	19.9	20.0	18.1	19.4	19.7	18.7	18.0	20.1	19.1	19.8	20.3	20.6
10-Aug	20.1	20.3	18.3	19.6	19.9	18.9	18.2	20.4	19.3	20.1	20.5	20.6
11-Aug	20.4	20.5	18.3	19.7	20.1	18.9	18.2	20.6	19.3	20.1	20.7	21.0
12-Aug	20.8	20.8	18.4	19.7	19.9	19.0	18.2	20.9	19.5	20.2	20.6	20.8
13-Aug	21.0	21.0	18.2	19.5	19.8	18.7	18.1	21.1	19.6	20.2	20.6	20.6
14-Aug	21.2	21.3	18.3	19.7	19.9	19.0	18.2	21.3	19.9	20.5	20.8	20.8

Average daily temperature for sites used in the longitudinal study. Red text indicates temperatures exceeding the daily average IDEQ standard of 19°C. Bold numbers highlight the spinning reserve experiment and forced outage.

	BR01	BR02	BR09	BR10	BR11	BR12	BR17	BR20	BR22	BR23	BR24	BR25
15-Aug	21.1	21.1	18.0	19.4	19.7	18.7	18.0	21.2	19.8	20.3	20.5	20.6
16-Aug	20.6	20.6	17.1	18.7	19.1	18.0	17.3	20.8	19.2	19.6	19.9	20.2
17-Aug	20.3	20.4	17.5	19.0	19.2	18.3	17.6	20.6	19.0	19.6	19.9	19.9
18-Aug	20.1	20.1	17.4	18.7	19.0	18.0	17.4	20.2	18.9	19.4	19.6	19.8
19-Aug	19.9	20.0	17.3	18.6	18.9	17.9	17.3	20.1	18.7	19.3	19.5	19.5
20-Aug	19.5	19.4	16.7	17.8	18.1	17.1	16.7	19.7	18.3	18.6	19.0	19.2
21-Aug	19.3	19.4	16.5	17.7	17.9	17.0	16.5	19.5	18.2	18.6	18.6	18.5
22-Aug	18.6	18.5	16.1	17.1	17.5	16.4	16.1	18.8	17.6	17.9	18.3	18.5
23-Aug	18.4	18.6	16.2	17.3	17.5	16.6	16.2	18.7	17.7	18.0	18.0	17.8
24-Aug	18.0	18.1	16.2	17.1	17.5	16.5	16.2	18.4	17.4	17.8	18.2	18.4
25-Aug	17.8	17.9	16.3	17.3	17.5	16.6	16.3	18.0	17.1	17.8	18.1	18.2
26-Aug	17.5	17.6	15.8	16.7	17.0	16.0	15.8	17.8	16.7	17.1	17.4	17.6
27-Aug	17.5	17.4	15.2	15.8	16.2	15.3	15.2	17.5	16.4	16.7	16.7	16.7
28-Aug	17.2	17.4	14.8	15.6	15.9	15.1	14.8	17.3	16.1	16.8	16.7	16.4
29-Aug	16.2	16.6	15.4	16.3	16.5	15.7	15.4	17.1	16.1	16.9	17.1	17.2
30-Aug	16.2	16.3	15.3	16.0	16.3	15.4	15.3	16.5	15.5	16.2	16.8	17.3
31-Aug	16.5	16.7	15.4	16.1	16.4	15.5	15.3	16.7	15.6	16.5	16.9	17.1
1-Sep	16.7	16.7	15.2	16.0	16.2	15.4	15.2	16.8	15.7	16.5	16.9	17.1
2-Sep	16.5	16.6	15.1	15.9	16.1	15.3	15.0	16.8	15.7	16.4	16.8	16.9
3-Sep	16.5	16.6	15.1	15.9	16.1	15.3	15.1	16.7	15.7	16.5	16.9	17.1
4-Sep	16.5	16.6	15.1	15.8	16.1	15.3	15.1	16.8	15.7	16.2	16.8	17.0
5-Sep	16.6	16.7	15.3	16.2	16.4	15.6	15.3	16.9	16.0	16.6	16.9	17.1
6-Sep	16.7	16.7	15.4	16.1	16.4	15.6	15.3	16.9	15.9	16.6	17.0	17.2
7-Sep	16.8	17.0	15.6	16.4	16.6	15.8	15.6	17.1	16.0	16.8	17.2	17.2
8-Sep	17.0	17.1	15.7	16.5	16.8	15.9	15.7	17.3	16.2	16.8	17.1	17.4
9-Sep	17.2	17.2	15.3	16.1	16.3	15.5	15.3	17.2	16.0	16.8	16.9	16.8
10-Sep	17.1	17.2	15.2	16.0	16.3	15.5	15.2	17.3	15.9	16.7	17.0	17.1
11-Sep	17.0	17.0	15.0	15.8	16.0	15.3	15.0	17.1	15.7	16.3	16.6	16.7
12-Sep	16.7	16.7	14.4	15.1	15.4	14.6	14.4	16.8	15.3	15.8	16.0	15.9
13-Sep	16.6	16.6	14.6	15.3	15.5	14.8	14.6	16.6	15.4	16.1	16.1	16.0
14-Sep	16.4	16.4	14.2	14.9	15.2	14.4	14.2	16.4	15.0	15.7	15.7	15.8

Average daily temperature for sites used in the longitudinal study. Red text indicates temperatures exceeding the daily average IDEQ standard of 19°C. Bold numbers highlight the spinning reserve experiment and forced outage.												
	BR01	**BR02**	**BR09**	**BR10**	**BR11**	**BR12**	**BR17**	**BR20**	**BR22**	**BR23**	**BR24**	**BR25**
15-Sep	15.9	16.1	14.3	14.9	15.2	14.5	14.4	16.3	14.8	15.4	15.4	15.4
16-Sep	15.7	15.8	14.4	15.0	15.2	14.6	14.4	16.1	14.8	15.6	15.6	15.6
17-Sep	15.4	15.5	14.0	14.7	14.9	14.2	14.0	15.8	14.5	15.2	15.4	15.5
18-Sep	15.1	15.4	14.2	14.7	14.9	14.3	14.1	15.7	14.6	15.4	15.5	15.6
19-Sep	15.0	15.1	13.7	14.2	14.4	13.8	13.7	15.2	13.8	14.5	14.9	15.1
20-Sep	14.8	14.8	13.6	14.0	14.2	13.7	13.5	15.0	13.6	14.2	14.7	14.7
21-Sep	14.7	14.6	12.9	13.4	13.5	13.1	12.9	14.5	13.0	13.4	13.6	13.7
22-Sep	14.3	14.5	13.4	13.9	13.9	13.5	13.4	14.7	13.4	13.9	14.1	13.9
23-Sep	14.1	14.2	13.2	13.6	13.6	13.3	13.2	14.4	13.1	13.6	14.0	14.1
24-Sep	14.0	14.0	12.6	13.0	13.0	12.8	12.6	13.9	12.9	13.2	13.2	13.2
25-Sep	13.7	13.6	12.0	12.5	12.4	12.3	12.0	13.3	12.2	12.6	12.6	12.6
26-Sep	13.1	13.2	12.0	12.5	12.4	12.2	12.1	13.2	12.2	12.4	12.6	12.4
27-Sep	12.7	12.7	12.2	12.6	12.5	12.4	12.3	13.1	12.2	12.5	12.5	12.4
28-Sep	12.6	12.7	12.5	12.9	12.8	12.7	12.6	13.0	12.5	13.0	13.0	13.0
29-Sep	12.6	12.7	12.7	13.0	12.8	12.8	12.7	13.1	12.6	13.2	13.5	13.5
30-Sep	12.7	13.0	13.2	13.4	13.4	13.3	13.2	13.4	13.0	13.7	14.0	14.2
1-Oct	12.7	12.6	12.2	12.6	12.4	12.5	12.2	13.0	12.3	12.6	13.0	13.1
2-Oct	12.5	13.1	13.0	13.2	13.1	13.1	13.0	13.1	12.8	13.5	13.5	13.5
3-Oct	12.5	13.1	13.3	13.5	13.5	13.4	13.3	13.5	13.2	14.2	14.6	14.7
4-Oct	12.7	12.7	12.7	12.9	12.8	12.9	12.7	13.1	12.6	13.4	14.0	13.9
5-Oct	12.7	12.5	11.7	12.1	11.8	12.1	11.8	12.5	11.9	12.0	12.7	12.7
6-Oct	12.5	12.2	11.1	11.5	11.1	11.5	11.1	11.9	11.2	11.0	11.7	11.4
7-Oct	12.2	11.7	10.7	11.2	10.6	11.2	10.8	11.5	10.7	10.3	10.9	10.5
8-Oct	11.8	11.5	10.2	10.8	10.1	10.8	10.3	11.1	10.8	10.5	10.2	10.0
9-Oct	11.0	10.6	9.7	10.1	9.4	10.2	9.8	10.7	9.9	8.8	9.9	9.3
10-Oct	10.7	10.2	9.8	10.2	9.4	10.3	9.9	10.2	10.3	9.6	9.3	8.5
11-Oct	9.9	10.0	9.8	10.2	9.4	10.3	9.9	10.0	10.4	9.8	9.6	8.9
12-Oct	9.2	9.2	9.6	9.9	9.1	9.9	9.7	9.7	10.2	9.7	9.5	9.1
13-Oct	8.8	8.2	9.1	9.5	8.5	9.7	9.3	8.9	9.5	8.6	9.3	8.7
14-Oct	8.7	7.5	7.3	8.0	6.5	8.2	7.5	7.4	8.3	6.8	6.8	6.2
15-Oct	8.4	7.6	7.3	7.6	6.3	7.8	7.5	7.1	8.4	7.1	6.9	6.0

Average daily temperature for sites used in the longitudinal study. Red text indicates temperatures exceeding the daily average IDEQ standard of 19°C. Bold numbers highlight the spinning reserve experiment and forced outage.

	BR01	BR02	BR09	BR10	BR11	BR12	BR17	BR20	BR22	BR23	BR24	BR25
16-Oct	7.7	7.5	8.0	8.4	7.1	8.5	8.1	7.6	9.2	8.5	7.9	7.4
17-Oct	7.6	7.3	8.7	9.0	8.0	9.2	8.8	8.1	9.7	9.2	9.1	8.7
18-Oct	7.5	7.3	8.7	8.9	8.0	9.1	8.8	8.1	9.7	9.3	9.4	9.2
19-Oct	7.4	7.1	8.7	8.8	7.9	9.1	8.8	8.0	9.7	9.4	9.5	9.4
20-Oct	7.4	7.1	8.9	9.0	8.0	9.1	8.9	8.0	9.6	9.3	9.7	9.6
21-Oct	7.5	7.3	9.0	9.0	8.0	9.1	9.0	7.9	9.7	9.3	9.6	9.6
22-Oct	7.7	7.5	9.5	9.5	8.5	9.6	9.4	8.5	10.4	10.4	10.3	10.4
23-Oct	7.7	7.9	9.6	9.5	8.7	9.7	9.5	8.9	10.2	10.2	10.9	10.7
24-Oct	7.8	7.6	8.9	9.0	8.3	9.3	8.9	9.0	10.0	9.7	9.8	10.2
25-Oct	7.9	7.9	9.0	9.1	8.4	9.4	9.0	9.1	10.2	10.0	10.3	10.2
26-Oct	8.1	7.6	8.9	9.1	8.4	9.4	9.0	9.0	9.9	9.7	9.8	10.0
27-Oct	8.2	8.2	9.6	9.5	8.6	9.7	9.5	9.1	10.4	10.4	10.3	10.3
28-Oct	8.5	8.2	9.4	9.4	8.6	9.6	9.4	8.9	10.2	10.2	10.3	10.3
29-Oct	8.4	8.3	9.2	9.3	8.3	9.5	9.1	8.8	9.7	9.4	10.0	10.0
30-Oct	8.4	7.5	7.9	8.3	7.1	8.6	7.9	8.0	8.7	7.7	8.1	7.9
31-Oct	8.2	6.9	7.1	7.4	6.2	7.7	7.2	7.2	7.7	6.2	6.6	5.8
1-Nov	8.0	6.9	7.8	7.8	6.6	8.0	7.7	7.2	8.3	7.4	6.7	6.0
2-Nov	7.7	7.4	8.4	8.4	7.3	8.7	8.4	7.4	8.8	8.3	8.2	7.8
3-Nov	7.5	6.8	7.5	7.6	6.4	7.9	7.4	7.1	8.3	7.4	7.4	7.1
4-Nov	7.2	6.1	7.2	7.2	6.0	7.5	7.1	6.8	7.5	6.2	7.0	6.0
5-Nov	7.0	5.9	7.2	7.3	6.0	7.6	7.2	6.6	8.2	7.1	6.1	5.8
6-Nov	6.6	5.6	6.6	6.7	5.3	7.0	6.7	5.8	7.2	5.9	6.4	5.4
7-Nov	6.1	5.0	6.0	6.3	4.7	6.6	6.1	5.6	7.1	5.7	5.2	4.2
8-Nov	5.5	4.7	5.7	6.0	4.3	6.3	5.7	5.0	7.0	5.5	5.5	4.4
9-Nov	5.3	4.1	5.0	5.5	3.6	5.8	5.1	4.5	6.3	4.6	4.9	3.9
10-Nov	5.1	4.0	5.4	5.8	3.8	6.1	5.5	4.3	6.8	5.4	4.9	4.3
11-Nov	4.8	3.7	4.5	5.4	2.9	5.8	4.6	3.7	6.1	4.3	4.8	4.1
12-Nov	4.2	3.3	4.3	4.7	2.7	5.4	4.4	3.6	6.0	4.3	4.0	3.2
13-Nov	4.1	2.9	4.3	4.8	2.6	5.3	4.4	3.5	6.0	4.1	3.9	3.0
14-Nov	3.9	2.9	4.5	5.0	2.8	5.3	4.6	3.4	6.1	4.4	4.1	3.2
15-Nov	4.0	2.9	4.6	5.0	2.8	5.4	4.6	3.4	6.3	4.7	4.3	3.5

Average daily temperature for sites used in the longitudinal study. Red text indicates temperatures exceeding the daily average IDEQ standard of 19°C. Bold numbers highlight the spinning reserve experiment and forced outage.												
	BR01	**BR02**	**BR09**	**BR10**	**BR11**	**BR12**	**BR17**	**BR20**	**BR22**	**BR23**	**BR24**	**BR25**
16-Nov	3.9	3.1	5.0	5.2	3.1	5.6	5.0	3.6	6.5	5.1	4.7	4.2
17-Nov	3.8	3.4	5.4	6.0	3.7	6.3	5.5	3.8	7.0	6.0	5.9	5.4
18-Nov	3.8	2.4	3.9	4.3	2.2	5.1	4.0	3.3	5.8	3.8	3.8	3.8
19-Nov	3.8	2.4	4.0	4.5	2.3	5.0	4.1	3.1	5.9	4.0	3.2	2.5
20-Nov	3.8	2.5	3.9	4.3	2.0	4.9	4.0	2.8	5.8	4.0	3.4	2.8
21-Nov	3.7	2.5	3.7	4.3	1.8	4.8	3.9	2.8	5.6	3.5	3.1	2.5
22-Nov	3.8	2.9	4.7	5.0	2.8	5.3	4.8	3.1	6.1	4.5	3.9	3.1
23-Nov	3.7	2.7	4.8	5.0	2.9	5.4	4.9	3.2	6.0	4.6	4.3	3.9
24-Nov	3.6	2.8	4.7	5.1	2.8	5.6	4.7	3.2	6.1	4.4	4.0	3.7
25-Nov	3.5	2.5	4.0	4.7	2.2	5.1	4.0	2.9	6.0	4.3	3.9	3.7
26-Nov	3.4	2.0	3.5	3.9	1.7	4.7	3.6	2.7	5.6	3.7	3.4	3.0
27-Nov	3.5	2.3	4.4	4.8	2.5	5.1	4.4	2.8	5.9	4.2	3.6	2.9
28-Nov	3.6	2.7	4.9	5.2	2.9	5.4	4.9	3.0	6.4	5.1	4.4	3.9
29-Nov	3.5	3.0	5.1	5.4	3.1	5.6	5.0	3.3	6.7	5.6	5.1	4.8
30-Nov	3.5	2.7	5.1	5.4	3.3	5.6	5.2	3.5	6.5	5.2	5.1	5.0
1-Dec	3.5	2.3	4.6	5.0	2.8	5.3	4.7	3.1	5.9	4.4	4.3	3.9
2-Dec	3.4	2.1	3.5	3.7	1.7	4.8	3.6	2.5	5.6	3.5	3.2	2.6
3-Dec	3.4	2.1	3.8	4.4	2.0	4.9	4.0	2.4	5.6	3.7	3.2	2.5
4-Dec	3.4	1.7	2.5	2.0	0.9	3.8	2.8	1.9	4.8	2.4	2.1	1.7
5-Dec	3.5	1.4	1.8	1.4	0.4	3.1	2.2	1.4	4.0	1.0	1.0	0.2
6-Dec	3.5	1.7	2.1	1.6	0.4	3.5	2.4	1.3	4.5	1.8	0.7	0.0
7-Dec	3.5	1.5	2.1	1.7	0.4	3.3	2.4	1.4	4.5	1.7	0.9	0.1
8-Dec	3.4	2.1	3.2	3.7	1.3	4.4	3.3	1.9	5.5	3.4	2.1	0.6
9-Dec	3.2	2.4	3.7	4.3	1.8	4.7	3.7	2.1	5.8	4.1	3.4	2.5
10-Dec	3.2	1.9	3.5	4.1	1.7	4.6	3.6	2.3	5.5	3.6	3.1	2.3
11-Dec	3.2	2.1	3.8	4.4	2.0	4.7	3.9	2.3	5.5	3.8	3.4	2.6
12-Dec	3.3	1.5	3.2	3.8	1.4	4.4	3.4	2.0	4.7	2.3	2.2	1.8
13-Dec	3.2	1.5	2.5	2.1	0.7	3.8	2.7	1.6	4.7	2.1	1.4	0.7
14-Dec	3.2	1.3	2.1	1.5	0.5	3.4	2.4	1.3	4.6	1.6	0.9	0.2
15-Dec	3.3	1.8	2.9	3.0	0.9	4.1	3.1	1.7	5.2	3.0	1.6	0.5
16-Dec	3.3	2.0	2.8	2.5	0.8	4.0	3.0	1.7	5.3	2.9	2.2	1.4

Average daily temperature for sites used in the longitudinal study. Red text indicates temperatures exceeding the daily average IDEQ standard of 19°C. Bold numbers highlight the spinning reserve experiment and forced outage.												
	BR01	**BR02**	**BR09**	**BR10**	**BR11**	**BR12**	**BR17**	**BR20**	**BR22**	**BR23**	**BR24**	**BR25**
17-Dec	3.3	1.9	3.2	3.6	1.3	4.4	3.4	2.1	5.4	3.1	2.3	1.5
18-Dec	3.3	2.5	4.4	4.8	2.4	5.0	4.4	2.6	6.0	4.7	3.9	3.2
19-Dec	3.2	2.3	4.2	4.7	2.3	5.0	4.3	2.7	5.9	4.1	4.0	3.8
20-Dec	3.2	2.0	3.8	4.3	1.9	4.7	4.0	2.7	5.9	4.0	3.4	3.0
21-Dec	3.2	2.1	4.4	4.9	2.5	5.1	4.5	2.8	6.0	4.4	3.9	3.4
22-Dec	3.2	1.9	3.6	4.0	1.8	4.7	3.8	2.3	5.6	3.3	3.5	2.8
23-Dec	3.2	1.5	3.1	3.5	1.3	4.3	3.3	2.1	5.3	2.7	2.4	1.3
24-Dec	3.3	1.9	3.8	4.3	1.8	4.7	3.9	2.1	5.6	3.8	2.9	2.0
25-Dec	3.3	2.3	3.9	4.2	2.0	5.1	4.0	2.2	5.9	4.3	3.7	3.2
26-Dec	3.2	1.9	3.1	2.7	1.3	4.4	3.3	2.1	5.7	3.1	3.2	2.8
27-Dec	3.2	1.5	2.5	1.9	0.9	3.8	2.8	1.8	5.2	2.3	2.3	1.2
28-Dec	3.1	1.4	2.0	1.1	0.5	3.0	2.3	1.3	4.8	1.8	1.9	0.7
29-Dec	3.1	1.1	1.8	1.9	0.3	3.3	2.2	1.1	4.2	0.9	1.2	0.0
30-Dec	3.1	0.8	2.2	2.4	0.4	3.6	2.5	1.0	4.1	1.0	0.9	0.0
31-Dec	3.0	1.1	1.6	0.9	0.2	2.4	2.1	0.5	4.1	0.7	0.8	0.0
2019	5.9	5.9	6.7	6.6	5.5	7.2	6.7	5.8	7.7	6.9	6.9	3.5
1-Jan	2.9	0.7	1.2	1.0	0.1	2.1	1.7	0.4	3.4	0.1	0.8	0.0
2-Jan	3.0	1.0	1.6	1.4	0.1	2.6	2.0	0.7	4.2	1.1	0.7	0.0
3-Jan	3.0	1.1	1.7	1.5	0.2	2.6	2.1	0.7	4.2	1.3	0.7	0.0
4-Jan	2.9	1.1	1.7	1.7	0.2	2.7	2.1	0.9	4.2	1.2	0.7	0.0
5-Jan	3.0	1.3	1.9	1.9	0.2	3.0	2.2	1.0	4.4	1.2	0.7	0.0
6-Jan	3.0	1.6	2.6	2.6	0.5	3.6	2.8	1.5	4.8	2.7	0.7	0.0
7-Jan	2.9	1.3	2.5	2.2	0.5	3.5	2.7	1.6	4.9	2.5	1.0	0.0
8-Jan	3.0	1.0	2.0	1.3	0.3	3.0	2.3	1.3	4.7	1.8	1.2	0.0
9-Jan	3.0	1.7	2.8	2.8	0.8	3.8	2.9	1.6	5.2	3.0	1.7	0.0
10-Jan	3.1	1.8	3.1	3.3	1.1	4.1	3.2	1.8	5.4	3.3	2.3	0.1
11-Jan	3.0	2.2	3.8	4.3	1.9	4.7	3.9	2.4	6.0	4.8	3.5	0.8
12-Jan	2.9	1.4	2.4	1.8	0.9	3.6	2.7	1.7	5.3	2.4	3.2	1.6
13-Jan	2.9	1.0	1.8	1.3	0.5	3.1	2.2	1.3	4.5	0.9	1.6	0.2
14-Jan	2.9	0.8	1.4	1.0	0.2	2.7	1.9	0.8	4.0	0.6	1.0	0.1
15-Jan	3.0	0.8	1.6	1.2	0.1	2.7	2.0	0.7	3.9	0.8	0.9	0.0

Average daily temperature for sites used in the longitudinal study. Red text indicates temperatures exceeding the daily average IDEQ standard of 19°C. Bold numbers highlight the spinning reserve experiment and forced outage.

	BR01	**BR02**	**BR09**	**BR10**	**BR11**	**BR12**	**BR17**	**BR20**	**BR22**	**BR23**	**BR24**	**BR25**
16-Jan	3.1	1.5	2.6	2.4	0.5	3.7	2.7	1.4	4.9	2.9	0.9	0.0
17-Jan	3.1	2.0	3.4	3.8	1.4	4.4	3.5	2.0	5.2	3.8	1.9	0.1
18-Jan	3.0	1.7	3.7	4.1	1.8	4.6	3.8	2.3	5.6	4.4	3.1	1.5
19-Jan	3.0	1.6	3.5	3.9	1.8	4.5	3.7	2.2	5.4	3.4	3.4	2.7
20-Jan	3.0	2.0	4.3	4.5	2.3	4.9	4.4	2.6	5.6	4.5	3.6	3.5
21-Jan	2.9	2.1	3.9	3.5	2.1	4.6	4.0	2.2	5.7	3.6	3.9	3.3
22-Jan	2.7	1.1	2.3	1.6	0.7	3.4	2.6	1.8	5.0	2.1	2.0	0.9
23-Jan	2.8	0.7	2.2	2.5	0.6	3.8	2.5	1.1	4.2	1.0	1.6	0.1
24-Jan	2.8	1.2	3.0	2.8	1.0	4.2	3.1	1.4	5.1	3.2	1.6	0.6
25-Jan	2.8	1.6	3.2	3.3	1.2	4.4	3.4	1.5	5.3	3.2	2.7	2.5
26-Jan	2.8	1.5	3.0	3.0	1.2	4.2	3.2	1.8	5.3	3.3	2.7	2.2
27-Jan	2.7	1.4	3.2	3.2	1.3	4.2	3.3	1.8	5.2	3.0	2.9	2.3
28-Jan	2.8	1.4	2.9	2.3	1.1	4.0	3.1	1.7	5.4	3.1	2.8	2.4
29-Jan	2.8	1.2	2.3	1.4	0.6	3.4	2.5	1.4	5.2	2.7	2.5	1.7
30-Jan	2.8	1.0	1.8	1.0	0.3	2.8	2.1	1.1	4.7	1.7	2.0	0.8
31-Jan	2.9	1.3	2.1	1.3	0.4	3.1	2.3	1.3	5.0	2.7	1.9	0.9
1-Feb	2.9	1.4	2.3	1.6	0.6	3.5	2.4	1.4	5.1	2.7	2.3	1.5
2-Feb	3.0	1.8	3.1	3.3	1.4	4.2	3.2	1.9	5.3	3.3	2.7	1.8
3-Feb	3.0	2.2	4.2	4.4	2.3	4.7	4.2	2.5	5.7	4.6	3.8	3.4
4-Feb	2.8	1.6	3.5	3.7	1.6	4.5	3.5	2.2	5.4	3.6	3.7	3.2
5-Feb	2.6	1.3	3.5	3.6	1.6	4.5	3.5	1.9	5.3	3.2	3.1	2.5
6-Feb	2.7	1.3	2.6	1.7	0.8	3.7	2.6	1.3	5.0	2.3	2.5	1.8
7-Feb	2.7	1.3	2.2	1.6	0.6	3.3	2.3	1.2	4.5	1.8	1.8	0.7
8-Feb	2.8	0.9	1.6	0.9	0.3	2.8	1.9	1.0	4.1	1.5	1.4	0.5
9-Feb	2.9	1.2	1.8	1.0	0.3	2.7	2.0	0.9	4.4	1.8	1.5	0.1
10-Feb	2.9	1.5	2.5	2.2	0.8	3.7	2.6	1.3	4.8	2.6	2.0	1.0
11-Feb	2.8	1.0	2.0	1.6	0.5	3.4	2.1	1.0	4.1	0.9	1.5	0.4
12-Feb	2.8	0.8	2.0	1.6	0.5	3.3	2.2	1.1	4.2	1.6	0.9	0.2
13-Feb	2.7	1.4	2.6	2.7	0.8	3.9	2.7	1.2	4.3	2.4	1.5	0.3
14-Feb	2.8	1.7	3.8	4.0	1.9	4.5	3.8	2.1	4.8	3.7	2.6	2.3
15-Feb	2.7	1.9	3.6	3.8	1.8	4.5	3.7	2.1	5.3	3.8	3.7	3.5

Average daily temperature for sites used in the longitudinal study. Red text indicates temperatures exceeding the daily average IDEQ standard of 19°C. Bold numbers highlight the spinning reserve experiment and forced outage.												
	BR01	**BR02**	**BR09**	**BR10**	**BR11**	**BR12**	**BR17**	**BR20**	**BR22**	**BR23**	**BR24**	**BR25**
16-Feb	2.7	1.3	3.4	3.6	1.6	4.5	3.5	2.1	5.1	3.2	2.9	2.6
17-Feb	2.7	1.5	3.3	3.1	1.6	4.4	3.4	1.9	5.5	3.9	2.8	2.5
18-Feb	2.6	1.2	2.2	1.2	0.8	3.2	2.3	1.2	4.9	2.6	2.9	2.4
19-Feb	2.6	1.3	2.4	2.1	0.9	3.6	2.6	1.5	5.0	2.7	2.8	2.1
20-Feb	2.7	0.9	2.4	2.3	0.9	3.8	2.5	1.2	4.3	1.6	1.8	0.7
21-Feb	2.7	1.0	1.9	1.0	0.6	2.7	2.0	0.8	4.5	2.1	1.7	0.8
22-Feb	2.7	1.0	1.5	0.7	0.4	2.2	1.7	0.7	3.9	1.7	1.7	1.1
23-Feb	2.7	1.0	1.8	1.5	0.4	2.9	2.0	0.9	3.8	1.0	1.4	0.2
24-Feb	2.7	1.0	2.5	2.6	0.7	3.6	2.6	1.3	4.2	2.4	1.3	0.6
25-Feb	2.7	1.5	3.3	3.5	1.5	4.2	3.4	1.8	5.1	4.6	3.0	2.6
26-Feb	2.5	2.1	4.2	4.4	2.3	4.6	4.3	2.1	5.7	5.1	4.5	4.8
27-Feb	2.4	2.2	4.5	4.6	2.7	4.9	4.5	2.4	5.5	4.5	4.3	4.7
28-Feb	2.4	2.0	4.7	4.8	3.0	5.1	4.8	3.0	5.7	4.9	4.2	4.4
1-Mar	2.4		4.4	4.5	2.7	4.9	4.4	3.3	5.9	4.9	4.2	4.5
2-Mar	2.5		4.3	4.4	2.7	5.0	4.3	3.2	6.0	4.9	4.7	5.0
3-Mar	2.5		3.3	2.8	1.8	4.1	3.2	3.0	5.4	3.6	4.1	4.3
4-Mar	2.6		2.9	2.6	1.5	3.7	2.9	2.8	5.0	3.0	3.4	3.3
5-Mar	2.7		3.0	2.7	1.6	3.9	3.2	2.9	5.1	3.3	3.3	3.2
6-Mar	2.7		4.3	4.6	2.6	4.8	4.4	3.3	5.7	4.4	4.2	4.2
7-Mar	2.7		4.8	4.9	3.1	5.1	4.8	3.7	6.0	5.3	4.5	4.6
8-Mar	2.7		4.4	4.7	2.8	5.1	4.5	3.4	5.9	4.2	4.4	4.4
9-Mar	2.7		4.1	4.3	2.6	4.9	4.2	3.4	5.6	4.0	3.7	3.3
10-Mar	2.7		4.0	3.7	2.5	4.7	4.0	3.2	5.8	4.6	4.1	4.2
11-Mar	2.8		3.9	3.7	2.5	4.6	4.0	3.3	5.9	5.0	4.7	5.0
12-Mar	3.2		4.3	4.2	2.9	5.0	4.4	3.8	6.3	5.7	5.3	5.7
13-Mar	3.4		4.6	4.9	3.2	5.4	4.7	3.9	6.4	4.8	5.3	5.4
14-Mar	3.5		4.3	4.2	2.9	5.1	4.3	3.9	6.4	5.2	4.4	4.5
15-Mar	3.5		4.4	4.3	2.9	4.9	4.3	3.9	6.5	5.6	5.0	5.3
16-Mar	3.2		4.3	4.2	3.0	4.9	4.4	3.7	6.4	5.6	5.6	6.1
17-Mar	3.1		4.7	4.7	3.3	5.2	4.7	3.8	6.5	5.8	5.7	6.4
18-Mar	3.1		5.0	5.1	3.7	5.6	5.0	3.9	6.7	6.2	6.3	6.9

Average daily temperature for sites used in the longitudinal study. Red text indicates temperatures exceeding the daily average IDEQ standard of 19°C. Bold numbers highlight the spinning reserve experiment and forced outage.

	BR01	BR02	BR09	BR10	BR11	BR12	BR17	BR20	BR22	BR23	BR24	BR25
19-Mar	3.1		5.1	5.0	3.7	5.6	5.1	4.0	6.7	6.0	6.3	7.0
20-Mar	3.2		5.4	5.4	4.0	5.9	5.4	4.1	6.8	6.2	6.3	6.8
21-Mar	3.2		5.2	5.3	3.8	5.8	5.2	4.0	6.6	5.3	6.1	6.3
22-Mar	3.3		5.9	5.9	4.6	6.0	6.0	4.3	6.7	6.2	6.1	6.3
23-Mar	2.8	3.0	4.9	4.6	3.9	5.0	4.8	4.1	6.5	5.7	6.5	7.1
24-Mar	2.9	2.6	3.6	3.6	3.4	4.1	3.7	3.6	5.9	4.5	5.0	5.5
25-Mar	3.4	3.2	5.5	5.7	3.7	5.9	5.6	4.1	6.4	6.7	5.4	6.0
26-Mar	3.5	3.7	6.1	6.1	4.5	6.4	6.1	4.3	7.1	7.1	7.3	7.9
27-Mar	3.5	3.7	6.5	6.5	4.9	6.6	6.5	4.8	7.3	7.2	7.6	8.1
28-Mar	3.5	3.7	6.9	6.9	5.3	6.9	6.9	4.9	7.5	7.8	7.8	8.3
29-Mar	3.5	3.5	6.4	6.4	5.3	6.7	6.4	4.7	7.2	6.4	7.5	7.7
30-Mar	3.6	3.7	6.8	6.9	5.3	7.0	6.8	4.9	7.4	7.5	7.0	7.5
31-Mar	3.5	3.8	6.6	6.6	5.5	7.0	6.6	4.7	7.5	7.6	7.8	8.6
1-Apr	3.5	4.0	7.2	7.1	5.8	7.3	7.2	5.1	7.6	7.6	8.6	9.3
2-Apr	3.4	3.9	7.3	7.1	6.1	7.4	7.3	5.1	7.7	7.6	8.2	8.7
3-Apr	3.4	3.8	7.3	7.1	5.9	7.3	7.3	5.0	7.6	7.8	7.9	8.4
4-Apr	3.3	3.9	7.6	7.3	6.1	7.5	7.5	4.7	7.5	7.9	8.3	9.0
5-Apr	3.3	3.6	7.4	7.1	6.1	7.4	7.3	4.8	7.4	7.3	8.4	9.4
6-Apr	3.1	3.3	6.2	5.9	5.7	6.3	6.1	4.6	6.9	6.7	8.0	8.6
7-Apr	3.3	3.2	4.5	4.4	4.5	4.9	4.5	4.0	5.7	5.2	5.9	6.8
8-Apr	3.8	4.0	6.9	6.9	4.9	7.1	6.9	4.2	6.0	5.9	6.4	7.0
9-Apr	4.3	4.3	7.4	7.3	6.0	7.6	7.4	4.8	6.1	5.9	6.6	7.4
10-Apr	4.7	4.6	6.3	6.4	5.3	7.1	6.3	4.7	5.6	5.4	5.5	5.8
11-Apr	4.8	4.9	6.4	6.7	5.2	7.0	6.4	5.0	6.0	6.0	5.9	6.1
12-Apr	4.8	4.9	7.2	7.4	5.7	7.6	7.2	5.2	6.5	6.4	6.8	7.3
13-Apr	4.6	4.6	7.2	7.3	6.1	7.6	7.2	5.2	6.4	6.3	6.7	7.1
14-Apr	4.7	4.5	6.6	6.6	5.7	7.1	6.6	4.8	6.1	5.7	5.9	7.5
15-Apr	5.0	5.2	7.3	7.3	5.6	7.7	7.3	5.2	6.9	6.7	6.8	
16-Apr	5.4	5.4	7.7	7.7	6.4	8.1	7.7	5.7	7.0	6.8	7.4	
17-Apr	5.5	5.6	8.1	8.2	6.6	8.4	8.1	5.9	7.2	7.2	7.4	
18-Apr	5.7	6.0	9.6	9.4	7.8	9.4	9.5	6.3	7.8	8.1	8.8	

Average daily temperature for sites used in the longitudinal study. Red text indicates temperatures exceeding the daily average IDEQ standard of 19°C. Bold numbers highlight the spinning reserve experiment and forced outage.												
	BR01	**BR02**	**BR09**	**BR10**	**BR11**	**BR12**	**BR17**	**BR20**	**BR22**	**BR23**	**BR24**	**BR25**
19-Apr	5.9	6.4	10.5	10.2	8.8	10.2	10.4	6.9	8.5	9.0	9.8	
20-Apr	6.2	6.4	10.2	10.0	9.1	10.2	10.1	7.0	8.6	8.8	10.1	
21-Apr	6.9	6.8	9.3	9.3	8.4	9.6	9.3	7.2	8.4	8.3	9.0	
22-Apr	8.3	8.2	9.5	9.5	8.3	9.8	9.4	7.6	8.9	9.2	9.4	
23-Apr	9.3	9.3	10.5	10.6	9.1	10.5	10.3	9.0	10.0	10.4	10.7	
24-Apr	10.1	10.1	11.6	11.6	10.5	11.5	11.5	10.3	11.0	11.3	11.9	
25-Apr	10.9	11.0	11.8	12.0	11.0	11.7	11.7	10.8	11.3	11.9	12.2	
26-Apr	11.3	11.3	11.6	11.4	11.1	11.5	11.5	11.9	11.8	12.1	12.7	
27-Apr	11.7	11.4	11.0	11.1	10.3	11.1	11.0	11.4	11.1	11.4	11.7	
28-Apr	11.9	11.5	10.8	11.0	10.3	11.0	10.8	11.1	10.3	10.5	11.7	
29-Apr	11.7	11.4	9.5	10.0	9.7	10.1	9.7	11.2	10.4	10.3	10.2	
30-Apr	11.0	10.7	9.5	9.9	9.8	10.1	9.7	11.2	10.2	10.0	10.1	
1-May	10.1	10.0	9.2	9.7	9.2	9.8	9.3	10.3	10.0	9.9	9.2	
2-May	9.4	9.3	9.8	10.0	9.3	10.1	9.8	9.7	9.9	9.9	9.7	
3-May	9.3	9.6	10.4	10.7	9.5	10.6	10.3	9.4	10.2	10.6	10.6	
4-May	8.9	9.4	11.4	11.4	10.4	11.4	11.1	10.0	10.8	11.2	11.8	
5-May	9.5	9.7	11.8	11.9	10.8	11.7	11.6	10.1	11.0	11.5	12.3	
6-May	10.0	10.1	11.1	10.9	10.8	11.2	11.1	11.0	11.2	11.8	12.5	
7-May	10.2	10.2	10.6	10.5	10.1	10.6	10.5	10.6	10.8	11.1	11.4	
8-May	10.6	10.7	10.7	10.7	10.2	10.7	10.7	10.7	11.1	11.5	11.8	
9-May	11.2	10.7	10.5	10.5	10.2	10.6	10.5	10.5	10.5	10.9	11.3	
10-May	11.0	11.4	11.1	11.1	10.4	11.0	11.0	11.1	11.5	12.1	11.9	
11-May	10.6	11.2	11.6	11.6	10.9	11.6	11.6	11.6	11.8	12.6	14.1	
12-May	10.5	11.5	12.0	12.0	11.0	12.0	12.0	12.1	12.3	13.1	14.3	
13-May	10.8	11.6	12.6	12.6	11.3	12.5	12.5	12.6	12.7	13.5	14.4	
14-May	11.0	11.8	13.0	12.9	11.7	12.8	12.9	13.1	13.3	14.4	14.9	
15-May	11.2	12.1	13.2	13.1	12.2	13.1	13.2	13.3	13.4	14.5	15.4	
16-May	11.7	12.1	12.9	12.9	12.2	12.8	12.9	12.9	12.8	13.6	14.7	
17-May	12.3	11.7	11.6	11.7	11.8	11.8	11.6	11.7	11.3	11.5	12.4	
18-May	13.2	12.5	10.8	11.1	11.1	11.3	10.9	11.6	11.1	11.0	11.1	
19-May	13.2	12.8	11.1	11.4	11.0	11.4	11.1	12.4	11.6	11.5	11.2	

Average daily temperature for sites used in the longitudinal study. Red text indicates temperatures exceeding the daily average IDEQ standard of 19°C. Bold numbers highlight the spinning reserve experiment and forced outage.											
	BR01	**BR02**	**BR09**	**BR10**	**BR11**	**BR12**	**BR17**	**BR20**	**BR22**	**BR23**	**BR24**	**BR25**
20-May	12.8	12.7	11.5	11.8	11.3	11.7	11.5	12.6	12.0	12.0	12.1	
21-May	12.1	12.2	12.0	12.3	11.7	12.1	12.0	12.6	12.2	12.4	12.7	
22-May	12.0	11.8	11.8	12.0	11.8	11.9	11.8	11.9	11.9	12.3	12.4	
23-May	11.9	11.7	10.3	10.4	11.0	10.9	10.4	11.7	10.9	10.7	11.0	
24-May	11.4	11.4	11.1	11.3	10.7	11.3	11.1	11.5	11.1	11.0	10.8	
25-May	11.2	11.5	12.4	12.6	11.5	12.3	12.2	11.7	12.0	12.5	12.6	
26-May	11.4	11.6	13.4	13.5	12.6	13.1	13.2	12.1	12.5	13.2	13.8	
27-May	11.3	11.2	11.9	11.9	12.4	12.1	11.9	11.7	11.5	11.7	12.5	
28-May	11.4	11.6	12.4	12.5	11.8	12.3	12.2	11.7	12.0	12.6	12.7	
29-May	11.7	11.8	13.6	13.7	12.7	13.2	13.4	12.1	12.6	13.3	13.9	
30-May	12.3	12.6	14.2	14.3	13.5	13.8	13.9	12.7	13.1	13.7	14.5	
31-May	13.0	13.0	14.0	14.2	13.9	13.8	13.9	13.3	13.3	13.9	14.9	
1-Jun	13.9	14.1	14.7	14.9	13.9	14.2	14.3	14.1	14.2	14.9	15.2	
2-Jun	14.6	14.7	15.4	15.7	15.1	15.0	15.1	14.8	14.8	15.3	16.1	
3-Jun	15.4	15.7	15.4	15.8	15.1	15.1	15.1	15.5	15.3	15.8	15.9	
4-Jun	15.8	16.1	16.4	16.9	16.1	16.0	16.1	16.3	16.3	17.1	17.3	
5-Jun	16.2	16.5	16.6	17.1	16.4	16.3	16.3	16.7	16.5	17.5	18.1	
6-Jun	16.6	16.7	16.5	16.9	16.8	16.4	16.3	16.9	16.3	17.2	18.2	
7-Jun	17.1	16.8	15.1	15.6	16.0	15.3	15.2	16.8	15.6	16.1	17.1	
8-Jun	17.2	16.8	13.0	13.5	14.2	13.3	13.3	16.3	14.8	15.1	14.6	
9-Jun	16.2	16.4	14.2	15.1	14.5	14.3	14.1	16.7	15.7	16.2	15.9	
10-Jun	15.2	14.9	14.0	14.6	16.0	15.0	14.9	16.3	15.1	15.1	15.9	

APPENDIX B

DAILY AMBIENT AIR TEMPERATURE DATA

Average daily, maximum, and minimum ambient temperature downloaded from Idaho Transportation Department weather station in the Gem Valley.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Jun	**Avg**	52.9	52.7	60.3	64.0	63.3	63.4	64.2	63.9	63.8	49.8	50.5	54.0	62.0	63.6	57.4	57.7	60.3	53.3	53.7	59.3	63.3	62.6	58.2	58.1	62.4	65.4	65.9	67.3	61.0	56.0	
	Max	56.8	71.8	77.7	82.2	79.5	80.4	79.7	80.2	79.9	57.2	66.6	75.9	84.6	76.8	64.9	69.3	72.3	59.0	66.6	74.1	78.3	75.2	71.4	72.1	83.8	82.8	88.9	83.8	68.2	69.1	
	Min	40.5	32.0	38.5	42.6	46.0	41.4	47.1	43.9	43.0	38.3	28.9	31.5	36.5	47.8	49.1	48.9	49.8	46.9	41.2	43.2	43.7	45.1	46.0	41.2	41.2	44.8	42.6	45.9	46.4	37.8	
Jul	**Avg**	61.3	66.3	58.6	59.2	68.1	71.1	71.4	73.5	76.0	72.2	70.6	69.7	70.5	68.7	71.6	68.8	68.3	69.5	71.0	71.1	75.7	69.6	69.2	70.4	72.1	71.6	70.6	70.0	68.7	70.0	70.4
	Max	78.1	81.0	72.7	82.2	86.7	91.6	90.5	93.2	92.7	87.3	87.1	87.4	90.3	88.3	90.5	84.9	87.1	90.1	89.4	91.8	88.3	83.3	87.4	89.6	**90.7**	**89.8**	**89.2**	**90.5**	**87.3**	88.5	91.2
	Min	40.5	46.8	41.9	37.0	45.5	51.1	51.3	52.2	59.5	61.2	55.2	47.5	44.2	47.7	50.5	54.7	49.8	44.8	49.3	48.0	55.9	57.0	49.6	47.1	54.7	50.9	50.0	45.7	45.1	47.5	46.2
Aug	**Avg**	74.9	68.1	70.6	63.5	65.7	63.5	65.0	68.7	69.5	66.3	73.0	69.2	68.3	65.4	68.3	64.5	64.3	63.0	63.9	56.4	60.2	62.1	62.7	60.7	55.6	51.8	58.3	65.2	61.6		
	Max	91.6	86.0	86.4	83.8	80.1	83.3	86.2	90.5	93.0	**95.0**	86.2	87.4	89.2	85.8	88.2	79.7	83.1	78.6	81.1	69.6	78.6	81.1	82.2	75.2	63.1	69.6	78.8	84.4	76.5		
	Min	57.9	53.4	56.5	39.2	50.0	39.0	41.5	43.9	46.9	50.2	63.9	49.1	45.0	43.7	46.9	44.6	43.5	45.0	41.7	46.2	43.5	42.6	43.2	45.0	46.2	34.0	37.8	43.0	42.4		
Sep	**Avg**	58.3	58.0	60.0	60.6	62.9	62.6	65.4	67.9	61.7	62.9	59.8	56.4	57.6	57.5	61.3	59.4	58.3	57.9	55.2	53.8	51.0	58.1	56.2	48.8	44.7	46.5	52.1	59.3	60.6	65.6	
	Max	76.3	79.7	81.0	82.0	83.5	80.8	84.6	82.6	80.1	82.2	80.2	73.8	71.8	76.5	80.8	78.8	79.3	79.7	76.6	65.5	74.3	78.6	69.8	61.3	63.7	67.6	73.8	77.5	79.3	72.7	
	Min	35.8	36.0	34.5	38.3	39.7	40.8	48.0	52.9	40.8	42.6	39.2	34.5	48.9	39.4	36.9	37.6	35.1	36.5	32.9	37.8	27.7	35.6	33.4	34.3	27.7	23.5	30.4	38.1	40.5	50.4	
Oct	**Avg**	51.9	56.9	57.9	50.2	43.1	41.8	42.6	39.2	35.6	38.5	40.2	41.2	38.0	28.1	29.8	40.8	42.4	42.2	43.1	44.6	46.9	49.8	46.3	45.0	45.2	45.8	52.2	49.4	41.7	33.4	31.3
	Max	71.1	75.6	66.6	56.1	51.1	48.6	54.1	53.6	40.3	42.4	48.6	52.3	49.1	37.8	48.2	58.5	61.7	61.3	63.0	66.4	66.7	66.0	50.2	60.3	52.2	59.5	64.2	67.1	49.5	43.3	41.4
	Min	31.8	43.2	51.4	43.7	37.9	36.0	34.2	28.2	27.5	34.2	34.2	26.8	27.3	19.9	16.3	21.4	25.7	24.6	25.5	26.1	26.8	33.8	41.4	31.6	37.2	36.9	41.4	32.5	31.8	23.9	20.8
Nov	**Avg**	40.0	44.9	37.9	35.9	36.5	30.7	25.7	25.0	25.1	31.9	24.6	22.7	23.4	30.3	30.3	33.5	28.7	21.3	22.7	25.1	27.9	33.5	32.6	29.5	20.3	18.1	31.1	31.5	32.1	31.0	
	Max	49.1	52.3	46.4	41.7	41.7	35.4	36.3	35.6	37.0	37.9	33.4	34.5	37.9	46.9	49.1	49.6	36.3	35.1	39.6	43.3	47.3	37.4	34.3	40.1	31.8	31.6	37.2	34.7	36.7	33.4	
	Min	33.6	39.9	28.8	32.9	32.7	23.2	16.9	15.4	12.4	23.5	17.1	10.6	11.7	16.3	16.0	17.1	15.6	8.6	10.6	11.5	12.4	28.0	30.0	20.1	12.0	5.2	20.8	28.4	28.2	26.8	
Dec	**Avg**	24.5	16.3	19.0	4.7	8.3	11.7	9.2	20.1	19.4	20.1	23.8	25.1	10.7	15.0	27.1	23.6	28.7	34.0	33.6	25.8	33.8	21.0	22.9	25.6	14.4	15.0	7.6	13.3	21.2	10.8	
	Max	27.7	25.3	24.1	16.2	16.3	23.0	22.3	28.6	30.0	23.7	28.2	29.8	23.7	26.2	37.0	33.4	36.0	36.9	39.4	36.0	41.5	26.4	29.5	27.0	21.7	18.3	15.6	18.9	27.1	16.2	
	Min	14.2	4.6	8.1	-8.0	-10.8	-0.2	-4.5	15.6	7.0	15.4	20.7	19.2	-2.4	3.2	16.5	11.8	15.1	29.5	22.5	14.5	25.2	10.4	14.5	24.6	4.5	6.3	-4.2	0.5	10.4	0.0	
Jan	**Avg**	0.9	5.6	8.3	9.7	19.3	28.5	25.7	12.9	28.2	26.3	24.0	9.5	4.7	3.4	13.4	28.1	33.9	28.4	27.6	35.2	27.9	16.4	19.8	27.0	21.8	18.8	21.0	14.8	10.2	3.8	13.7
	Max	5.7	14.0	19.0	18.3	34.9	32.0	32.5	26.4	34.7	30.6	30.9	23.2	16.2	14.5	25.2	34.0	36.9	33.4	33.4	38.3	37.0	22.6	23.2	31.6	30.9	27.1	31.6	26.4	22.3	19.0	28.4
	Min	-8.9	-4.7	-3.1	-3.1	6.3	23.5	10.6	1.4	22.3	17.6	8.1	0.7	-5.1	-6.2	-6.2	21.0	31.8	11.3	14.2	30.7	16.0	12.2	12.7	14.4	5.7	5.4	7.0	2.3	0.1	-8.9	4.1
Feb	**Avg**	19.9	32.5	34.1	32.4	24.4	15.1	-1.5	4.6	14.6	23.5	14.5	19.7	29.5	34.4	28.7	23.0	17.8	7.5	11.3	15.7	4.5	0.7	15.9	27.0	33.8	35.8	35.5	32.8			
	Max	33.8	38.7	39.0	36.3	32.9	20.8	11.1	19.4	20.3	30.9	19.9	27.5	32.4	38.5	35.1	26.4	25.2	15.8	17.8	19.9	13.3	15.6	22.8	32.2	37.9	39.2	41.0	37.0			
	Min	5.2	19.9	30.6	30.4	11.7	7.9	-10.7	-8.3	3.6	16.2	1.4	7.5	24.8	32.0	22.5	18.1	5.9	-2.2	5.2	8.2	-6.3	-12.1	4.3	22.5	29.3	33.3	31.5	30.2			
Mar	**Avg**	23.9	17.5	11.1	8.5	20.2	33.9	32.8	27.7	23.0	18.1	19.3	19.8	26.5	21.9	16.1	18.6	20.8	24.1	24.7	30.6	32.5	33.8	34.1	31.9	33.2	34.2	37.4	36.2	32.3	30.7	29.7
	Max	31.3	24.6	24.4	23.2	30.2	37.2	37.4	31.6	36.1	27.7	31.6	33.3	29.5	29.8	27.1	29.8	31.3	35.4	33.6	38.8	39.4	35.4	37.8	36.1	40.8	42.8	51.1	42.4	37.2	41.0	43.0
	Min	11.3	5.0	-0.4	-2.0	1.9	28.8	28.9	21.0	15.4	8.1	8.1	3.0	21.2	12.6	4.8	9.0	9.7	13.5	12.7	18.0	24.1	32.5	28.6	26.6	22.6	25.2	26.1	31.8	23.5	23.2	17.2
Apr	**Avg**	34.1	36.7	38.6	40.9	40.0	39.7	40.6	45.9	41.3	35.6	35.3	34.6	37.4	39.9	42.0	40.8	40.2	47.3	52.1	51.4	45.3	47.5	49.1	53.6	51.0	53.5	48.4	40.3	36.8	34.3	
	Max	45.5	41.2	45.5	50.0	49.5	46.0	46.2	57.4	51.8	42.4	43.5	42.6	45.5	44.6	49.3	46.2	51.8	61.3	66.2	65.3	47.3	55.9	63.5	63.7	64.8	64.8	61.2	52.2	50.7	43.0	
	Min	21.7	34.0	33.4	35.2	34.7	34.5	34.9	35.8	35.4	30.7	28.9	25.7	31.1	36.7	36.1	36.7	30.6	30.6	34.0	37.4	43.2	40.3	31.6	42.6	33.3	44.1	30.0	27.3	22.5	24.6	
May	**Avg**	34.5	43.1	45.3	51.6	53.8	53.1	46.8	47.9	40.2	41.4	52.1	56.1	57.8	57.5	59.7	57.9	42.1	43.6	43.1	42.4	43.0	37.7	41.4	43.2	48.0	52.3	45.4	50.9	53.0	56.1	56.1
	Max	45.3	55.6	60.8	66.7	66.9	66.9	57.4	58.6	49.1	60.6	67.6	73.9	74.3	74.3	71.8	69.3	45.7	50.7	55.2	47.8	50.9	48.0	45.0	50.2	61.2	65.1	49.3	60.4	64.0	68.2	65.1
	Min	23.2	29.1	24.6	31.1	34.5	37.6	38.1	34.7	35.4	25.3	32.9	36.7	39.0	40.8	43.9	45.0	38.1	37.4	34.3	37.8	36.5	36.3	38.8	38.1	34.5	38.1	42.1	43.7	37.6	37.4	43.0

Bold temperatures in July are spinning reserve, and force outage ambient temperature days. Red maximum temperature denotes peak temperature recorded during the study.