Placer County Water Agency
Middle Fork American River Project
(FERC Project No. 2079)

2006 RALSTON AFTERBAY WATER TEMPERATURE INVESTIGATION STUDY REPORT

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1.0 INTRODUCTION

During the Placer County Water Agency's (PCWA's) Middle Fork American River Project (MFP or Project) flow-temperature subcommittee meeting held on May 6, 2005, the United States Department of Agriculture – Forest Service (USDA-FS) requested that PCWA conduct a reconnaissance-level investigation to characterize the water temperature regime in Ralston Afterbay, particularly along the reservoir margins and sediment bars. Ultimately, water temperature information collected could be used, in part, to evaluate the potential suitability of the water temperature regime in Ralston Afterbay for hardhead (*Mylopharodon conocephalus*), an USDA-FS Sensitive Species.

1.1 STUDY GOALS / OBJECTIVES

The goal of this study, along with the on-going reservoir water temperature profiling, is to characterize the water temperature regime in Ralston Afterbay under typical operations. The locations that were selected for water temperature monitoring: (1) were representative of the available habitat in Ralston Afterbay; (2) contained habitat characteristics that resemble those habitat conditions reported to be within the range of reported suitability for the various life stages of hardhead; and (3) allowed for the sufficient longitudinal coverage of the reservoir. A detailed study plan was developed in collaboration with and was approved by the flow-temperature subcommittee (PCWA 2006).

1.2 STUDY SETTING

1.2.1 Ralston Afterbay

Ralston Afterbay (2,782 acre-feet gross storage) is located approximately 50 miles northeast of Sacramento, California, and about 32 miles upstream from Folsom Dam. Ralston Afterbay Dam is an 89 foot-high, 560 foot-long concrete gravity structure with a crest elevation of 1,189 feet above mean sea level (msl) and impounds the Middle Fork American and the Rubicon rivers. Water also is discharged into the Ralston Afterbay on the Rubicon River through the Ralston Powerhouse (79 MW, approximately 900 cfs). Up to approximately 1,000 cfs can be routed from Ralston Afterbay through the Oxbow Powerhouse (6.1 MW) into the Middle Fork American River. When Ralston and Oxbow powerhouses are running full load, the residence time of water in Ralston Afterbay is approximately 18 hours assuming there is approximately 1,400 AF of active storage (gross storage minus dead pool volume and accumulated sediment volume).

1.2.2 2006 Hydrology and Project Operations

Based on the Sacramento Valley Water Year Hydrological Index, 2006 was a "wet (W)" water-year type that was characterized by a very wet March (15.67 inches) (the 5th wettest on record[1]) and April (14.90 inches) (the wettest on record). French Meadows

[1] Based on precipitation data compiled at the Foresthill Ranger Station, the nearest complete and summarized data to the MFP, between 1945 and 2006.

Reservoir spilled a total of approximately 25,600 acre-feet of water during May (29 days, approximately 20,800 acre-feet) and June (7 days, 4,800 acre-feet). Hell Hole Reservoir spilled a total of approximately 81,200 acre-feet of water in January (6 days, approximately 3,400 acre-feet) and late April through mid-June (46 days, approximately 77,800 acre-feet).

The provisional streamflow data from the Middle Fork American River downstream of Oxbow Powerhouse from July 1 through September 30 (the approximate duration of the study) is displayed in Figure 1. The daily elevations at Ralston Afterbay during the investigation are presented in Figure 2. It is important to note that the elevation at Ralston Afterbay is manually recorded once per day and may not be recorded at the same time each day.

All four project powerhouses were out-of-service January 1 and 2 due to high streamflows and Oxbow Powerhouse remained out-of-service through January 3. Oxbow Powerhouse was periodically out-of-service during a heat wave from July 22 through July 26 due to voltage problems. All Project powerhouses were out-of-service from September 6 through September 20 due to the Ralston Ridge Fire and resulting damage to Project transmission lines.

Maintenance outages occurred at Ralston and Oxbow powerhouses during 2006. Ralston and Oxbow powerhouses were out-of-service from October 3 through November 2, and Oxbow Powerhouse remained out-of-service through November 8. The 2006 maintenance outage was longer than typical because some additional work that is periodically required to be conducted was performed.

Other than described above, Project water delivery, generation, and maintenance operations were typical for a wet water year type, with reservoir levels, water releases, and generation output within normal ranges. Project powerhouses were operated full-load almost continuously during June, and between 14-16 hours per day during July and August. Typically, the powerhouses would be offline from approximately midnight to 8 – 10 am during July and August.

When the powerhouses are operating during the summer, the bulk of the water in Ralston Afterbay is supplied by Ralston Powerhouse, which is located near the upper end of Ralston Afterbay on the Rubicon River. During the summer of 2006, Ralston Powerhouse discharged as much as approximately 850 cfs into Ralston Afterbay. In contrast, during July and August 2006, the combined inflow to Ralston Afterbay from the Middle Fork American River and the Rubicon River was approximately 50 cfs plus an unknown (but likely small) amount of accretion. The water that is supplied to Ralston Afterbay through the Ralston Powerhouse originates from the bottom of Hell Hole Reservoir and is routed through the Middle Fork Powerhouse and a series of tunnels and, thus, is generally much cooler than the water that enters Ralston Afterbay from the Middle Fork American and Rubicon rivers. Please see PCWA 2007 for a summary of the results of the 2006 stream water temperature study. Stream water temperatures

observed in the vicinity of Ralston Afterbay during the summer of 2006 are discussed below.

1.2.3 2006 Meteorological and Stream Water Temperature Observations

Available meteorological data collected during July through September at Ralston Afterbay Dam and stream water temperature data collected in the Rubicon River upstream, and the Middle Fork American River upstream and downstream of Ralston Afterbay are presented (Figures 3 through 6) and briefly discussed below.

The July 10 through September 30 study period encompassed the hottest part of the summer (Figure 3). Daily maximum air temperature exceeded 90°F for much of July through September, and exceeded 100°F for approximately two weeks in late July (Figure 3). Water temperature in the Rubicon (Figure 4) and Middle Fork American (Figure 5) rivers upstream of Ralston Afterbay was the warmest during mid and late July and slowly decreased through early September. The peak daily maximum water temperatures in the Rubicon and the Middle Fork American rivers were approximately 81°F and 74°F, respectively, during July. A cold front during mid-September caused a substantial decrease in stream water temperature in the Rubicon and Middle Fork American rivers upstream of Ralston Afterbay. By the end of September, daily maximum water temperature in the Rubicon River and the Middle Fork American River was less than 65°F and 60°F, respectively.

Stream water temperature in the Middle Fork American River downstream of Oxbow Powerhouse was cool and relatively stable until the Ralston Ridge Fire (Figure 6). Water temperature from the Middle Fork American River downstream of Oxbow Powerhouse can be used as a surrogate for Ralston Powerhouse discharge water temperature because of: (1) the relatively short residence time of water in Ralston Afterbay; (2) the magnitude of the difference in volume of water that is discharged through Ralston Powerhouse compared to the Middle Fork American and Rubicon rivers; and (3) thermal heating in Ralston Afterbay is limited to the surface of water (discussed in Section 2.2).

Prior to the Ralston Ridge Fire when the MFP was forced to stop operations due to restricted access and damage to facilities, the daily average water temperature in the Middle Fork American River downstream of Oxbow Powerhouse did not exceed 53°F (Figure 6). The Ralston Ridge Fire forced the shut down of the MFP, including Ralston and Oxbow powerhouses. Without the inflow of cold water from the Ralston Powerhouse into Ralston Afterbay, water temperatures in the Middle Fork American River downstream increased by approximately 10°F, from a daily average of approximately 53°F to about 63°F at the warmest. When the Project resumed operations following the Ralston Ridge Fire, stream water temperatures in the Middle Fork American River downstream of Ralston Afterbay decreased to levels that were similar to pre-fire conditions (Figure 6).

2.0 METHODS AND RESULTS

2.1 SITE ASSESSMENT, SELECTION, INSTALLATION, AND MAINTENANCE

On July 10, 2006, ten candidate monitoring locations in Ralston Afterbay were assessed and six water temperature monitoring sites were established. Figure 7 shows the ten candidate sites, the six final monitoring sites, and the reservoir profile site that was established during 2005. Table 1 presents key characteristics from the ten sites assessed (including the six sites selected). The site assessment suggested that Ralston Afterbay, in terms of its habitat (substrate, large woody debris, water velocity, and shading, etc.), was relatively homogenous and gradually transitioned from a more riverine environment near the upper end of the afterbay and the Rubicon River and Ralston Powerhouse, to a more reservoir environment near the dam. The six sites were selected because they represented: (1) the range of depths observed; (2) both the riverine- and reservoir-like portions; (3) both upstream and downstream of the Middle Fork American River confluence; and (4) both river-left and river-right.

At the six monitoring sites, water temperature loggers were installed on July 10, 2006. Onset TidbiT™ water temperature loggers were suspended one meter below a standard fluorescent orange fishing marker buoy. The marker buoy was labeled to indicate that it was for water quality monitoring and was anchored with approximately eight ounces of lead. The water temperature loggers were set to record at 15-minute intervals. Each buoy-logger-weight set up was given approximately one to two feet of slack to allow for increases in reservoir elevation. At each of the six sites, the water temperature profile was measured during installation.

The monitoring sites were visited on August 9 to inspect each installation, download the water temperature data, and collect water temperature profiles. A second visit that was planned for September 7 was canceled due to of the Ralston Ridge Fire. The sites were visited on October 1, prior to the planned MFP maintenance outage, to download the water temperature data, collect water temperature profiles, and retrieve the monitoring equipment. Approximate water surface elevations during the three Ralston Afterbay visits are described below:

Date	Estimated Storage (AF)	Estimated Elevation (ft above mean sea level)
July 10	2,455	1175.0
August 9	2,526	1175.9
October 1	2,543	1176.1

Figure 8 shows the six sites selected for continuous water temperature monitoring in Ralston Afterbay relative to the most recent (2002) characterization of the locations and relative sizes of sediment bars. As presented in Figure 8, both main channel and sediment bar sites were selected for monitoring. A water temperature logger was installed at the upstream end of the reservoir (R2) to characterize inflow water temperature and to evaluate the longitudinal warming of water in the afterbay.

2.2 WATER TEMPERATURE PROFILES

Water temperature profiles were collected at the six continuous monitoring sites and the existing reservoir profile site (Figure 7) on July 10, August 9, and October 1. The profiles could not be collected in September due to the Ralston Ridge Fire. Figures 9, 10, and 11 show the water temperature profiles at each site on July 10, August 9, and October 1, respectively.

On July 10, the thermal profiles indicated that water temperature generally warmed in a downstream direction and cooled from the surface to the bottom (Figure 9). When comparing water temperatures at the surface, site R2 (the upstream-most site) was approximately 47°F, while site R10 (the downstream-most) was approximately 56°F. The thermal profile collected at the standard profile site illustrates the change in water temperature from the surface to the bottom of the reservoir (Figure 8). At this site, the water temperature at the surface was approximately 56°F and decreased to approximately 49°F at 10 feet and was approximately 48°F at the bottom (approximately 45 feet).

The thermal profiles collected on August 9 (Figure 10) were very similar in shape and water temperature to those collected on July 10. The largest difference was observed at sites R6 and R7 where at the surface R6 was approximately 3°F cooler and R7 was approximately 2°F warmer on August 9 than on July 10. Surface water temperature increased in a downstream direction from about 47°F at R2 to about 57°F at R10.

The October 1 thermal profiles indicated that surface water temperatures were warmer at the upper end of the reservoir and cooler at the lower end of the reservoir (Figure 11) than during August. There was an approximately 4°F difference in surface water temperature between R2 and R7, the largest difference observed during the October sample. Also, at the deeper monitoring locations (R6, R9, existing profile), water temperatures from the surface to the bottom were more similar in October than in July or August. The largest difference observed in water temperature on October 1 was less than 4°F from the surface to the bottom.

2.3 CONTINUOUS WATER TEMPERATURE MONITORING

Following installation of the continuous water temperature loggers on July 10, the water temperature loggers were downloaded on August 9 and downloaded and uninstalled on October 1, 2006. Inspection of the sites on August 9 revealed that the R4 buoy/logger had been damaged and had sunk, and the R6 buoy/logger had been displaced downstream to near the existing profile site and was approximately 10 feet below the surface. When the data was retrieved and the sites uninstalled on October 1, the R6 buoy and water temperature logger could not be located. The water temperature logger again could not be located during a second visit to the reservoir when it was drawn down for the maintenance outage.

Following download, the data was inspected for anomalous points. Data was removed from the R6 dataset from July 10 through August 9 because the water temperature

logger had sunk. This data was removed because the R6 site profiles indicated that there was a difference in water temperature between the 1-m monitoring depth and the bottom where the logger was lying. The R10 data was removed from July 14 through July 25 because the logger clearly was periodically dewatered during that period. It is not known how the logger was dewatered, but observed daily maximum water temperatures during that period were greater than 80°F. The datasets for the remaining four sites did not appear to have any anomalies.

After the data was QA/QC'd the daily average, maximum, and minimum water temperatures were calculated and plotted for each site. The daily average flow at the real-time gage located downstream of Ralston Afterbay Dam and Oxbow Powerhouse (CDEC Gage "OXB" and USGS Gage 11433300) also was plotted with water temperature. Ralston and Oxbow powerhouses typically are operated in unison or near unison and, for the purposes of this report, the flow at OXB is used as a surrogate for flow into Ralston Afterbay from Ralston Powerhouse because the data from Ralston Powerhouse were not available during this study.

Daily average, maximum, and minimum water temperatures at R2, R4, R7, R9, and R10 are shown in Figures 12, 13, 14, 15, and 16, respectively. Data from R6 is not presented because as mentioned previously, the water temperature logger was displaced during July and could not be located at the end of the investigation.

From July through early September, prior to the onset of the Ralston Ridge Fire and the suspension of the MFP operations, daily average water temperatures did not exceed 55°F at R2 and R4 and occasionally exceeded 55°F at R7 (6 days), R9 (2 days), and R10 (12 days) but did not exceed 57°F.

Prior to the Ralston Ridge Fire, daily maximum water temperatures observed reached 65°F at R2, 62°F at R4, 61°F at R7, 59°F at R9, and 60°F at R10, but were often below 55°F. The higher observed daily maximum water temperatures often appear to coincide with periods with relatively low daily average flow at the OXB gage. The magnitude of the daily average flow is dependent upon the number of hours the powerhouses are peaking and a relatively low daily average flow results when the powerhouses are offline for a longer period each day.

Site R2 was unique because it was located in the upper, more riverine-like section of Ralston Afterbay. R2 was more subject to reservoir fluctuations than the other sites because of its proximity to Ralston Powerhouse (the source of the majority of the water in the reservoir) and its location in the narrower, river-like portion of the reservoir. Figure 17 shows the 15-minute water temperature data at R2 from August 25 through August 31 and the corresponding flow at the real-time station located downstream of Oxbow Powerhouse (CDEC Gage "OXB"), when the Project was peaking the powerhouses. As illustrated in Figure 17, the warmest water temperatures during August 25 through August 31 occurred when the powerhouses were offline, represented by the lowest gaged flow at OXB. During this period, the powerhouses typically were offline from after midnight to about 8 or 9 am.

Daily minimum water temperatures prior to the Ralston Ridge Fire were always below 55°F at all sites and were often below 50°F at R2, R4, and R7 (Figures 12 through 16).

During the Ralston Ridge Fire, approximately September 6 through September 20, daily average, maximum, and minimum water temperatures at all sites exceeded 65°F reaching a maximum water temperature of approximately 71-72°F at R2, R4, and R7 (Figures 12 through 14). Relatively little difference was observed between the daily minimum and maximum water temperatures during the fire, especially at the downstream-most sites (R7, R9, and R10). Flows downstream of Ralston Afterbay were less than 200 cfs during the fire. Following the Ralston Fire, the Project returned to normal operations and water temperatures at the monitoring sites decreased to about pre-fire conditions (Figures 12 through 16).

3.0 NEXT STEPS

Although the data collected during 2006 well represents the water temperature conditions in Ralston Afterbay during July through September 2006, PCWA proposes to implement this study again in 2007 for two primary reasons. First, the Ralston Ridge Fire clearly affected water temperatures in Ralston Afterbay because it resulted in an unusual shut down of the MFP. Second, 2006 was a wet year and Project operations were typical of a wet year. An additional year of study potentially would provide water temperature information for different hydrologic and climatologic conditions. For 2007, PCWA proposes to again monitor water temperature at 1 meter in depth at the same six sites. Utilizing the same six sites will allow for a direct comparison between 2006 and 2007 water temperatures. Thermal profiles will continue to be collected at each monitoring site and the standard profile site during 2007. It is anticipated that the sites will be installed in early June, or as soon as flow conditions in Ralston Afterbay permit, and will run until the Project is shut down for maintenance, typically in early October. A summary report and tabular data files will be prepared and distributed in early 2008.

4.0 REFERENCES

Placer County Water Agency (PCWA). 2006. Ralston Afterbay Reservoir Reconnaissance-Level Hardhead Water Temperature Suitability Investigation Study Plan. July 11, 2006.

PCWA. 2007. Draft – 2005 Water Temperature Summary Report. April 2007.

TABLES

Table 1. Some key characteristics of the 10 sites assessed in Ralston Afterbay for selecting the six monitoring sites. Dissolved oxygen and water temperature were measured at a depth of 1 meter. Water velocity is the approximate average of the water column.

Site	Depth (ft)	1-m DO (mg/L)	1-m Water Temp(°F)	Water Velocity (fps)	Approximate Substrate Composition (%)				
					Silt/Sand	Gravel	Cobble	Boulder	Bedrock
R1	7.5	11.1	48	1.46	25	50	0	25	0
R2*	8.5	10.9	47	1.52	0	0	50	50	0
R3	13	11.1	48	0.40	0	0	25	25	50
R4*	11	10.9	48	0.20	75	0	25	0	0
R5	18	9.7	49	0	75	0	25	0	0
R6*	12	10.6	49	0	80	0	20	0	0
R7*	9	10.6	51	0	100	0	0	0	0
R8	22	10.5	51	0	95	5	0	0	0
R9*	7	10.2	51	0	100	0	0	0	0
R10*	23	10.4	52	0	100	0	0	0	0
*Site selected for water temperature monitoring									

FIGURES

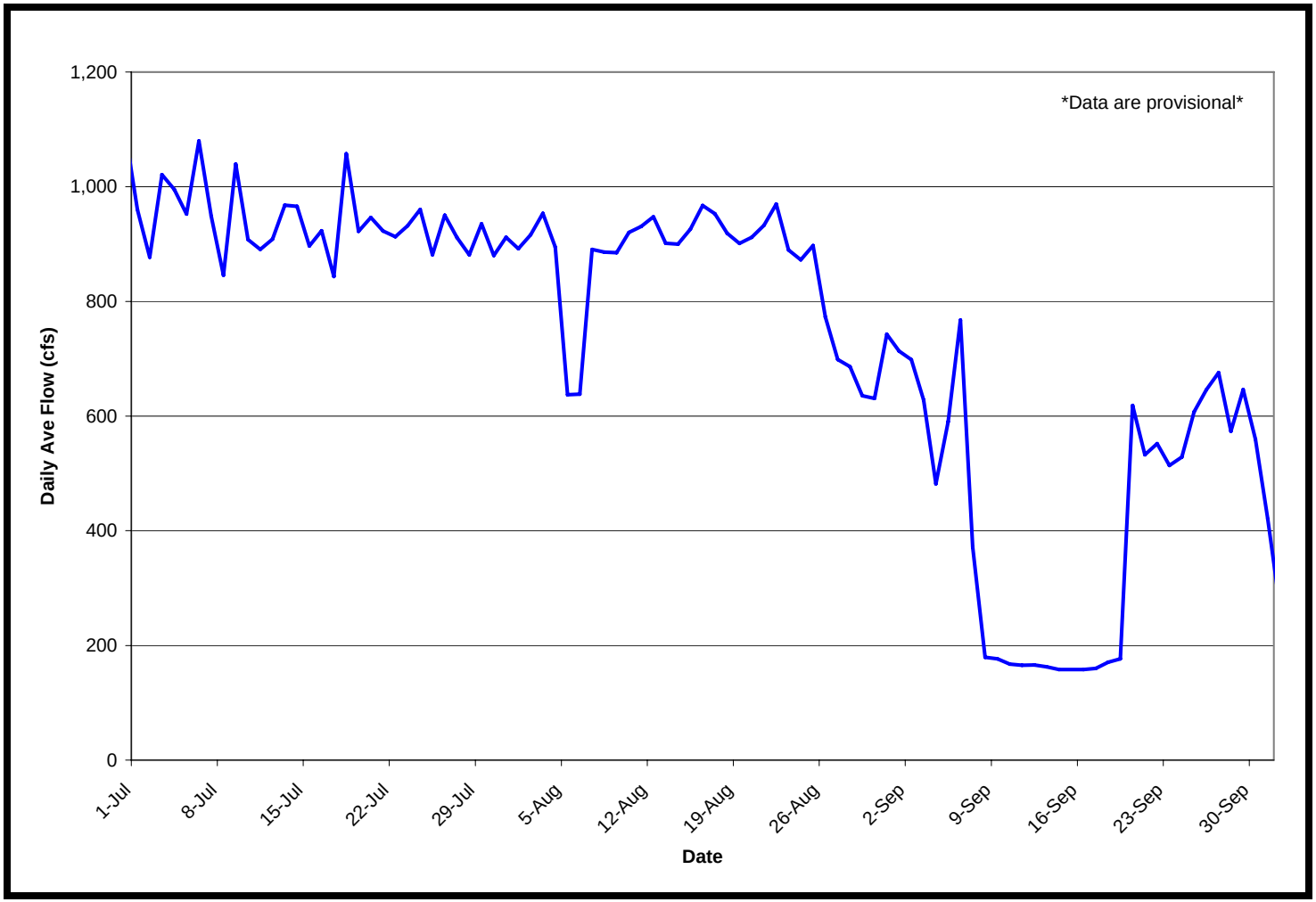

Figure 1. The daily average flow during July 1, 2006 through September 30, 2006 in the Middle Fork American River downstream of Ralston Afterbay and Oxbow Powerhouse as measured at USGS Gage "Middle Fork American River near Foresthill" (# 11433300).

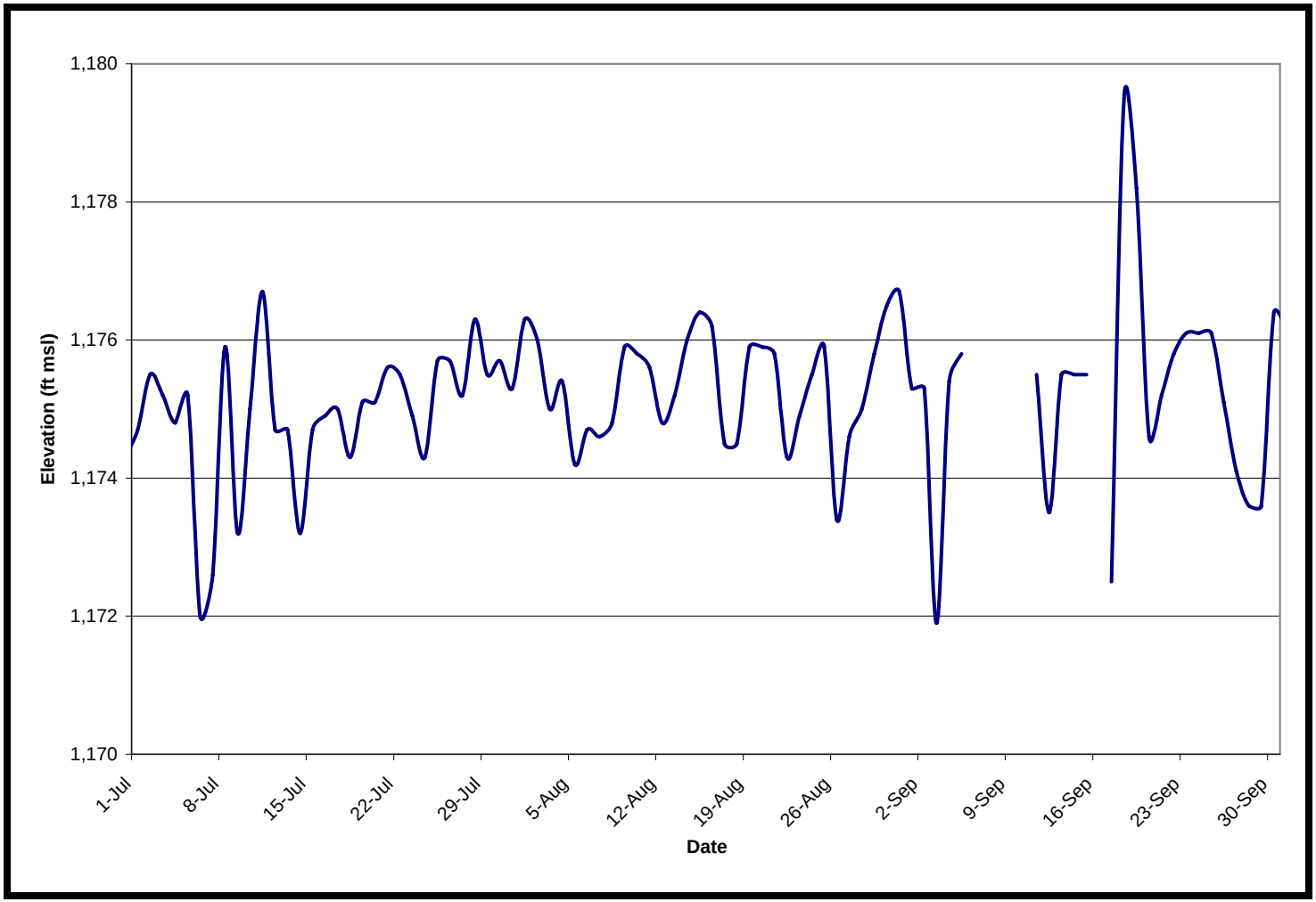

Figure 2. The daily reservoir elevation recorded at Ralston Afterbay during July 1, 2006 through September 30, 2006. The Ralston Ridge Fire affected Middle Fork Project operations from September 6 through about September 20, 2006; the data gaps during that period were the result of the fire.

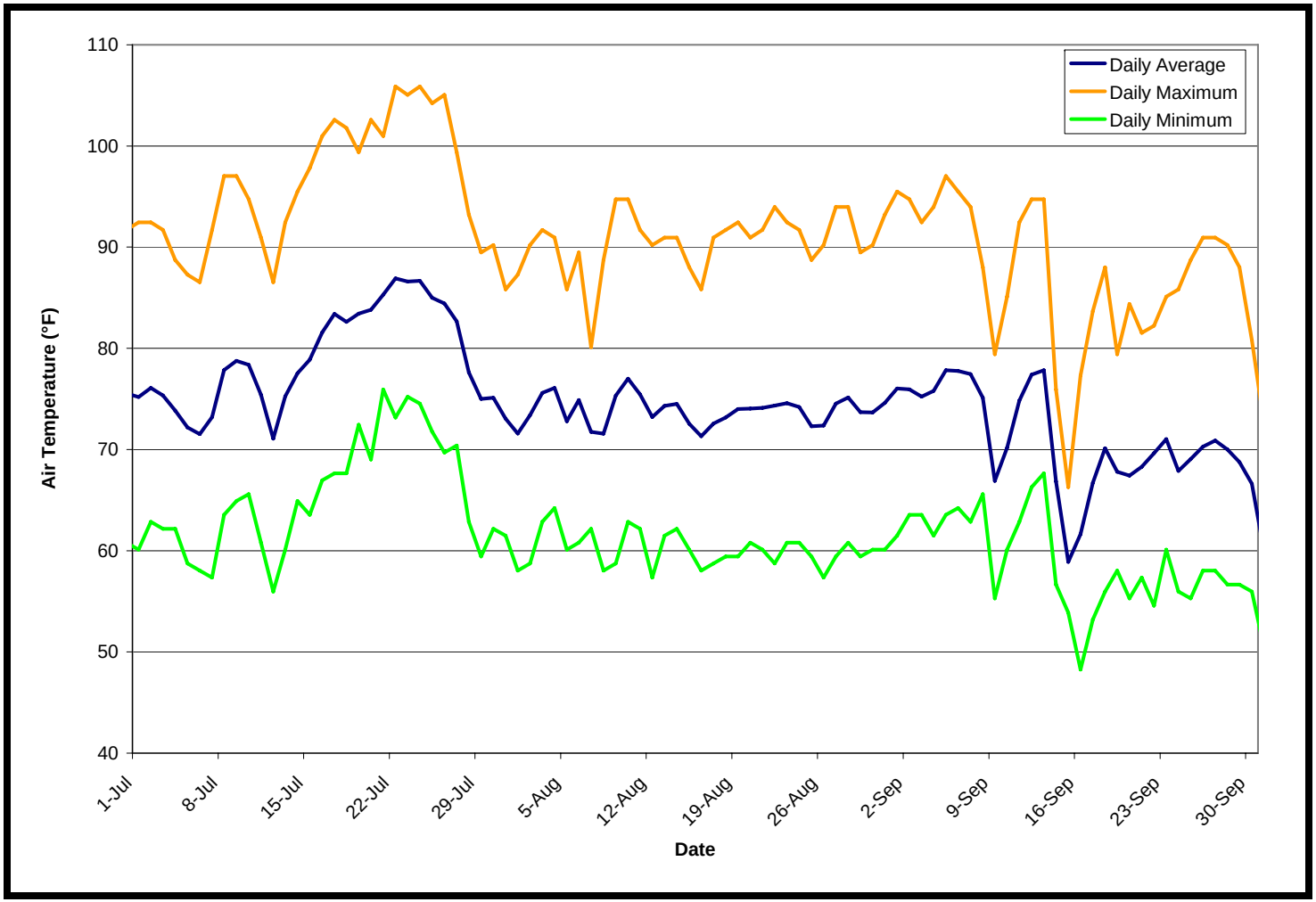

Figure 3. The daily average, maximum, and minimum air temperature recorded at Ralston Afterbay Dam during July 1, 2006 through September 30, 2006.

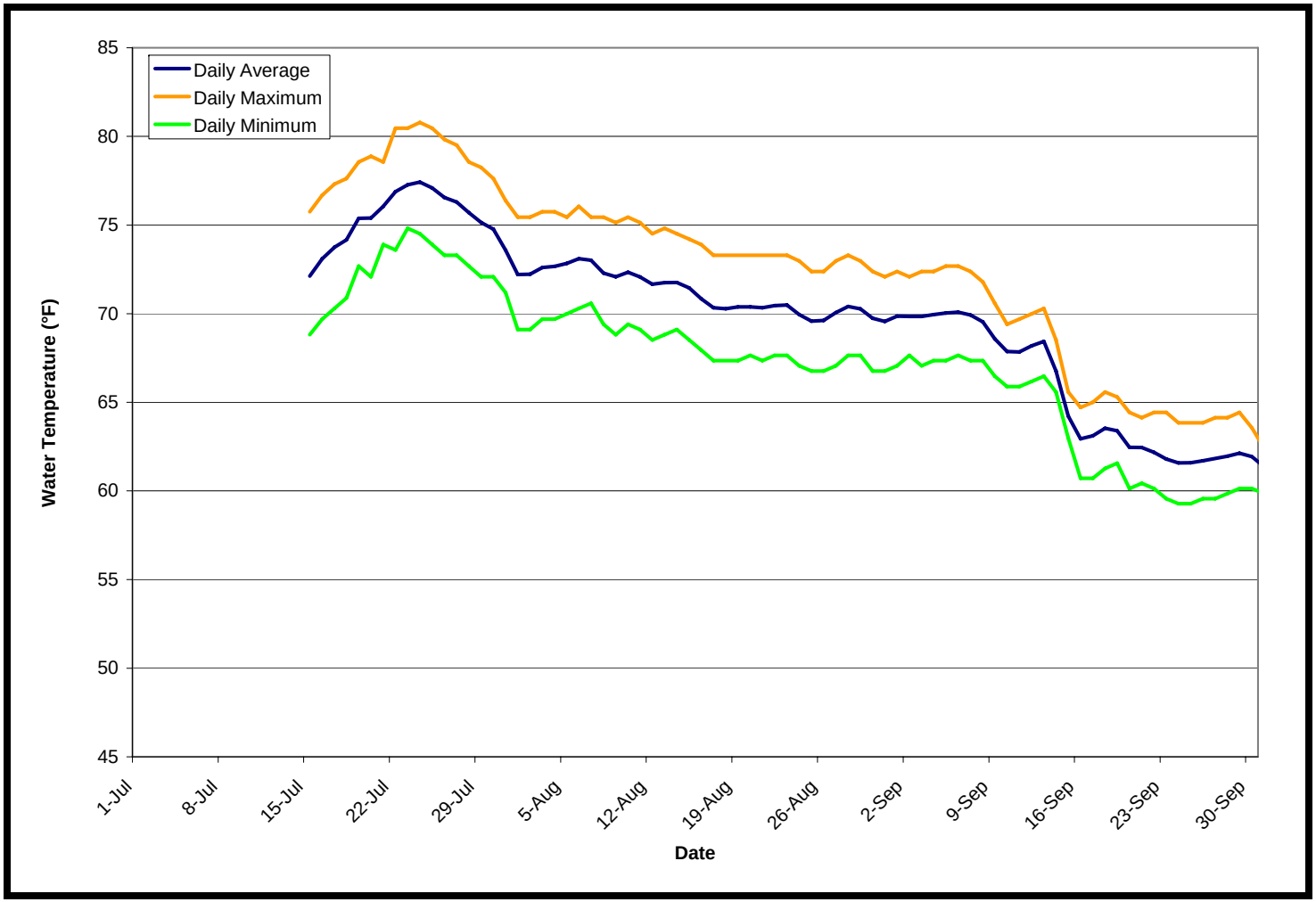

Figure 4. The daily average, maximum, and minimum water temperature recorded in the Rubicon River upstream of Ralston Afterbay (RR0.7) during July 1, 2006 through September 30, 2006.

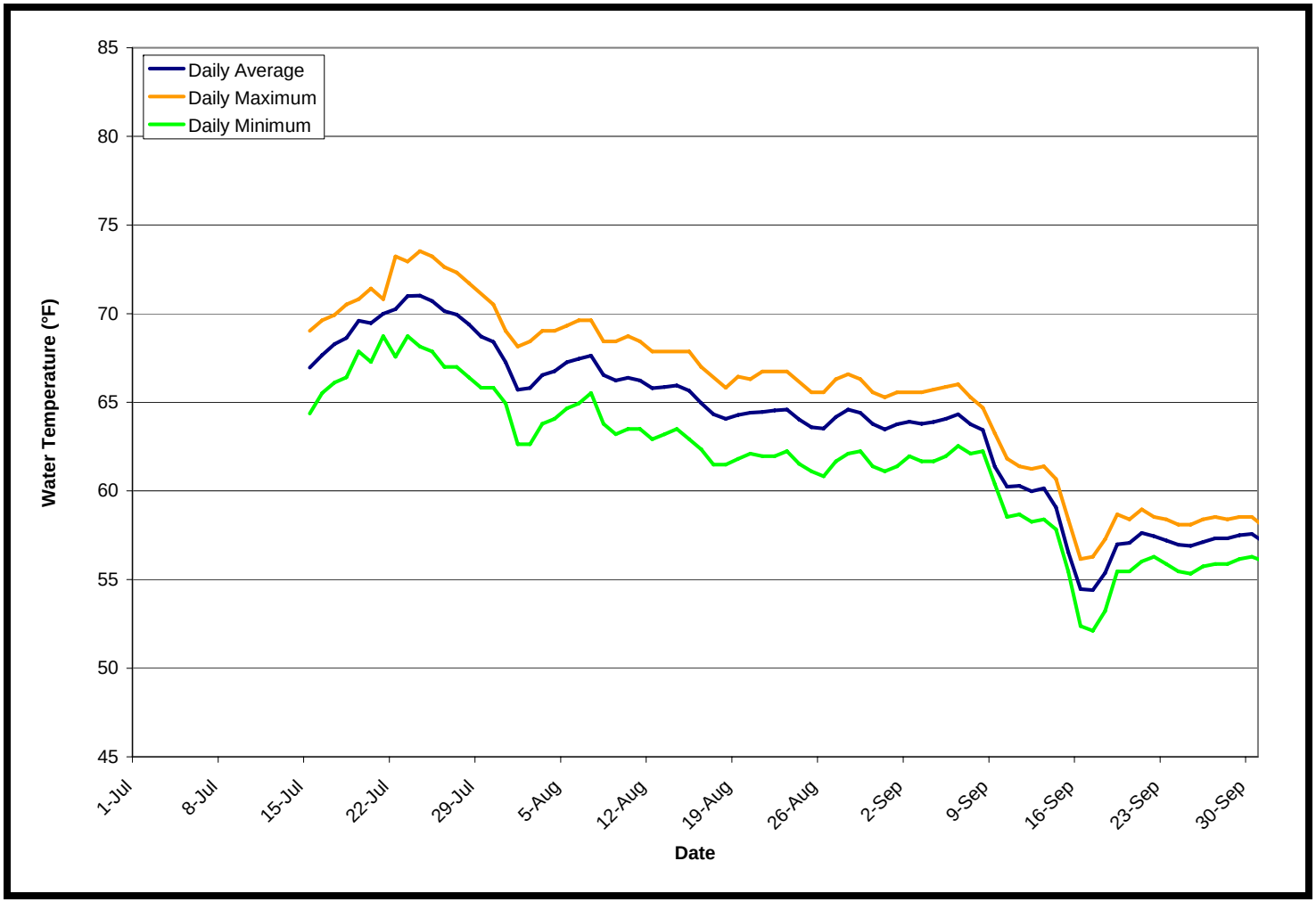

Figure 5. The daily average, maximum, and minimum water temperature recorded in the Middle Fork American River upstream of Ralston Afterbay (MF26.0) during July 1, 2006 through September 30, 2006.

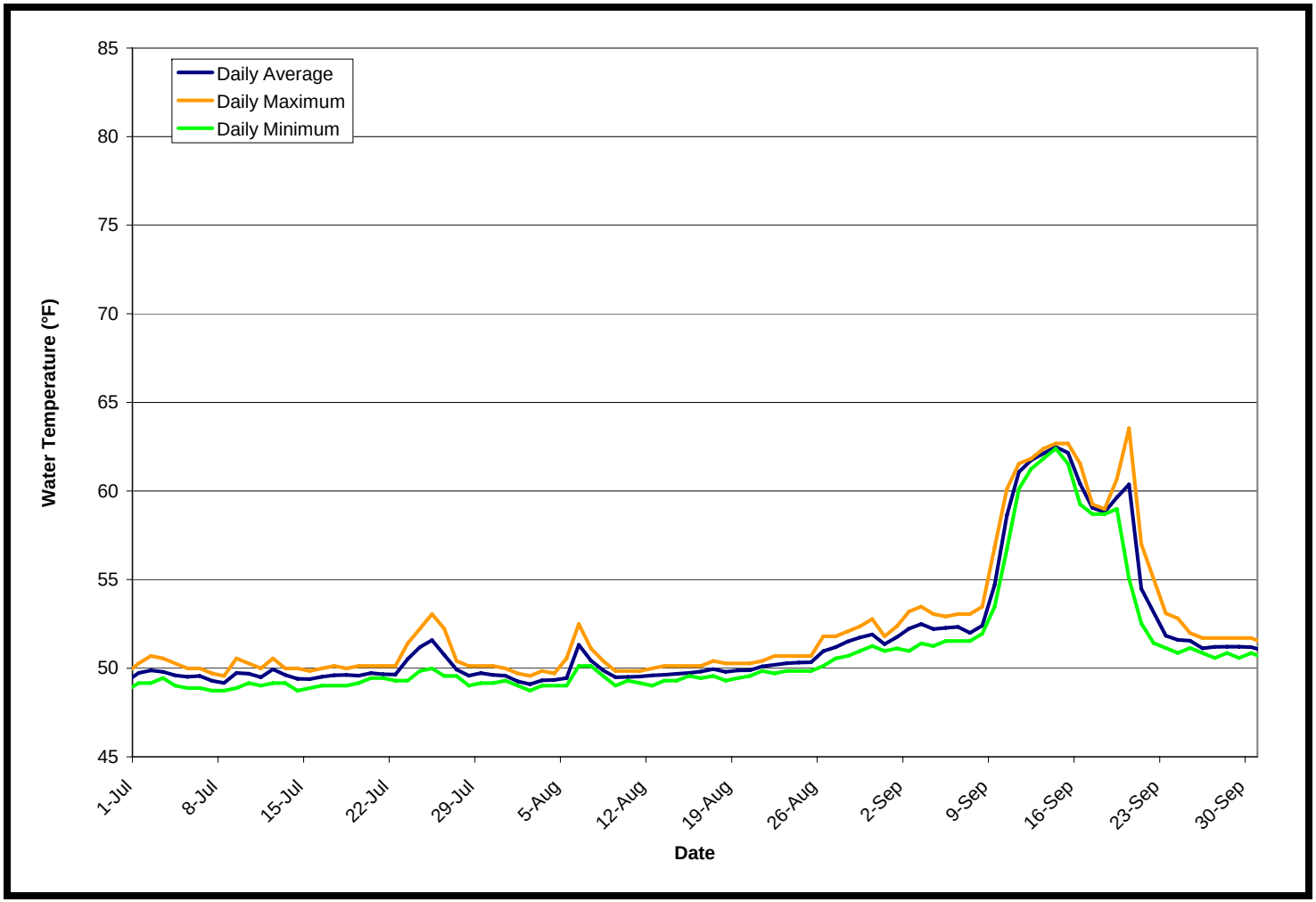

Figure 6. The daily average, maximum, and minimum water temperature recorded in the Middle Fork American River downstream of Oxbow Powerhouse (MF24.3) during July 1, 2006 through September 30, 2006.

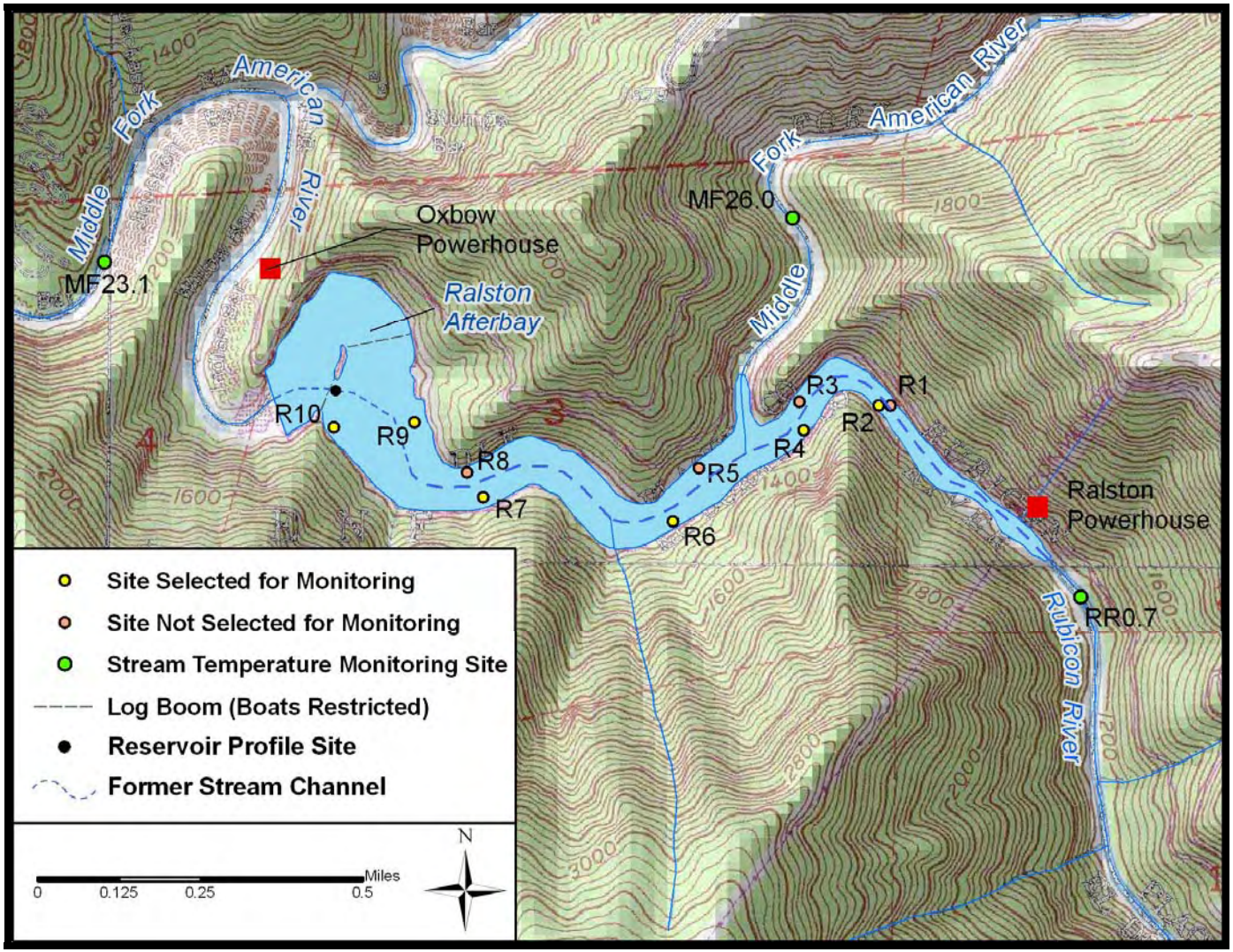

Figure 7. The locations in Ralston Afterbay of the 10 sites assessed and the 6 sites selected for continuous water temperature monitoring and the standard reservoir profile site that was established in 2005.

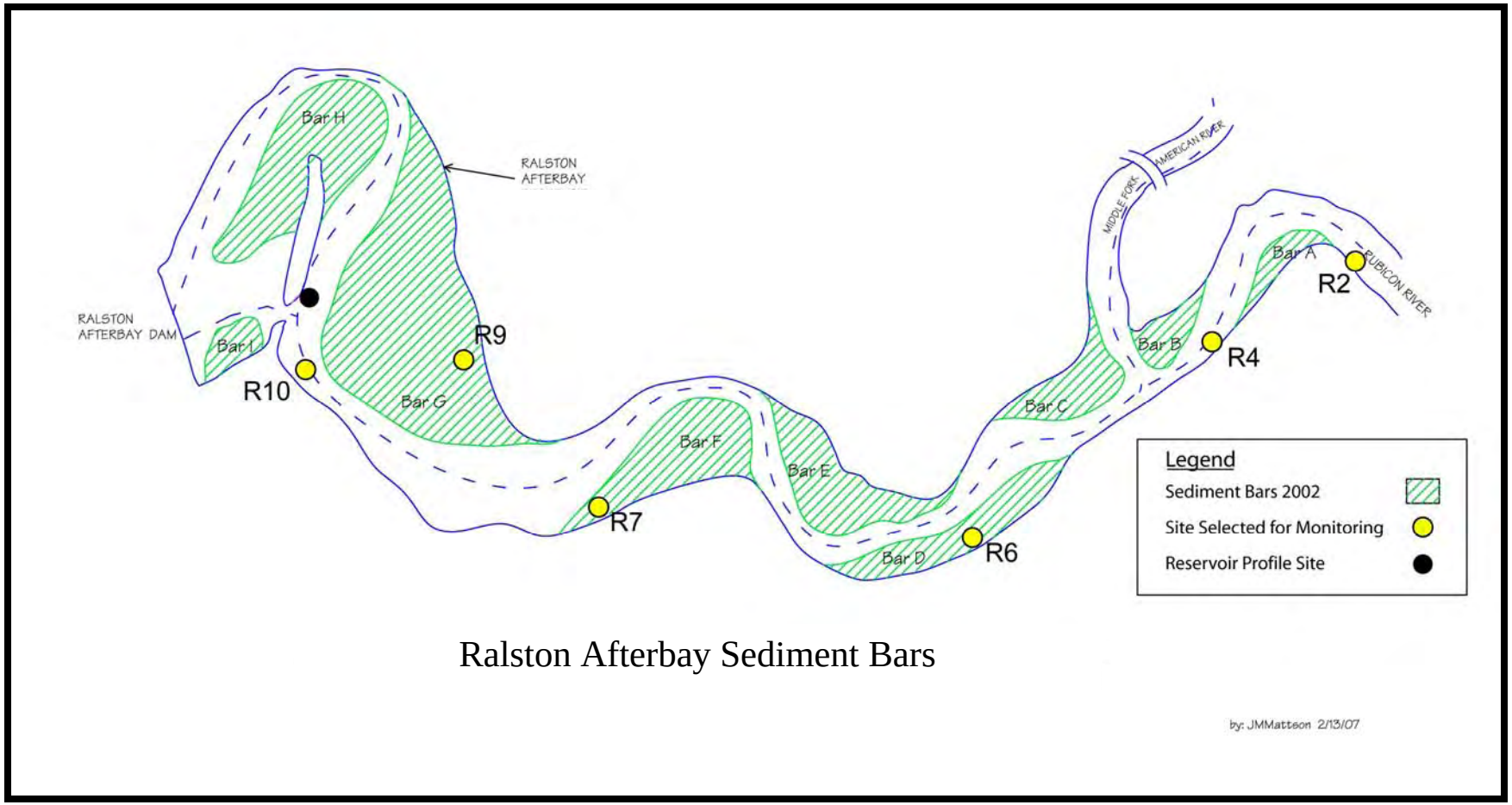

Figure 8. The locations of the 6 continuous water temperature monitoring sites overlaid on the most recent (2002) map of sediment bars in Ralston Afterbay.

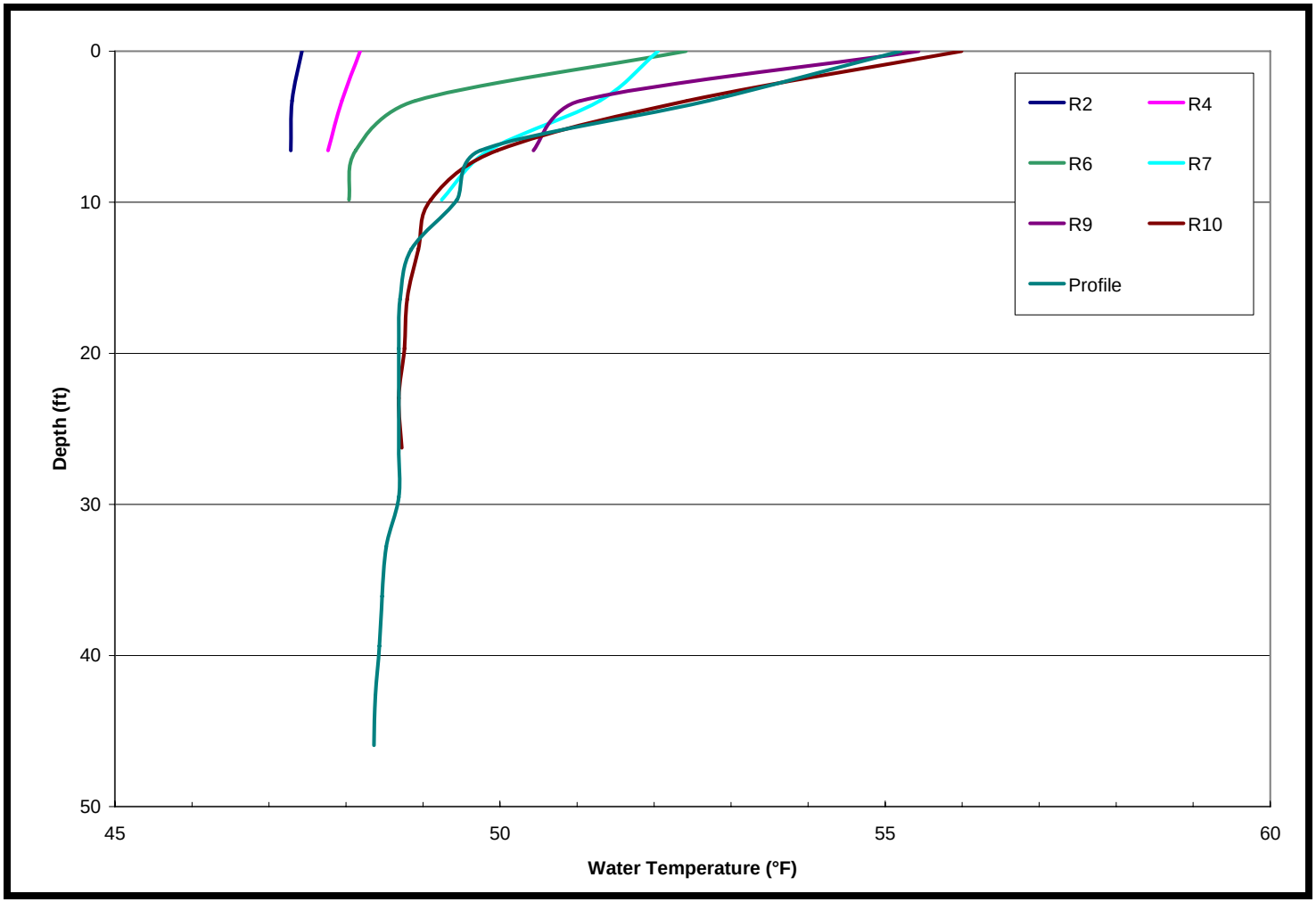

Figure 9. The water temperature profiles from the six monitoring locations and the reservoir profile location in Ralston Afterbay on July 10, 2006.

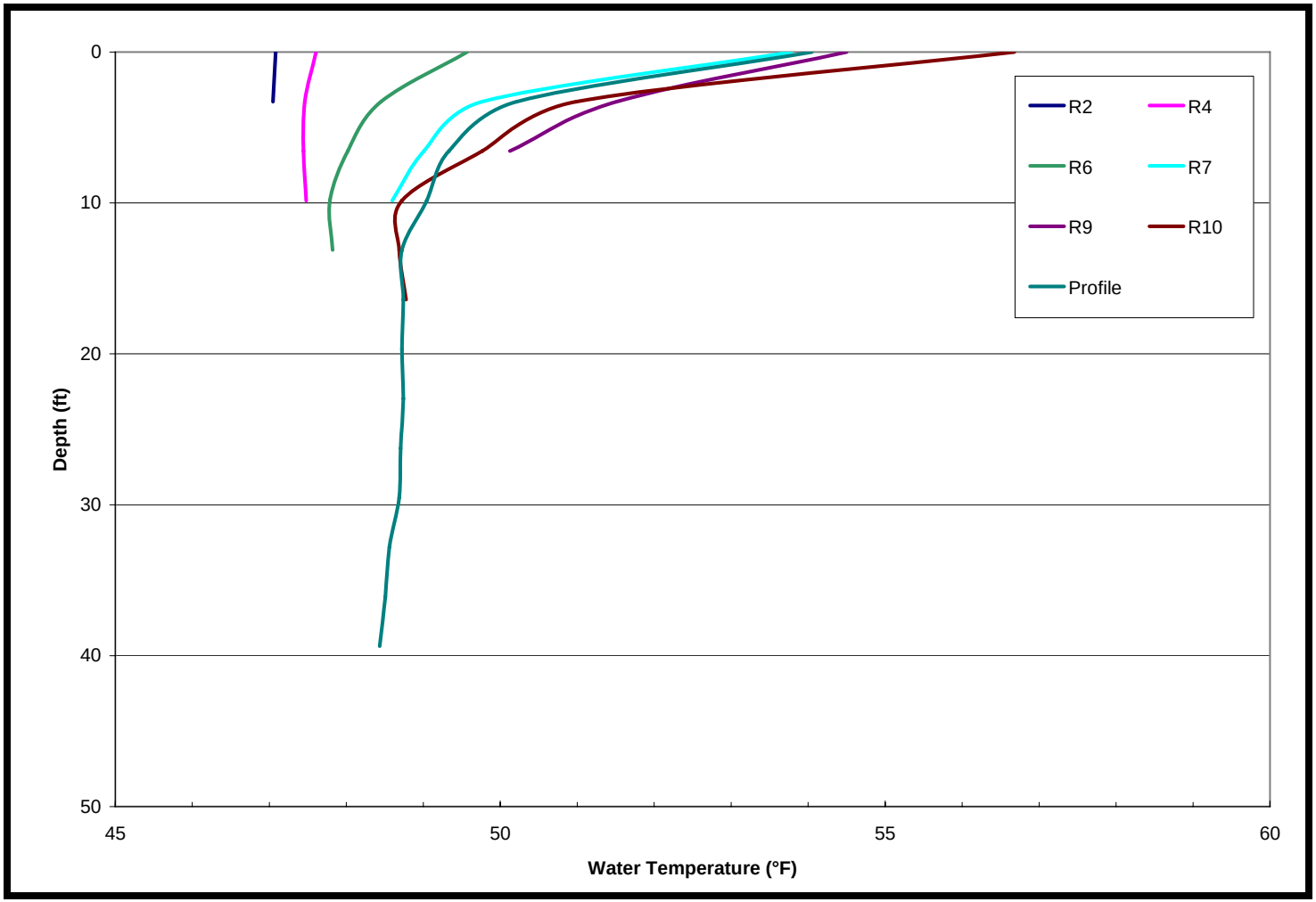

Figure 10. The water temperature profiles from the six monitoring locations and the reservoir profile location in Ralston Afterbay on August 9, 2006.

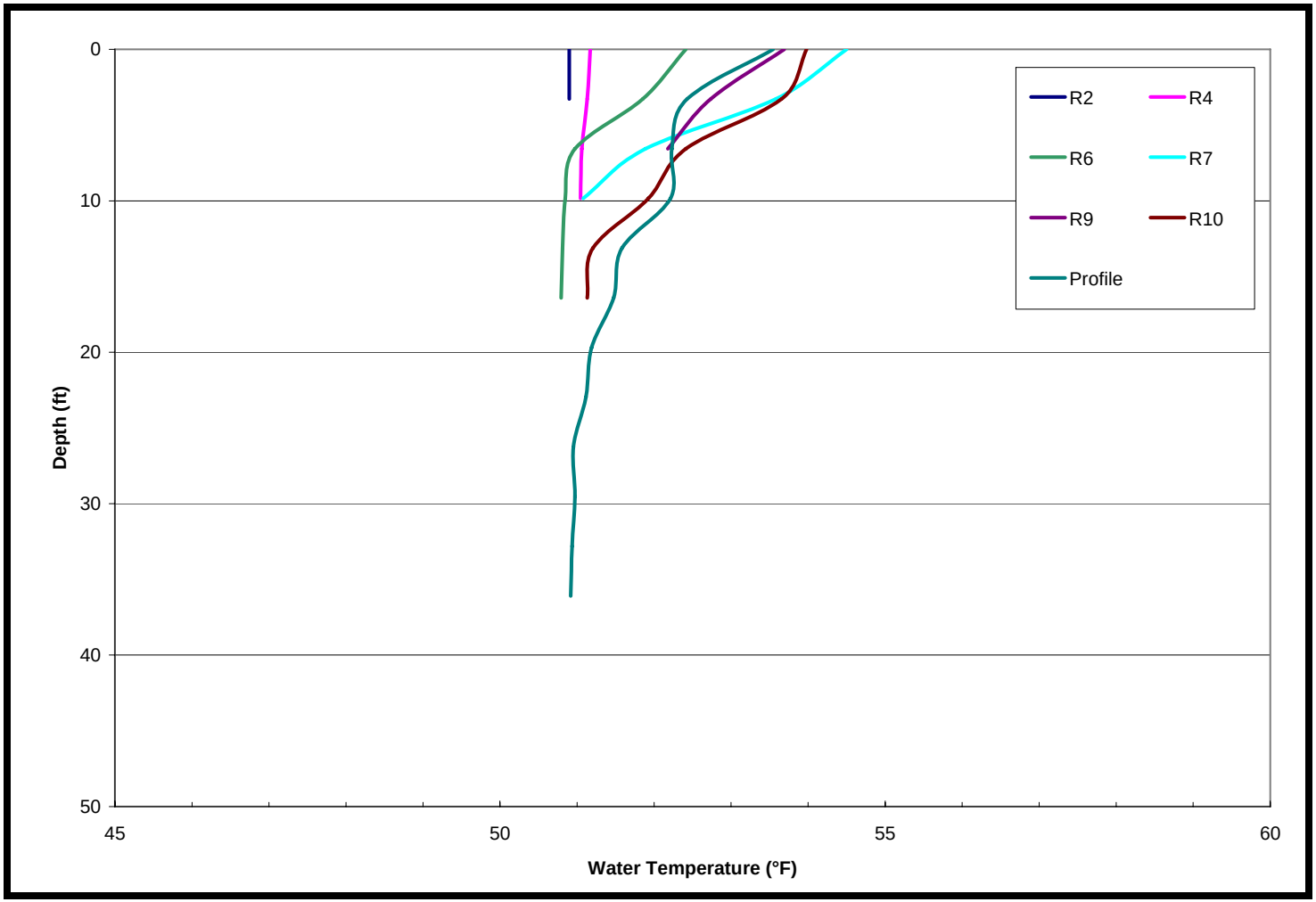

Figure 11. The water temperature profiles from the six monitoring locations and the reservoir profile location in Ralston Afterbay on October 1, 2006.

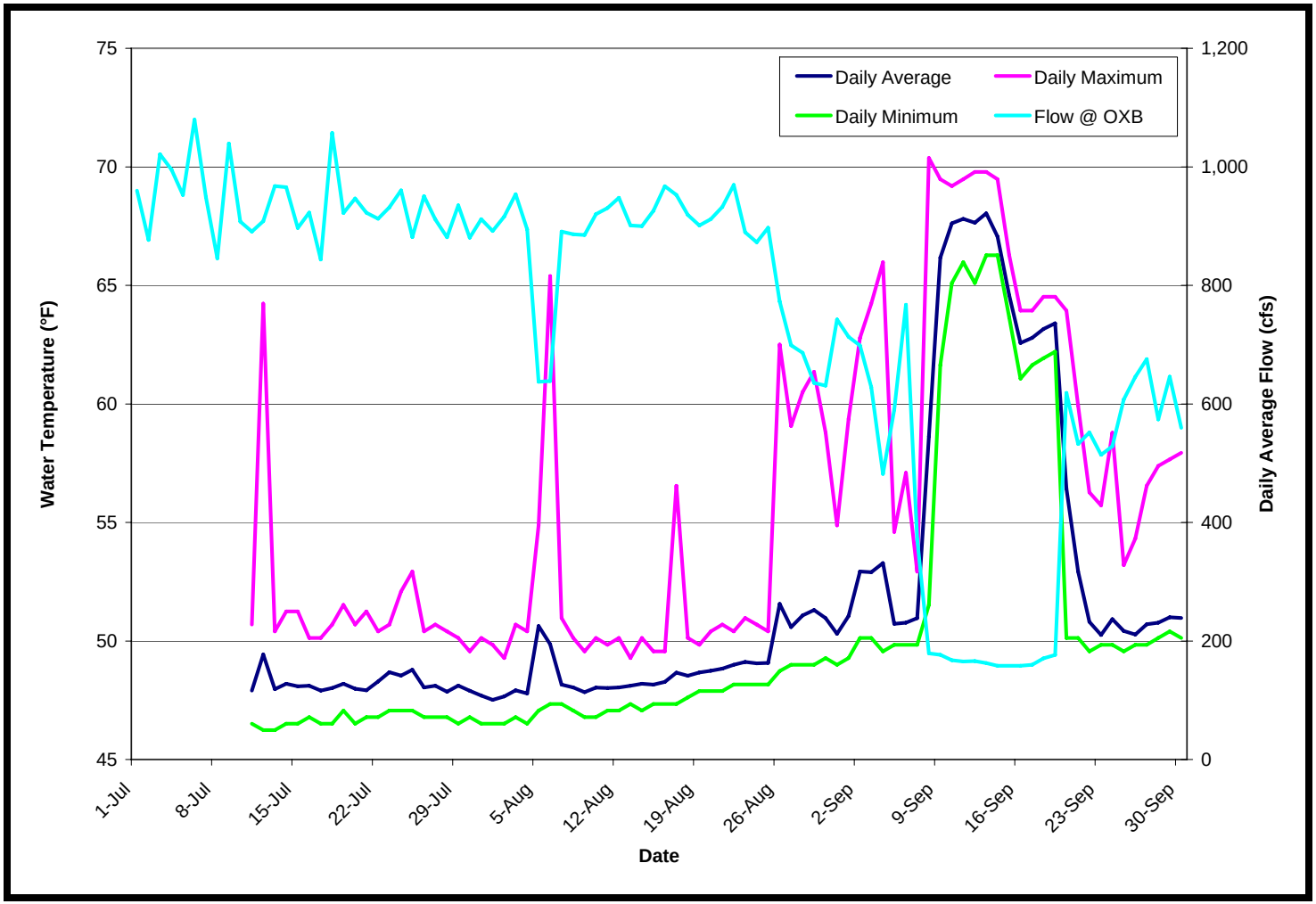

Figure 12. The daily average, maximum, and minimum water temperatures observed in Ralston Afterbay at site R2 and the daily reservoir elevation during the investigation period.

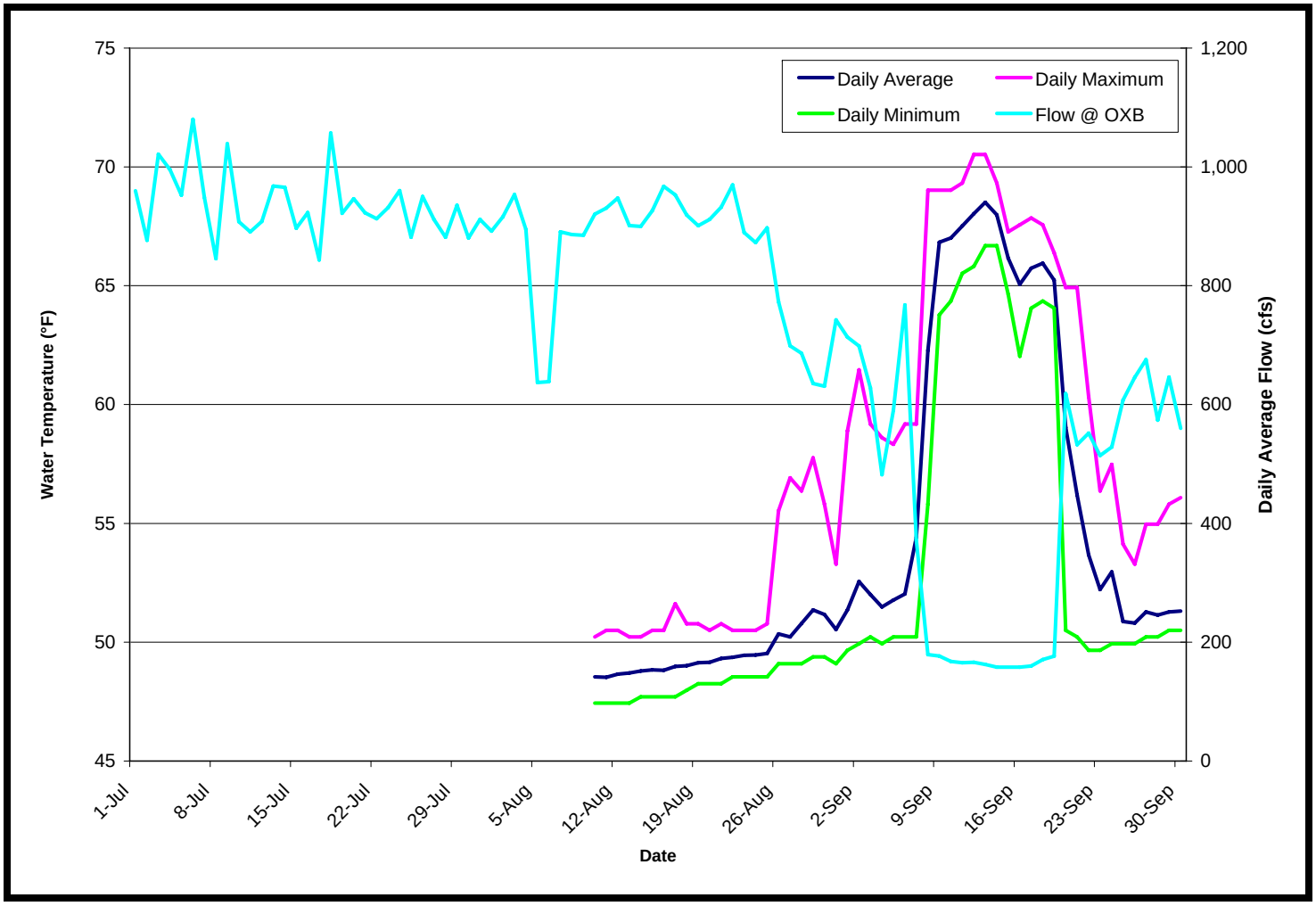

Figure 13. The daily average, maximum, and minimum water temperatures observed in Ralston Afterbay at site R4 and the daily reservoir elevation during the investigation period.

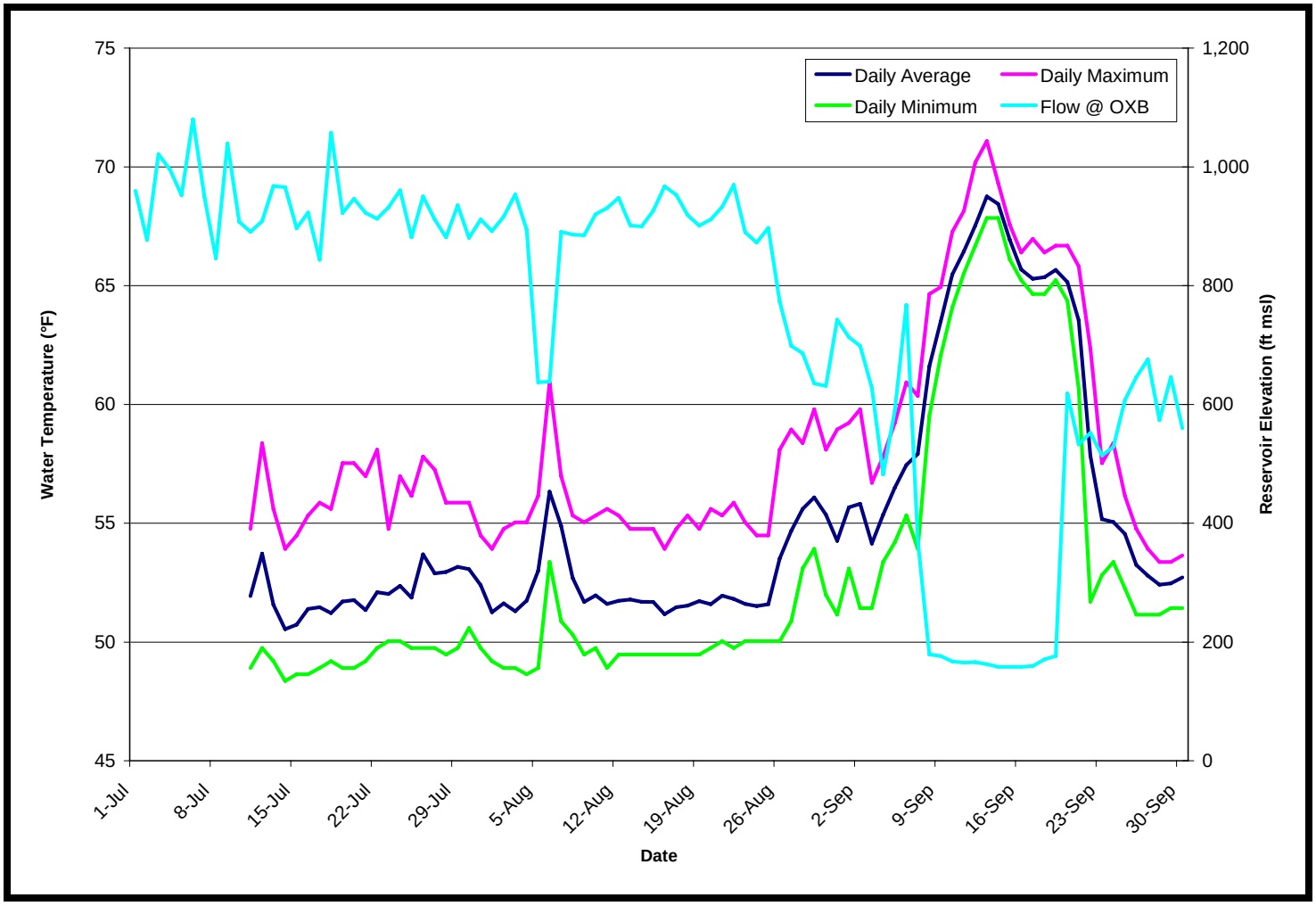

Figure 14. The daily average, maximum, and minimum water temperatures observed in Ralston Afterbay at site R7 and the daily average flow downstream of the Oxbow Powerhouse (USGS Gage 11433300) during the investigation period.

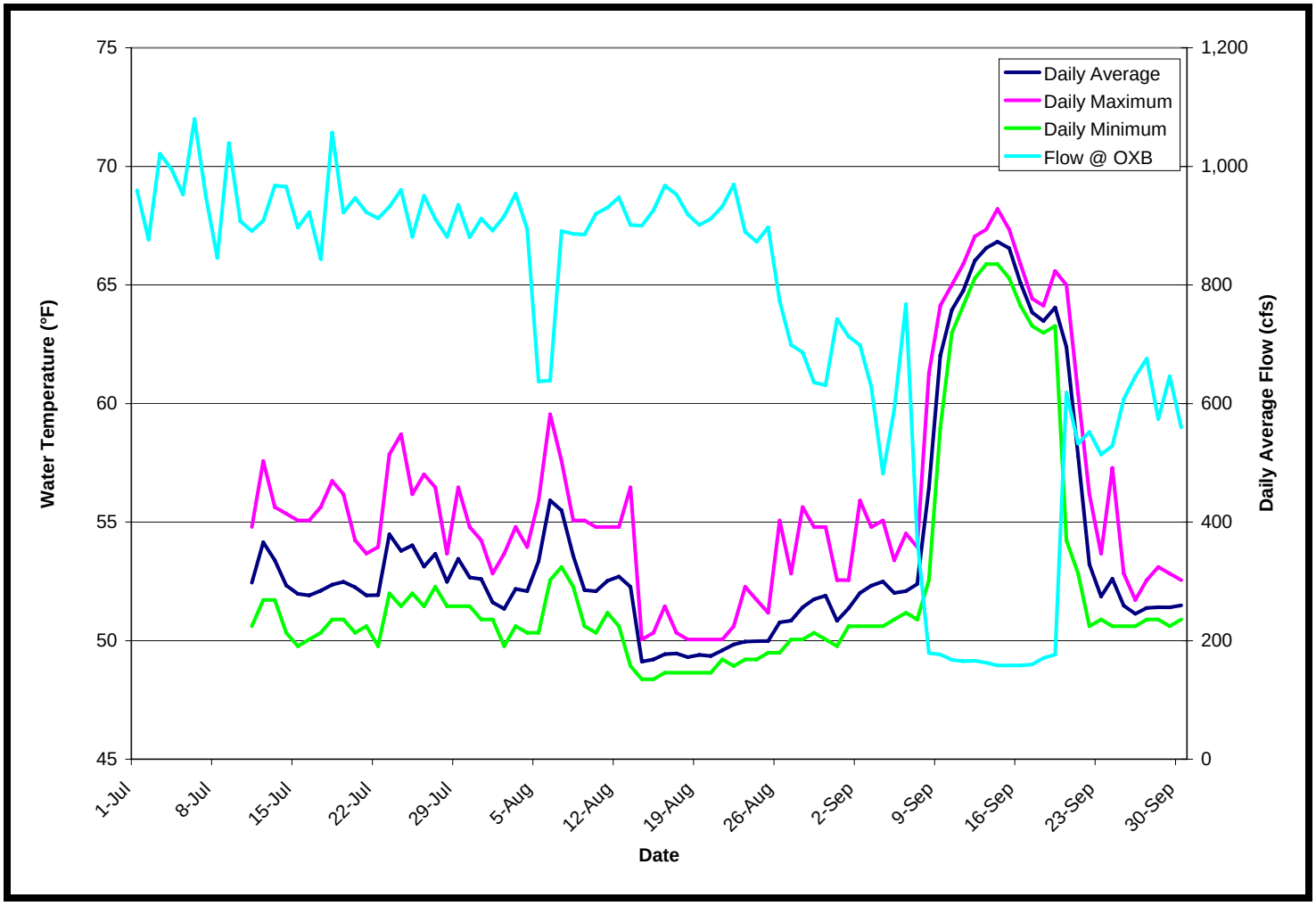

Figure 15. The daily average, maximum, and minimum water temperatures observed in Ralston Afterbay at site R9 and the daily reservoir elevation during the investigation period.

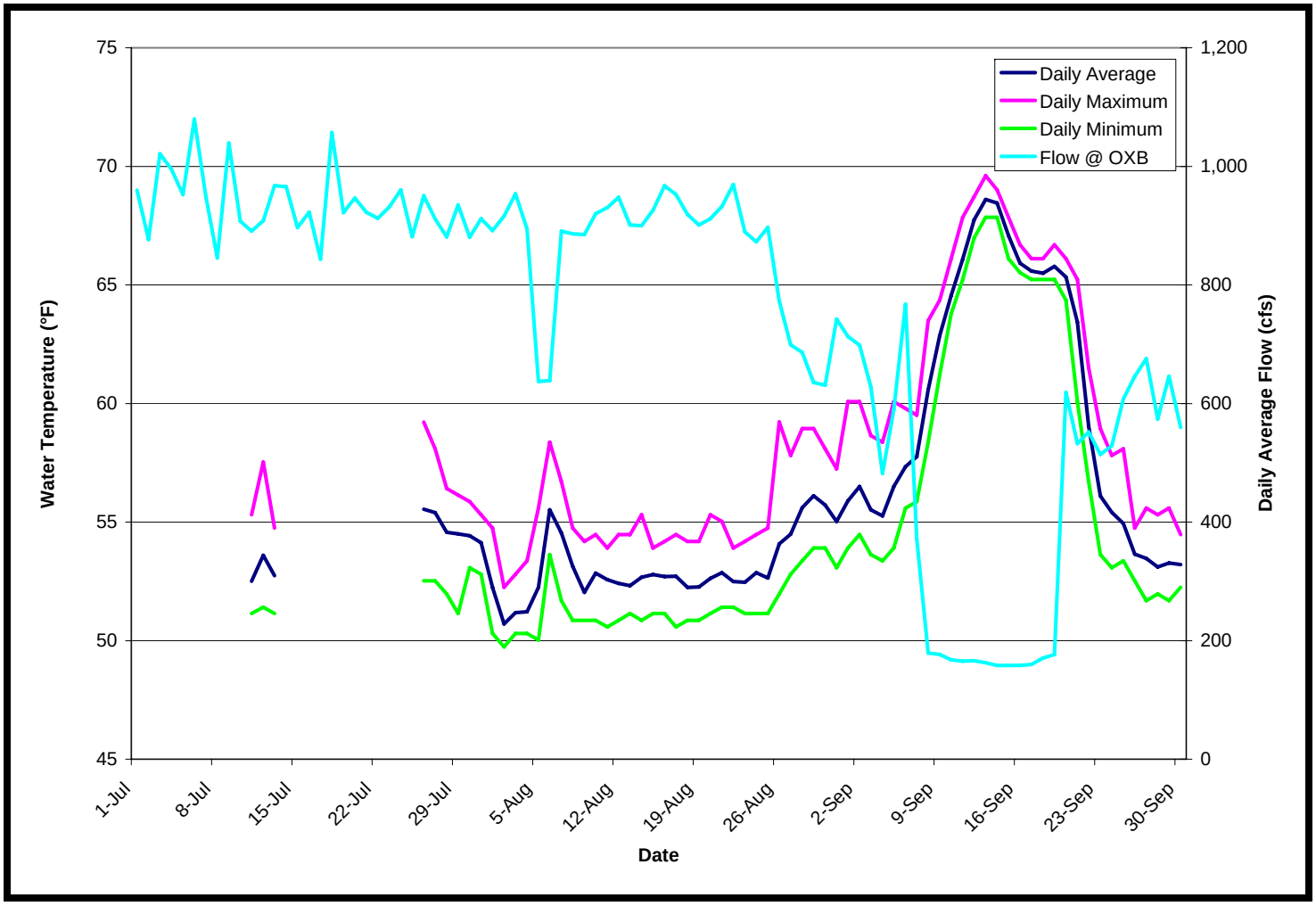

Figure 16. The daily average, maximum, and minimum water temperatures observed in Ralston Afterbay at site R10 and the daily average flow downstream of the Oxbow Powerhouse (USGS Gage 11433300) during the investigation period.

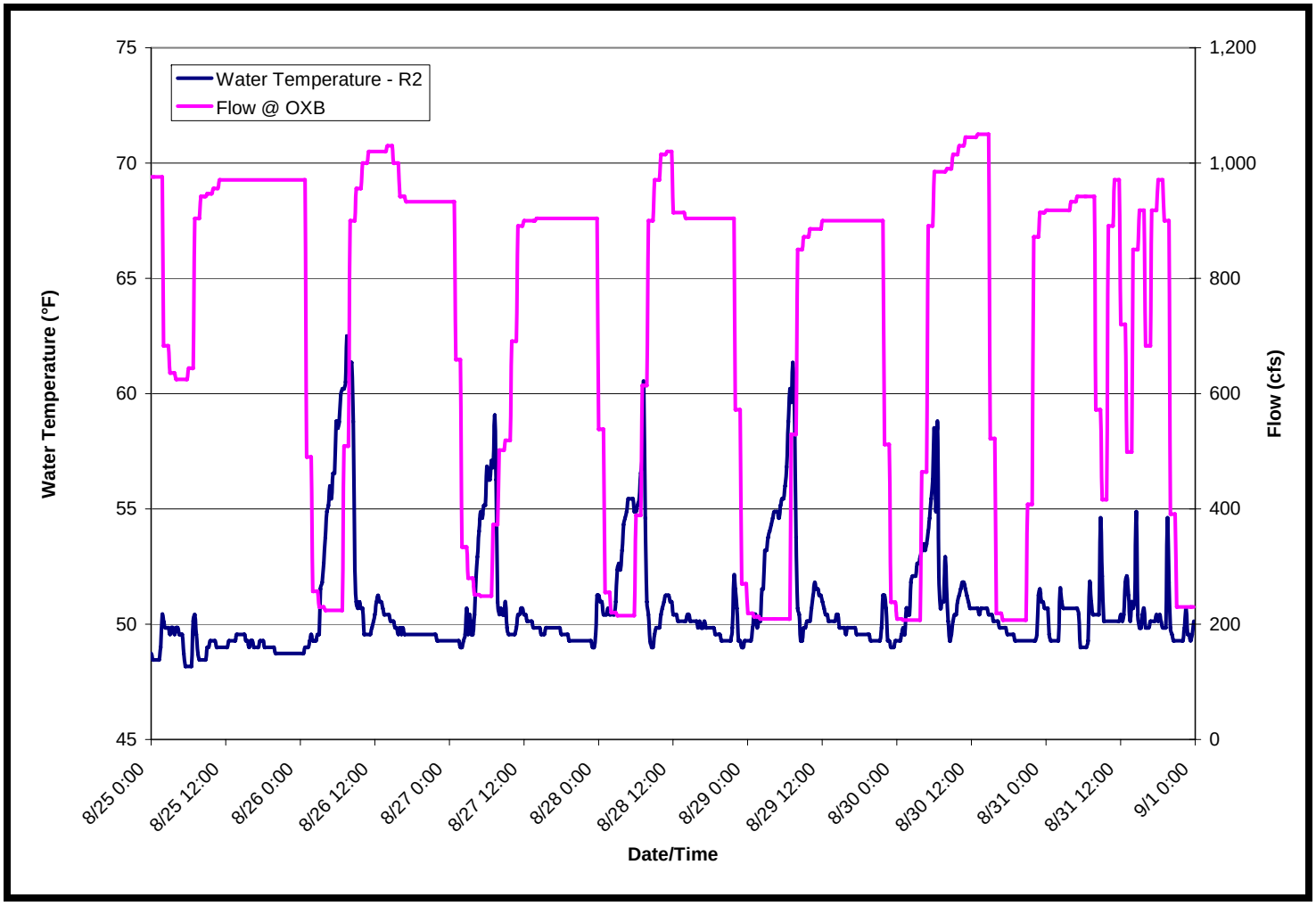

Figure 17. The 15-minute water temperature data observed in Ralston Afterbay at site R2 and flow downstream of the Oxbow Powerhouse (USGS Gage 11433300) during typical peaking operations from August 25 through August 31, 2006.