

Hydrodynamic & Temperature TMDL Models

Island Park Reservoir and Henry's Fork River

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ANNEAR WATER RESOURCES

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List of Abbreviations

ADCP	Acoustic Doppler Current Profiler
AgriMet	AgriMet, a conjunction of the words "agricultural" and "meteorology", is a satellite-based network of automated agricultural weather stations operated and maintained by the U.S. Bureau of Reclamation.
AMSL	Above Mean Sea Level
AU	Assessment Unit
BC	Boundary Condition
CE-QUAL-W2	Two-dimensional hydrodynamic and water quality model. (W2)
CWAL	Cold Water Aquatic Life
DEM	Digital Elevation Model
DEQ	Idaho Department of Environmental Quality
DO	Dissolved Oxygen
FRREC	Fall River Rural Electric Cooperative
GIS	Geographic Information System
GRASS	GRAphics Symbiosis System programming language
GUI	Graphical user interface, usually in the context of the CE-QUAL-W2 preprocessor
HFF	Henry's Fork Foundation
Hydromet	Hydromet, a conjunction of the words "hydrologic" and "meteorologic", is a ground-based network of automated hydrologic and meteorologic monitoring stations operated and maintained by the U.S. Bureau of Reclamation.
IDWW	Idaho Department of Water Resources
MAE	Mean Absolute Error
ME	Mean Error
METAR	Traditional weather reporting by the National Weather Service and the Federal Aviation Administration
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
POWER	NASA Prediction of Worldwide Energy Resources dataset
NASA	National Aeronautics and Space Administration
NRCS	National Resource Conservation Services
QGIS	Quantum Geographic Information Systems software
RM	River Mile
RMSE	Root Mean Square Error
RAWS	Remote Automated Weather Stations
SNOTEL	NRCS automated Snow Telemetry network

SRML	Solar Radiation Monitoring Lab, University of Oregon
TMDL	Total Maximum Daily Load
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey

Introduction

The State of Idaho Department of Environmental Quality (DEQ) publishes a list of impaired water bodies in Idaho's Integrated Report. The 2024 Integrated Report is currently under development (DEQ, 2024). In recent years, DEQ has assessed water temperature data collected in several Henry's Fork River assessment units (AUs) and determined that water quality standards for temperature are frequently exceeded. This has resulted in these Henry's Fork AUs to be added to the list of impaired waters published in the Integrated Report. DEQ is interested in developing a hydrodynamic and temperature model of the Island Park Reservoir and downstream sections of the Henry's Fork River using CE-QUAL-W2, a 2-dimensional hydrodynamic and water quality model to better understand factors that influence temperature dynamics in these waters and to inform the development of a water temperature total maximum daily load (TMDL) for the reservoir and downstream river, if applicable.

The models will allow DEQ to derive a baseline of temperature criteria violations, inform future waterbody assessments, and understand how the magnitude and frequency of violations occur in different management and operational scenarios. The models can also be used by DEQ to develop temperature targets and explore options that would be needed to meet those targets. DEQ will then be able to use this information to develop a potential temperature TMDL, if needed. The models can be used to perform model scenarios, in order to evaluate water quality improvement options of interest to DEQ and the Henry's Fork Foundation (HFF).

Project Overview

The model extent included the Island Park Reservoir AU (ID17040202SK020L_0L) and the Henry's Fork River AU (ID17040202SK015_05), extending from the Island Park Dam downstream by roughly 10 miles to the river's confluence with Thurmon Creek (Figure 1).

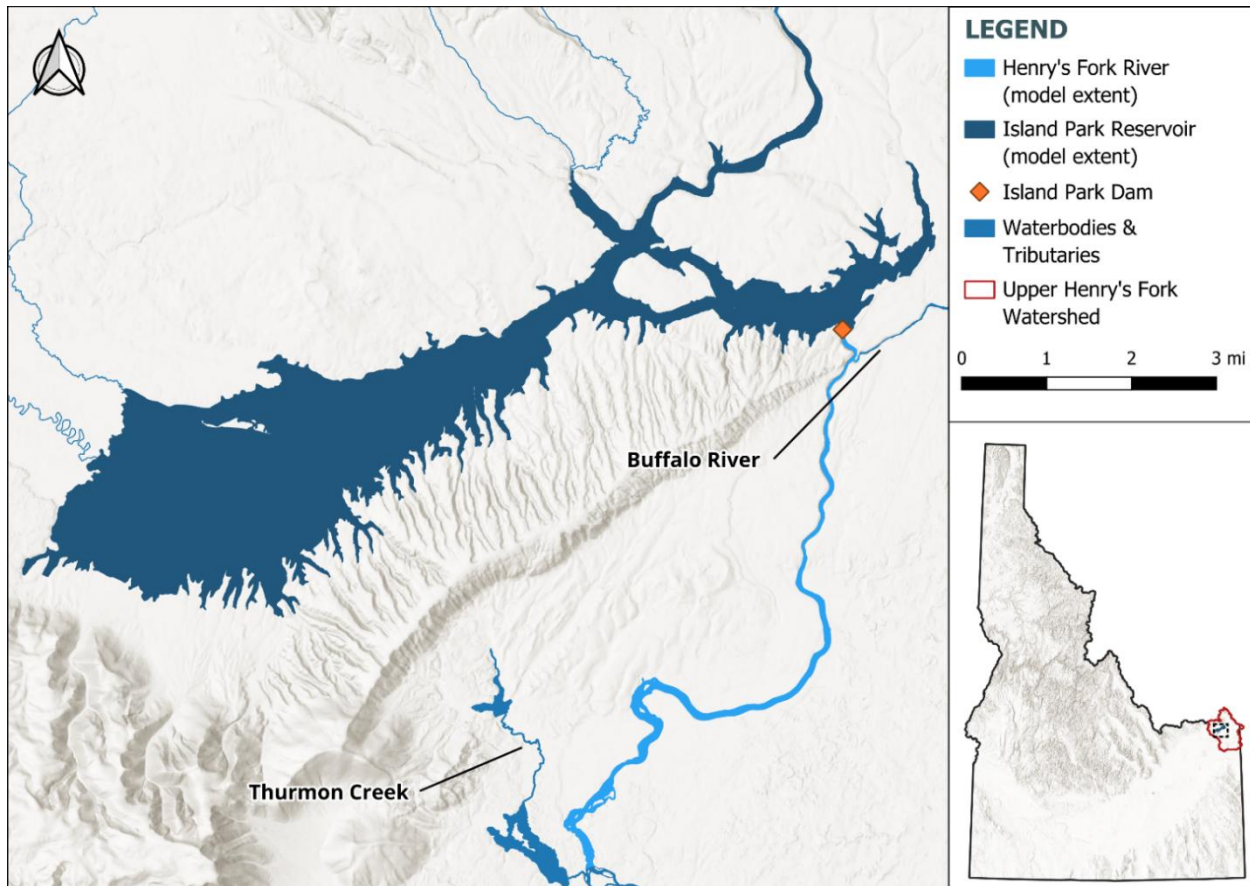


Figure 1. Extent of the Island Park Reservoir and Henry's Fork River CE-QUAL-W2 models.

Water Temperature Standards and Issues

The water quality – temperature standard for the Henry's Fork Watershed are shown Table 1 (provided by DEQ).

Table 1. Temperature Water Quality Standards.

Cold Water Aquatic Life	Salmonid Spawning
22 °C or less daily maximum	13 °C or less daily maximum
19 °C or less daily average	9 °C or less daily average

Each beneficial use has a daily maximum and daily average water temperature standard. DEQ evaluates the Salmonid Spawning standard during the times when local fish populations are likely to be spawning. Table 2 presents the spawning and egg incubation periods for native fish species in Idaho, derived from *Geography and Timing of Salmonid Spawning in Idaho* (BioAnalysts 2014). To be conservative, the Salmonid Spawning criteria can be evaluated all year long, but DEQ can also use local knowledge of spawning times to modify when the criteria are applicable.

Table 2. Spawning and egg incubation periods for select native and introduced salmonid species in Idaho (Table 8, BioAnalysts 2014).

Fish Species	Time Period
Chinook Salmon (spring/summer run)	August 15–June 1
Chinook Salmon (fall run)	October 1–April 15
Sockeye Salmon	October 1–June 1
Steelhead Trout	April 1–July 15
Redband/Rainbow Trout	March 15–July 15
Cutthroat Trout	April 1–July 1
Bull Trout	September 1–April 1
Kokanee Salmon	September 1–May 1
Mountain Whitefish	October 15–March 15
Brown Trout	October 1–April 1
Brook Trout	October 1–June 1

CE-QUAL-W2

CE-QUAL-W2 (W2) Version 4.5 (Wells, 2023) is a two-dimensional (longitudinal- vertical), laterally averaged, hydrodynamic and water quality model, originally developed by the U.S. Army Corps of Engineers (USACE) Waterways Experiments Station, was chosen as the appropriate tool for modeling this system. W2 includes the following features well suited for developing water temperature models to support a potential TMDL:

- Dynamic temperature predictive capability.
- Dynamic shading prediction based on detailed topographic and vegetative shading information.
- Dynamic ice cover predictive capability for Island Park Reservoir.
- The model can be used for water quality after the water temperature modeling where parameters of interest may include algae, periphyton, pH, and dissolved oxygen.
- Simulate complex hydraulic flow paths with multiple interconnected branches using hydraulic elements (weirs, pumps, spillways) between branches for the Henry's Fork River.
- Evaluate the thermal stratification in Island Park Reservoir.
- Simulate an entire river basin including upstream deep-density stratified reservoirs.
- Public domain executable and source code for quality-assurance and testing.

Two separate W2 models were developed, one for Island Park Reservoir and one for roughly 10 miles of the Henry's Fork River below Island Park Dam. The models were developed and calibrated separately, but designed so the model output of the reservoir model could be used as the upstream boundary condition for the Henry's Fork River model.

Once the models were developed for each reach, they were calibrated to field data, primarily provided by the HFF. This report outlines the model development, calibration, and preliminary sensitivity and operational scenarios for both models.

Model Development

The Island Park Reservoir and Henry's Fork River models were developed and calibrated from January 1 through December 31, 2023 using a combination of data provided by the HFF and time series data retrieved from local meteorological and streamflow monitoring stations.

Meteorology

The Island Park Reservoir and Henry's Fork River models share the same input meteorological data. Figure 2 shows the locations of the monitoring stations used to develop the meteorological inputs for the models. Table 3 links observed and derived meteorological parameters to respective monitoring stations.

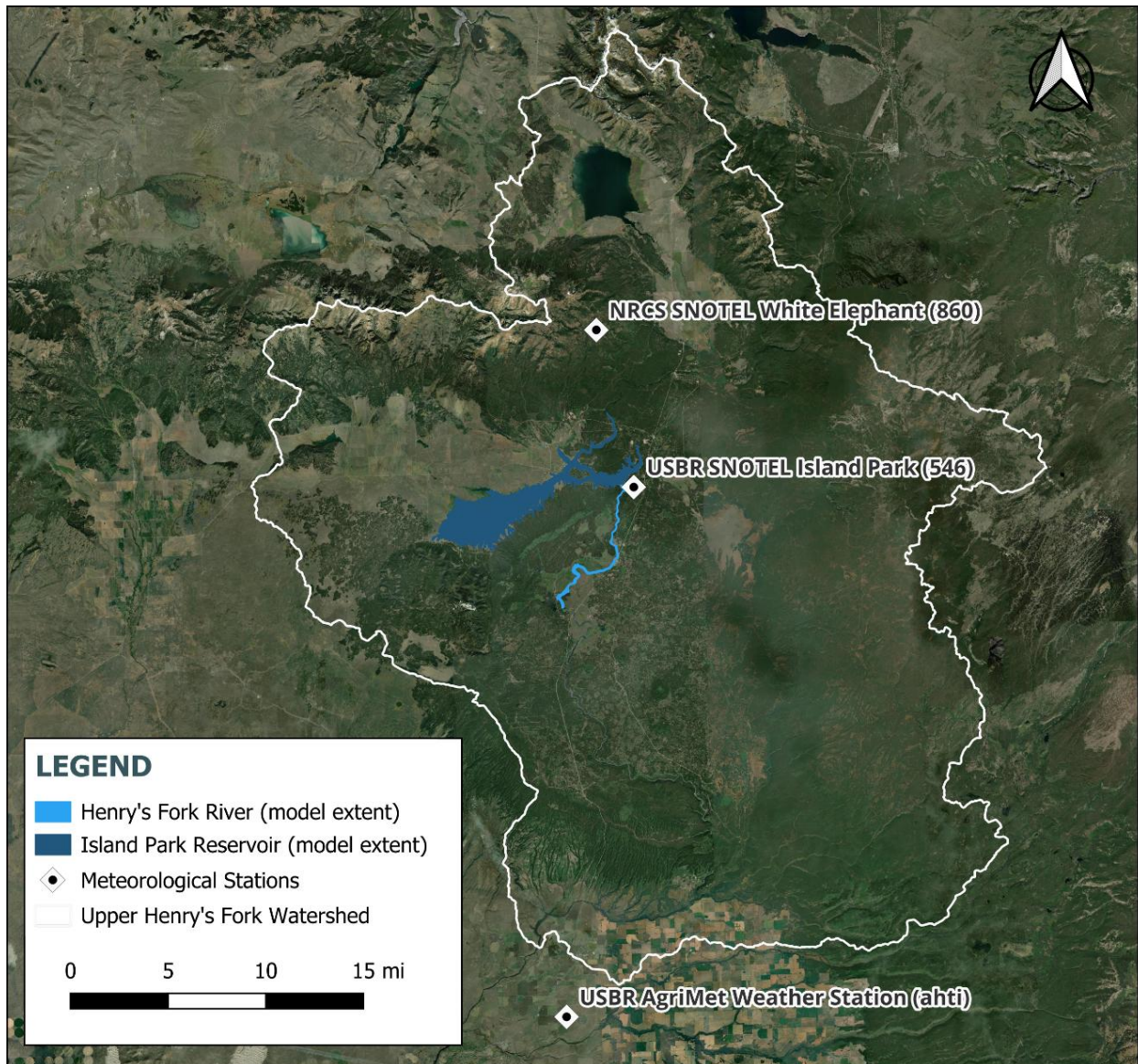


Figure 2. Island Park Reservoir and Henry's Fork River models' meteorological monitoring stations.

Table 3. Source of input meteorological data for the Island Park Reservoir and Henry's Fork River models.

Source / Site ID	Meteorological Parameter
NRCS SNOTEL Island Park (546) NRCS SNOTEL White Elephant (860)	Air temperature
USBR AgriMet Weather Station (ahti)	Dewpoint temperature, wind speed, wind direction, and solar radiation.
NASA-Prediction of Worldwide Energy Resources (POWER) Dataset	Cloud cover

Air Temperature

Hourly air temperatures in the model vicinity were characterized using measured air temperature at National Resource Conservation Services (NRCS) automated Snow Telemetry (SNOTEL) site 546 located near Island Park, Idaho. Gaps in the SNOTEL site 546 record were filled using measurements at the SNOTEL White Elephant (site 860). Temperature time series at both sites were corrected for known biases in SNOTEL air temperature measurements following Atwood et al. (2023) prior to interpolation. The organic correlation relationship, predicting a missing value y_i on water-year day i from a known value x_i was used to interpolate the SNOTEL White Elephant site and fill the SNOTEL Island Park 2023 time series:

$$y_i = \bar{y}_i + \frac{s_{y,i}}{s_{x,i}}(x_i - \bar{x}_i),$$

where $\bar{y}_i$ is the mean of y for Julian day i , $s_{y,i}$ is the standard deviation of y on day i , and $s_{x,i}$ is the standard deviation of x on day i . The means and standard deviations for each site were calculated for the available record at each station between January 1 and December 31, 2023. An eight-hour period on January 30 and one-hour period on January 31 in the Island Park SNOTEL record were filled using observed air temperatures at SNOTEL White Elephant. Figure 3 shows the resultant air temperature used in both the Island Park Reservoir and Henry's Fork River models.

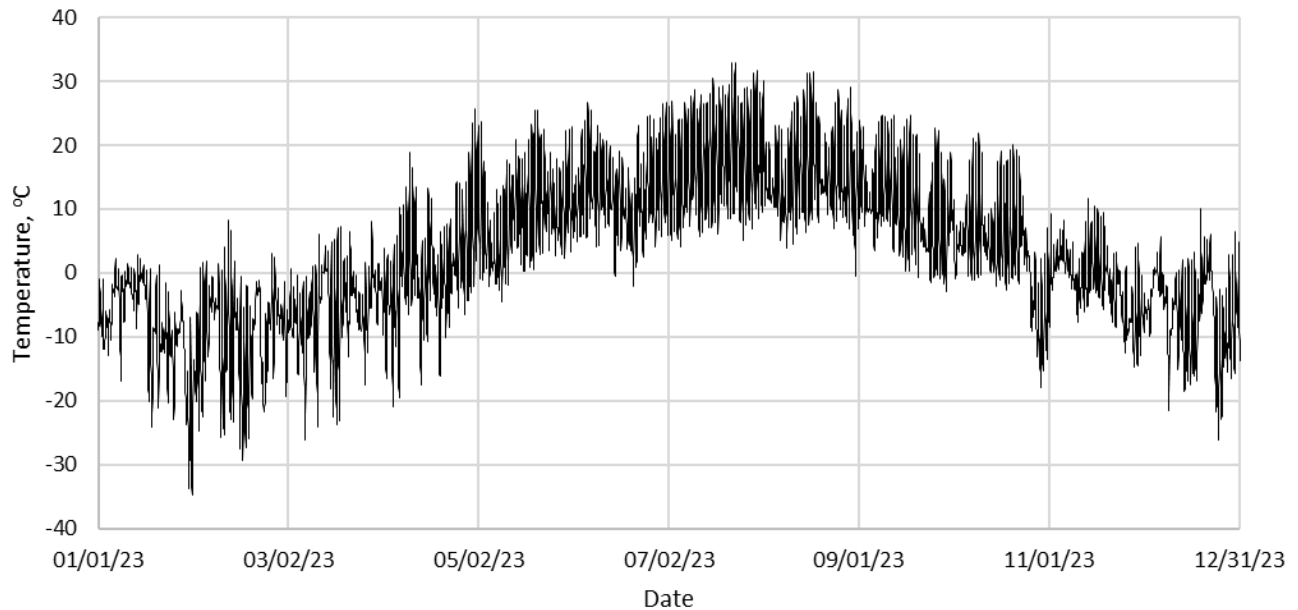


Figure 3. Air temperature in the Island Park Reservoir and Henry's Fork River models.

Dew Point Temperature, Wind Speed and Direction, and Solar Radiation

Dew point temperature (Figure 4), wind speed (Figure 5), wind direction (Figure 6), and short wave solar radiation (Figure 7) observed at the U.S. Bureau of Reclamation (USBR) AgriMet weather station located in Ashton, Idaho were used as inputs to the Island Park Reservoir and Henry's Fork River models for 2023. The USBR AgriMet meteorological records were corrected to mountain time before inclusion in the models. The figures show typical seasonal patterns for meteorological parameters. Figure 6 shows a typical pattern of wind direction dominated by winds from the 60 to 90 degrees (East) and roughly 240- 270 degrees (West). The solar radiation data (Figure 7) shows a typical seasonal pattern but reaches a maximum of less 1,000 W/m². Typically, short wave solar above the atmosphere is on average about 1,360 W/m². Observed solar radiation does not meet this threshold, but the time series is within a reasonable range of expected values.

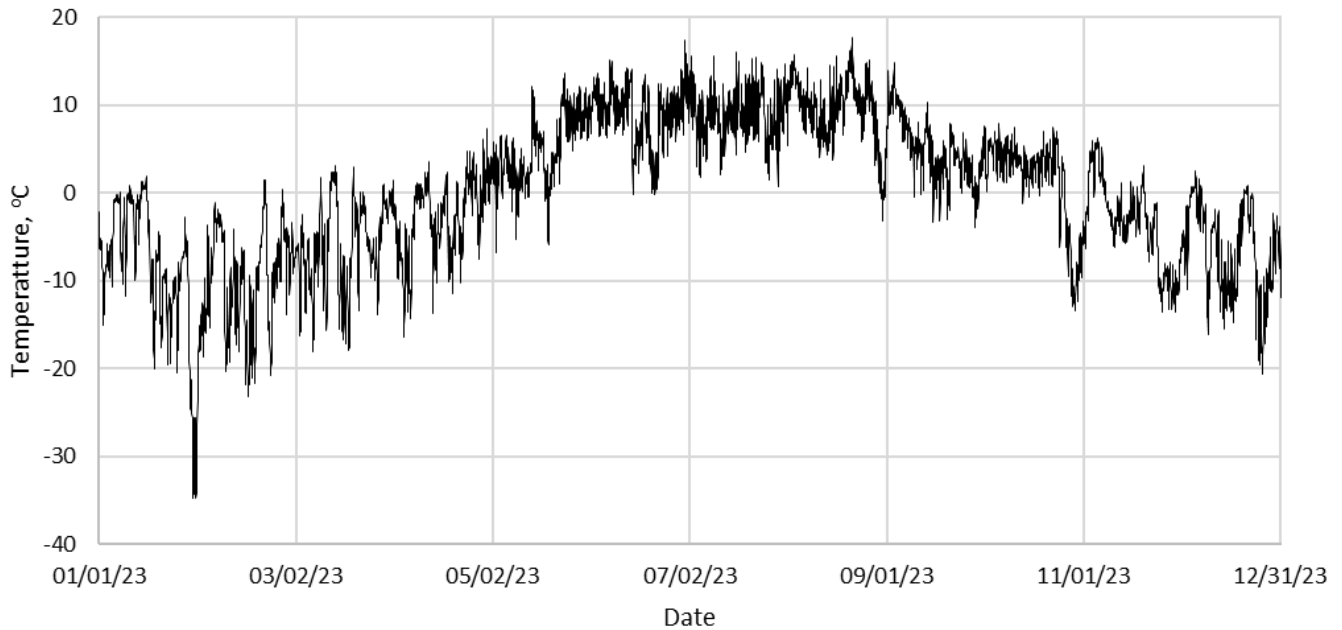


Figure 4. Dew point temperature in the Island Park Reservoir and Henry's Fork River models.

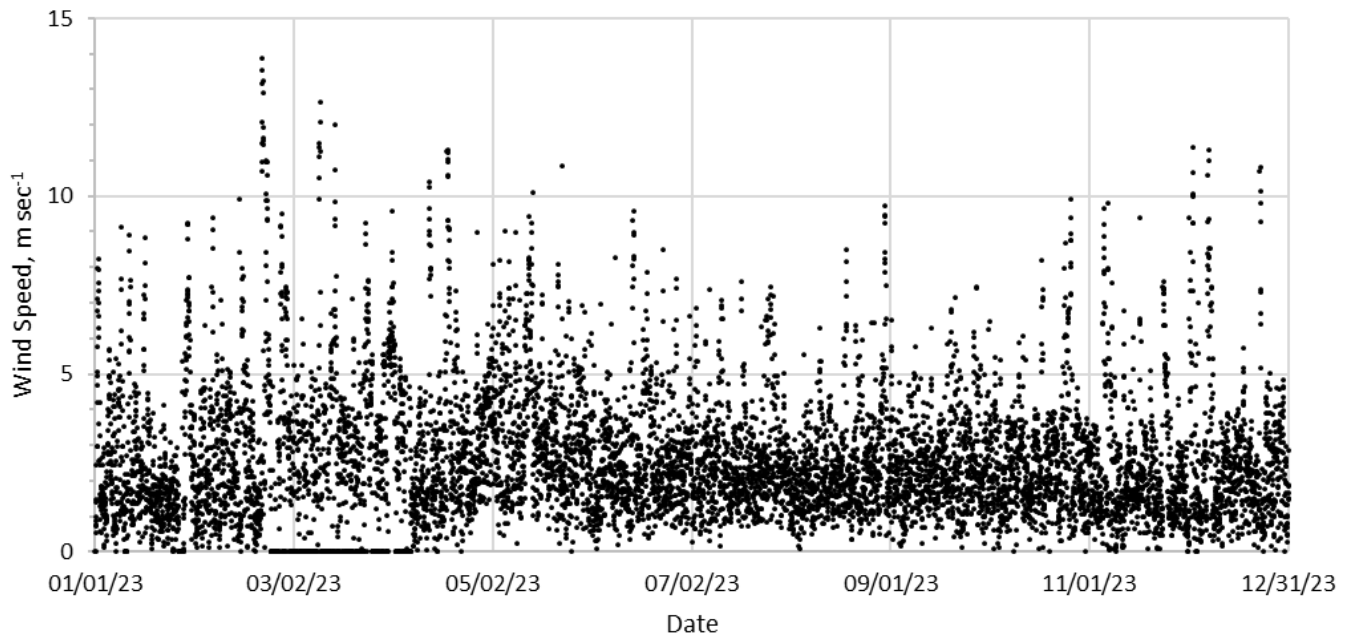


Figure 5. Wind speed in the Island Park Reservoir and Henry's Fork River models.

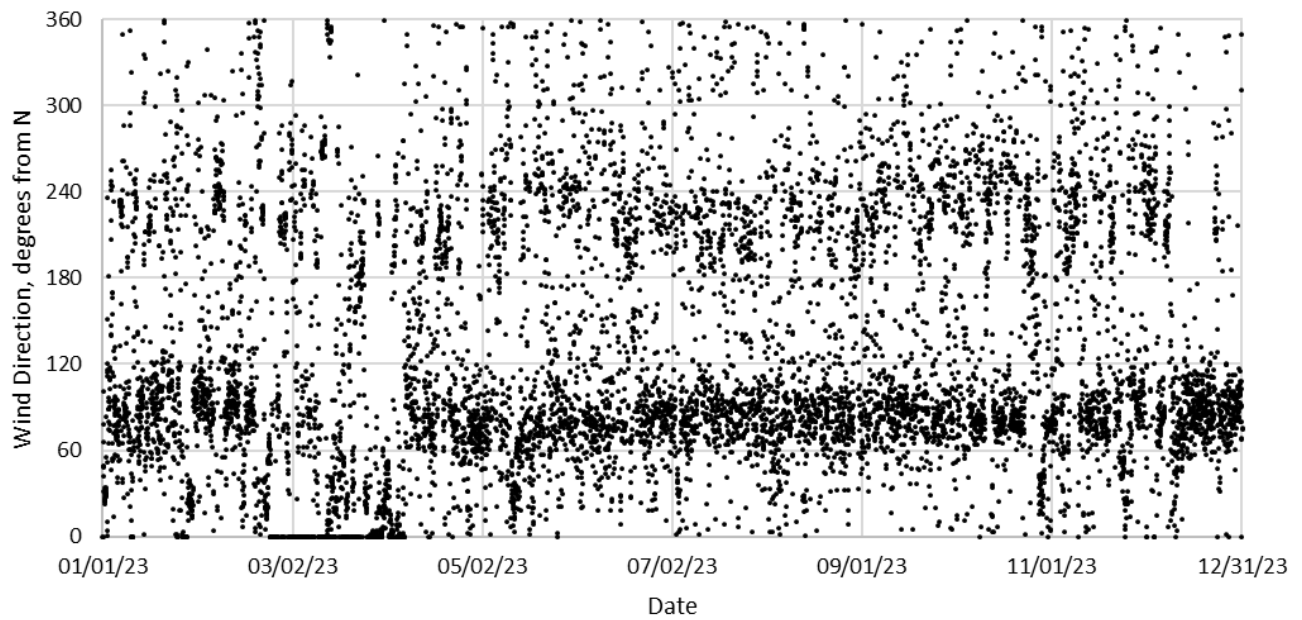


Figure 6. Wind direction in the Island Park Reservoir and Henry's Fork River models.

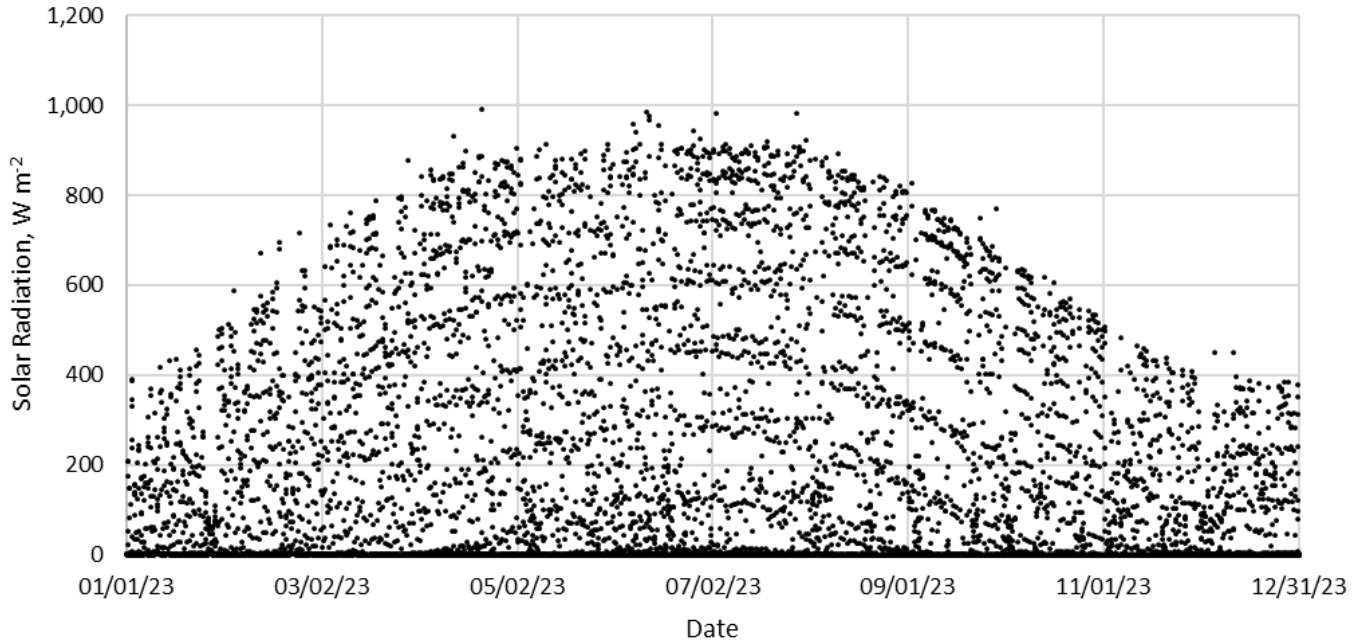


Figure 7. Shortwave solar radiation in the Island Park Reservoir and Henry's Fork River models.

Cloud Cover

Cloud cover was developed using the National Aeronautics and Space Administration's (NASA) POWER dataset with simulated all-sky and clear sky estimates at the Island Park Reservoir. This information was then used to calculate cloud cover using the equation from Wunderlich (1972):

$$\phi_{s-net} = \phi_{s-clearsky}(1 - 0.65C^2),$$

where,

- ϕ_{s-net} is the new short water solar radiation (W/m^2),
- $\phi_{s-clearsky}$ is the clear sky short wave solar radiation (W/m^2), and
- C is the cloud cover fraction between 0.0 and 1.0 (dimensionless).

A 24-hour rolling average was used to estimate cloud cover at night and allow smooth transition at sunrise and sunset. As check on the POWER estimated solar radiation, this data set was checked against measured solar radiation at the USBR Ashton Station and found to be track well. Figure 8 shows a time series of the resulting cloud cover estimates, which were used in the model.

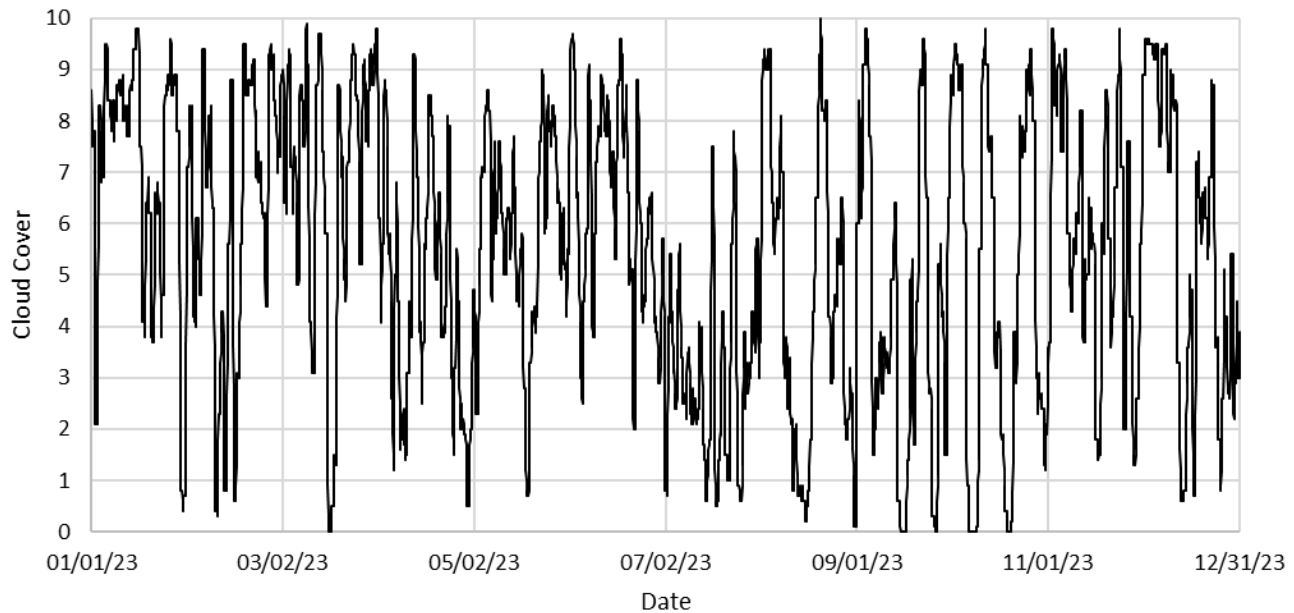


Figure 8. Cloud cover in the Island Park Reservoir and Henry's Fork River models.

Island Park Reservoir

The Island Park Reservoir drains 1,245 km² (481 mi²) of the Upper Henry's Fork subbasin located in northeastern Idaho. The reservoir has an approximate surface area of 31.6 km² (12.2 mi²), is seasonally covered by ice, and is fed by surface and spring inflows.

Bathymetry Data

The Island Park Reservoir model grid was developed from bathymetric data collected by HFF between June 6, 2017 and June 30, 2017. Reservoir depth was measured using a Lowrance® HDS-5 Gen-2 sonar/chart plotter with a sonar frequency set to 200 kilohertz (kHz). Reservoir water level during the field campaign varied by less than 0.04 m, with an average water level elevation of 1921.15 meters above mean sea level (AMSL).

Collected data was post-processed using Quantum Geographic Information Systems (QGIS) version 2.16 "Essen", a free GIS program based on the GRaphics Symbiosis System (GRASS) programming language, to develop a 75 ft. by 75 ft. grid shapefile representing the reservoir bathymetry. The bathymetry shapefile was then joined to a United States Geological Survey (USGS) 10-meter digital elevation model (DEM) for the region to capture the surrounding topography. Figure 9 shows the combined bathymetry shared by HFF and used to develop the Island Park Reservoir model grid.

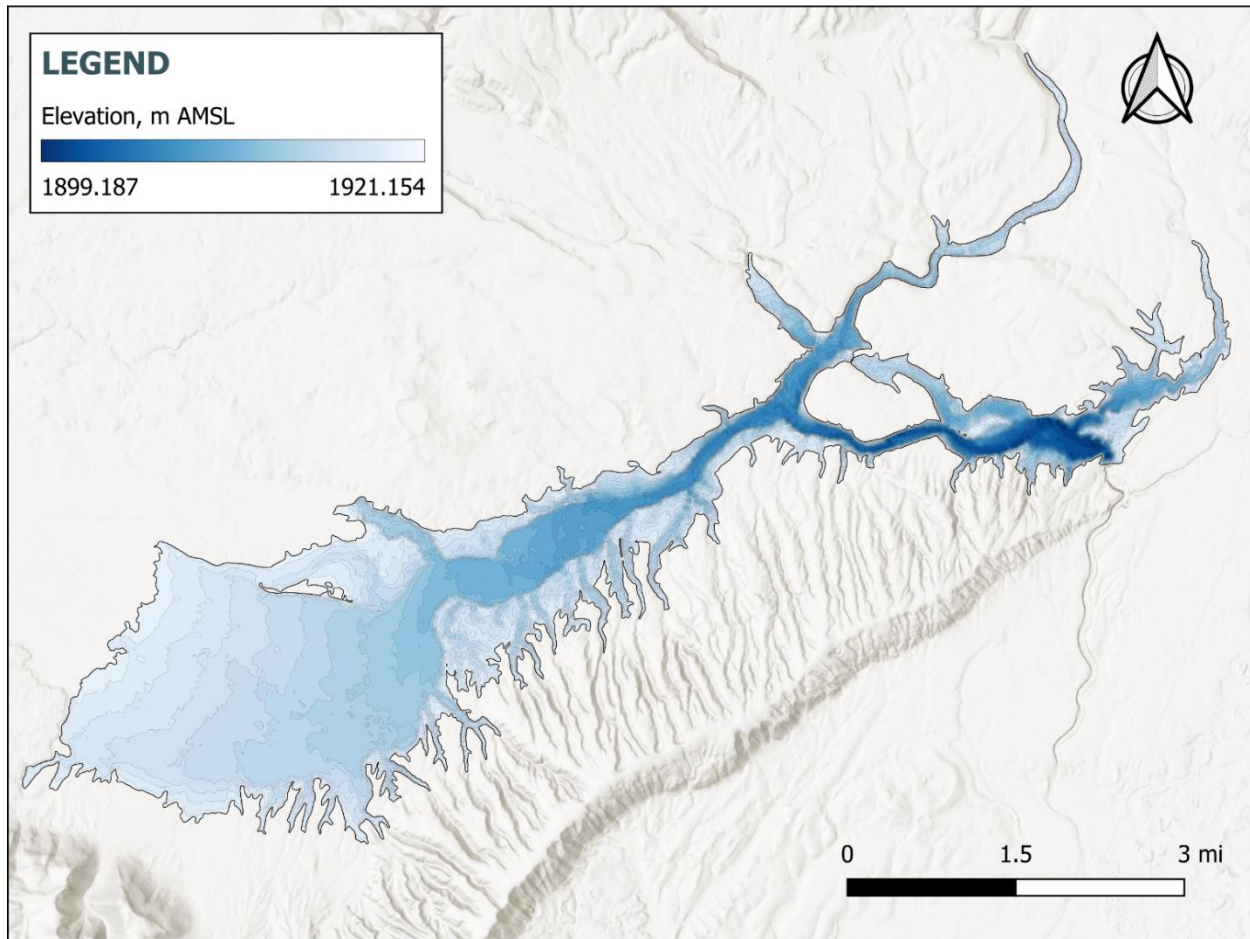


Figure 9. Island Park Reservoir bathymetry provided by HFF.

Model Grid

The model grid consists of a single waterbody comprised of five branches (Figure 10). The first branch represents the western limb of the reservoir to the Island Park Dam. The second branch receives inflow from the Henry's Fork River above the reservoir and connects with the first branch where it bends east. The third branch extends Branch 1 from the Island Park Dam to the reservoir's easternmost extent. Branches 4 and 5 represent side channels to the main reservoir water body. Branches 2 and 4 are not connected: the two sections of the reservoir are separated by a thin spit of land connecting Bill's Island and the surrounding area. The model grid contains 95 active (and 1 inactive) vertical layers with a resolution of 0.5 meters.

Table 4 details the branch specifications and boundary conditions. Figure 11 through Figure 15 show the model vertical resolution for each branch. Figure 16 shows the volume-elevation curves for Island Park Reservoir as derived from the model grid, HFF measured bathymetry, and bathymetry data from the U.S. Bureau of Reclamation (USBR). The model grid bathymetry compares very well with HFF and USBR measured data.

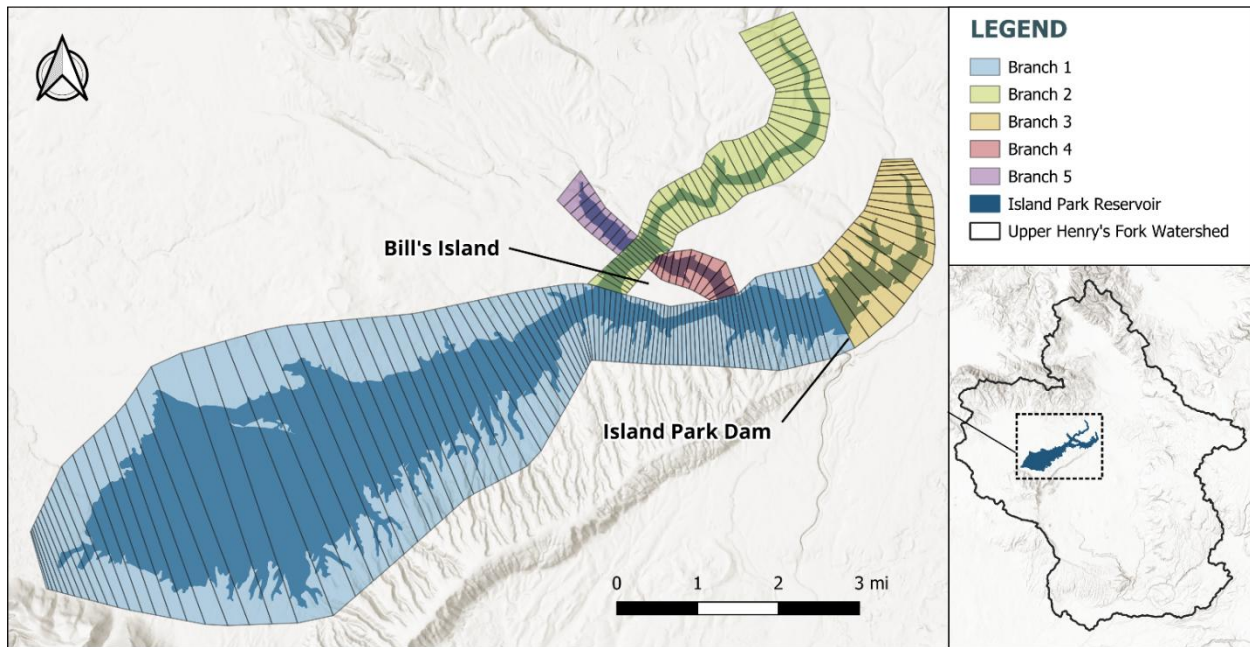


Figure 10. Layout of the CE-QUAL-W2 Island Park Reservoir model grid.

Table 4. Island Park Reservoir model grid layout and boundary conditions (BC).

Water Body	Branch	Starting Segment	Ending Segment	Length, km	Slope	Upstream BC	Downstream BC
1	1	2	99	17.80	0.0	flow	n/a
	2	102	150	7.76	0.0	flow	internal
	3	153	171	3.67	0.0	flow	internal
	4	174	185	1.79	0.0	flow	internal
	5	188	196	1.66	0.0	flow	internal

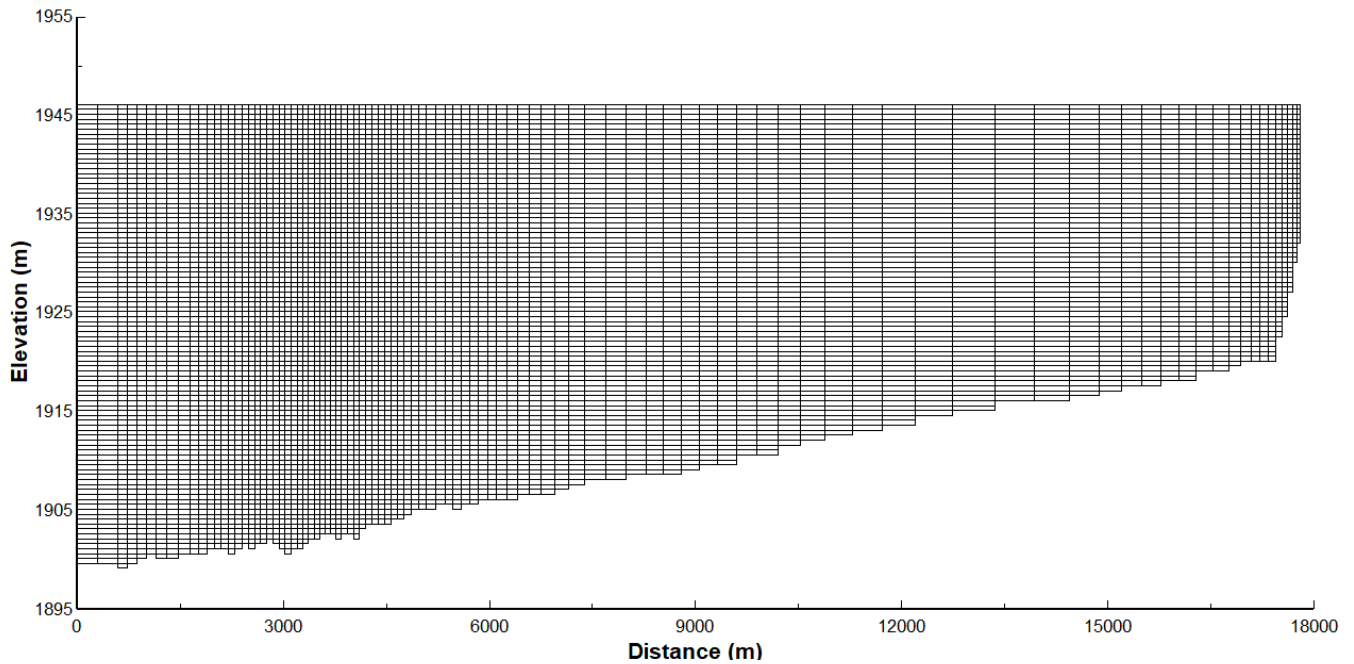


Figure 11. Island Park Reservoir, branch 1 vertical grid resolution (segments 2 to 99). Plotted distance measured from the furthest downstream segment (99), elevation set to AMSL.

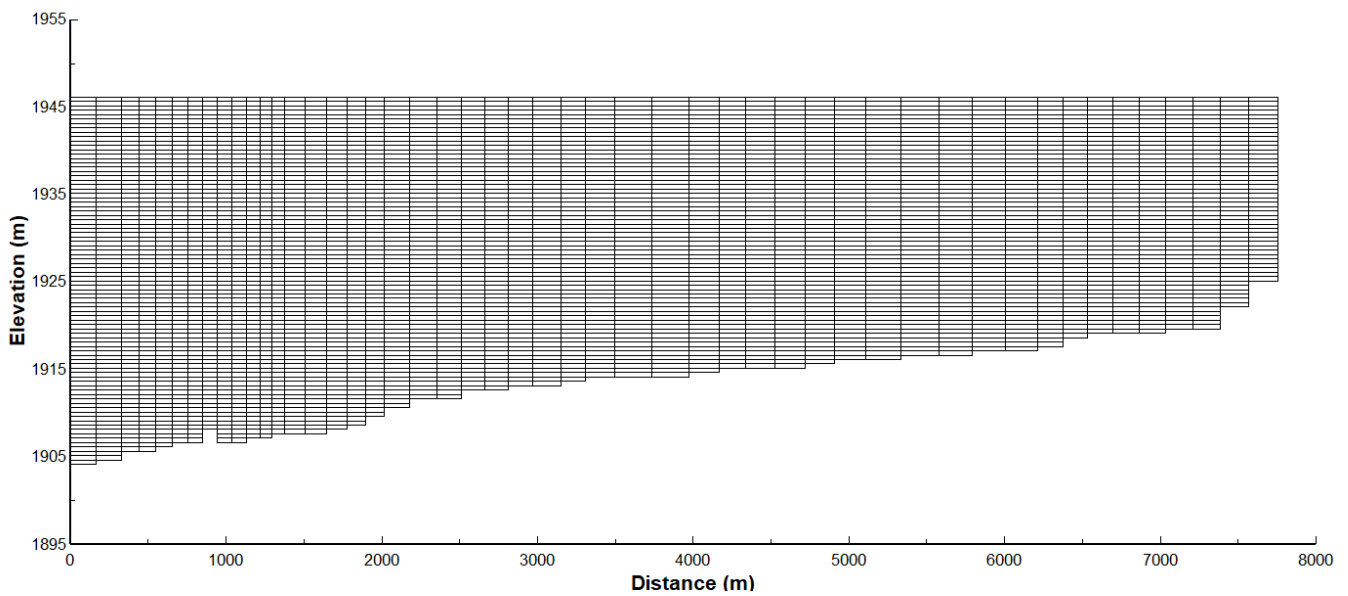


Figure 12. Island Park Reservoir, branch 2 vertical grid resolution (segments 102 to 150). Plotted distance measured from the furthest downstream segment (150), elevation set to AMSL.

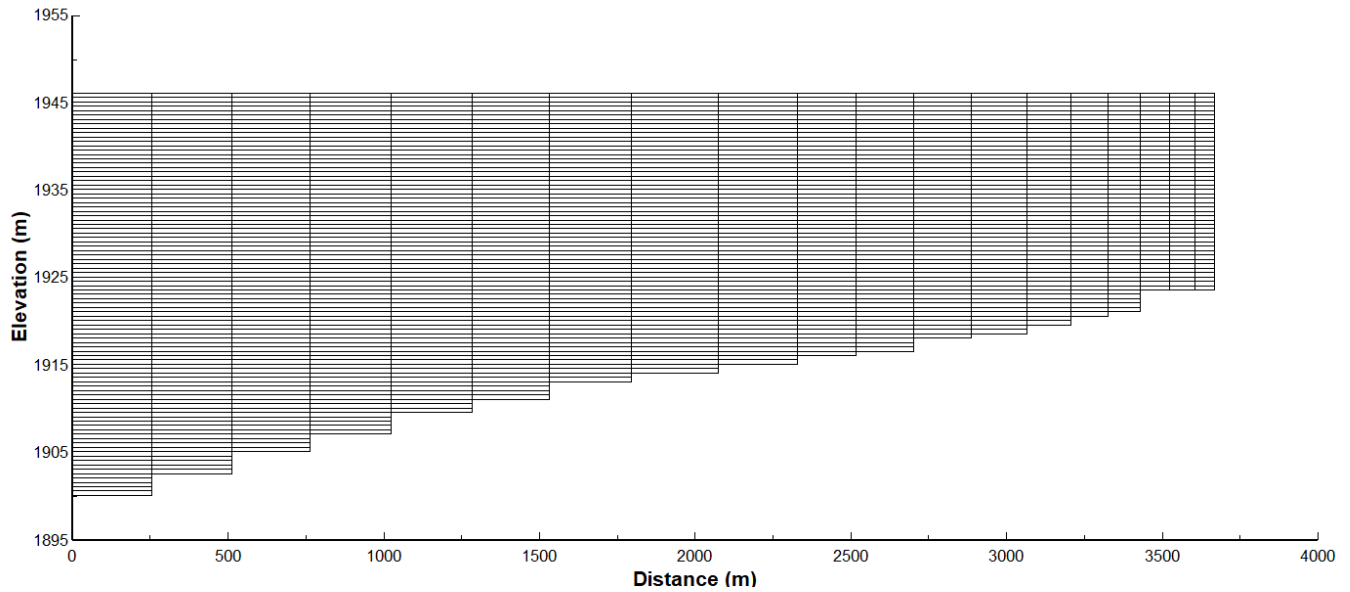


Figure 13. Island Park Reservoir, branch 3 vertical grid resolution (segments 153 to 171). Plotted distance measured from the furthest downstream segment (171), elevation set to AMSL.

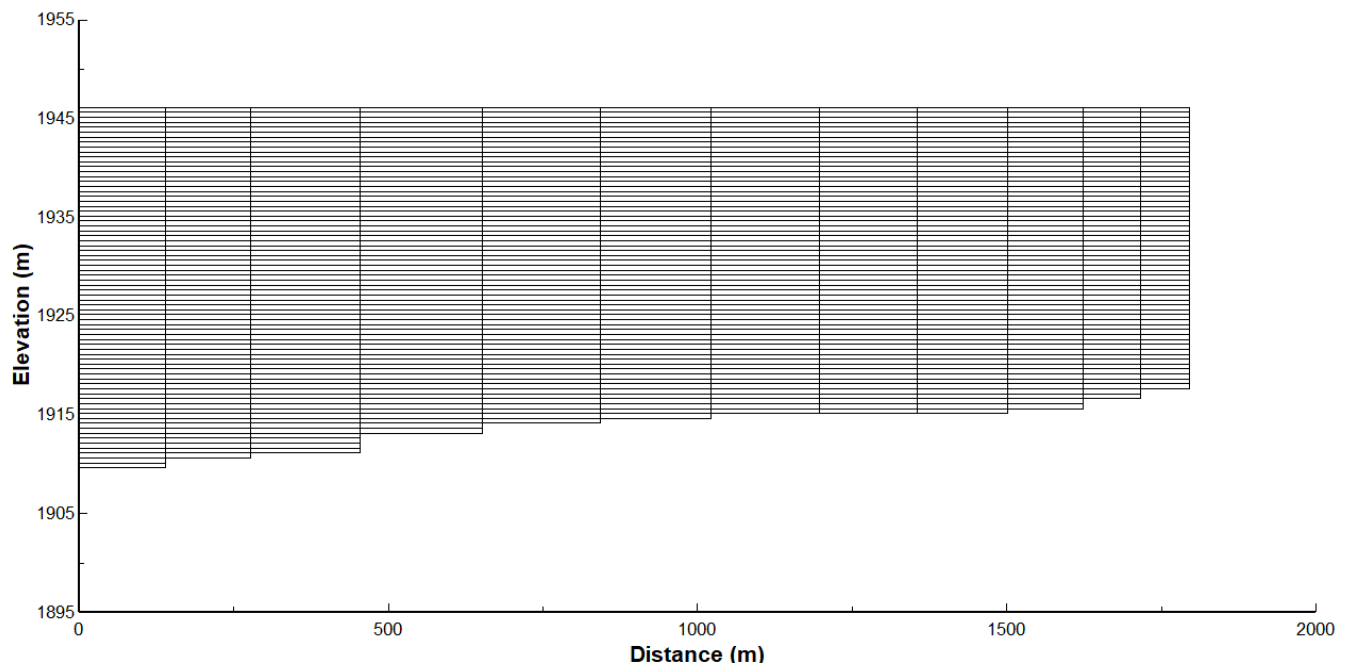


Figure 14. Island Park Reservoir, branch 4 vertical grid resolution (segments 174 to 185). Plotted distance measured from the furthest downstream segment (185), elevation set to AMSL.

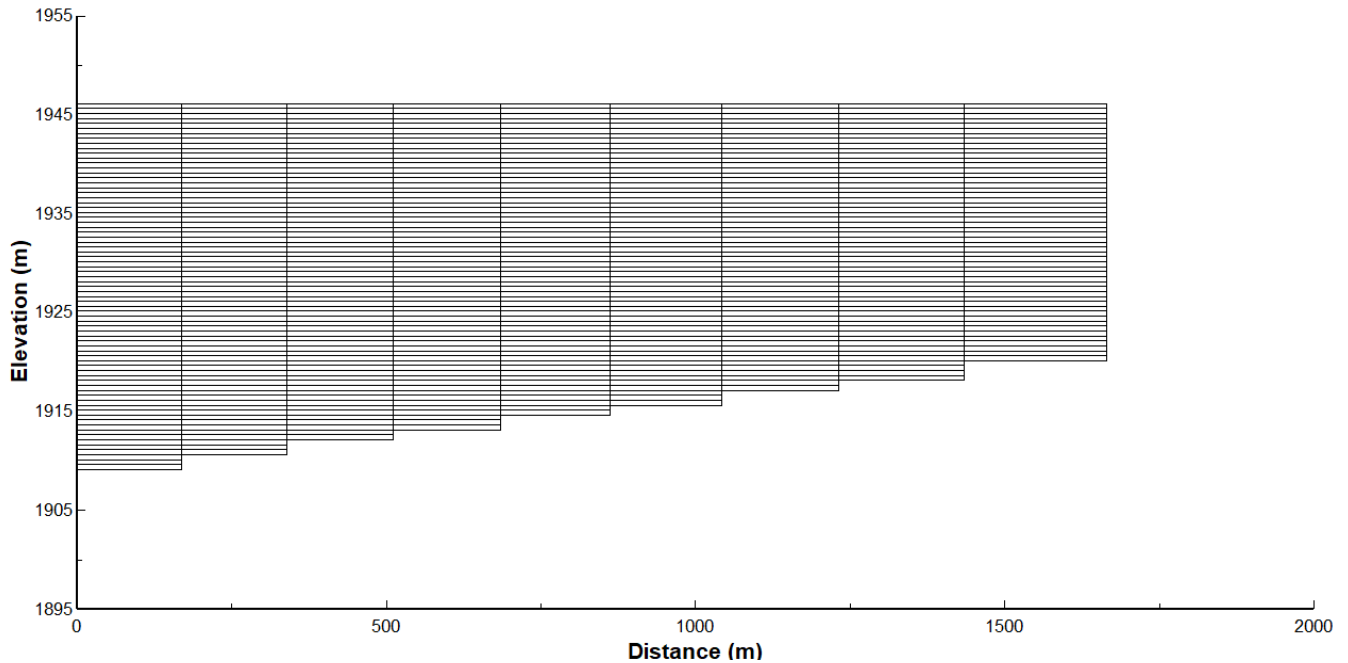


Figure 15. Island Park Reservoir, branch 5 vertical grid resolution (segments 188 to 196). Plotted distance measured from the furthest downstream segment (196), elevation set to AMSL.

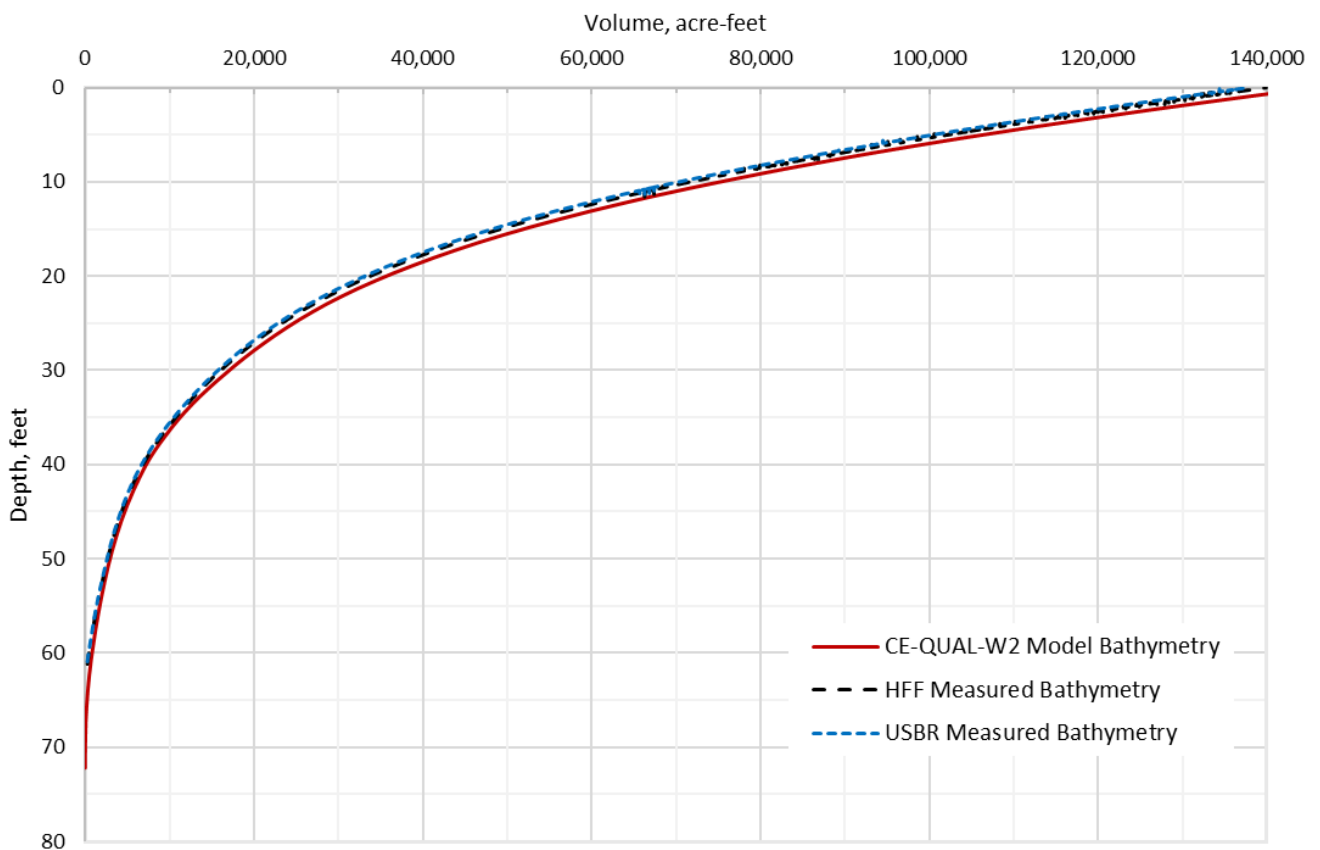


Figure 16. Comparison of derived volume-elevation curves for the modeled and simulated bathymetry of Island Park Reservoir.

Boundary Conditions

Hydrodynamic and temperature boundary conditions for the Island Park Reservoir model were derived from time series data provided by HFF and approximated from estimated annual spring flow. Figure 17 shows the location of modeled inflows and outflows along the reservoir. Table 5 describes how inflows were developed and added to the Island Park Reservoir model.

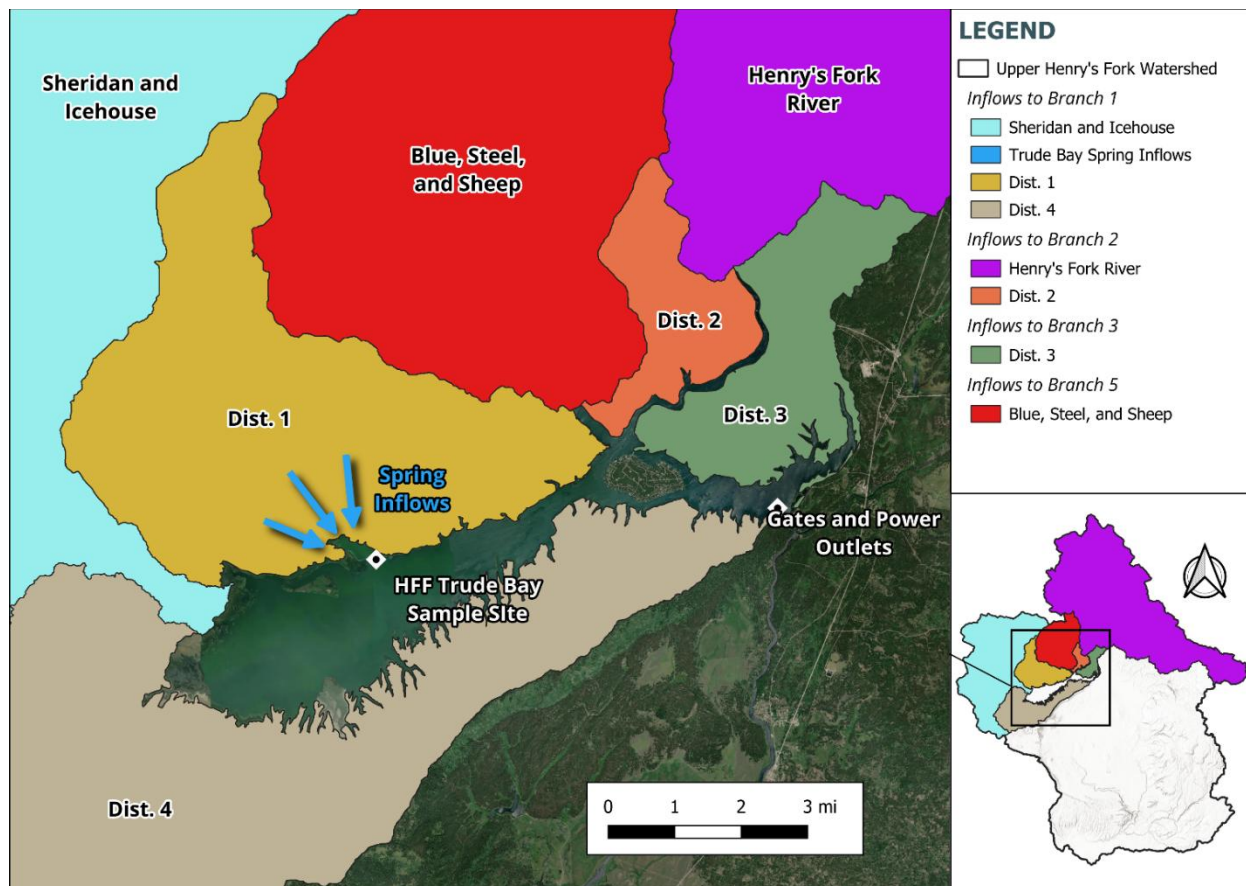


Figure 17. Inflows and outflows to the Island Park Reservoir CE-QUAL-W2 model.

Table 5. Inclusion of inflows in the Island Park Reservoir model.

Model Input	Sources of Inflow(s)	Drainage Area, km ² (% total)	Description
Tributary to branch 1	Spring inflows	n/a	Spring inflow, estimated from Zimmer (1981)
Distributed tributary to branch 1	Dist. 1, Dist. 4, Sheridan & Icehouse	455.4 (36.6%)	Inflow from multiple tributaries
Inflow to branch 2	Henry's Fork River	668.6 (53.7%)	Inflow from the Henry's Fork River
Distributed tributary to branch 2	Dist. 2	12.2 (1.0%)	Inflow from tributary
Distributed tributary to branch 3	Dist. 3	20.4 (1.6%)	Inflow from tributary
Inflow to branch 5	Blue, Steel & Sheep	89.1 (7.2%)	Inflow from tributary

Henry's Fork River

Time series of streamflow and temperature from the Henry's Fork River to the Island Park Reservoir were provided by the HFF. Figure 18 shows the time series of Henry's Fork River inflow for Branch 2 of the reservoir model based on daily hydrology estimates below the Coffee Pot rapids. Additional analysis was required to develop a representative water temperature time series for the Henry's Fork River inflow to the reservoir model.

The water temperature time series was constructed from measurements at HFF's Flat Rock monitoring site, which included 15-min data from March 29 to November 6, 2023 (Figure 19). Minor data gaps of 15 minutes to one hour were filled using linear interpolation. The March to November time period is the most critical for understanding and simulating water temperatures that may exceed the state's water quality standards. Since the model was being developed to simulate water temperatures between January 1 and December 31, 2023, data gaps were filled in the winter/spring and fall/winter, but these time periods are less critical to modeling and analysis, and therefore additional uncertainty may be acceptable. The overall approach is laid out in Table 6.

Table 6. Approach for developing the water temperature time series for the Henry's Fork River into Island Park Reservoir.

Time period	Approach	Justification
January 1 to February 16, 2023	Set to a fixed value of 3.7 °C. Based on Flat Rock water temperature data from February 16, 2018	Winter to early Spring 2018 followed a similar cold season to 2023.
February 16 – 19	Based on Flat Rock water temperature data in 2018	Winter to early Spring 2018 followed a similar cold season to 2023.
February 19 – March 15	Interpolated	
March 15 – 29	Based on Flat Rock water temperature data in 2018	Winter to early Spring 2018 followed a similar cold season to 2023.
March 29 to November 6, 2023	Flat Rock 2023 data	Available data
November 6 to December 4	Based on Flat Rock water temperature data in 2017	Late fall and early winter 2017 follow a similar cold season to 2023
December 4 to December 31	Interpolated with December 31 water temperature set at 3.7°C.	Late fall and early winter 2017 follow a similar cold season to 2023

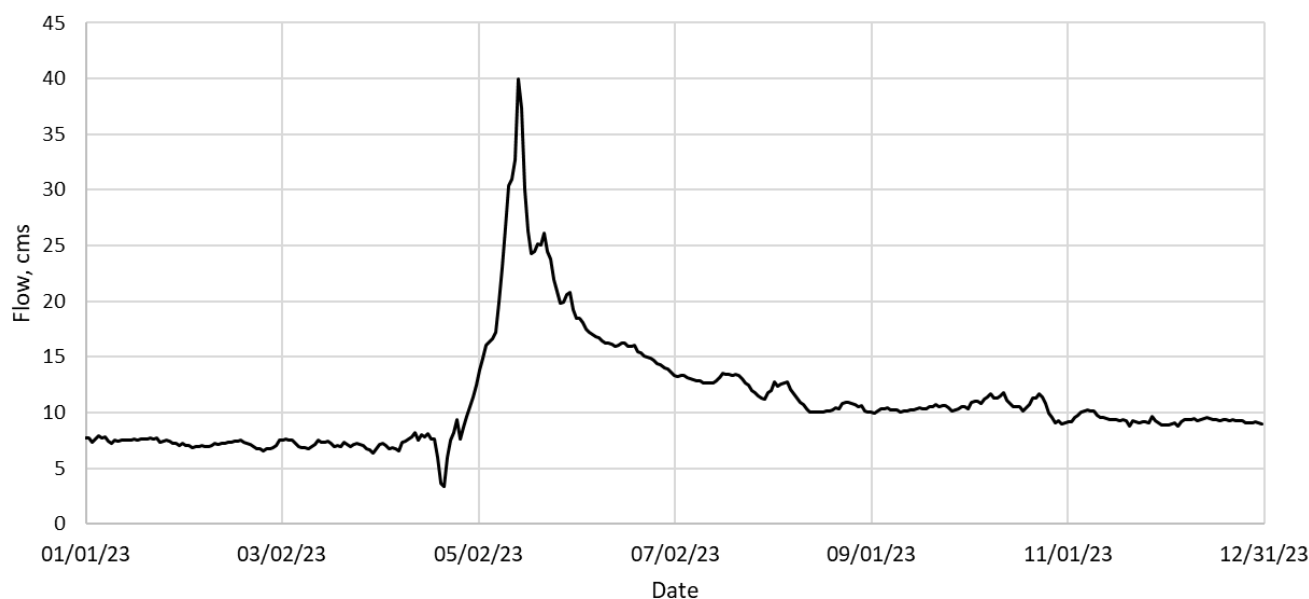


Figure 18. Inflow from the Henry's Fork River to the Island Park Reservoir model.

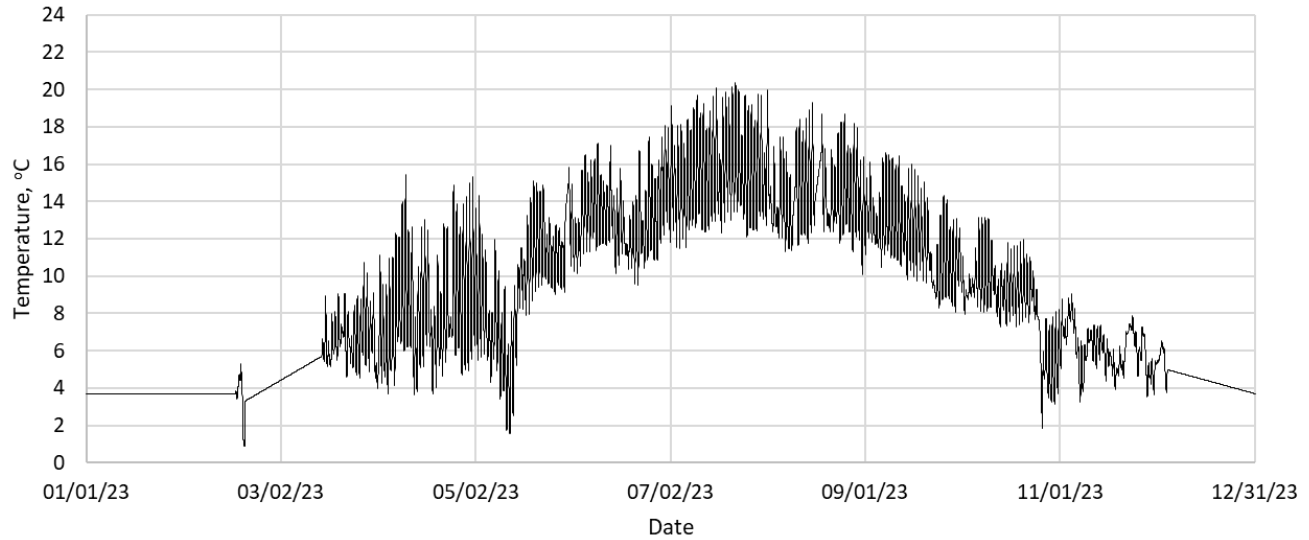


Figure 19. Temperature of Henry's Fork River inflow to the Island Park Reservoir model.

Seeps and Groundwater

Groundwater inflows were added to the reservoir model as a tributary to Trude Bay, an approximately 0.35 km² limb of the water body (Figure 17) corresponding to model Segment 28. HFF measurements of reservoir temperatures in Trude Bay indicate the presence of a thermal signal in the lowest three (3) meters of the reservoir (Figure 20). To capture this localized and vertically limited inflow, the elevations of the modeled tributary inflow were set to the lowest depth of the model grid at segment 28 (1,911.9 m, AMSL) and three (3) meters above the bottom elevation of the HFF measurement site (at 1,916 m, AMSL).

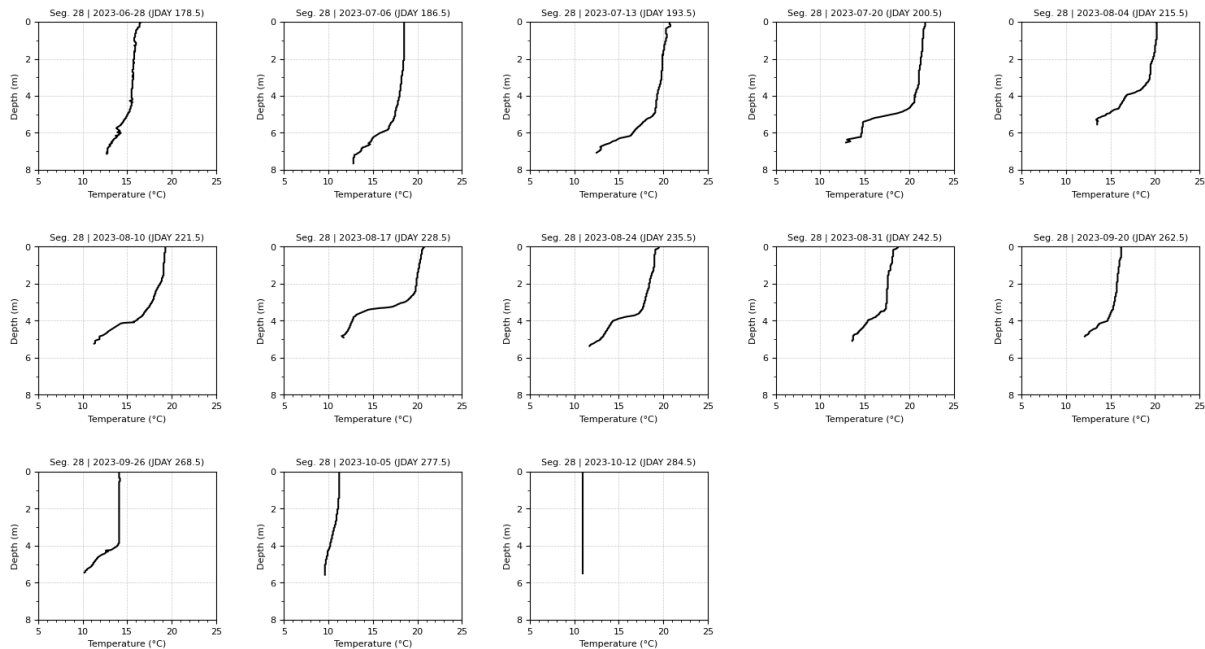


Figure 20. Observed vertical temperature profiles in Trude Bay, a limb of the Island Park Reservoir. Data provided by HFF.

Spring inflow temperature was set at a constant 11.3 °C, the average bottom depth temperature of the reservoir at Trude Bay between 2021 and 2023. Table 7 presents the summary statistics of HFF measured Trude Bay bottom temperature. Continual temperature measurements at the location of known Island Park Reservoir springs may be used in later iterations of the model to better represent and constrain spring flow temperatures.

Table 7. Summary statistics of HFF observed bottom depth temperature in Trude Bay between 2021 and 2023. HFF measurements of Trude Bay temperature were annually collected between late May and early November.

Year	Temperature, °C		
	Min	Max	Average
2021	5.9	14.5	10.5
2022	7.3	18.1	11.3
2023	9.6	13.6	11.9
All years	5.9	18.1	11.3

The volume of spring inflow entering Trude Bay was approximated using a sinusoidal function to better represent seasonal variations in flow:

$$Q(t) = Q_{avg} + \Delta Q \cdot \sin\left(\frac{2\pi(t - (t_{peak} + 0.25T))}{T}\right),$$

where,

- $Q(t)$ is the flow (cms) at time t (Julian day),
- Q_{avg} is the average flow (cms) between time t_0 and t_n (Julian day),
- ΔQ is the amplitude of seasonal variations in flow (cms),
- t_{peak} is the date of the peak flow (Julian day) between t_0 and t_n , and
- T is the period of the sinusoidal function ($t_n - t_0$, days).

Groundwater seepage was approximated to contribute $12.1 \times 10^6 \text{ m}^3$ (9,800 acre-feet) of water to the reservoir during the late summer drawn down of the water body in the 1930s for construction of the Island Park Dam (Zimmer, 1981). However, the duration of the draw down is unknown, preventing an estimate of the groundwater flow rate to the reservoir and hindering a comparison to the selected value for Q_{avg} .

Q_{avg} and t_{peak} were therefore set to better predict observed temperatures in the lowest three (3) meters of Trude Bay. Q_{avg} was approximated as 0.5 cms and t_{peak} was set to 134, the Julian date corresponding to May 15, 2023. ΔQ was assumed to be 40% of Q_{avg} (0.2 cms) and T was set to one year (365 days). Figure 21 shows the resultant time series of spring inflow added to the model.

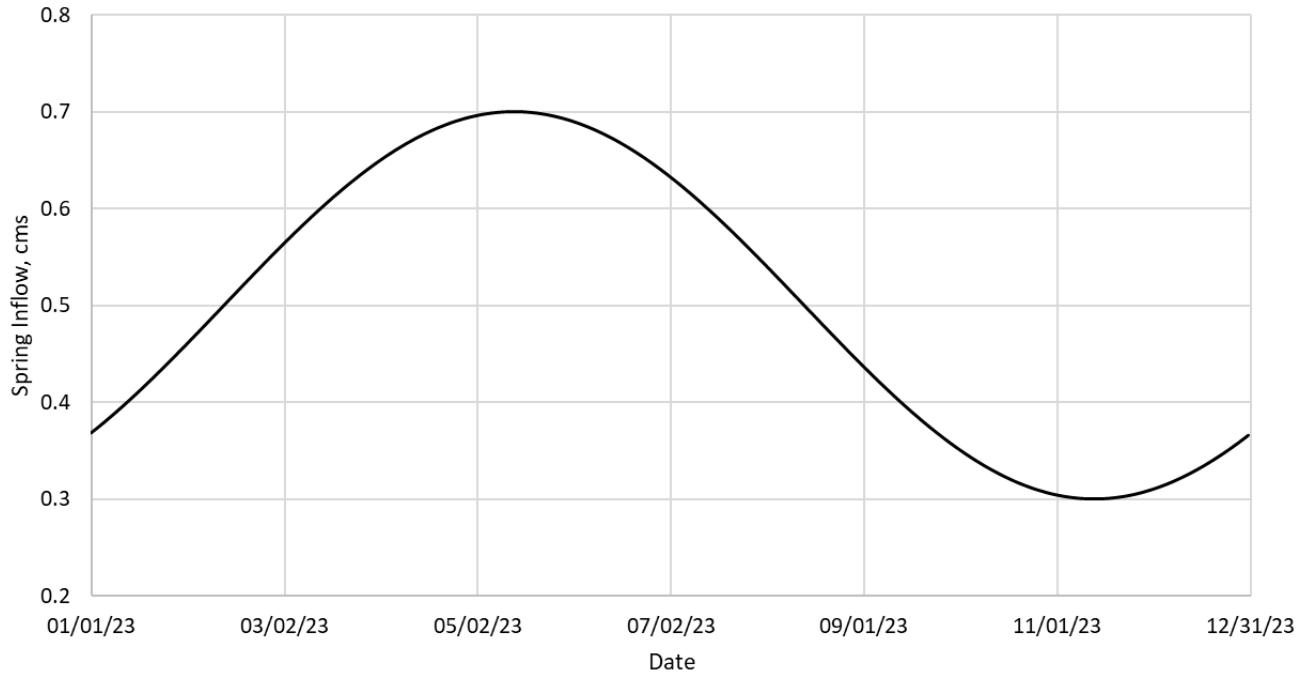


Figure 21. Spring inflow in the Island Park Reservoir model.

Proportioning of Tributary Inflows

HFF provided time series of total tributary inflow to the Island Park Reservoir between October 1, 1977 and April 14, 2024. Total tributary flow to the reservoir in 2023 was divided between individual tributaries according to their relative drainage area, with the drainage area of each tributary calculated using the USGS StreamStats application (USGS StreamStats 2025). The drainage area of each tributary and fraction of the total drainage area used to proportion inflow is presented in Table 8. Time series of the resultant inflows to each branch are shown in Figure 22.

Table 8. Portioning of tributary flows provided by HFF between drainage areas.

Tributary	Drainage Area, km ² (mi ²)	% of Total Drainage Area (excluding Henry's Fork)
Distributed Tributary 1 (Dist. 1)	66.0 (25.5)	5.3%
Distributed Tributary 2 (Dist. 2)	12.2 (4.7)	1.0%
Distributed Tributary 3 (Dist. 3)	20.4 (7.9)	1.6%
Distributed Tributary 4 (Dist. 4)	99.2 (38.3)	8.0%
Sheridan and Icehouse	290.2 (112.0)	23.23%
Blue, Steel, and Sheep	89.1 (34.4)	7.2%
Total (excluding Henry's Fork River)	577.2 (222.8)	

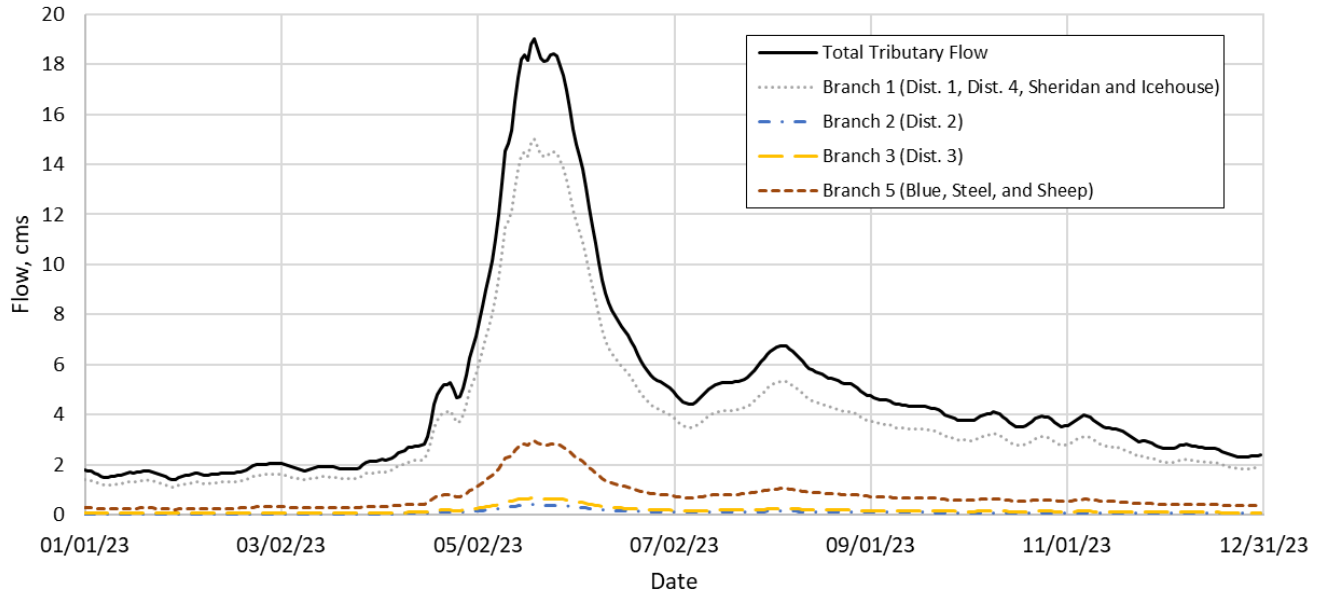


Figure 22. Portioning of tributary flows by model branch. Henry's Fork River inflow is not depicted.

Branch inflow temperatures were derived from Sheridan Creek temperature measurements collected by HFF between 2001 and 2008. The provided data was averaged by Julian date to create an approximate annual time series of the water temperature entering the reservoir from the inflow streams and distributed tributaries. Figure 23 shows the hourly-averaged Sheridan Creek temperature time series used to represent the water temperature of inflows in the reservoir model.

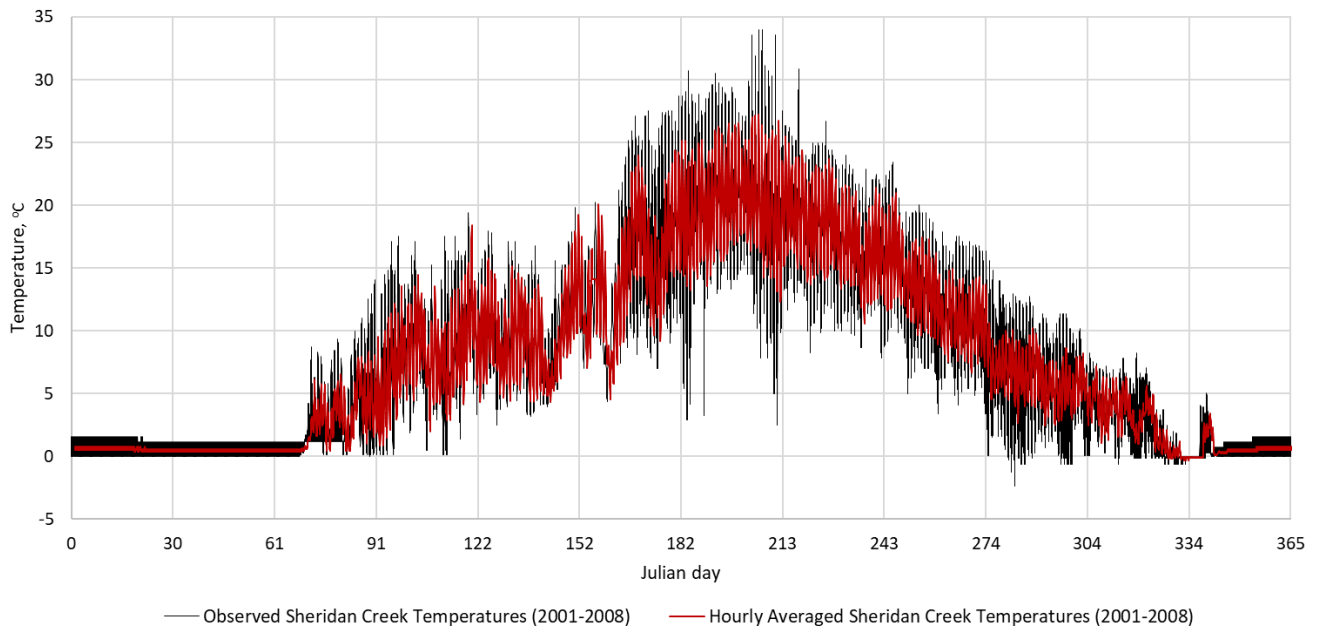


Figure 23. Island Park Reservoir model hourly inflow temperatures (branches 2, 3, and 5) derived from HFF measurements of Sheridan Creek.

Withdrawals

Water leaves the Island Park Reservoir through a spillway and two outlet structures located at Island Park Dam (Segment 99; Figure 17). The spillway only passes water out of the reservoir when the elevation exceeds 1,922.74 m AMSL. The outlet structures, hereafter referenced to as “Power” and “Gates”, are respectively operated by the Fall River Rural Electric Cooperative (FRREC) and USBR. The FRREC Power outlet consists of eight (8) gates situated on either side of four (4) “T”-shaped structures. The USBR Gates outlet consists of four (4) square gates located in series. Table 9 details the specifications of the outlet structures. The schematics for the FRREC Power and USBR gates structures are depicted in Figure 24.

Table 9. FRREC and USBR gate elevations and diameter. Shaded cells represent parameters used to develop the FRREC and USBR structures in the Island Park Reservoir model. Elevation measured above mean sea level (AMSL).

Owner	Gate No.	Elevation of Gate Center, m (ft)	Gate Dimensions, m (ft)
FRREC	1-2	1,902.13 (6,240.60)	Round, $\phi = 2.13$ (7)
FRREC	3-4	1,901.07 (6,237.10)	Round, $\phi = 2.13$ (7)
FRREC	5-6	1,899.97 (6,233.50)	Round, $\phi = 2.13$ (7)
FRREC	7-8	1,898.90 (6,230.00)	Round, $\phi = 2.13$ (7)
FRREC (average)	1-8	1,900.52 (6,235.30)	Round, $\phi = 2.13$ (7)
USBR	1-4	1,898.90 (6,230.00)*	Square, 1.52 (5) x 1.83 (6)

* The elevation of the USBR Gates withdrawal was set to 1899.9 m AMSL to raise the withdrawal elevation above the maximum depth of the model grid at segment 99 (1899.404 m AMSL).

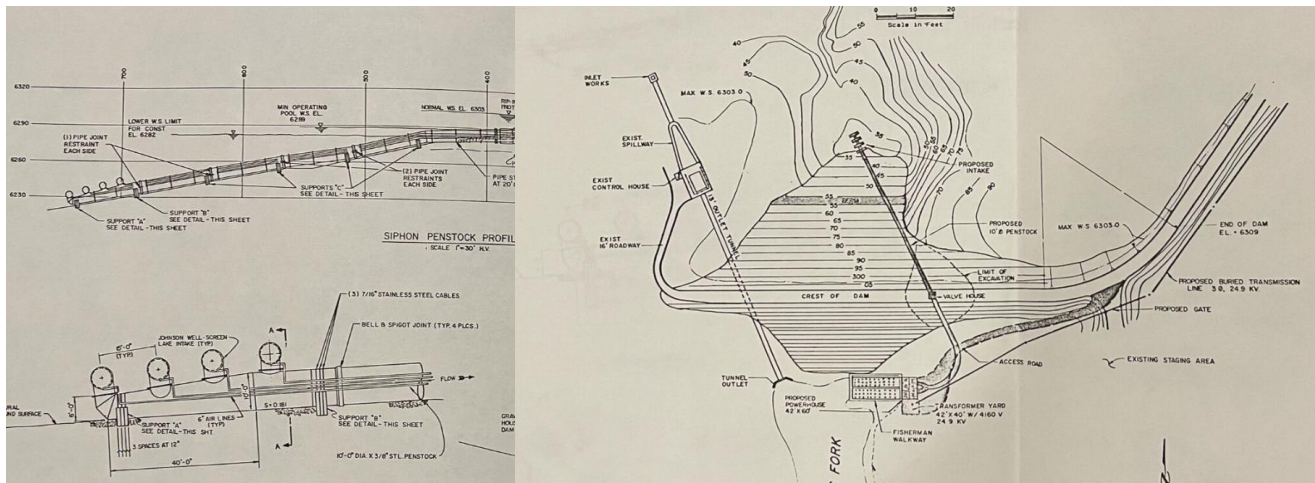


Figure 24. Schematics of outlet gates withdrawing water from the Island Park Reservoir.

HFF provided time series of the respective outflows through each structure between October 1, 1977 and April 14, 2024. However, the provided outflow data does not support flow partitioning through individual pipes or distinct elevations for each outlet structure. The elevation of modeled FRREC and USBR withdrawals were therefore set to the average elevation of the USBR and FRREC structures, respectively (Table 9). Figure 25 depicts the time series of the withdrawals from the FRREC and USBR structures over the model duration.

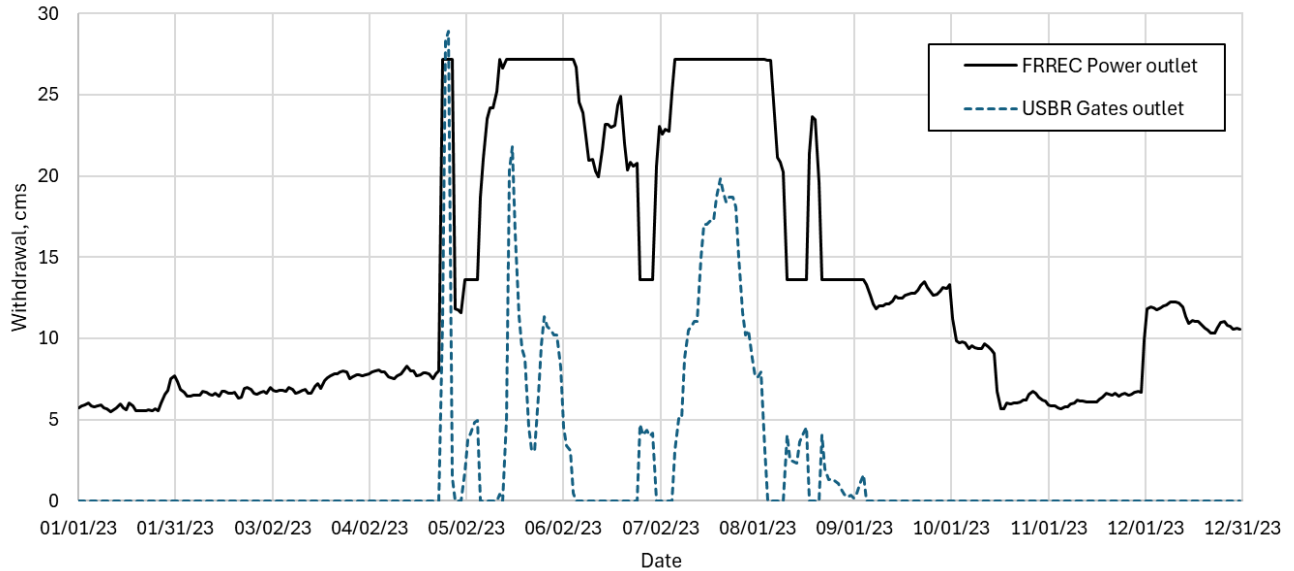


Figure 25. Island Park Reservoir withdrawals through the FRREC Power and USBR Gates structures.

Shading

The Island Park Reservoir is surrounded by moderate slopes that result in limited or no shading of the water surface. Tree cover is considerable around the reservoir and may result in some shading of the bank. However, tree shading was not included in the model due to the lack of data defining tree height, density, and attenuation of incoming solar radiation along the reservoir. Given the large surface area of the reservoir relative to the amount of tree shade possible, this is expected to have little impact on the model's water temperature predictions.

Precipitation

Hourly measurements of precipitation at NRCS SNOTEL site 546, located near Island Park, Idaho, were used to approximate precipitation on the Island Park Reservoir model water surface. The temperature of precipitation was set to air temperature (as measured at SNOTEL sites 546 and 860). Figure 26 shows the precipitation used in the reservoir model.

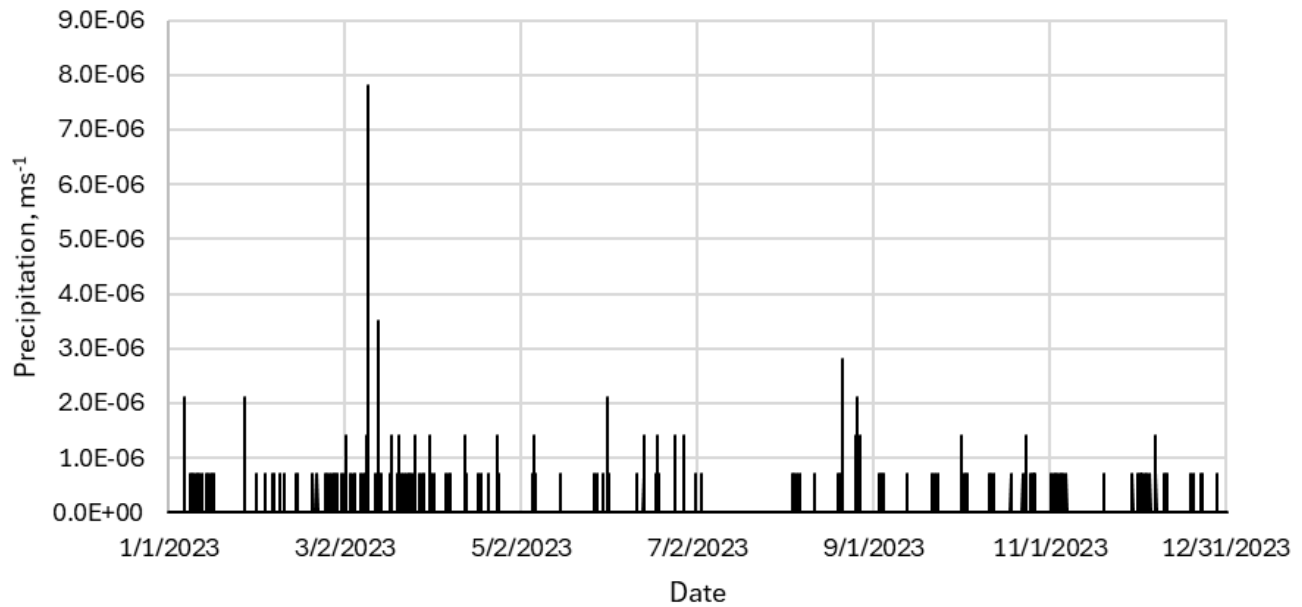


Figure 26. Precipitation in the Island Park Reservoir model.

Henry's Fork River

The hydrodynamics and temperature of the Henry's Fork River downstream of Island Park Dam (RM 91) to the confluence of the Henry's Fork River and Thurmon Creek (RM 81.3) is influenced by Island Park Dam operations and spring and surface water inflows. The modeled river reach drains 1,944.5 km² (604.1 mi²) of the Upper Henry's Fork subbasin located in eastern Idaho.

Bathymetry Data

The model grid was developed from cross-sections of the Henry's Fork River collected in May of 2024. Figure 27 shows the location of the 40 cross-sections used to develop the model grid. Figure 28 shows two example cross-sections of the Henry's Fork River derived from field measurements. The cross sections were used in combination with USGS DEM data of the shore lines to develop the W2 model grid.



Figure 27. Locations of Henry's Fork River cross-sections (white) used to develop the model bathymetry.

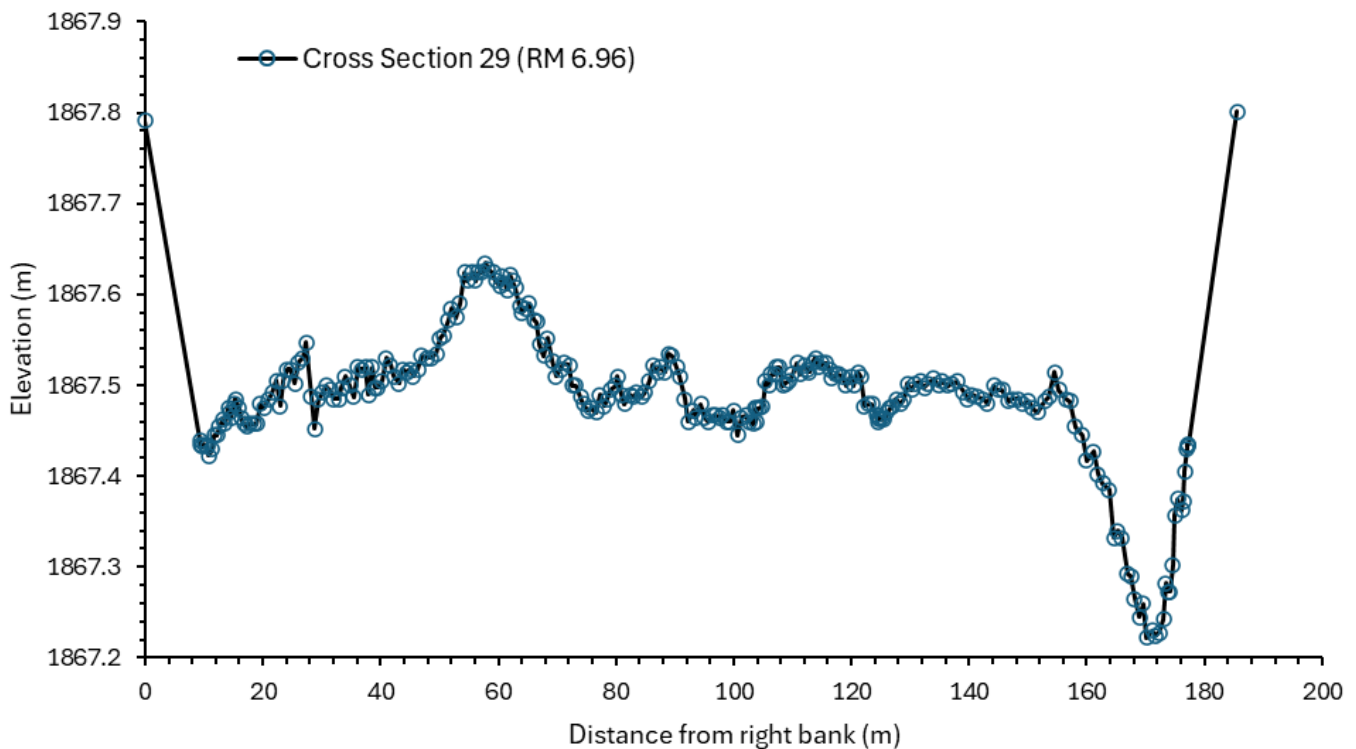
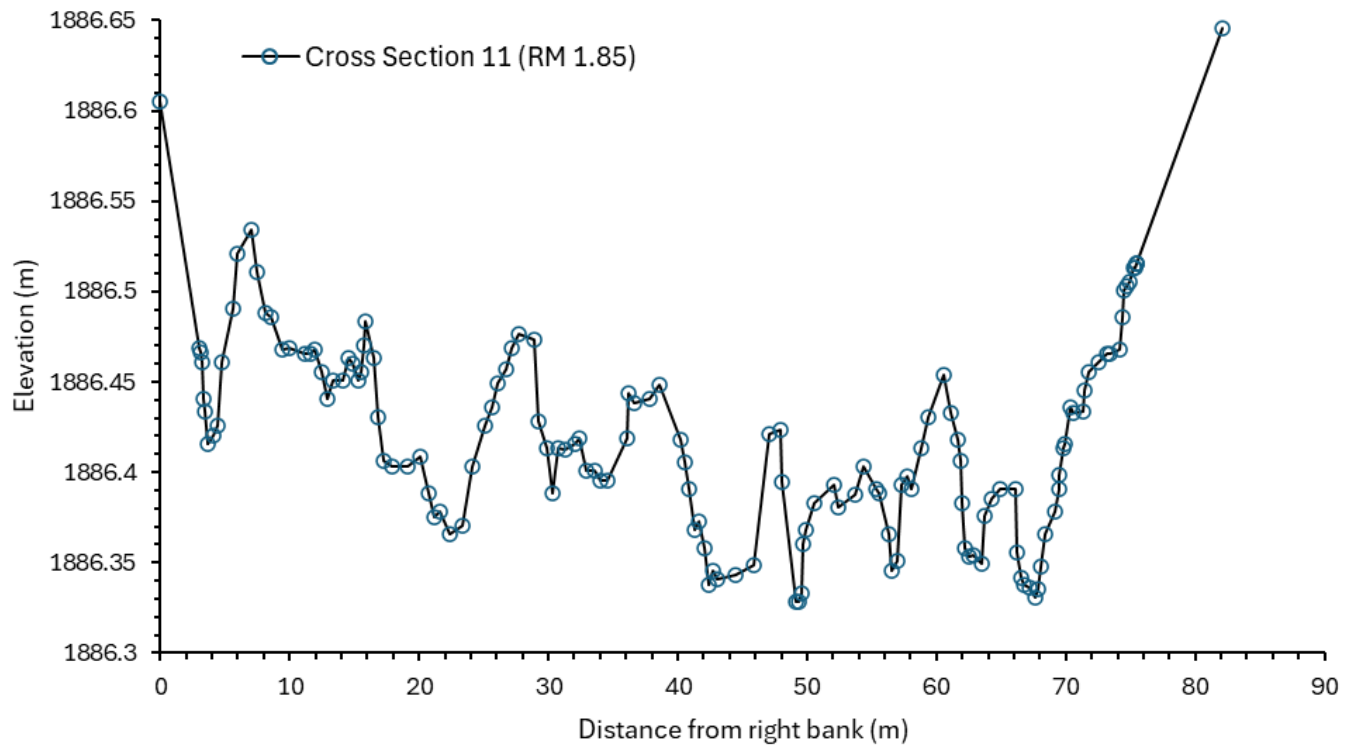


Figure 28. Measured Henry's Fork River cross-sections at RM 1.85 miles downstream (RM 89.15) and RM 6.96 miles downstream (RM 84.04).

Bathymetric data in the Henry's Fork River between RM 91 and RM 81.3 was collected using a Teledyne Marine acoustic doppler current profiler (ADCP) and a Juniper Systems Geode GNSS device by the HFF. A pair of transects were collected at each cross-section, and collected data was processed and output using the WinRiver II software. Each channel cross section was used to develop individual model grid segments for CE-QUAL-W2 and the adjacent DEM data was used to "pin down" each cross section relative to the shoreline as shown in Figure 29.

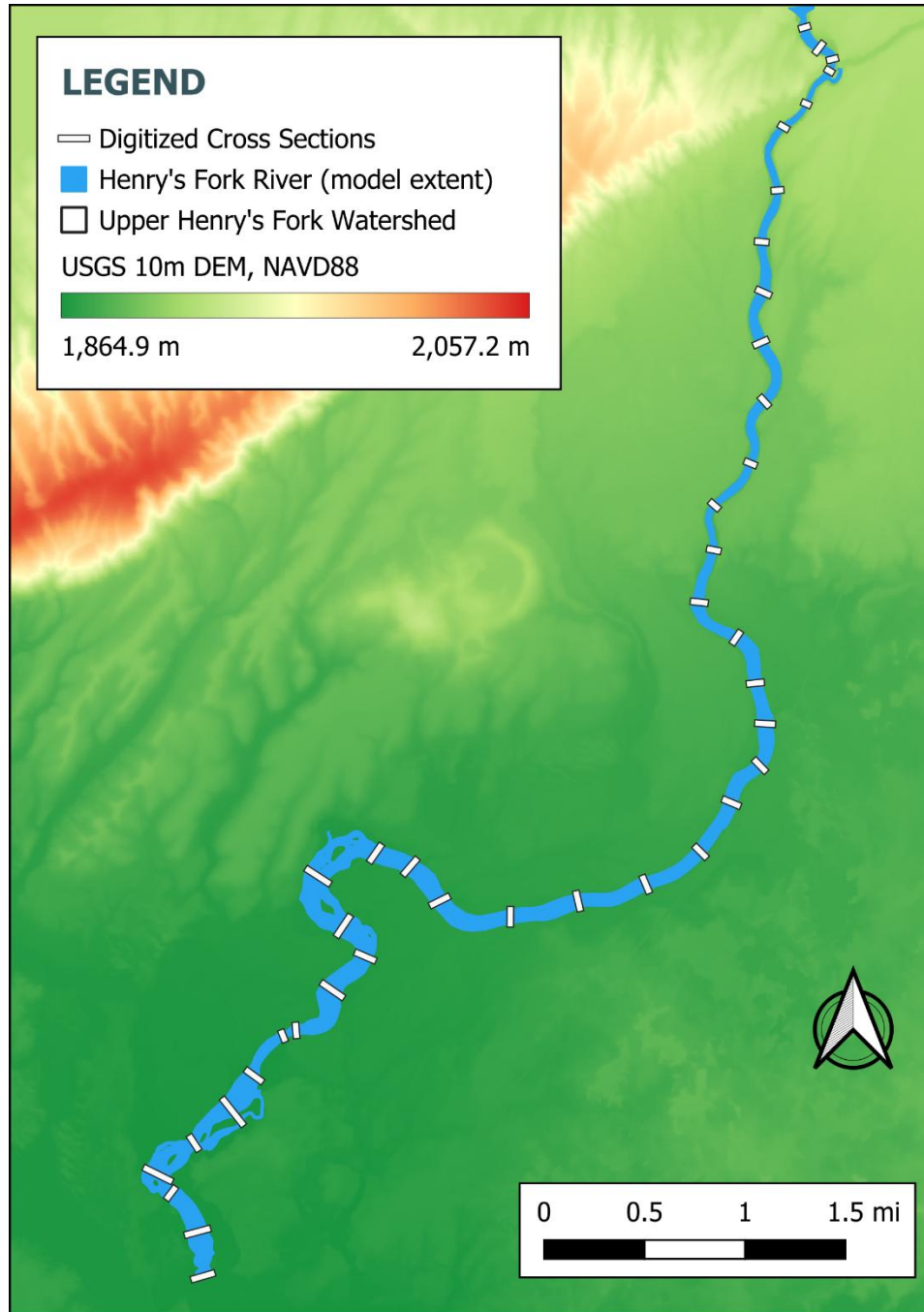


Figure 29. Henry's Fork River channel cross section and surrounding DEM information.

Model Grid Development

Using the river cross sections and the bathymetric contour plots discussed above, the model grid was developed for the Henry's Fork River. Figure 30 shows the resulting elevation longitudinal profile of the Henry's Fork River for the model grid and the river cross section bathymetry.

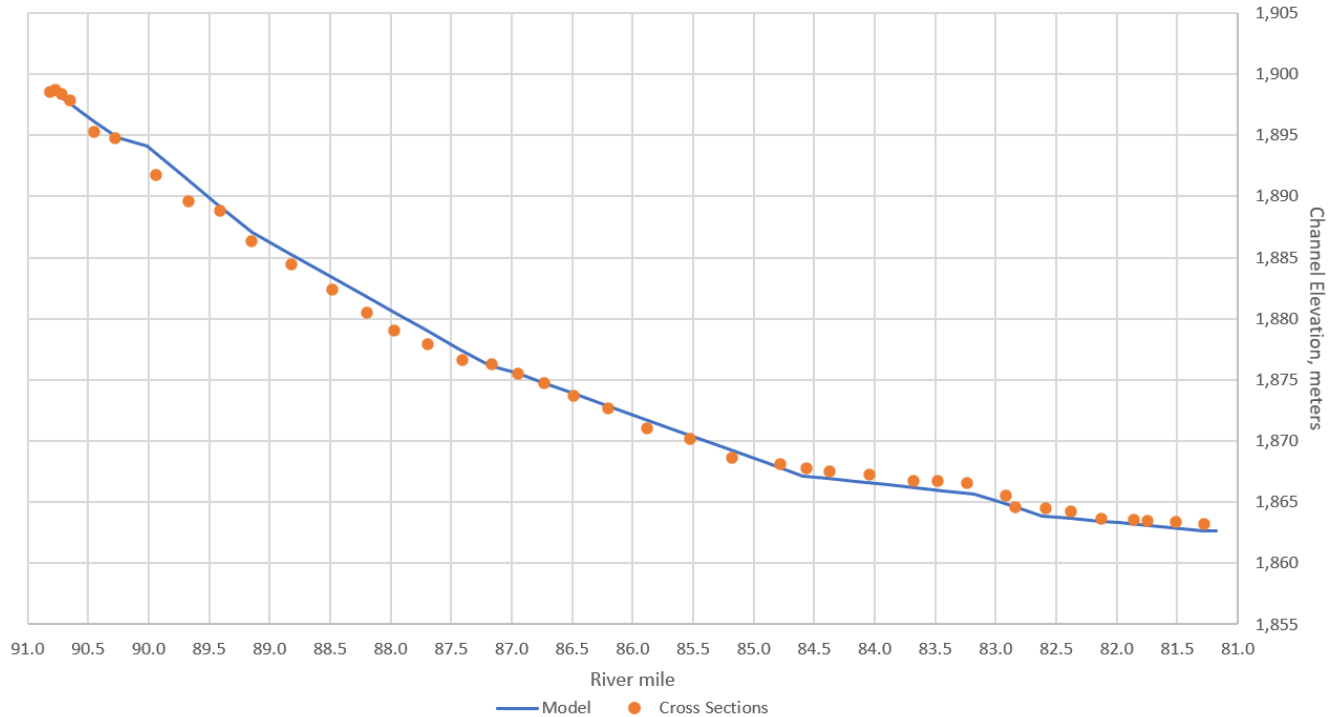


Figure 30. Henry's Fork River elevation longitudinal profile from RM 91 to RM 81.3.

Table 10 lists the model grid characteristics and boundary conditions for each branch. Figure 31 through Figure 37 show the model vertical resolution for each branch. The model vertical resolution varies; the bottom two layers have a vertical resolution of 0.25 m each and the overlying eight layers have a vertical resolution of 0.5 m each.

Table 10. Layout of the Henry's Fork River model grid.

Branch/ Waterbody	Upstream Segment	Downstream Segment	Slope	Average Segment Length, m	Branch Length, km	Branch Length, mi
1	2	6	0.44%	213.2	1.07	0.66
2	9	11	0.51%	457.7	1.37	0.85
3	14	21	0.34%	456.6	3.65	2.27
4	24	31	0.22%	471.6	3.77	2.34
5	34	39	0.06%	372.8	2.24	1.39
6	42	44	0.20%	321.7	0.97	0.60
7	47	53	0.06%	354.4	2.48	1.54
Total					15.55	9.66

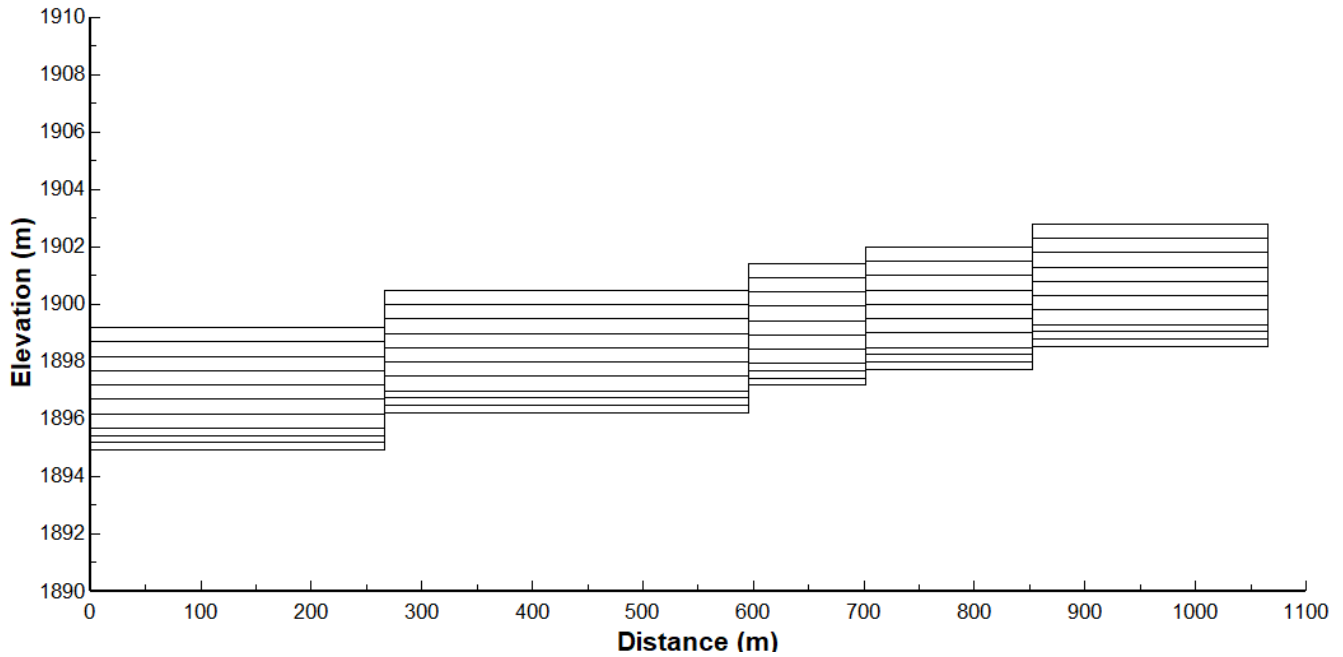


Figure 31. Henry's Fork River, Branch 1 vertical grid resolution (segments 2 to 6). Plotted distance measured from the furthest downstream segment (6), elevation reference is AMSL.

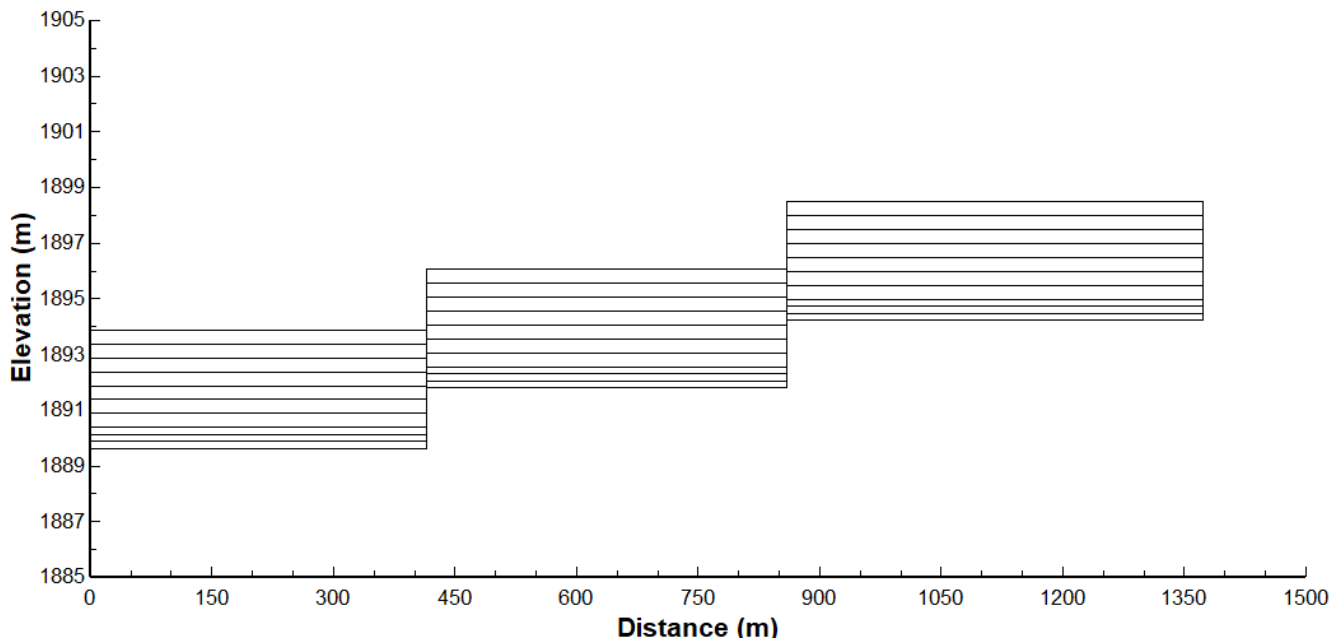


Figure 32. Henry's Fork River, Branch 2 vertical grid resolution (segments 9 to 11). Plotted distance measured from the furthest downstream segment (11), elevation reference is AMSL.

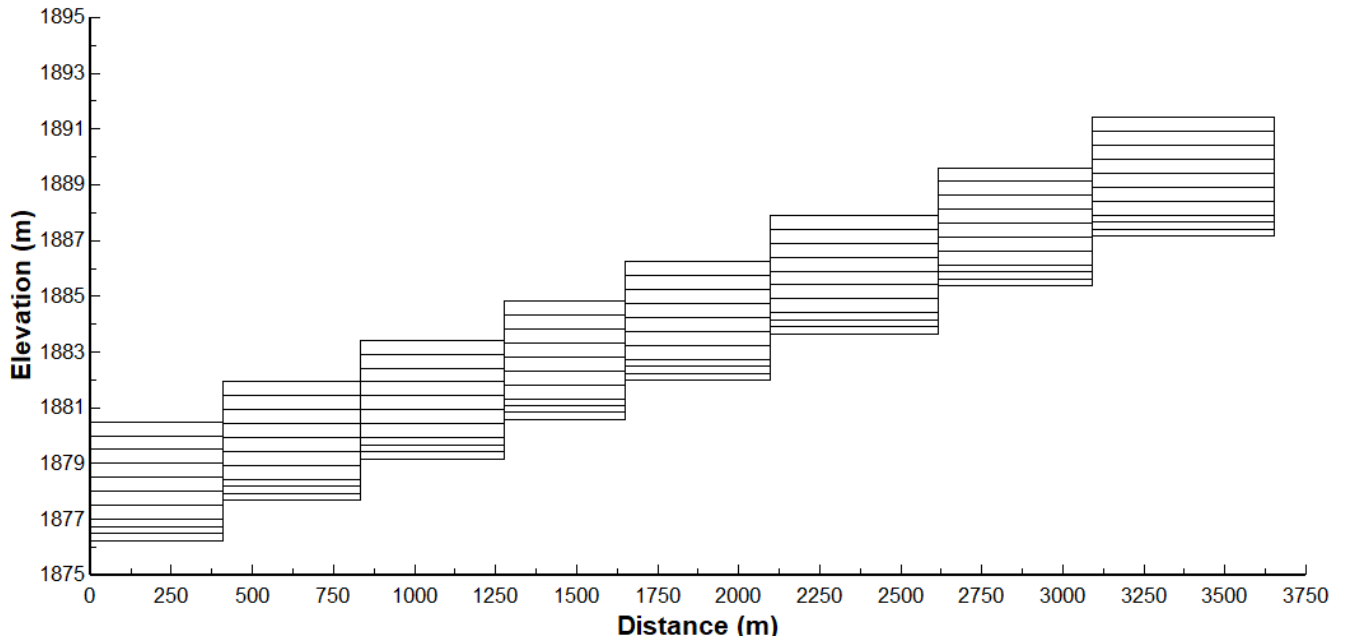


Figure 33. Henry's Fork River, Branch 3 vertical grid resolution (segments 14 to 21). Plotted distance measured from the furthest downstream segment (21), elevation reference is AMSL.

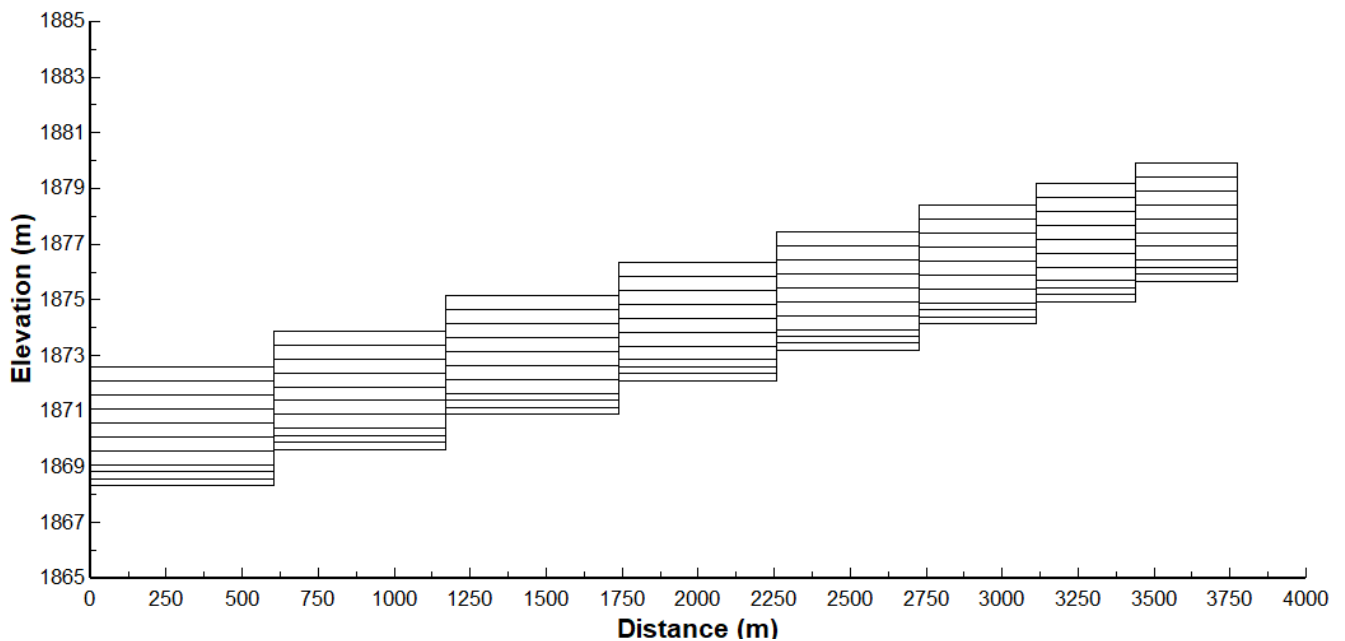


Figure 34. Henry's Fork River, Branch 4 vertical grid resolution (segments 24 to 31). Plotted distance measured from the furthest downstream segment (31), elevation reference is AMSL.

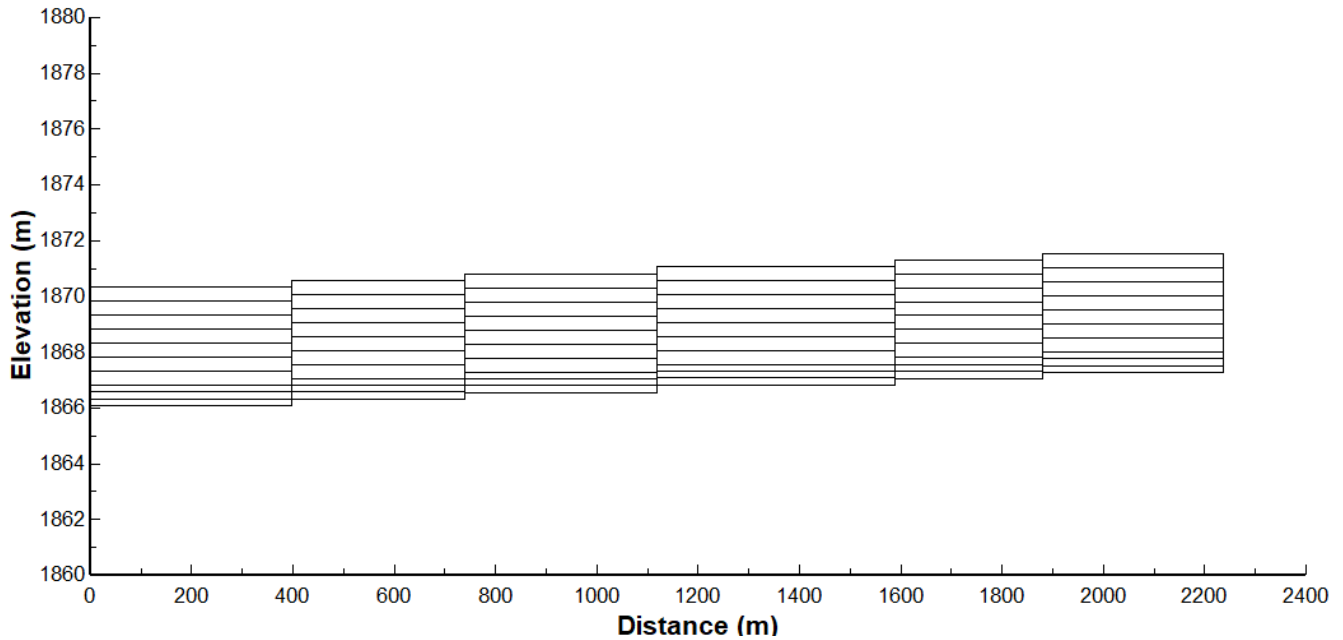


Figure 35. Henry's Fork River, Branch 5 vertical grid resolution (segments 35 to 39). Plotted distance measured from the furthest downstream segment (35), elevation reference is AMSL.

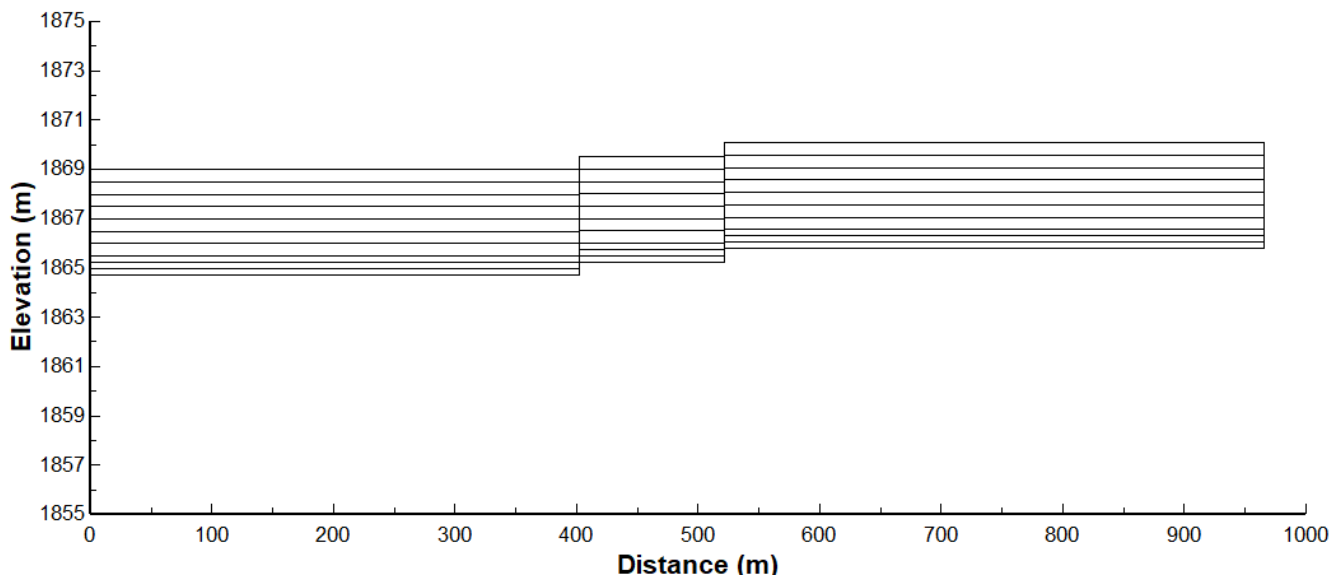


Figure 36. Henry's Fork River, Branch 6 vertical grid resolution (segments 42 to 44). Plotted distance measured from the furthest downstream segment (44), elevation reference is AMSL.

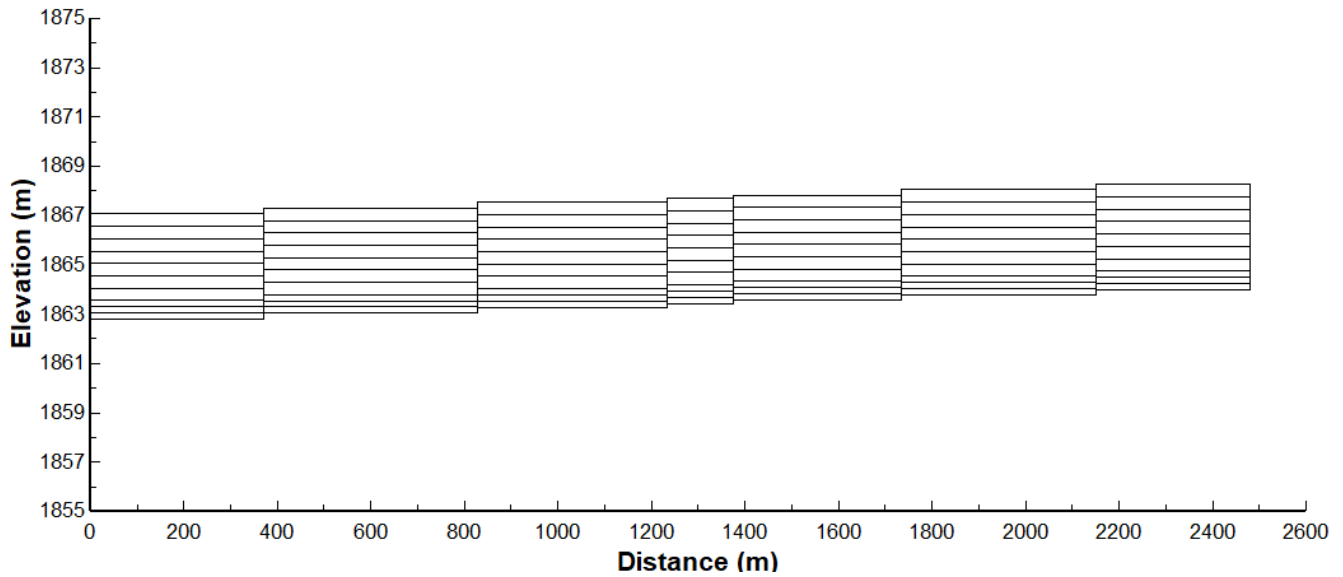


Figure 37. Henry's Fork River, Branch 7 vertical grid resolution (segments 47 to 53). Plotted distance measured from the furthest downstream segment (53), elevation reference is AMSL.

Boundary conditions – upstream and downstream

Flow and Water Temperature

The upstream boundary condition for the Henry's Fork River model was based on 15-min hydrodynamic data from the USGS gage station located on the Henry's Fork River below Island Park Dam (USGS 13042500). Figure 38 shows the time series of outflow from the Island Park Reservoir used as the upstream boundary conditions for the Henry's Fork River. The water temperature boundary conditions for the model were developed using the same USGS gage station. Figure 39 shows the water temperature time series for the upstream boundary condition for the Henry's Fork River.

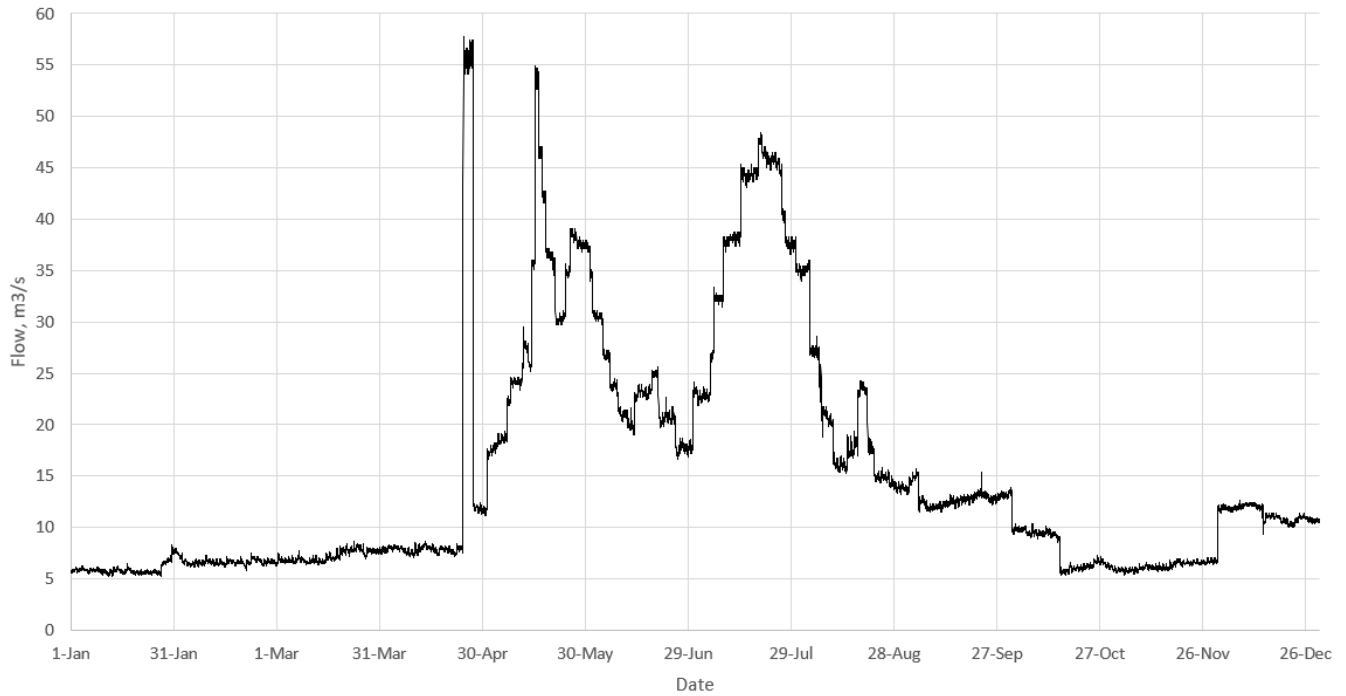


Figure 38. Henry Fork River upstream boundary condition flows, 2023.

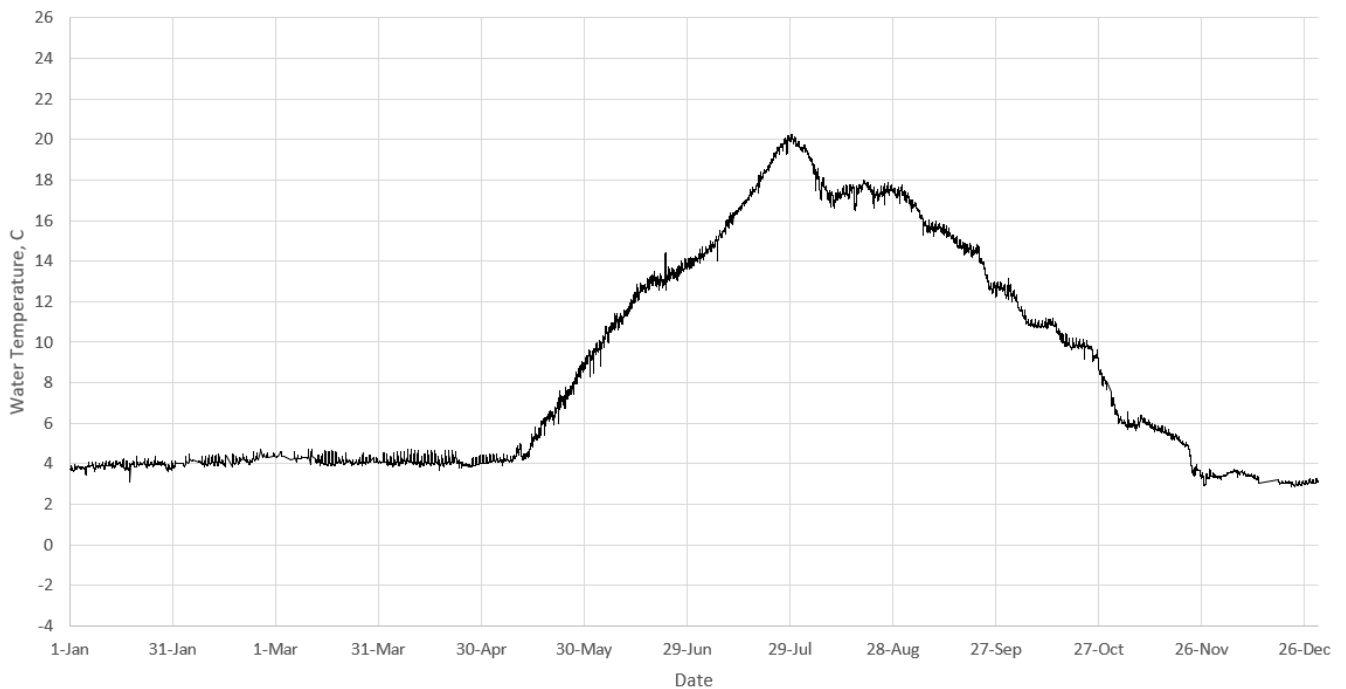


Figure 39. Henry Fork River upstream boundary condition water temperature, 2023.

Tributaries

The river model includes 9.66 miles of the Henry's Fork River. Along the river reach, the river gains inflow from Buffalo River and small tributaries and springs. Thurmon Creek enters the Henry's Fork River just below the end of the model grid domain and is therefore not included in the model. There are additional small tributaries and springs along this river reach but with limited or no flow data. Contributing flow from these sources was estimated during the calibration process and represented as a distributed tributary in the various branches in the model (discussed below). The locations of the two key tributaries along the Henry's River are shown in Figure 27.

Buffalo River

The Buffalo River enters the Henry's Fork River just below the Island Park Reservoir at RM 90.66 (Segment 3). Streamflow in the Buffalo River is relatively unregulated; limited USGS flow measurements were collected between 1935 and 1941 from a since decommissioned flow gage (ID: 13043000). From January 1, 2006, to April 8, 2022, daily river stage was recorded by the FRREC. The HFF calculated discharge using the USGS rating curve at the decommissioned gage with stage measurements to calculate discharge from 2006 to August 10, 2016. On April 9, 2022, HFF installed a pressure transducer in the Buffalo River and established a new rating curve. Figure 40 shows the daily average flows from the Buffalo River to the Henry's Fork River (provided by the HFF).

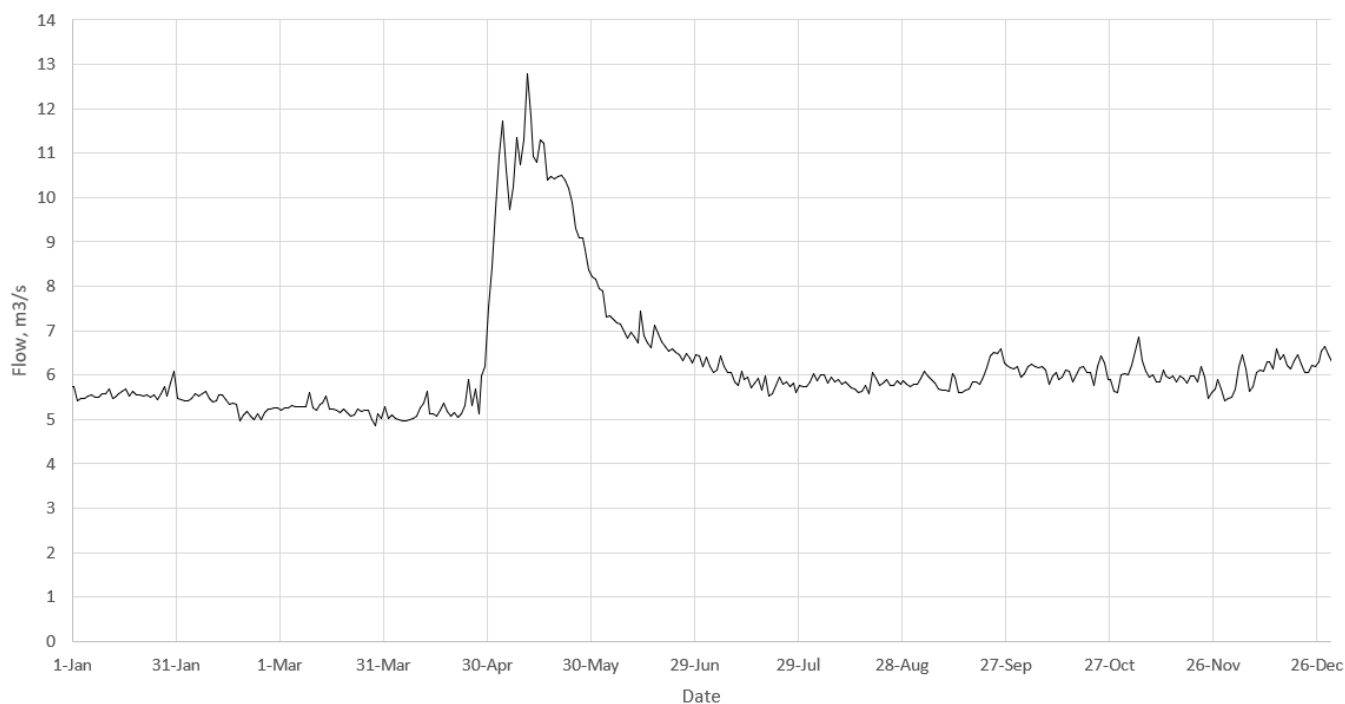


Figure 40. Buffalo River inflows to the Henry's Fork River, 2023.

Buffalo River water temperatures are recorded by the HFF every 15 minutes. This data was used to characterize the Buffalo River inflow to the model. Figure 41 shows Buffalo River water temperatures in 2023.

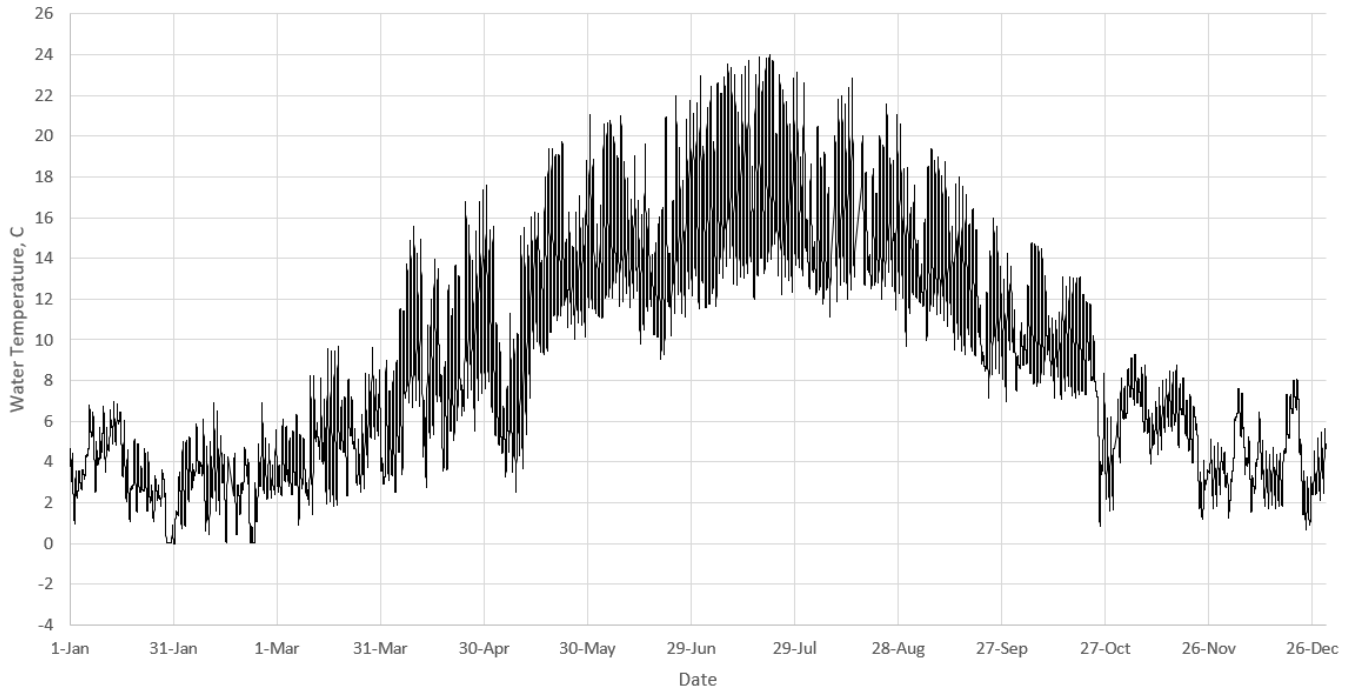


Figure 41. Buffalo River inflow water temperature to the Henry's Fork River, 2023.

Shading

Tree cover is considerable along the banks of the Henry's Fork River for some reaches. However, tree shading was not included in the model due to the lack of data defining tree height, density, and attenuation of incoming solar radiation along the reservoir's banks. In addition, there are many wide reaches to the Henry's Fork River where shading would be expected to be limited relative to the overall river surface area.

Model Calibration

Island Park Reservoir

Introduction

The Island Park Reservoir model was calibrated using measurements of water level, reservoir and outflow water temperature, and outflow data between January 1 and December 31, 2023. The calibrated model has been developed to simulate the reservoir hydrodynamics and water temperature in 2023.

Calibration Data

Modeled Island Park Reservoir water temperatures were compared to vertical temperature profiles collected by the HFF between June 28 and October 10, 2023. Modeled outflow temperatures were similarly compared to measured discharge at the USGS gauge on the Henry's Fork River near Island Park (USGS Gauge 13042500). Measured water level elevations at the USBR Hydromet station (near the dam) were compared to predicted water level in calibrating the reservoir water level and balance.

Figure 42 shows the location of HFF sample sites and USGS gauge 13042500 used to calibrate the reservoir model. Table 11 summarizes the sources of model calibration data and related sampling sites to their corresponding model segment.

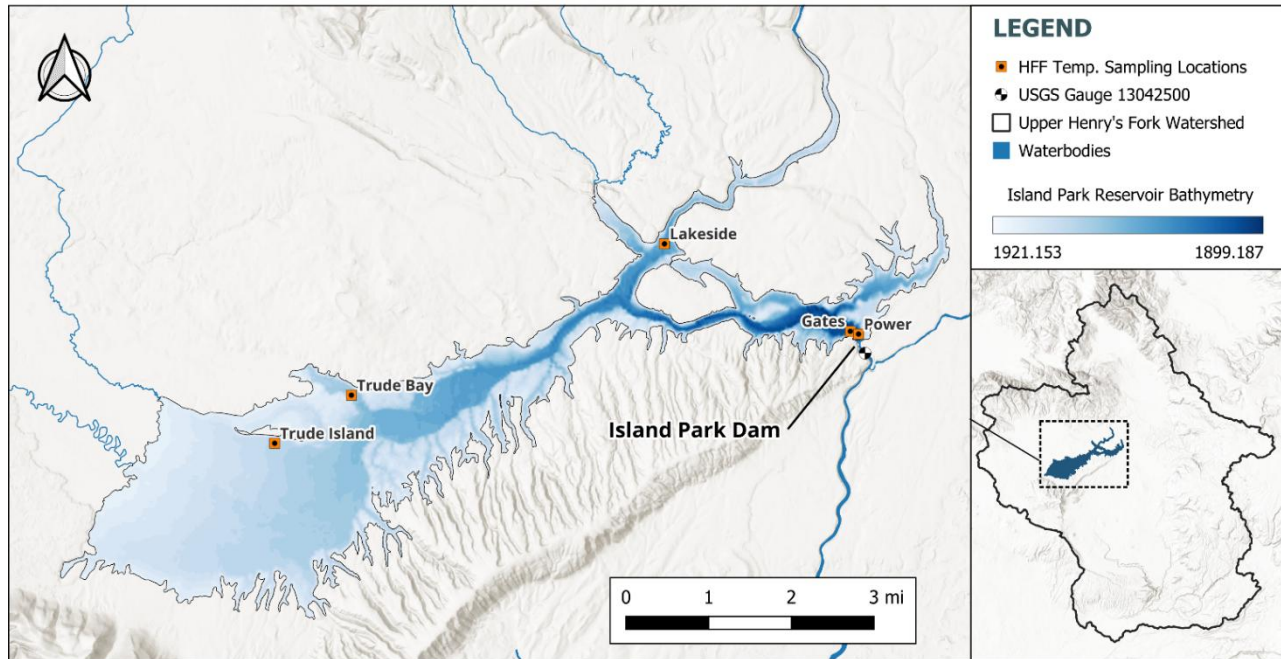


Figure 42. Island Park Reservoir hydrodynamic and temperature sampling sites. USBR Hydromet site ISL, used to calibrate model water level elevations, is not depicted.

Table 11. Island Park Reservoir hydrodynamic and temperature calibration sites.

Site ID	Site Description	Calibration Parameter(s)	Model Segment
USBR Hydromet ISL	Island Park Reservoir and Dam	Water level elevation	94
USGS 13042500	Henry's Fork near Island Park	Outflow, outflow temperature	99
Trude Island	HFF temperature sampling site	Vertical temperature profiles	24
Trude Bay	HFF temperature sampling site	Vertical temperature profiles	28
Lakeside	HFF temperature sampling site	Vertical temperature profiles	138
Gates	HFF temperature sampling site	Vertical temperature profiles	99
Power	HFF temperature sampling site	Vertical temperature profiles	99

Hydrodynamics

The Island Park Reservoir model was developed using detailed hydrologic data provided by HFF. The hydrodynamic calibration of the model required minimal input given the accuracy of constrained reservoir inflows and outflows. The CE-QUAL-W2 WaterBalance.exe post-processing tool was applied to modeled and USBR-measured water level elevations to correct remaining deviations in the water balance, with the output water balance file added to Branch 4 as a distributed tributary. The model-data error statistics for the 2023 reservoir hydrodynamic model calibration are presented in Table 12. Predicted water level and outflow demonstrate good model-data agreement and captures the variations in reservoir hydrodynamics over the model duration.

Table 12. Island Park Reservoir model continuous hydrodynamic model-data error statistics.

Water Level Elevation, m AMSL				
Site	Sample Size	Mean error (ME)	Mean absolute error (MAE)	Root mean square error (RMSE)
USBR Hydromet site ISL	365	0.00	0.01	0.01
Flow, cms				
Site	Sample Size	Mean error (ME)	Mean absolute error (MAE)	Root mean square error (RMSE)
USGS Gauge 13042500	35,032	-0.01	0.63	2.14

Water Surface Elevation

The modeled reservoir water surface elevations were compared with daily averaged water level derived from USBR Hydromet site ISL and provided by HFF. Figure 43 shows the modeled and measured reservoir water level elevations with relevant thresholds. The figure shows excellent model-data agreement.

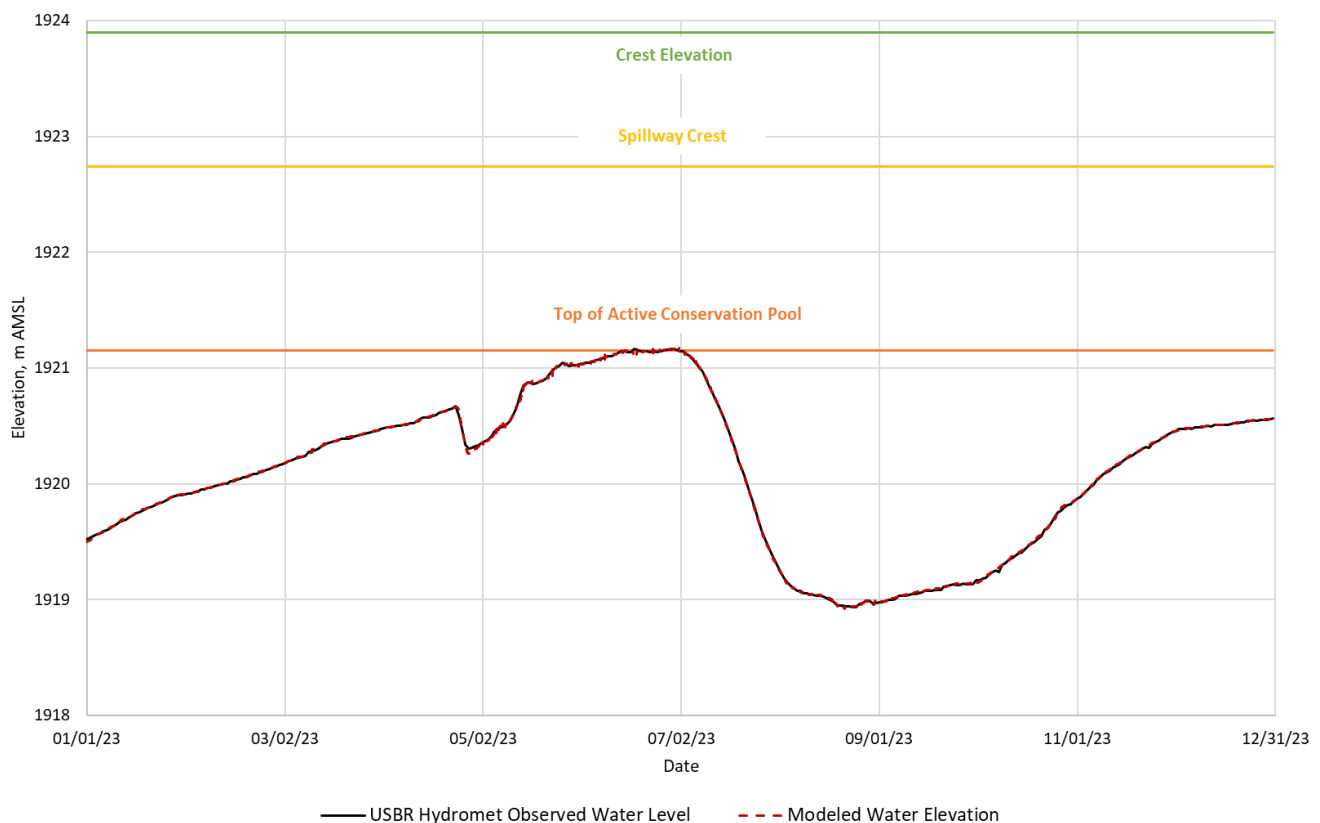


Figure 43. Comparison of modeled and measured water level elevations in the Island Park Reservoir.

Water Balance Flows

Figure 44 shows a time series comparison of simulated and observed outflows from the Island Park Reservoir in 2023. The water balance correction applied to the Island Park Reservoir model is also depicted.

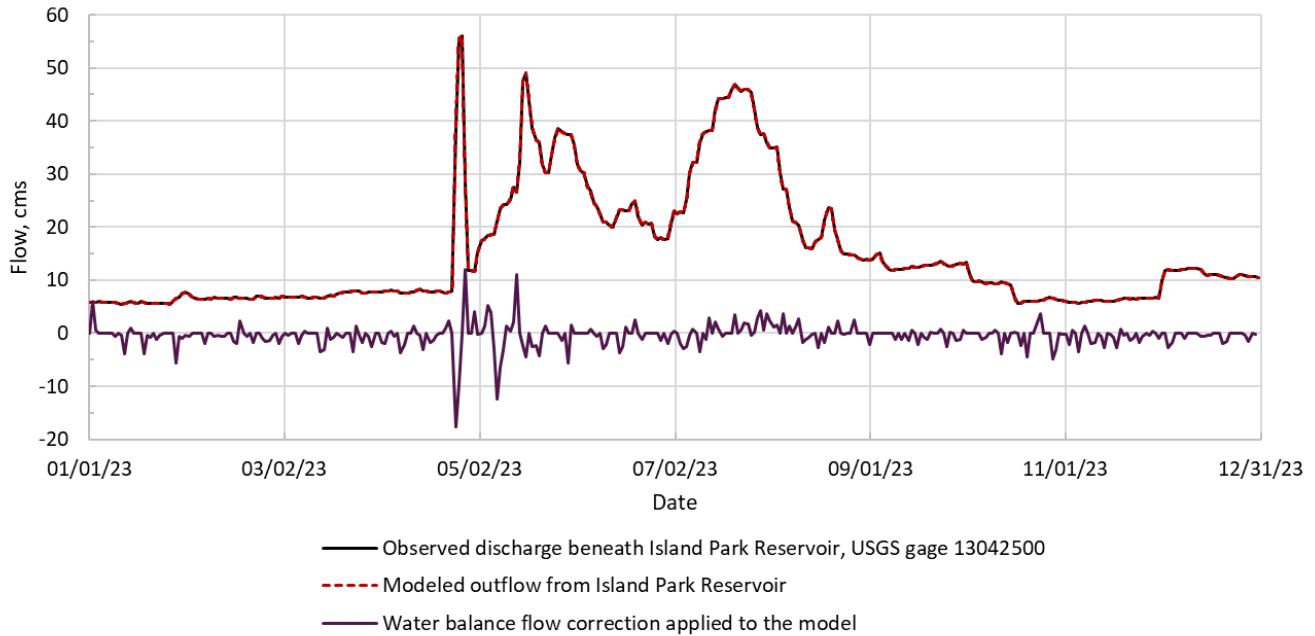


Figure 44. Comparison of simulated and observed continuous outflows from the Island Park Reservoir, 2023. The water balance correction applied to the model is also shown.

Water Temperature

The modeled reservoir water temperatures were calibrated by comparing predicted temperatures with HFF-provided temperature vertical profiles and outflow temperatures in 2023. The reservoir is covered by ice during the winter and early spring, the first part of the temperature calibration involved adjusting the W2 ice cover parameters to extend the duration of simulated ice cover to match observed ice cover. The model wind height [WINDH] and wind sheltering coefficient file [wsc.csv] were subsequently adjusted to better simulate observed temperature profiles at five HFF field sampling sites. Additional details on the temperature calibration are provided below.

Temperature Profiles

Model-data error statistics comparing vertical temperature profiles are presented in Table 13. Figure 45 through Figure 49 compare predicted and measured temperature profiles. The Island Park Reservoir model generally predicts reservoir temperatures less than 1°C, with the exception of Trude Bay. However, uncaptured processes at segments 28 and 99 result in greater deviations between modeled and measured data for some sampling dates.

Table 13. Island Park Reservoir vertical temperature profile calibration model-data error statistics, 2023.

Site ID	Model Segment	No. of Comparisons	Average Error Statistics, °C		
			ME	MAE	RMSE
Trude Island	24	1,513	0.06	0.49	0.54
Trude Bay	28	2,503	-0.86	1.30	1.88
Power	99	5,369	0.60	0.76	0.86
Gates	99	11,286	0.29	0.72	0.85
Lakeside	138	10,446	0.54	0.73	0.87
Average			0.13	0.90	1.00

Spring inflow near the Trude Bay sampling site (Segment 28) may account for the divergence between modeled and measured vertical temperature profiles in 2023. The CE-QUAL-W2 model outputs laterally-averaged temperature profiles for each model segment, but does not allow the selection of specific output locations laterally across a segment. Lateral segment averaging can obscure localized processes, such as any spring flow observed at the Trude Bay site. There could also be other factors influencing the local water temperature profiles at Trude Bay, that are simply not captured by the laterally averaged model segment predictions. This could be tested by simply collecting a few vertical profiles in the main channel on the same day as the vertical profiles taken at the Trude Bay site. This would provide a sense of how different the local conditions are Trude Bay relative to the main channel.

Divergence between modeled and measured temperature at the Gates and Power sampling sites (segment 99) coincides with changes in withdrawals from the USBR Gates and FRREC Power outlets. Between July 6 and August 5, 2023, withdrawals from the USBR Gates outlet increased from 0 cms to a peak of 20 cms on July 21. Over the same duration, disagreement between measured and modeled temperature vertical profiles at the Gates and Power sampling sites increased from a mean absolute error (MAE) below 0.4°C on July 6 to a MAE over 1.6°C on July 23. USBR Gates operations in August do not result in similar increases in MAE, though this may be a reflection of the lower rate of withdrawal (under 5 cms).

Varying intake operations in the Island Park Reservoir withdrawal input file (e.g., directing all outflows through the FRREC Power outlet in July and August) did not result in increased model performance. The HFF provided withdrawal time series used in the model was derived from guidelines of reservoir operations (e.g., limits on infrastructure) applied to measured streamflow at the USGS gauge immediately downstream of Island Park Dam (USGS gauge 1342500). Confirmation of reservoir operations and further refinement of the partitioning of flows between intake pipes (set at varying elevations) may result in improvements in model performance for this time period. As noted in Table 13 the overall model-data agreement is quite good.

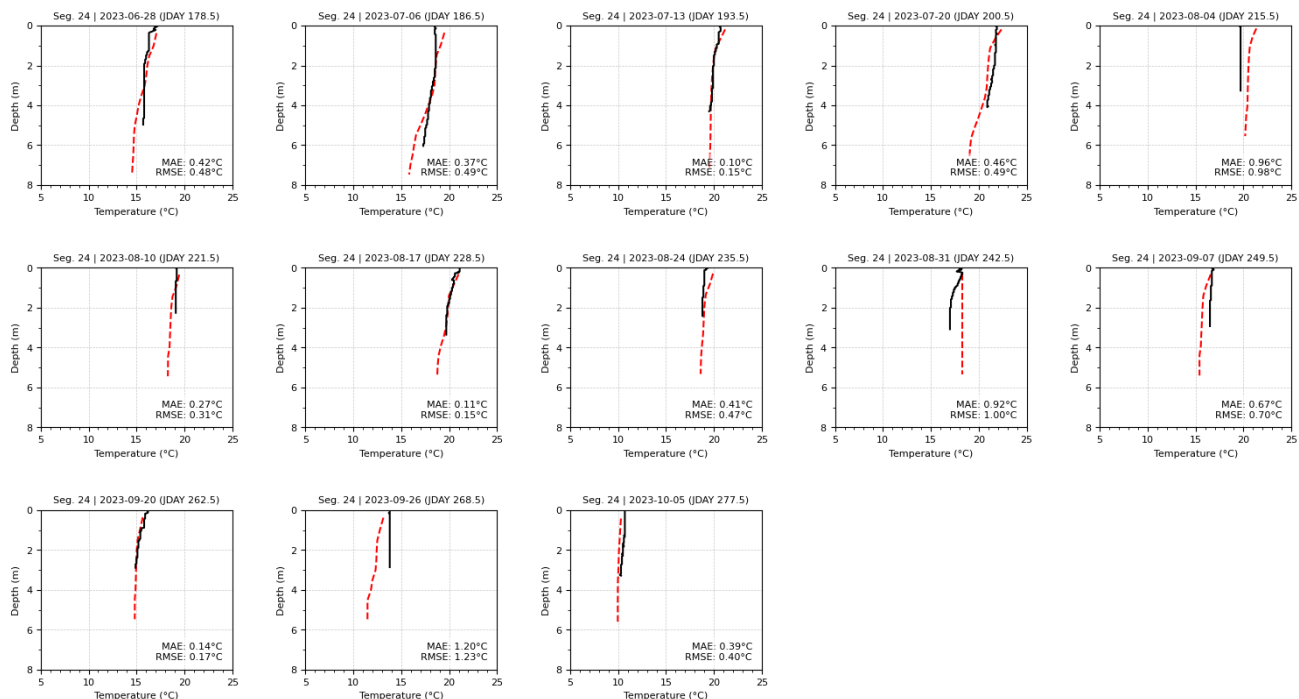


Figure 45. Comparison of observed (black line) and modeled (red dashed-line) Island Park Reservoir temperature profiles at the HFF Trude Island sampling site.

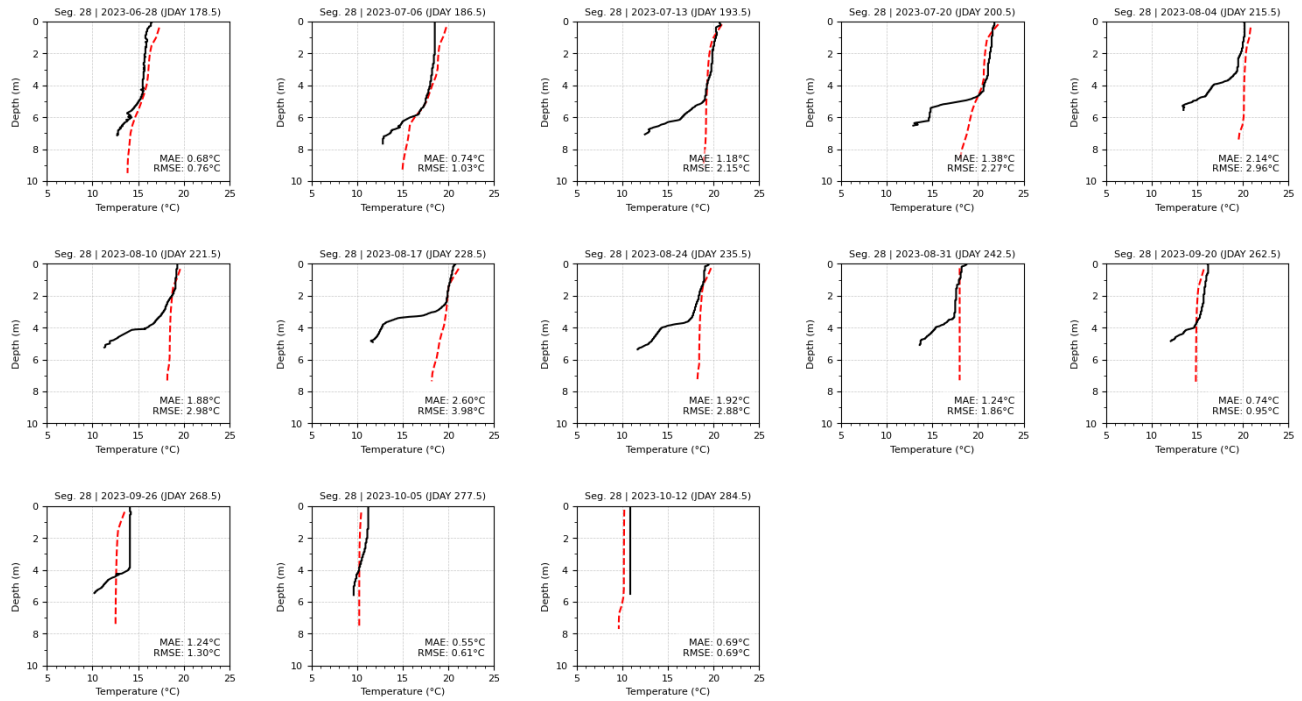


Figure 46. Comparison of observed (black line) and modeled (red dashed-line) Island Park Reservoir temperature profiles at the HFF Trude Bay sampling site.

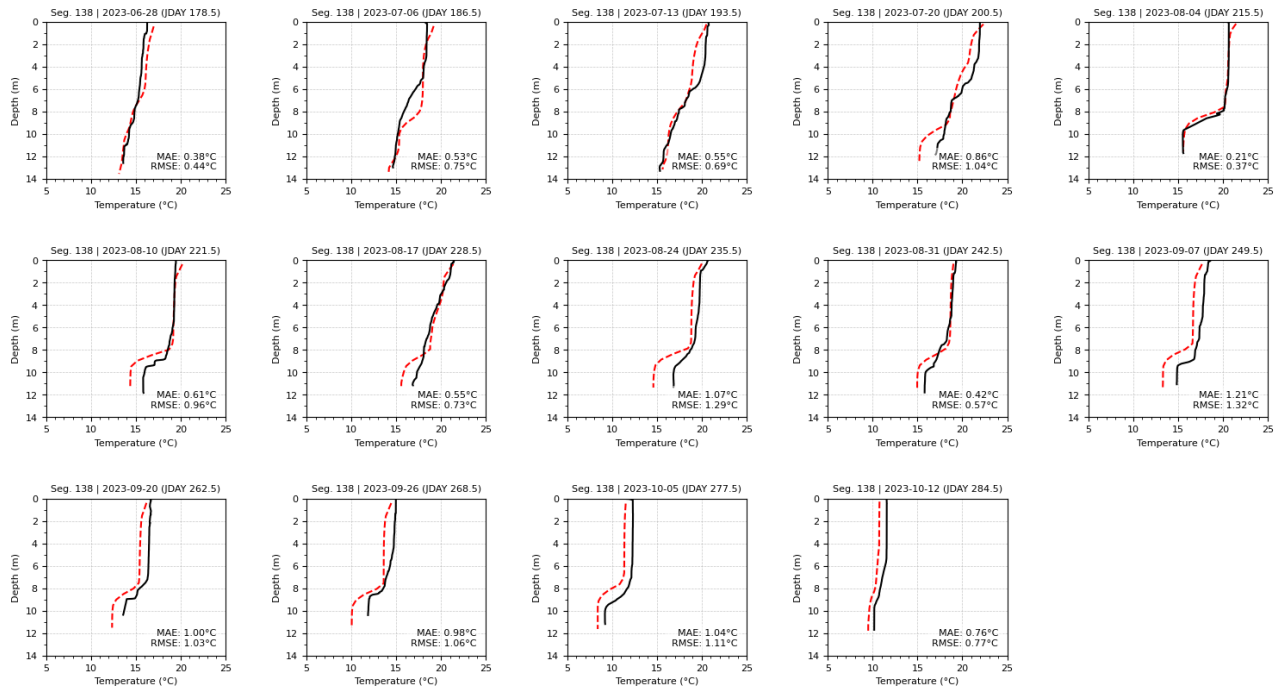


Figure 47. Comparison of observed (black line) and modeled (red dashed-line) Island Park Reservoir temperature profiles at the HFF Lakeside sampling site.

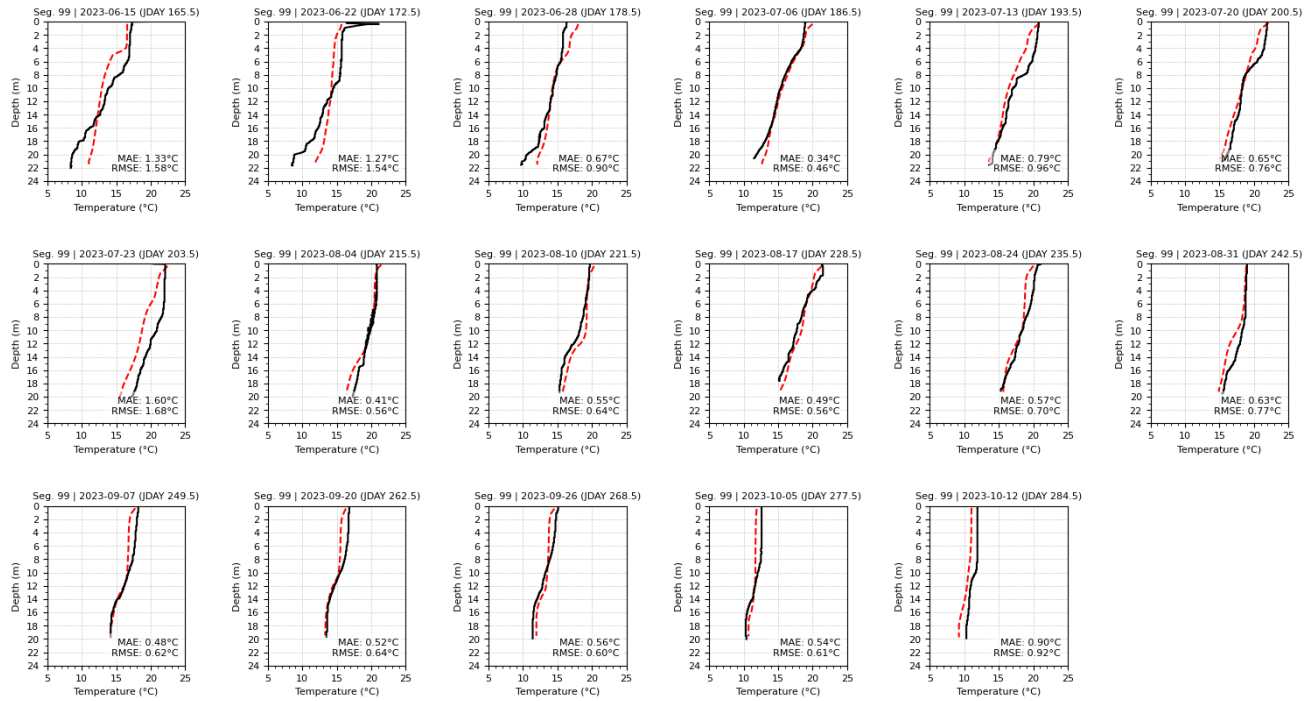


Figure 48. Comparison of observed (black line) and modeled (red dashed-line) Island Park Reservoir temperature profiles at the HFF Gates sampling site.

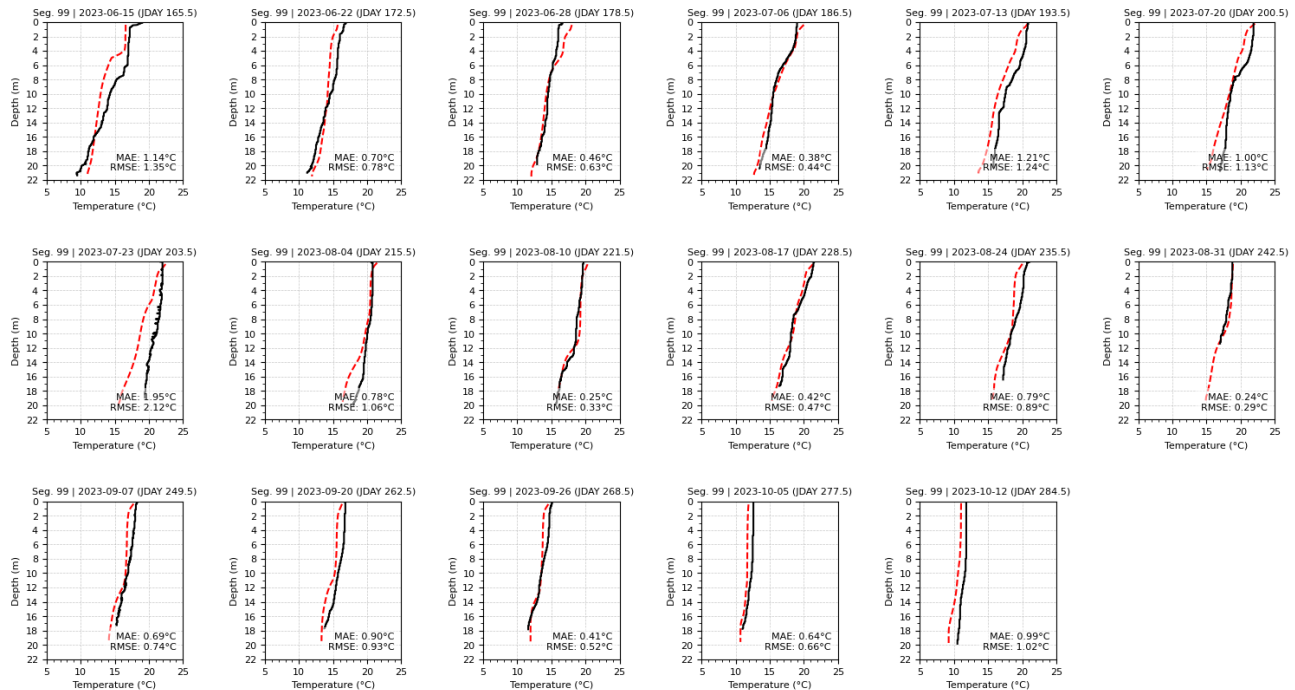


Figure 49. Comparison of observed (black line) and modeled (red dashed-line) Island Park Reservoir temperature profiles at the HFF Power sampling site.

Outflow Temperature

Model-data error statistics comparing modeled outflow temperatures with measured temperatures at the USGS gauge on the Henry's Fork River below Island Park Dam (USGS gauge 13042500) are presented in Table 14. Figure 50 through Figure 52 compare time series of modeled outflow temperatures, flow-weighted outflow temperature, and measured temperature beneath the reservoir.

Table 14. Island Park Reservoir continuous outflow temperature model-data error statistics, 2023.

No. of Comparisons	ME, °C	MAE, °C	RMSE, °C
32,094	-0.05	0.75	1.06

Modeled and measured outflow temperatures compare favorably through late April. On April 29, however, modeled outflow temperature increases considerably while observed outflow temperature begins rising at a slower rate. This divergence may be attributed to the duration of simulated and observed ice cover. Simulated reservoir ice cover ends on April 29, and while the duration of actual ice cover in 2023 is unknown, observed outflow temperatures indicate ice cover likely continues through mid-May. The CE-QUAL-W2 ice cover parameters were adjusted across several model runs in an attempt to extend modeled ice cover further into the later Spring. However, the model is unable to capture late spring reservoir dynamics influencing ice cover, without more details on the ice thickness, spatial coverage, and direct data on the ice conditions throughout the year. Additional information regarding depth and duration of ice cover in the reservoir could be used to fine-tune modeled ice cover in future iterations of the Island Park Reservoir model. Despite this, the model still demonstrates good model-data agreement with a MAE of 0.75°C and RMSE of 1.06°C when compared to instream temperature measurements below the dam.

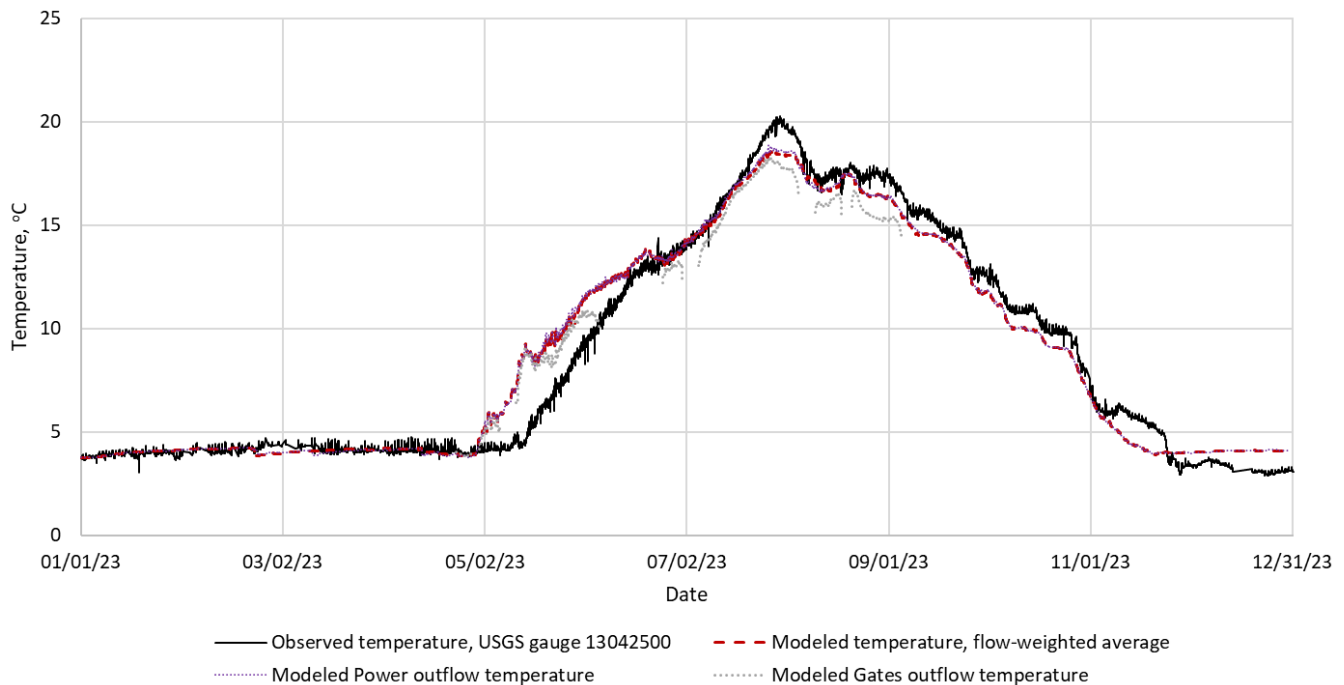


Figure 50. Comparison of measured and modeled continuous outflow temperatures from Island Park Reservoir.

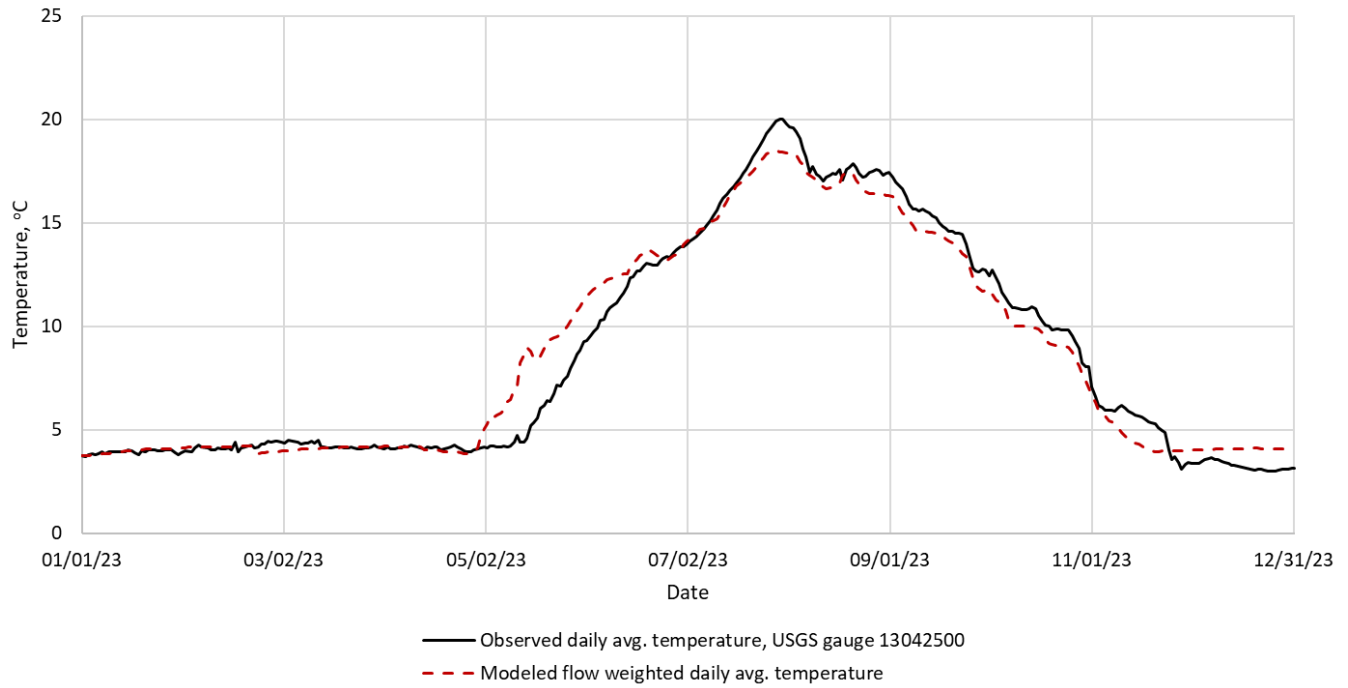


Figure 51. Comparison of measured and modeled daily average outflow temperatures from Island Park Reservoir.

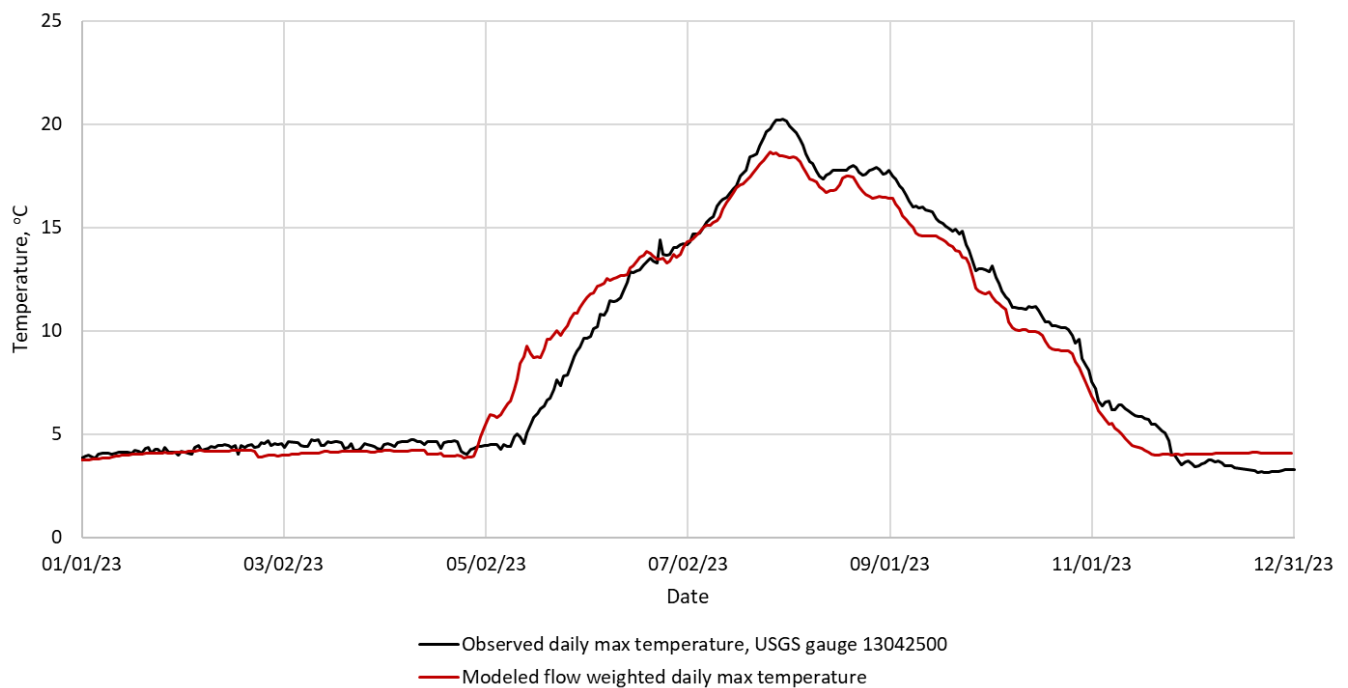


Figure 52. Comparison of measured and modeled daily maximum outflow temperatures from Island Park Reservoir.

Henry's Fork River

Introduction

The Henry's Fork model was first calibrated to flow and then to water temperature, using data collected by the HFF.

Calibration Data

The HFF provided daily flow estimates for the Henry's Fork River at Box Canyon just below the confluence of the Buffalo River and the Henry's Fork River. In addition, the HFF provided daily Henry's Fork River flow estimates at Pinehaven (RM 76.7), which is roughly 4.6 miles downstream of the river's confluence with Thurman Creek, the end of the model domain. Although the Pinehaven site is downstream of the model domain, observed streamflow provides valuable insights into model performance and supports a water balance approach to calibrating flow. Table 15 provides a list of the two locations where model flow predictions could be compared to data.

Table 15. Flow Calibration Sites for the Henry's Fork River, 2023.

Location	Site	Model Segment	RM
Box Canyon	Boxcyn	4	90.6
End of the model Grid	n/a	53	81.3
Pinehaven	PH	53+	76.7

HFF provided 15-min water temperature time series at multiple locations along the Henry's Fork River for model calibration. Table 16 provides a list of the monitoring sites and corresponding model segments where simulated and observed temperature were compared. Two sites, Osborne Bridge and Pinehaven, are respectively located 0.9 miles and 4.6 miles downstream of the model domain. The data collected at these sites provided valuable insights into how well the model matches data but were not expected to perfectly match simulated model temperatures due to their distance from the model domain.

Table 16. Water Temperature Calibration Sites for the Henry's Fork River, 2023.

Location	Site	Model Segment	RM
Last Chance Right	LCR	24	86.9
Last Chance Left	LCL1/2	24	86.9
Bonefish Flats	BF	37	83.9
Millionaire's pool	MI	49	82.1
Osborne Bridge	OB	53+	80.4
Pinehaven (1)	PH	53+	76.7
Pinehaven (2)	PH	53+	76.7

Hydrodynamics

Flow

The hydrodynamic calibration of the Henry's Fork River involved the comparison of simulated and observed river flows, as a lack of water level data along the modeled reach prevented a water level elevation comparison. A model-data river flow comparison was first conducted at segment 4 (RM 90.6) located below the confluence of the Buffalo River and the Henry's Fork River. Figure 53 shows a time series plot of model predicted river flow and daily flow estimates from the HFF and Table 17 presents the model-data error statistics. Both the time series and error statistics indicate good model-data agreement.

A second location at the end of the model domain (segment 53) was used to calibrate river flow. A lack of data at this location led to the use of daily streamflow estimates at the Pinehaven site, located 4.6 miles downstream of the model domain, as an additional point of comparison in the hydrodynamic calibration. Figure 54 shows a time series plot of model predicted river flow and daily flow estimates provided by the HFF for the Pinehaven site. Table 17 presents the model-data error statistics. Both the time series and error statistics indicate good model-data agreement.

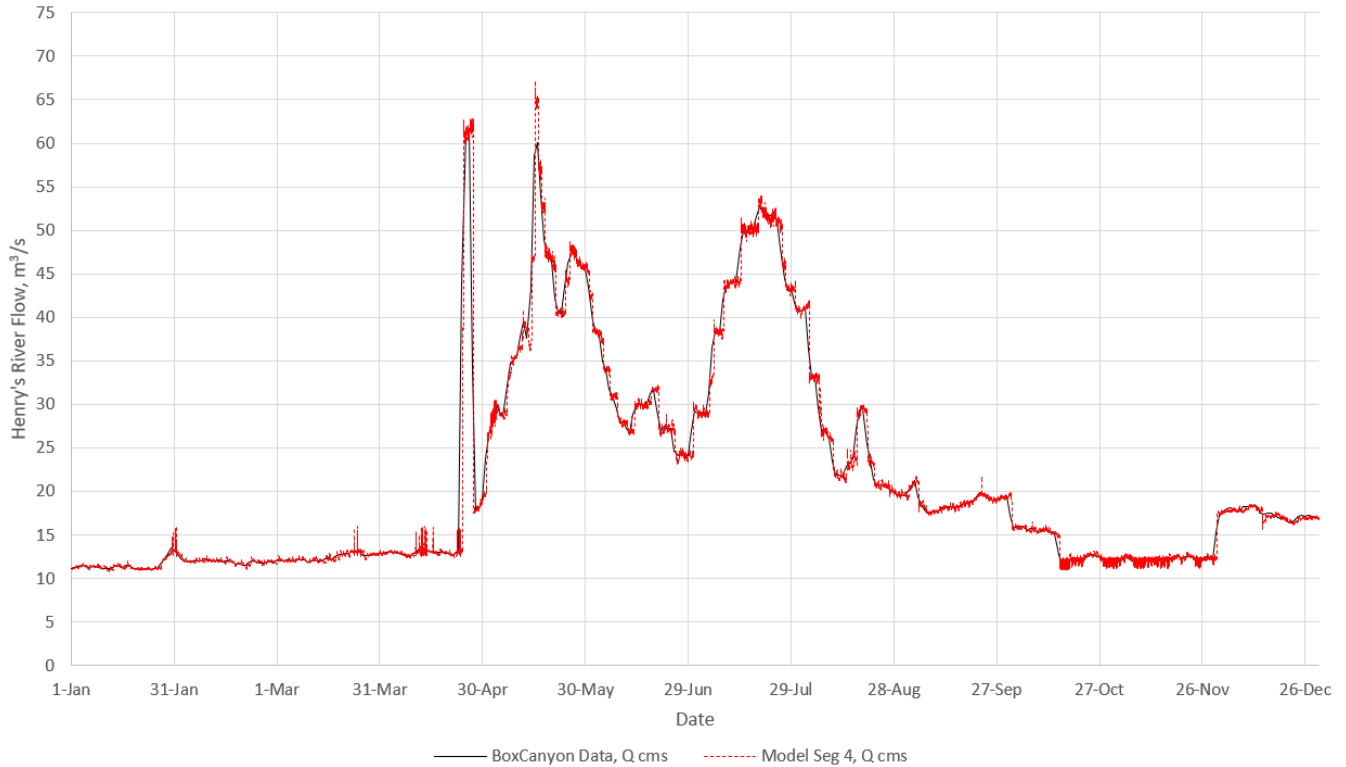


Figure 53. Henry's Fork River, model-data comparison at Box Canyon (segment 4), 2023.

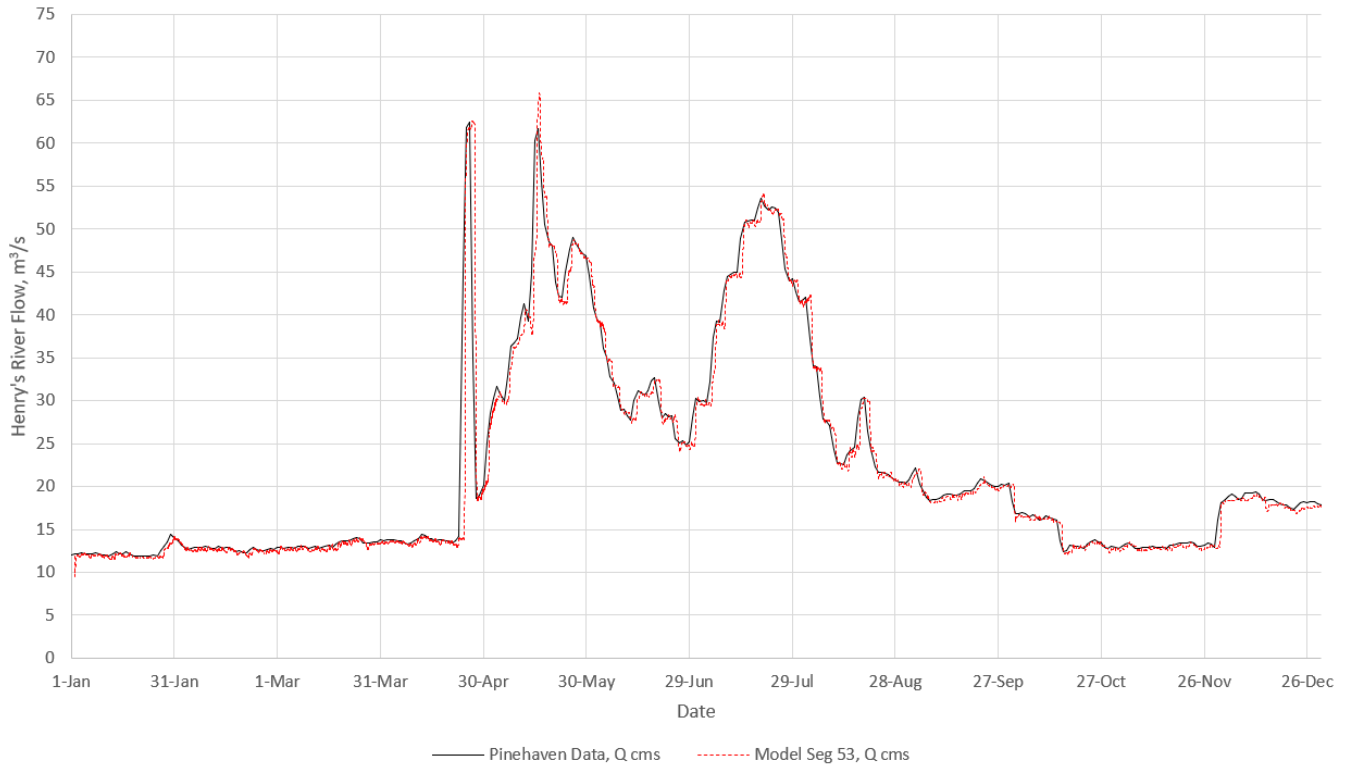


Figure 54. Henry's Fork River, model-data comparison at the end of the model domain (segment 53) compared with daily flow estimates at Pinehaven, 2023.

Table 17. River flow model-data error statistics, 2023.

Location	Site	Model Segment	RM	ME, cms	MAE, cms	RMSE, cms
Box Canyon	Boxcyn	4	90.6	0.17	0.46	1.53
Pinehaven	PH	53+	76.7	-0.07	0.29	1.06

Water Balance Flows

The hydrodynamic model calibration of Henry's Fork River streamflow was achieved by conducting a water balance between the simulated and observed flows, first at Segment 4 and then at Segment 53, to develop a time series of daily flows to add back into the model as distributed tributaries. Corrective flows were divided among the seven (7) branches in the model domain based on their length. A distributary tributary for each branch is designed to distribute the flows (positive or negative) among the segments within the branch to minimize the impact on local hydrodynamics.

Figure 55 shows a time series comparison between the total distributed tributary flow needed to calibrate the model, outflow from the Island Park Reservoir, and Buffalo River inflow to the Henry's Fork River. Table 18 compares basic flow statistics between the total distributed tributary, Buffalo River, and reservoir outflows. The table shows the mean and median of the total distributed tributary inflow is roughly 5 to 6% of the total flow from the Buffalo River and Island Park Reservoir outflow, which is small.

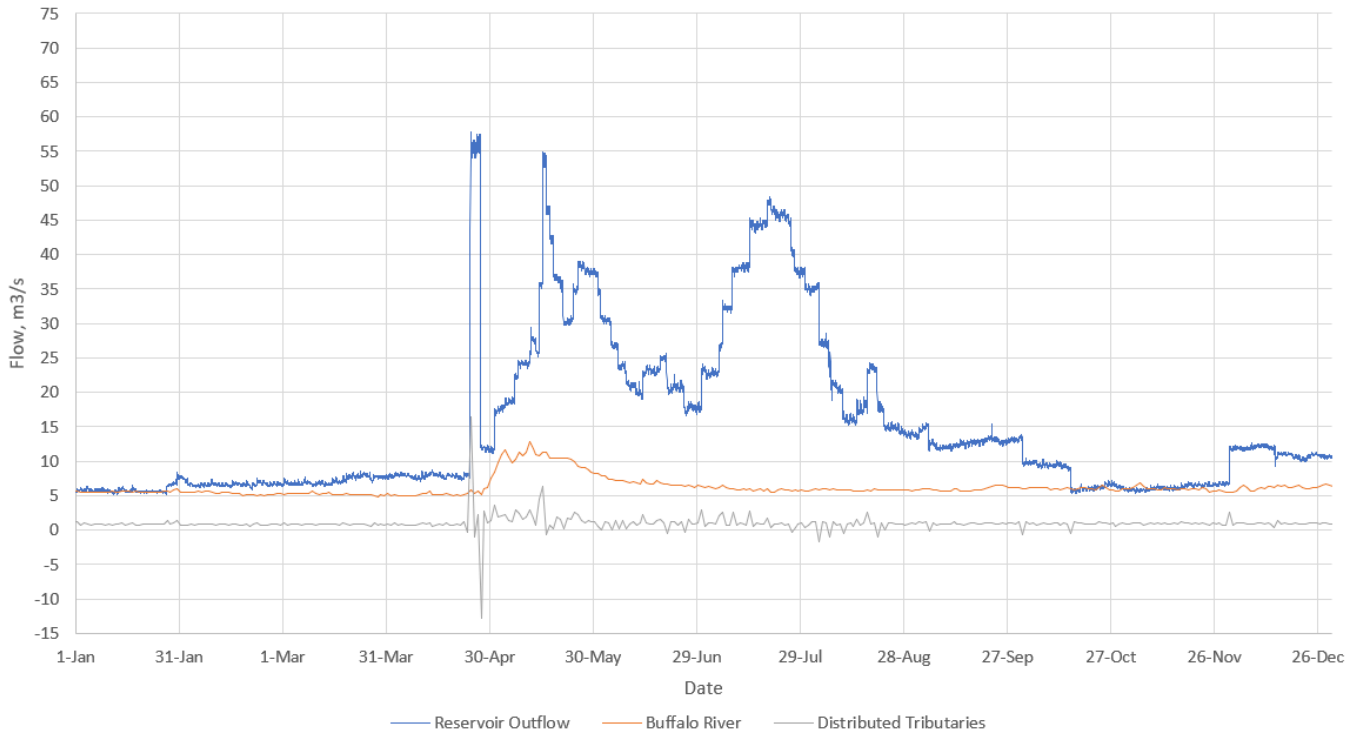


Figure 55. Comparison of water balance flows relative to the Buffalo River flow, and Island Park Reservoir outflow., 2023.

Table 18. Water balance flow statistical comparison, 2023.

Statistic	Island Park Reservoir Outflow, cms	Buffalo River flow, cms	Total Distributed Tributary inflow, cms	Total Distributed Tributary inflow, %
Minimum	5.2	4.9	-12.8	
Maximum	57.8	12.8	16.5	
Mean	15.2	6.2	1.0	4.6%
Median	10.8	5.8	0.9	5.6%

Water temperature time series needed to be associated with each of the distributed tributary inflows to the model. It was important to select data sets that represents groundwater or spring flow, as some fraction of calculated water balance flows is likely due to these natural sources as opposed to uncertainty in gage measurements or developed daily flow estimates. The distributary tributary inflow temperatures were therefore based on daily water temperature data from Canal Springs, collected by the HFF from June to December of 2023. Data gaps were filled by correlating daily average water temperatures and daily average air temperatures and applying a 7-day rolling average with a bias correction to the correlated values (Figure 56). Figure 57 shows a comparison between the Canal Springs water temperature time series used for the distributed tributary inflows and the Island Park Reservoir and Buffalo River water temperature time series for 2023.

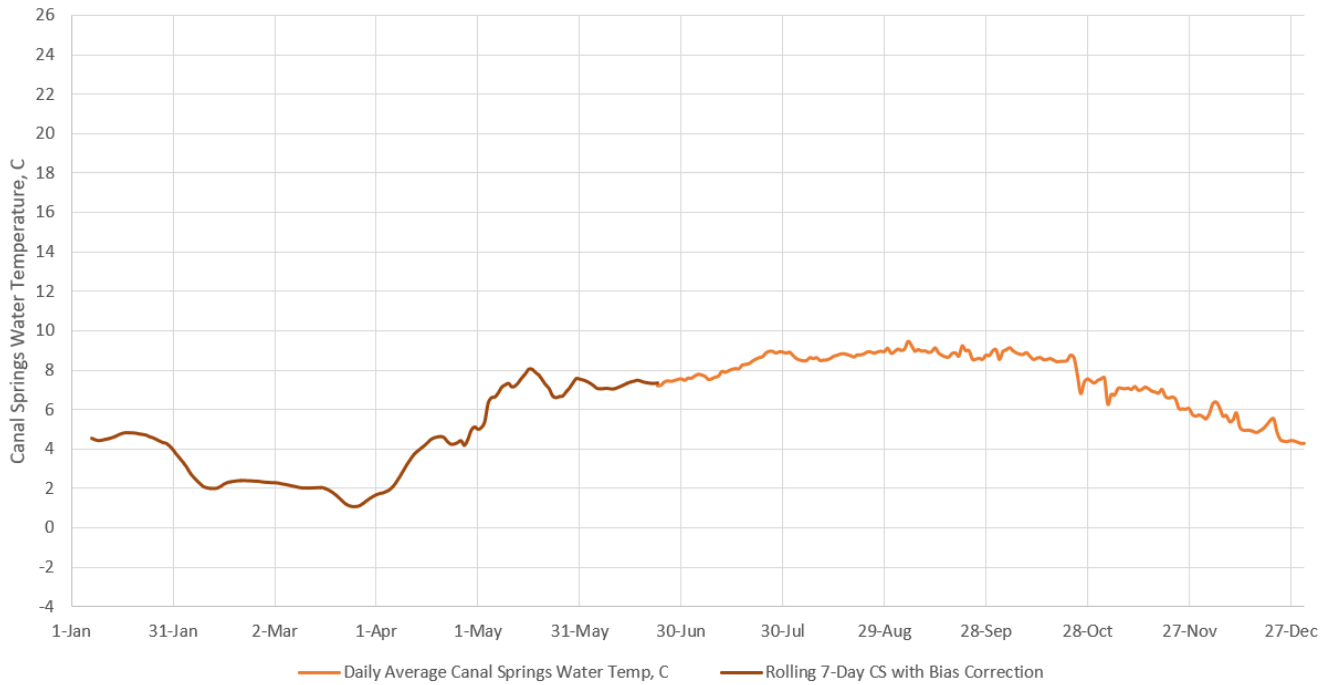


Figure 56. Canal Springs Water Temperature data and estimates, 2023.

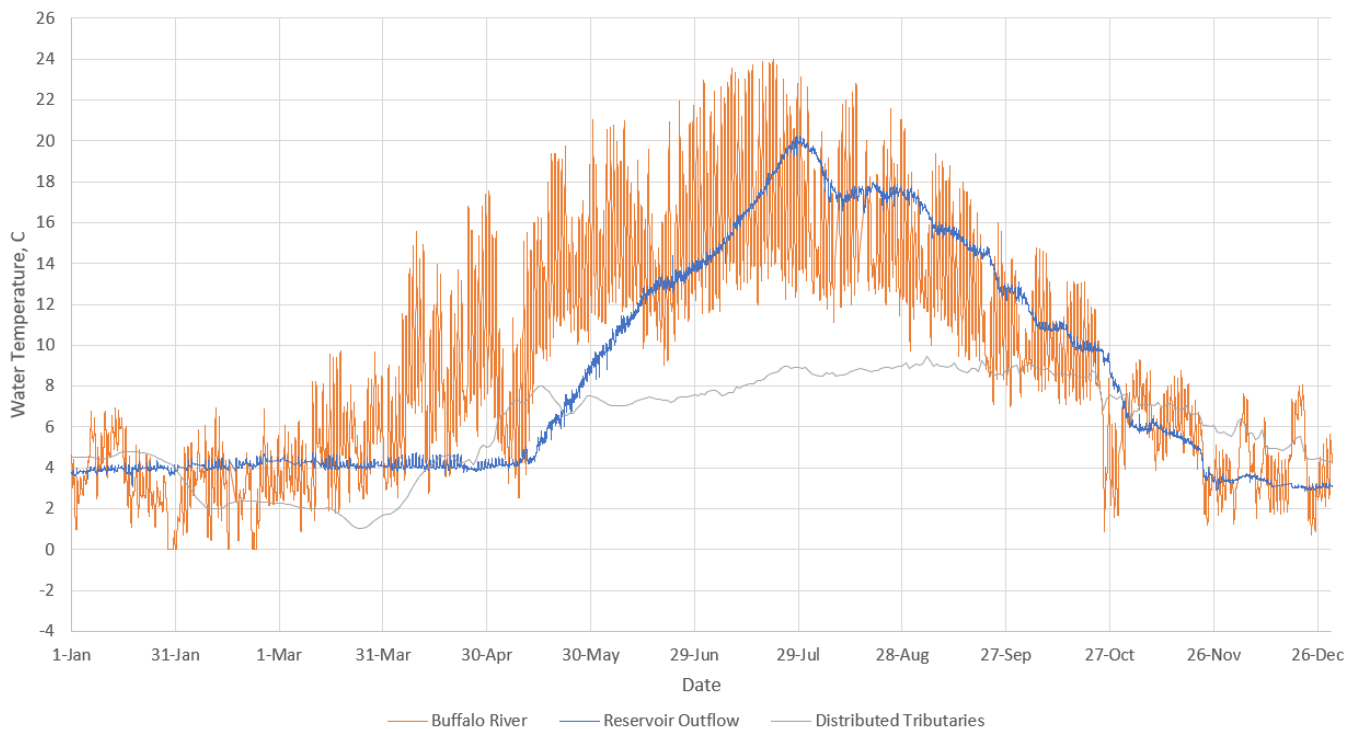


Figure 57. Comparison of Canal Springs (Distributed Tributary) water temperature data with Island Park Reservoir and Buffalo River water temperatures, 2023.

Water Temperature

The water temperature calibration was conducted by comparing continuous water temperature data to the model output, and calibrating from upstream to downstream by adjusting model input coefficients until a reasonable model-data agreement was achieved. Model adjustments included, but are not limited to:

- Adjusting the effective slope of each branch,
- Adjusting the Manning's friction factor, n ,
- Adjusting the temperature of the sediment bed,
- Minor adjustments to the channel bathymetry at key locations, and
- Adjusting the wind sheltering coefficient, which changes the effective wind on the water surface.

Daily maximum and daily average simulated and observed water temperatures were also compared since both of these statistics are used for regulatory compliance.

Continuous Temperatures

The Henry's Fork River was calibrated to continuous (15 min) water temperature data. Figure 58 compares time series of modeled and observed continuous stream temperatures at segment 24 using data from Last Chance Left 1 (RM 86.9) in 2023. The figure shows there is a good model-data agreement throughout the summer with some larger disagreement in late October.

Figure 59 compares time series of modeled and observed continuous stream temperatures at segment 24 using data from Last Chance Left 2 (RM 86.9). The figure shows there is a good model-data agreement throughout the summer with some larger disagreement in late October. The model appears to have slightly less diurnal variation compared to observed values.

Figure 60 compares time series of modeled and observed continuous stream temperatures at segment 24 using data from Last Chance Right (RM 86.9). The figure shows there is a good model-data agreement throughout the summer with the model predicting slightly cooler temperatures than the data.

Figure 61 compares time series of modeled and observed continuous stream temperatures at segment 37 using data from Bonefish Flats at RM 83.9. The figure shows there is a good model-data agreement throughout the summer. The model displays less diurnal variation than observed values.

Figure 62 compares time series of modeled and observed continuous stream temperatures at segment 49 using data from Millionaire's Pool (RM 82.1). The figure shows there is a good model-data agreement throughout the summer and well into October.

Figure 63 compares time series of modeled and observed continuous stream temperatures at segment 53, the end of the model domain, using data from Osborne Bridge (RM 80.4) located 0.9 miles downstream of segment 53. The figure shows good model-data agreement, although modeled temperature displays less diurnal variations than the observed data.

Two sets of temperature observations at Pinehaven (RM 76.7) were compared to simulated temperature despite the site's location 4.6 miles downstream of the end of the model domain. The site was not used for the temperature calibration, but model-data comparison provides a useful tool for evaluating the degree of model-data divergence downstream of the model domain. Figure 64 and Figure 65 compare modeled temperature at segment 53, the end of the model domain, with the two Pinehaven continuous temperature time series. Both figures show, in general, that the model tracks seasonal and diurnal patterns in observed temperature. Figure 64 indicates the model may have less diurnal variation than observed values, while Figure 65 shows closer agreement.

Table 19 shows the model-data error statistics for each of the locations used in the model-data comparison. The Pinehaven sampling site is excluded from the calculation of overall model performance given the site's displacement from the model domain. While Osborne Bridge is also downstream of the model domain, this offset is relatively small (0.9 miles). Observed temperatures at Osborne Bridge were therefore included in the overall model-data error statistics. The table shows the mean error (ME) is very low at each site, with a MAE less than 0.7°C. The root mean square error (RMSE) is also low with values below 0.9°C. Overall, the model is well calibrated for water temperatures.

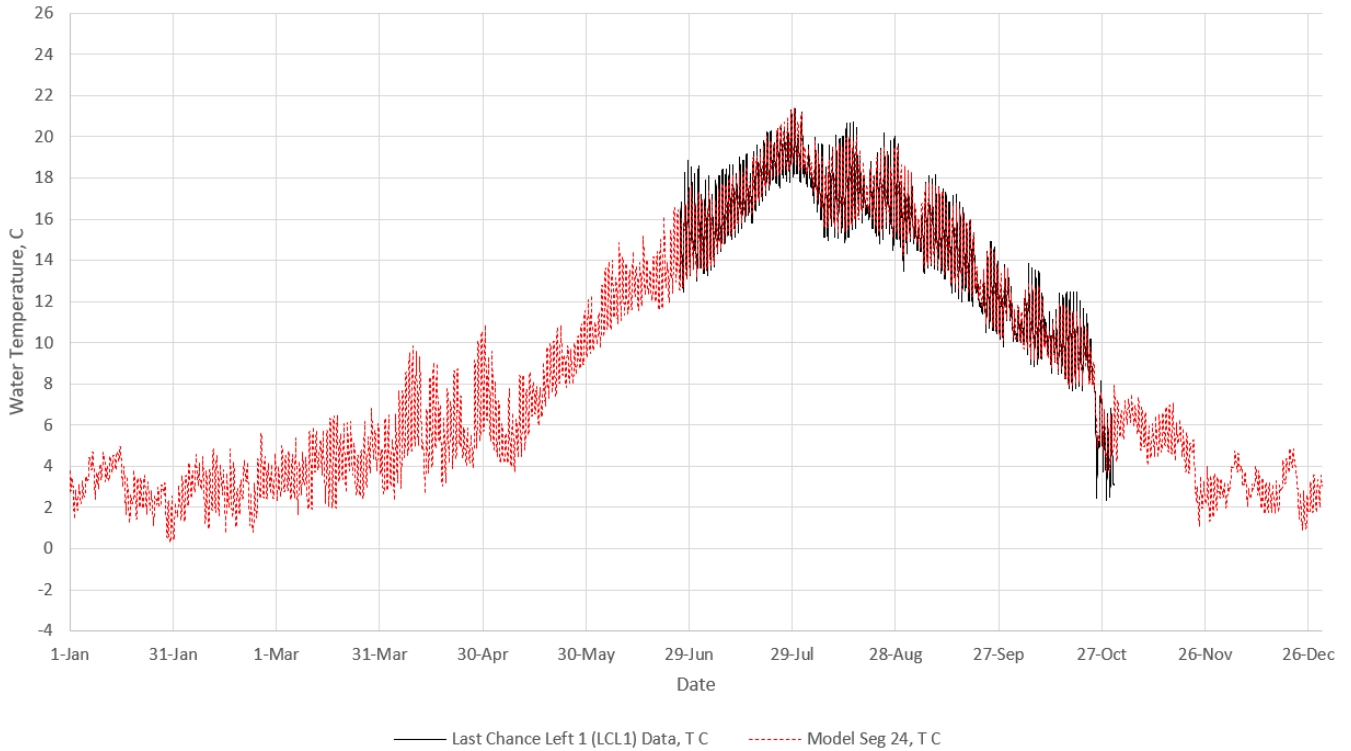


Figure 58. Henry's Fork River, model-data water temperature comparison at model segment 24 with data from Last Chance Left 1, 2023.

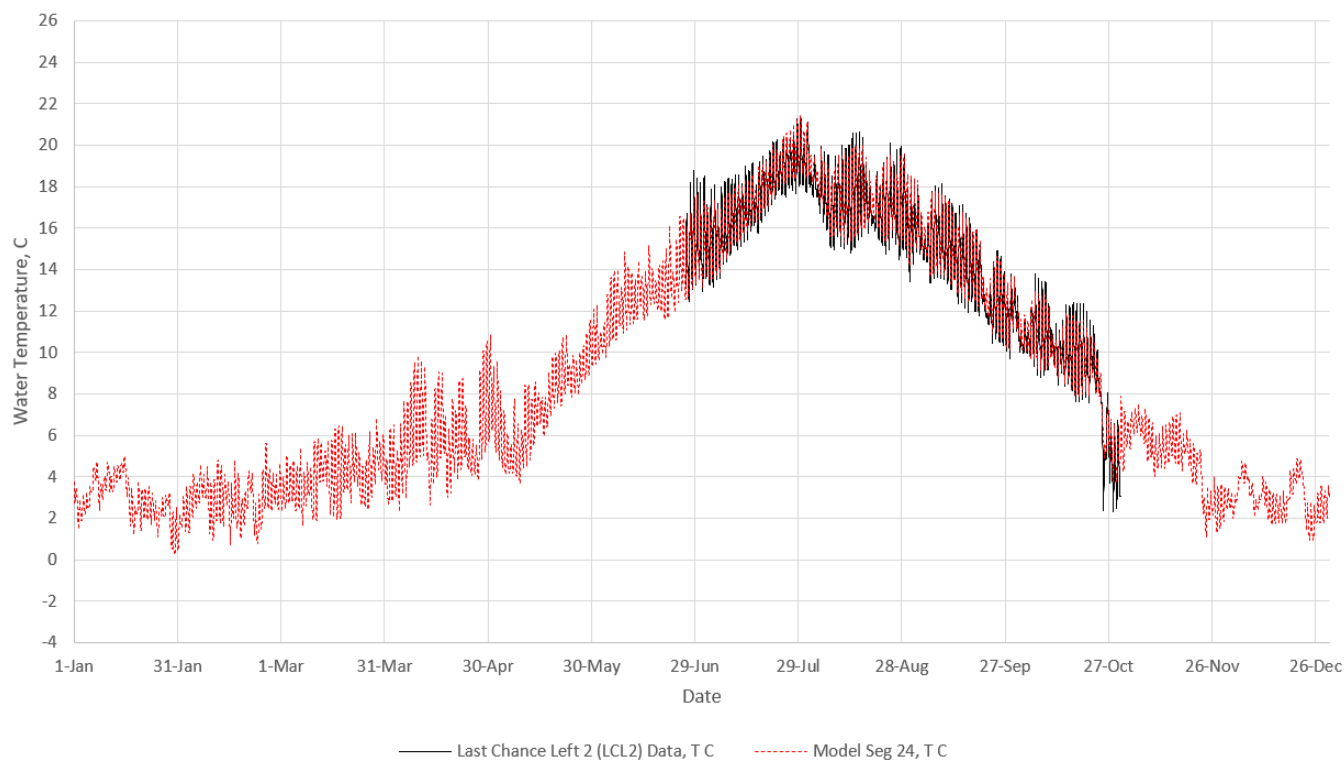


Figure 59. Henry's Fork River, model-data water temperature comparison at model segment 24 with data from Last Chance Left 2, 2023.

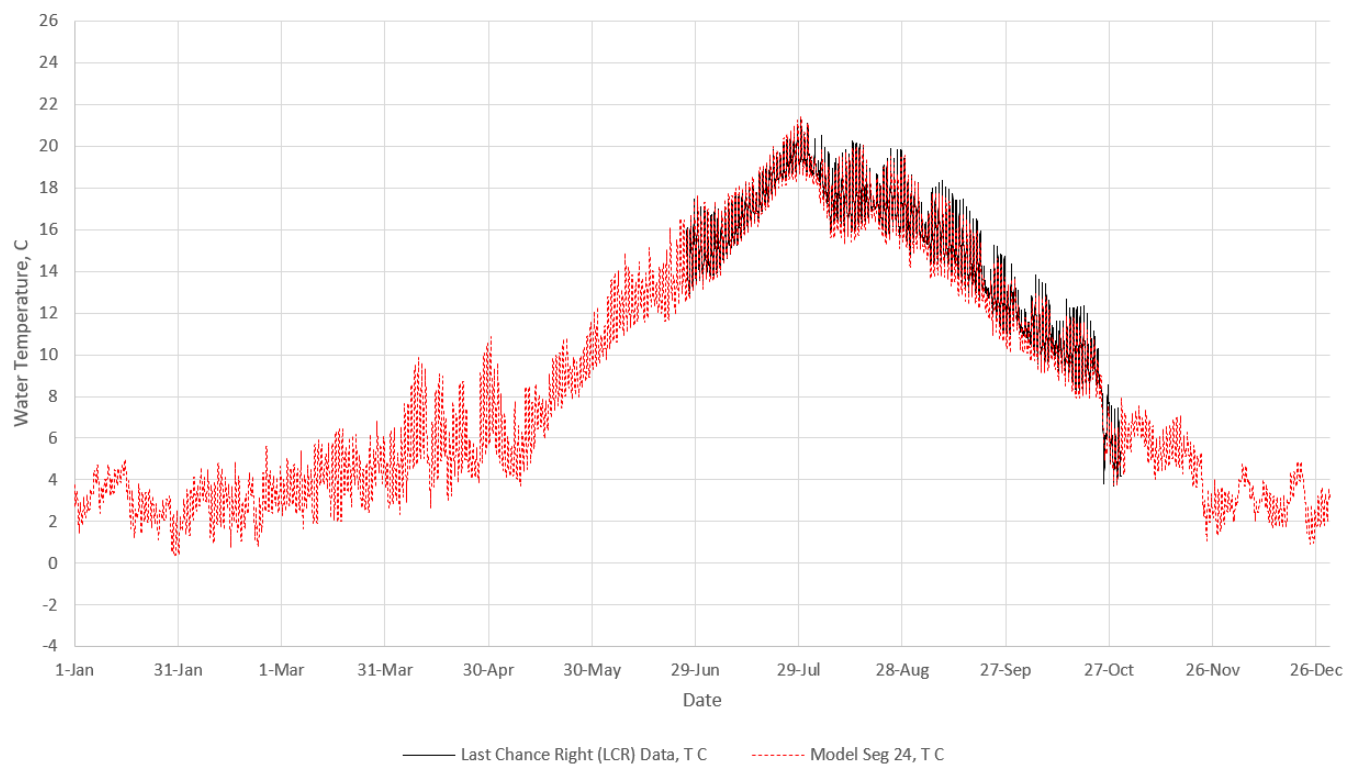


Figure 60. Henry's Fork River, model-data water temperature comparison at model segment 24 with data from Last Chance Right, 2023.

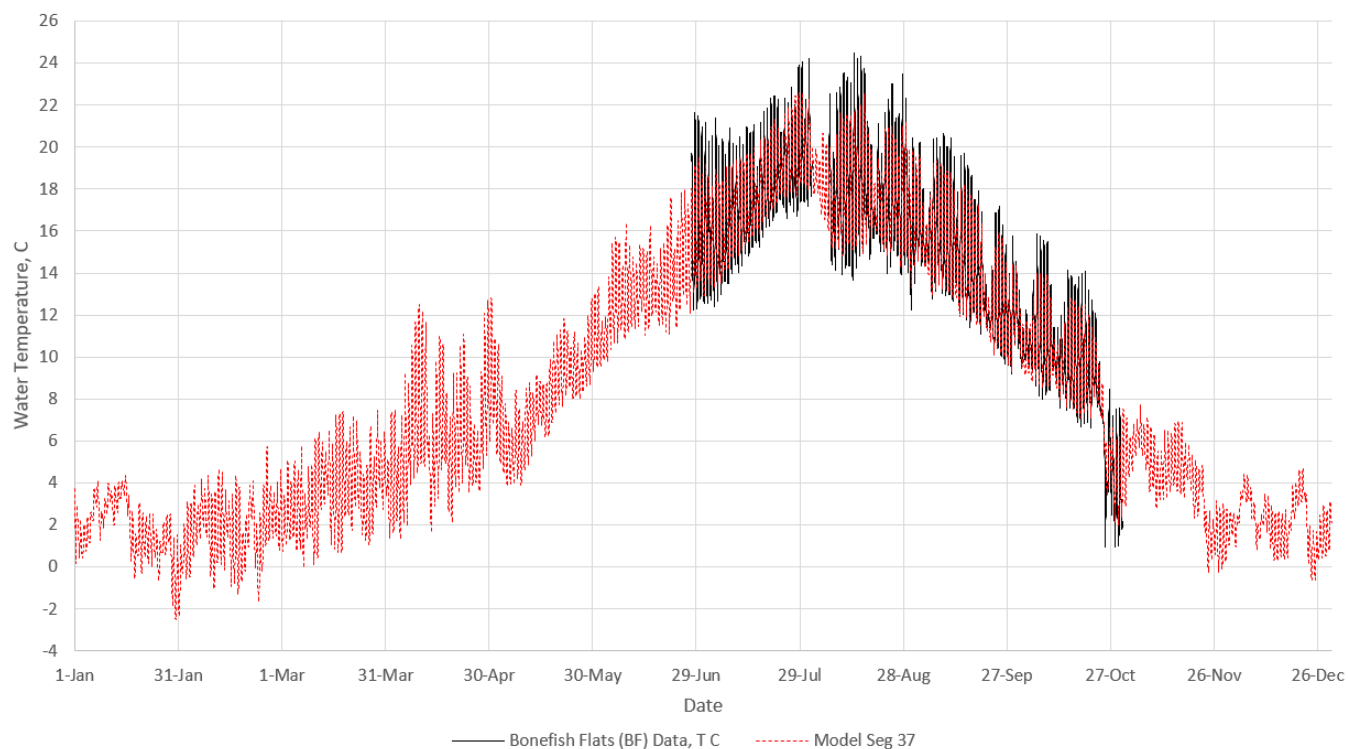


Figure 61. Henry's Fork River, model-data water temperature comparison at model segment 37 with data from Bonefish Flats, 2023.

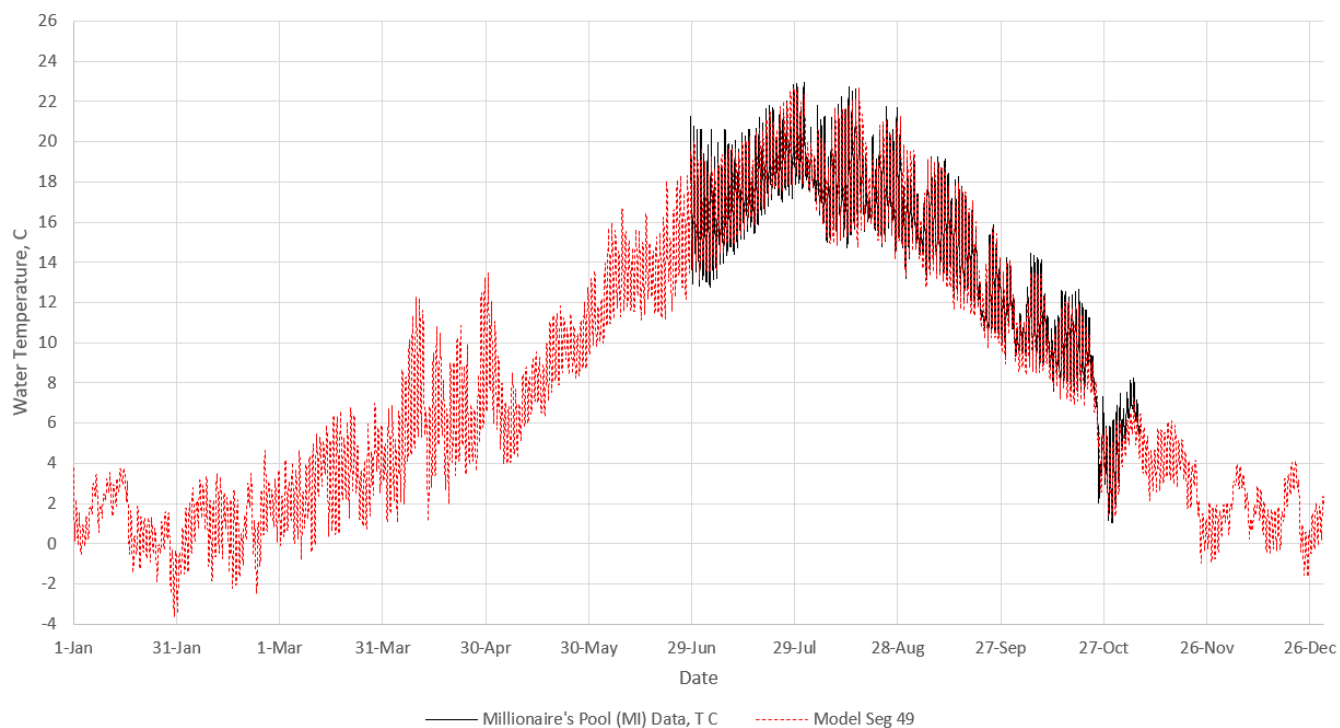


Figure 62. Henry's Fork River, model-data water temperature comparison at model segment 49 with data from Millionaire's Pool, 2023.

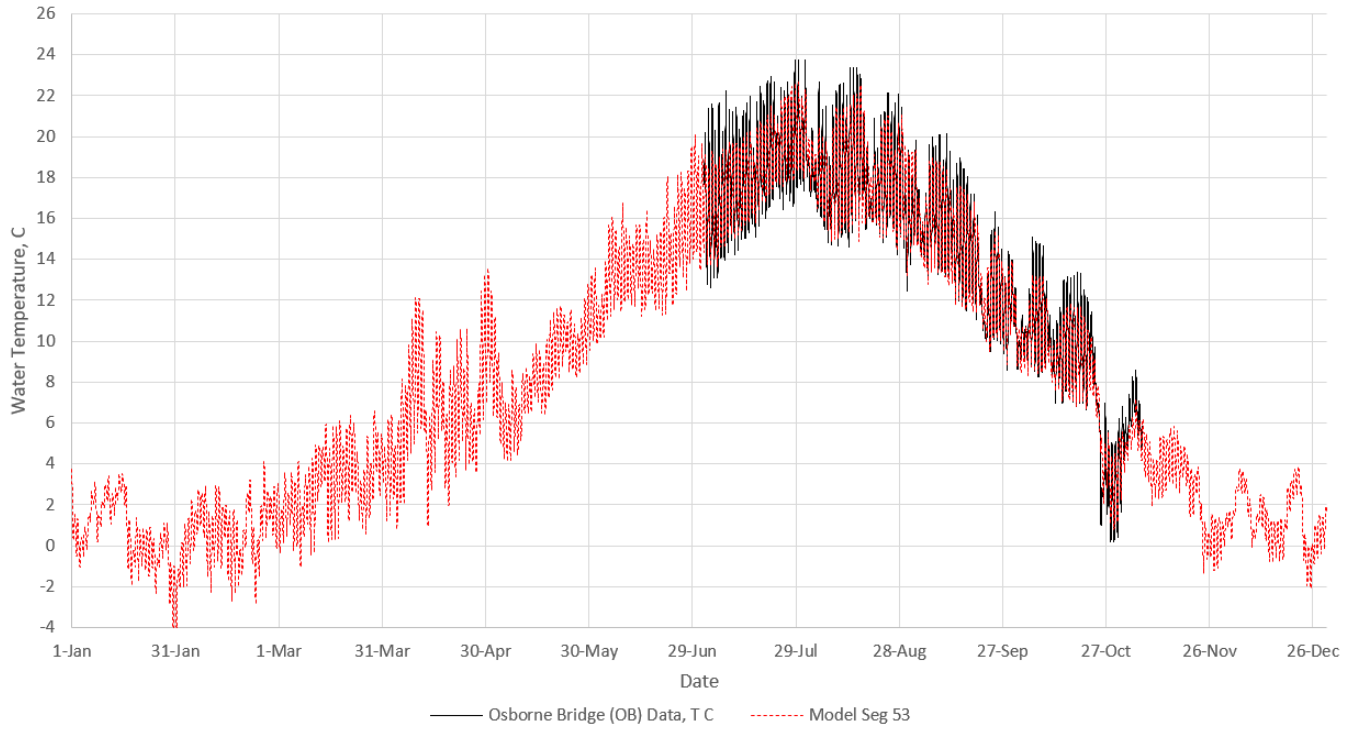


Figure 63. Henry's Fork River, model-data water temperature comparison at model segment 53 with data from Osborne Bridge, 0.9 miles downstream of the model domain, 2023.

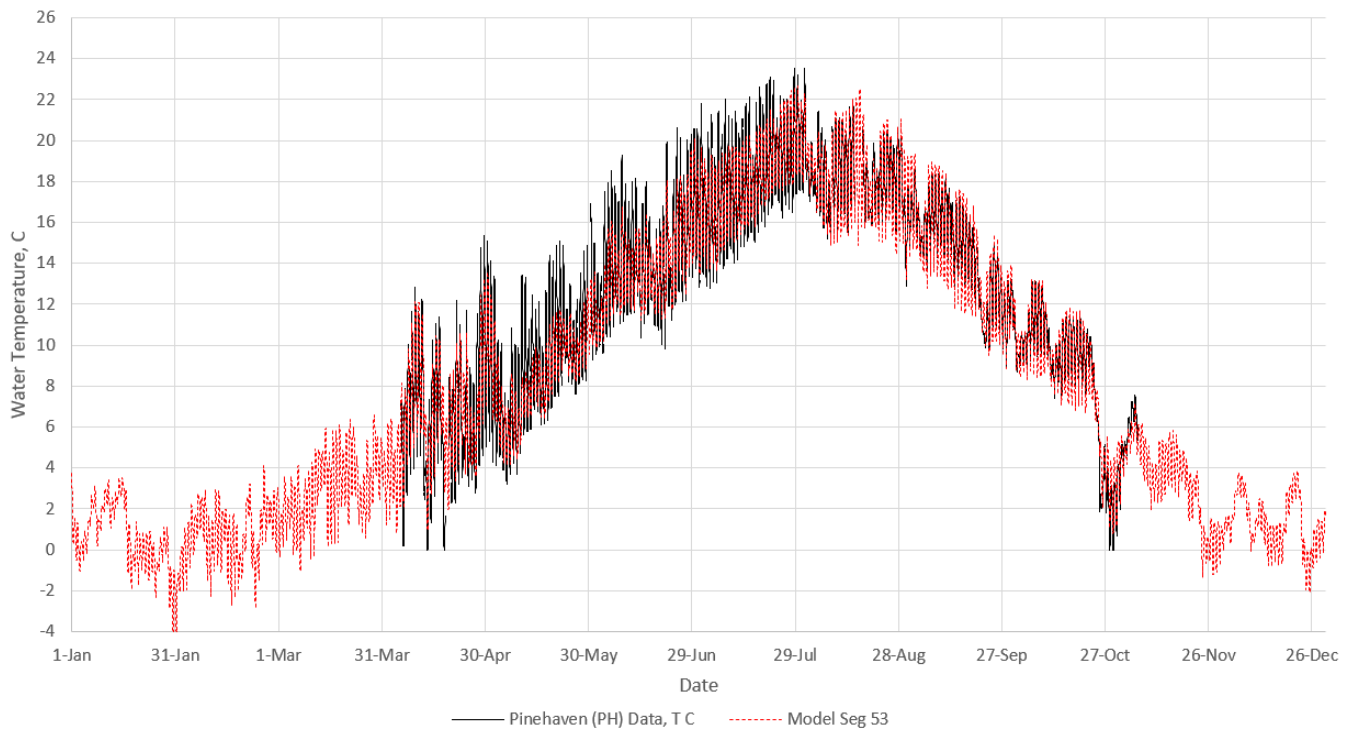


Figure 64. Henry's Fork River, model-data water temperature comparison at model segment 53 with data from Pinehaven (1), 4.6 miles downstream of the model domain, 2023.

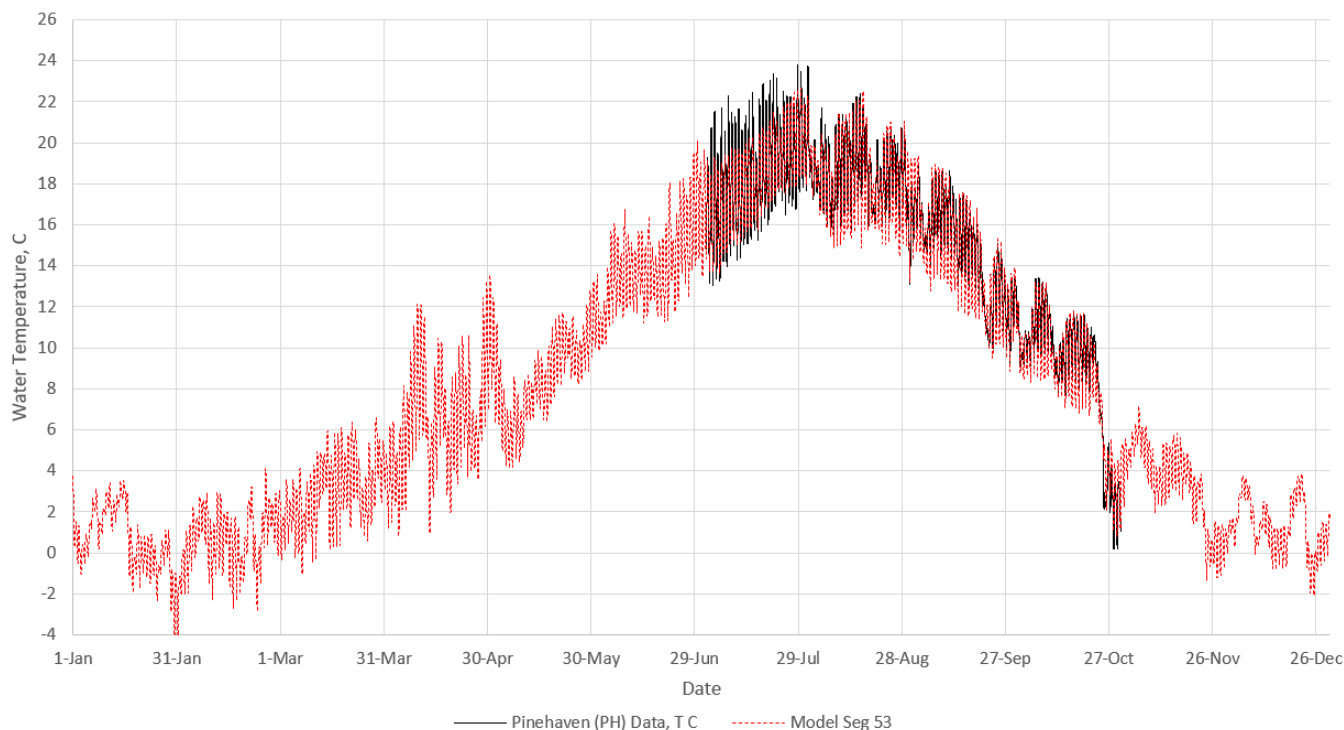


Figure 65. Henry's Fork River, model-data water temperature comparison at model segment 53 with data from Pinehaven (2), 4.6 miles downstream of the model domain, 2023.

Table 19. Model-data error statistics for continuous water temperatures at four locations, 2023.

Location	Site	Model Segment	RM	ME, °C	MAE, °C	RMSE, °C
Last Chance Right	LCL1	24	86.9	-0.05	0.47	0.59
Last Chance Right	LCL2	24	86.9	0.01	0.46	0.59
Last Chance Left	LCR	24	86.9	-0.22	0.37	0.44
Bonefish Flats	BF	37	83.9	-0.11	0.65	0.86
Millionaire's pool	MI	49	82.1	-0.18	0.51	0.66
Osborne Bridge	OB	53+	80.4	-0.07	0.57	0.74
Pinehaven (1)	PH	53+	76.7	-0.26	0.79	1.04
Pinehaven (2)	PH	53+	76.7	-0.41	0.84	1.08
Average (not including Pinehaven)				-0.10	0.51	0.65

Daily Maximum Temperatures

Although the Henry's Fork River model was calibrated to continuous water temperature measurements, the daily maximum water temperature time series data and model results for the same locations were also compared since this parameter is often used in evaluating adherence to water quality standards. Figure 66 through Figure 73 show model-data comparisons of the daily maximum water temperatures for each of the sites used in the continuous water temperature calibration (listed in Table 19). The figures show there is good model-data agreement at most sites with Bonefish Flats showing the model having cooler daily

maximums than the data, but better agreement downstream at Millionaire's Pool. The figures also show a little less model-data agreement at Osborne Bridge and Pinehaven, which is to be expected since these sites are downstream of the model domain.

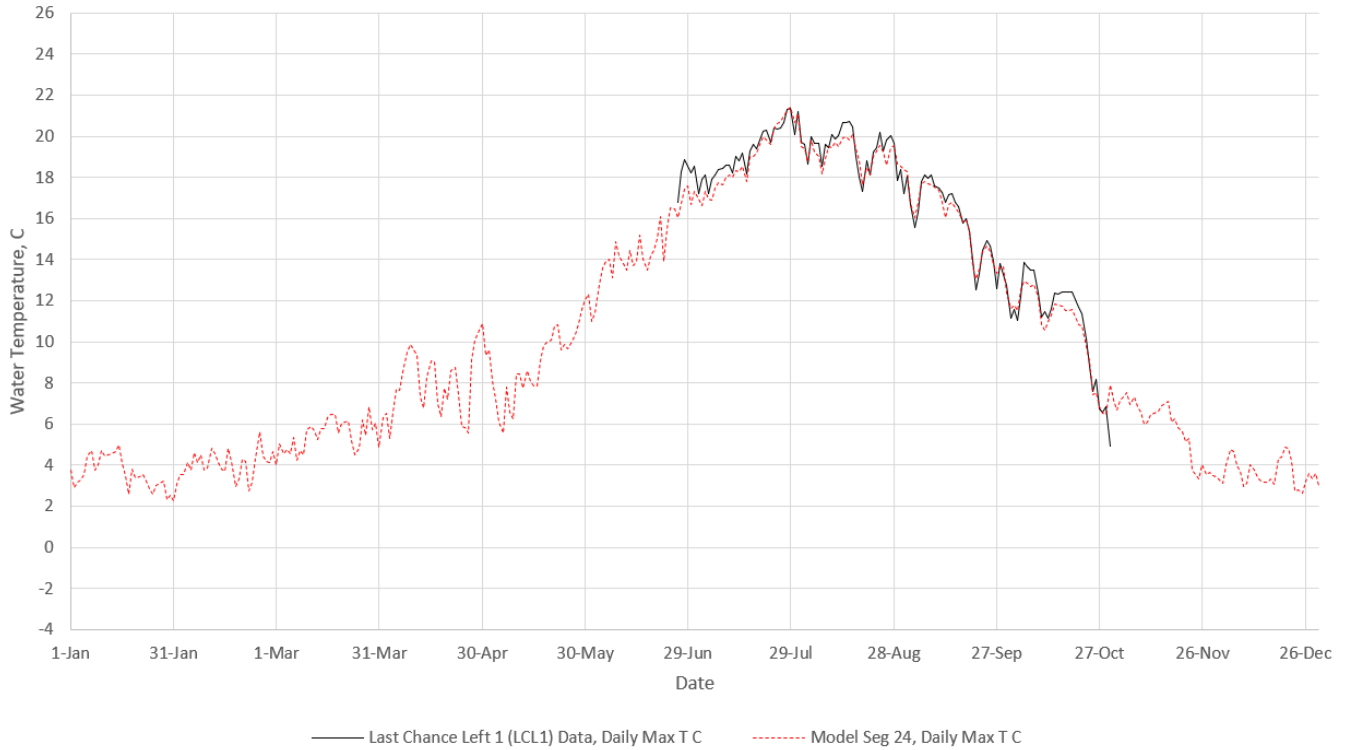


Figure 66. Henry's Fork River, model-data daily maximum water temperature comparison at model segment 24 with data from Last Chance Left 1, 2023

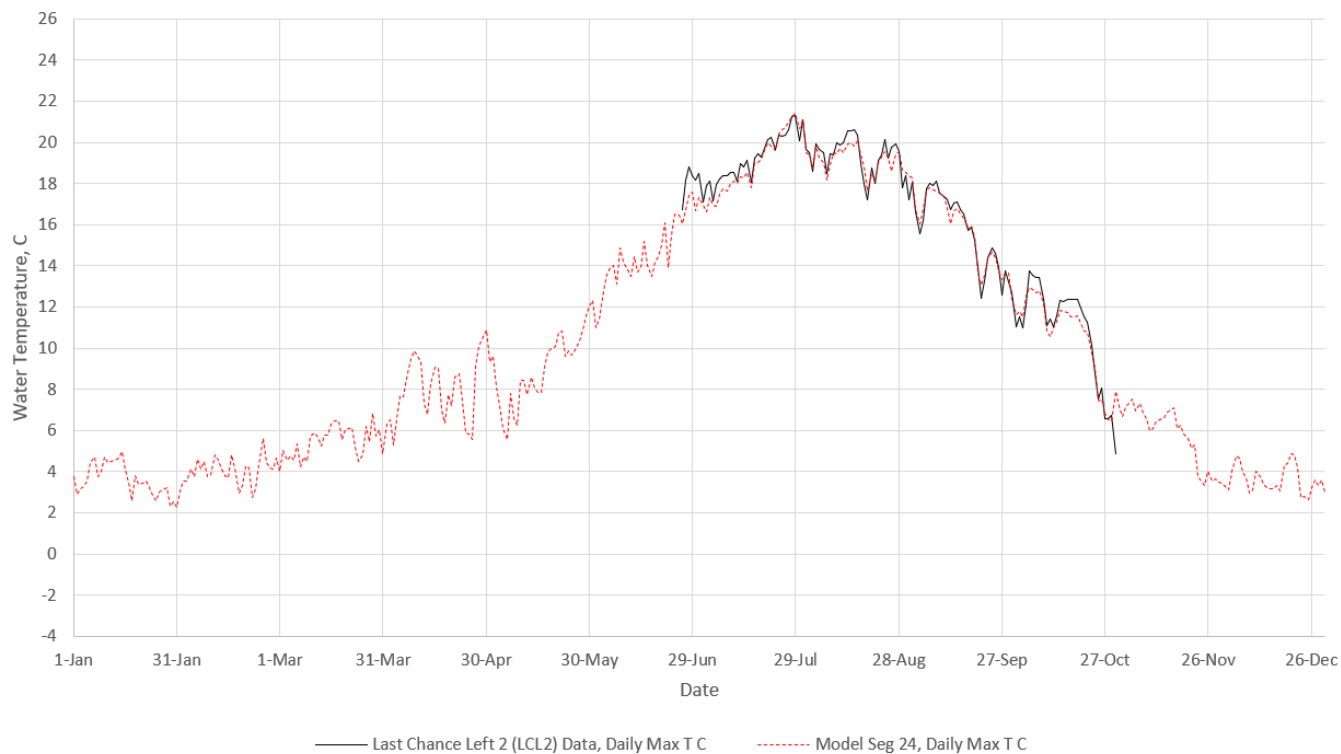


Figure 67. Henry's Fork River, model-data daily maximum water temperature comparison at model segment 24 with data from Last Chance Left 2, 2023.

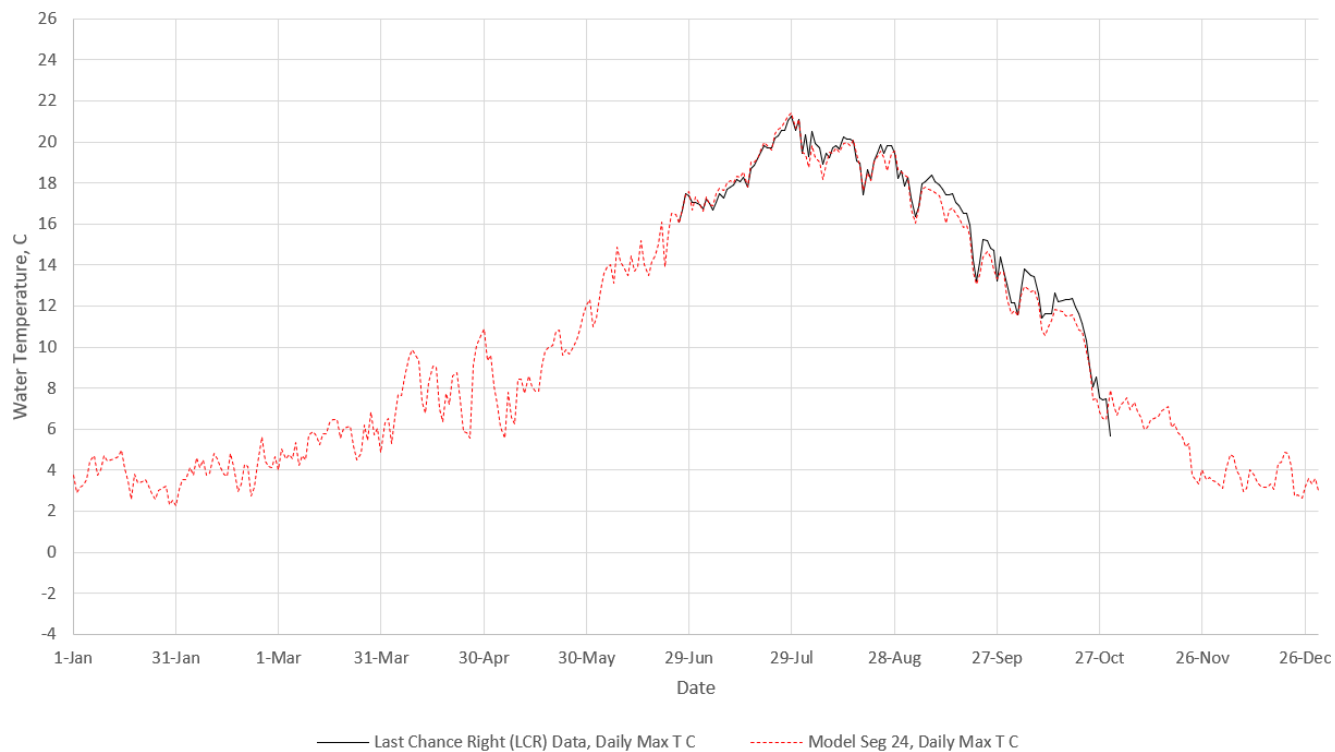


Figure 68. Henry's Fork River, model-data daily maximum water temperature comparison at model segment 24 with data from Last Chance Right, 2023.

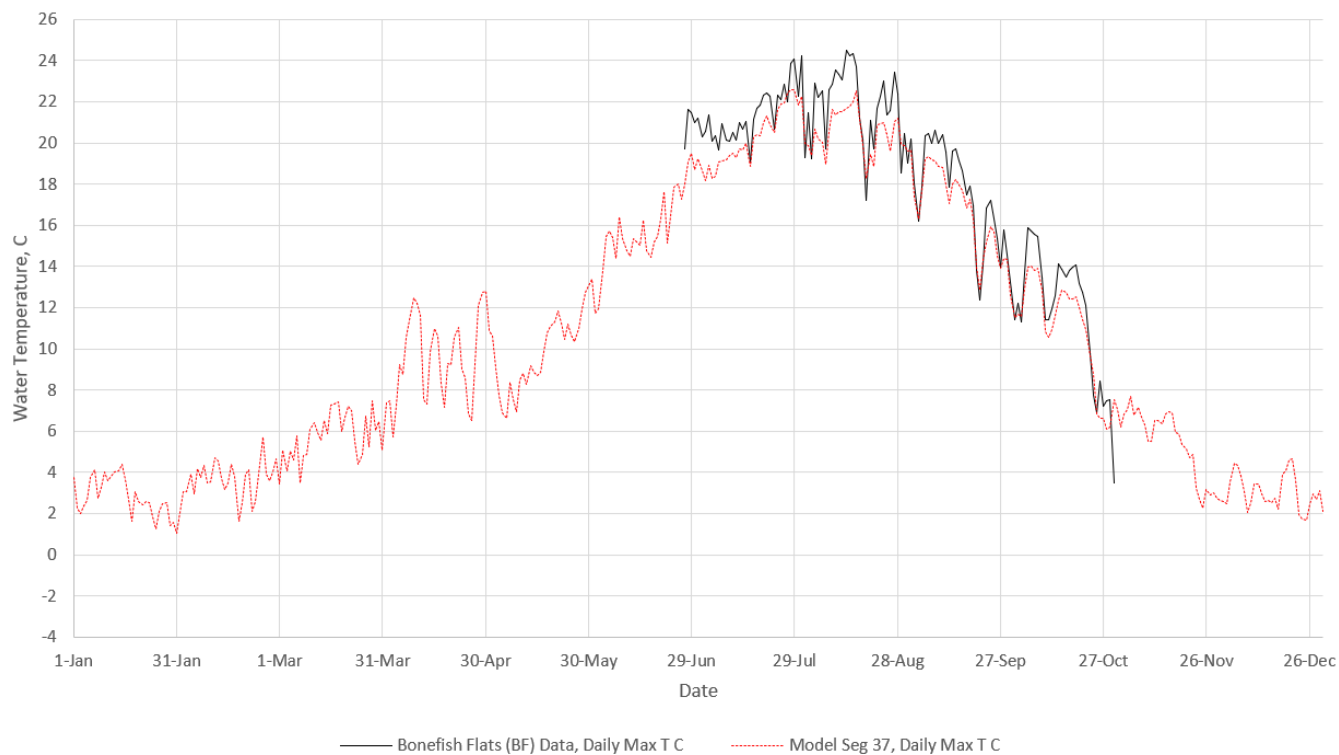


Figure 69. Henry's Fork River, model-data daily maximum water temperature comparison at model segment 37 with data from Bonefish Flats, 2023.

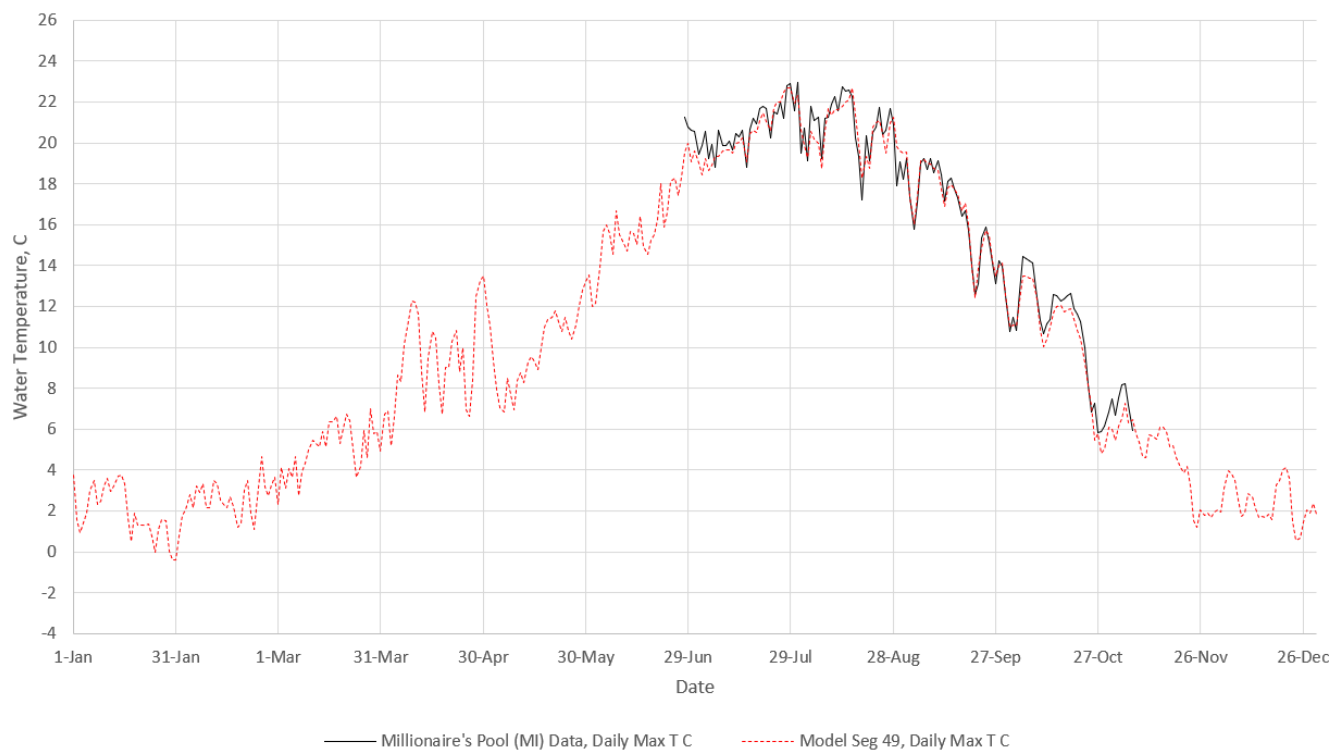


Figure 70. Henry's Fork River, model-data daily maximum water temperature comparison at model segment 49 with data from Millionaire's Pool, 2023.

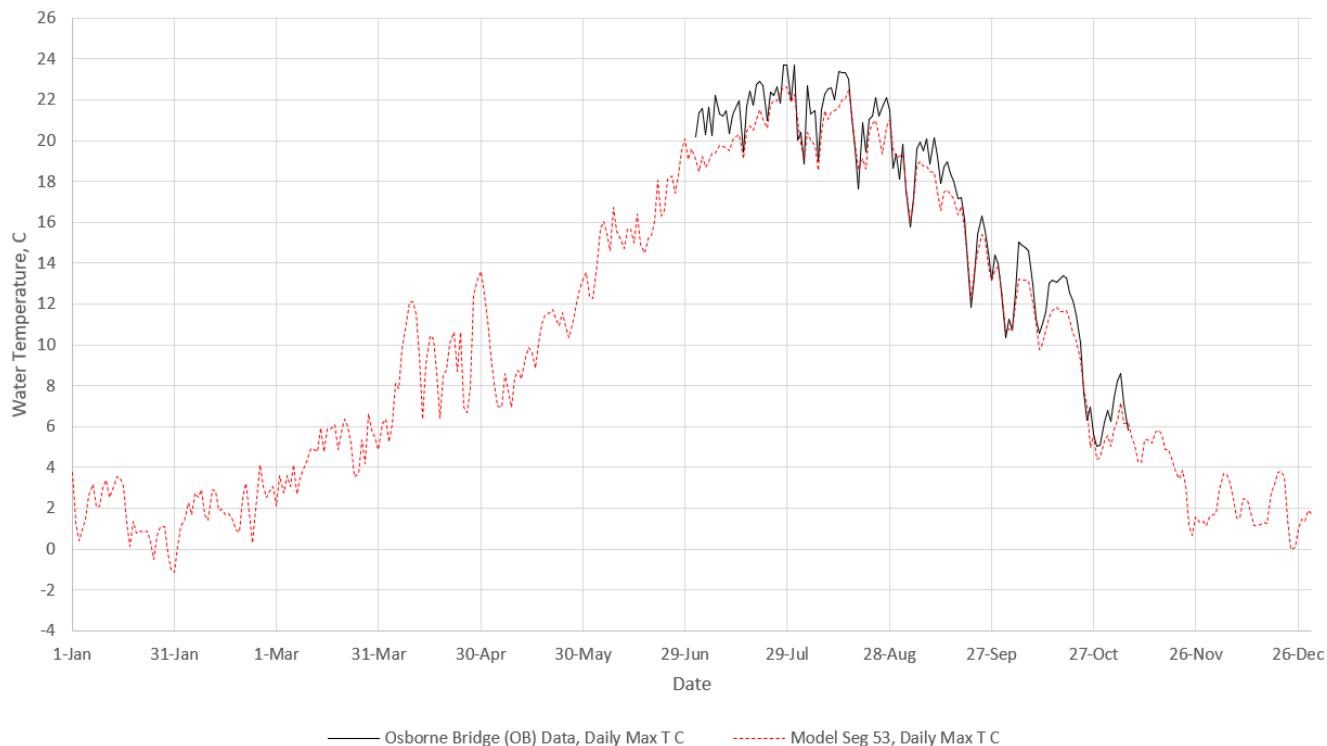


Figure 71. Henry's Fork River, model-data daily maximum water temperature comparison at model segment 53 with data from Osborne Bridge, 0.9 miles downstream of the model domain, 2023.

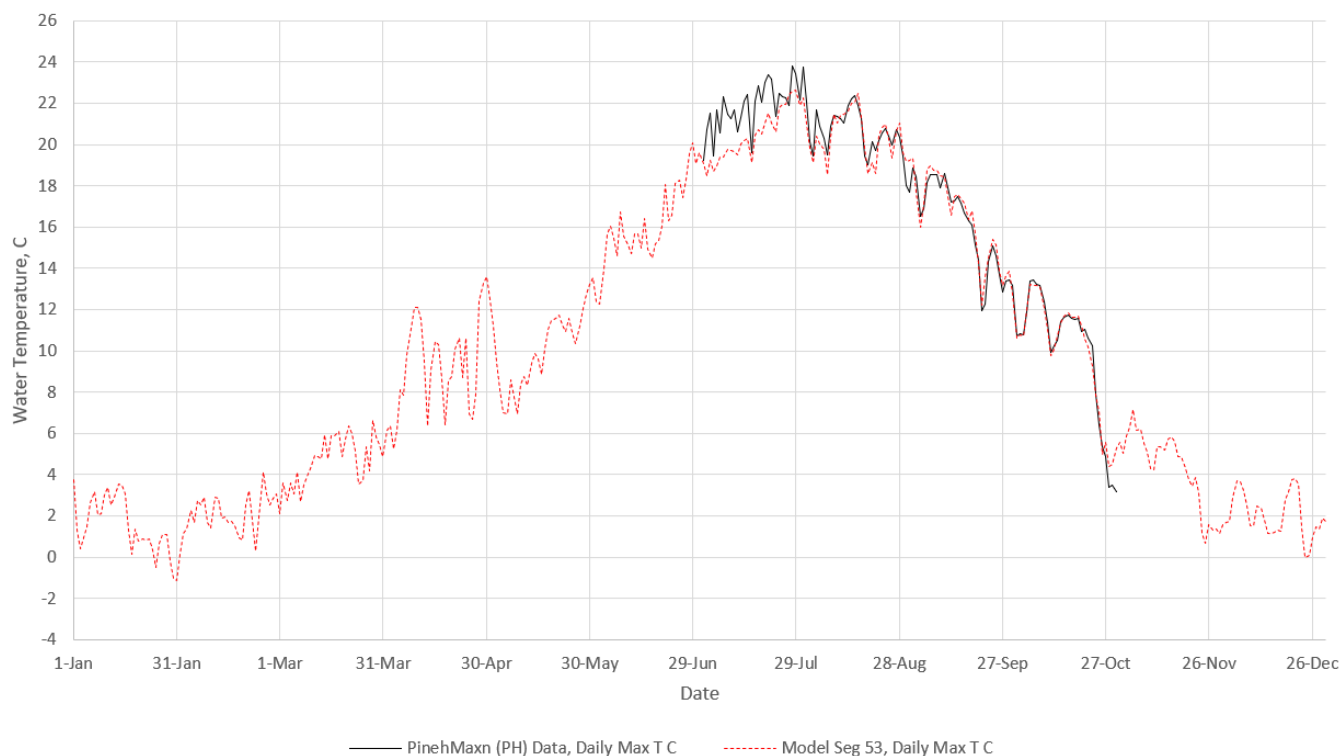


Figure 72. Henry's Fork River, model-data daily maximum water temperature comparison at model segment 53 with data from Pinehaven (1), 4.6 miles downstream of the model domain, 2023.

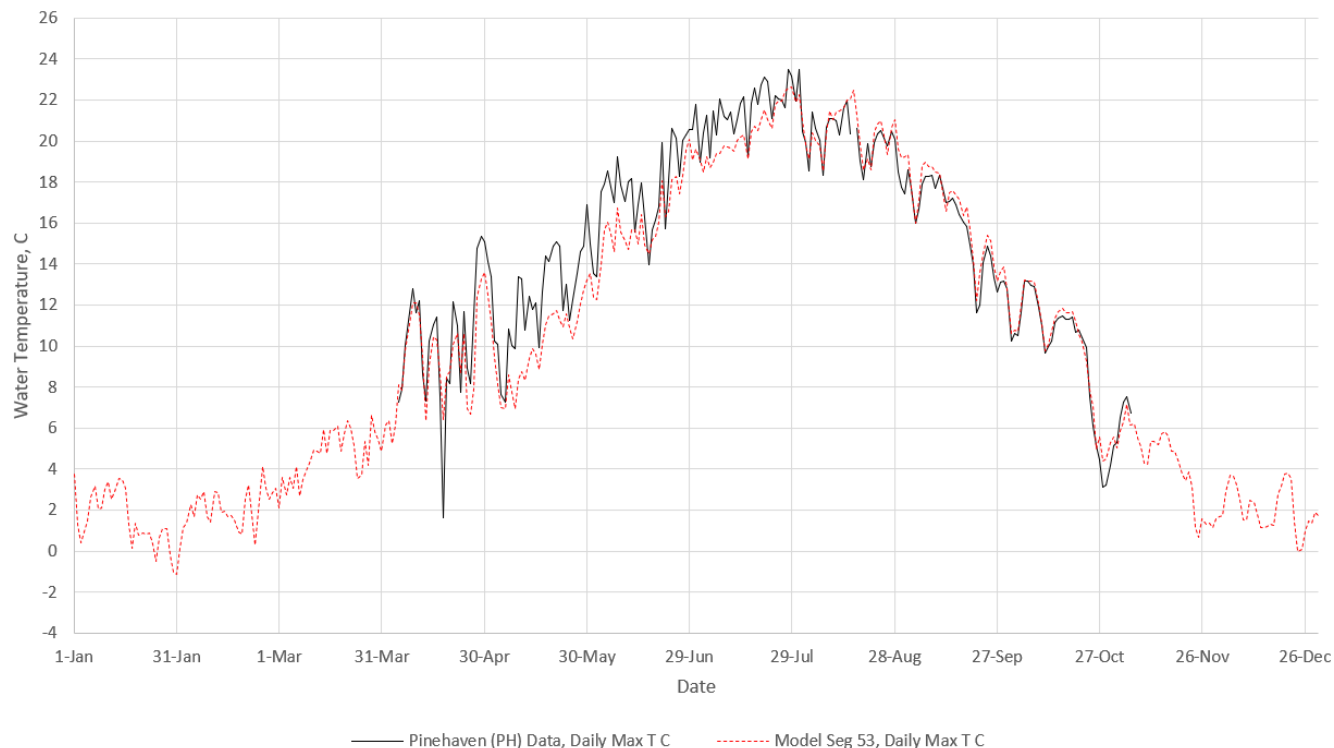


Figure 73. Henry's Fork River, model-data daily maximum water temperature comparison at model segment 53 with data from Pinehaven (2), 4.6 miles downstream of the model domain, 2023.

Daily Average Temperatures

Although the Henry's Fork River model was calibrated to continuous water temperature measurements, the daily average water temperature time series data and model results for the same locations were also compared since this parameter is often used in evaluating adherence to water quality standards. Figure 74 through Figure 81 show model-data comparisons of the daily average water temperatures for each of the sites used in the continuous water temperature calibration (listed in Table 19). The figures show there is good model-data agreement at all of the sites with the exception of one of the Pinehaven data sets, which is to be expected since this site is located downstream of the model domain.

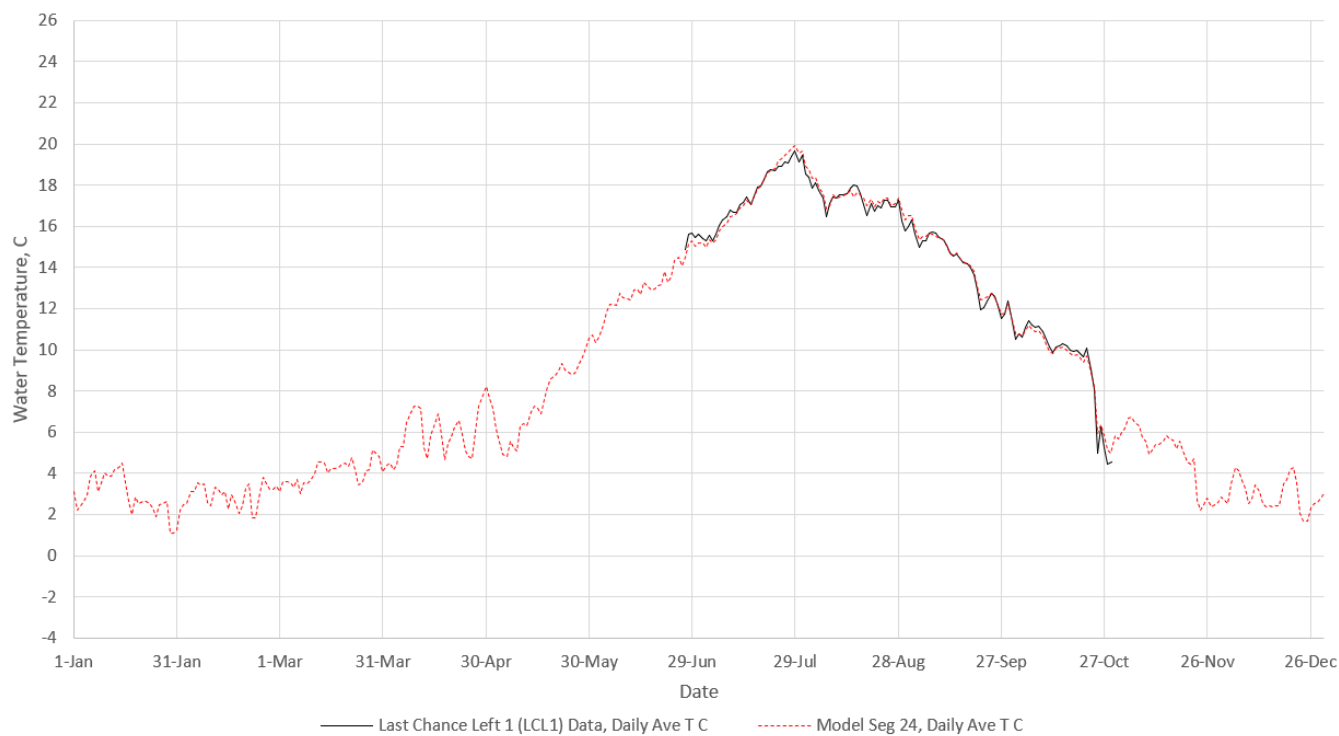


Figure 74. Henry's Fork River, model-data daily average water temperature comparison at model segment 24 with data from Last Chance Left 1, 2023.

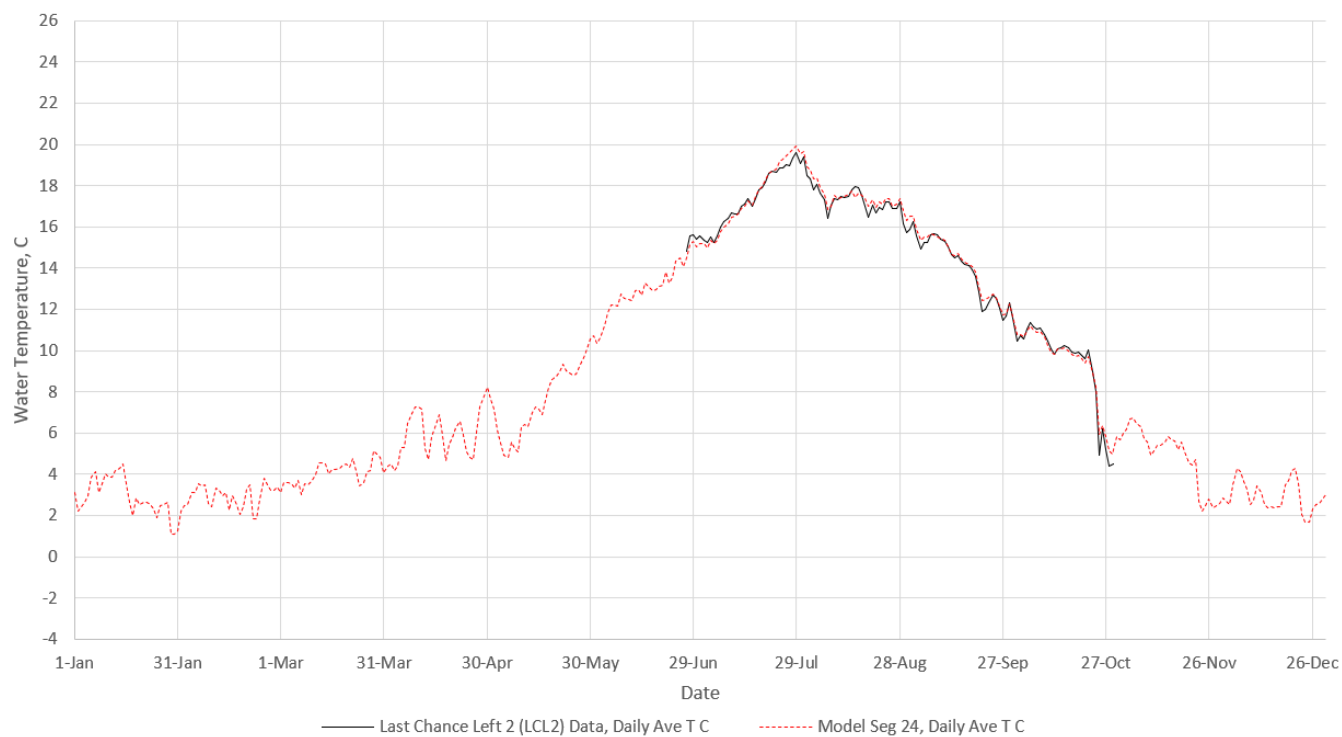


Figure 75. Henry's Fork River, model-data daily average water temperature comparison at model segment 24 with data from Last Chance Left 2, 2023.

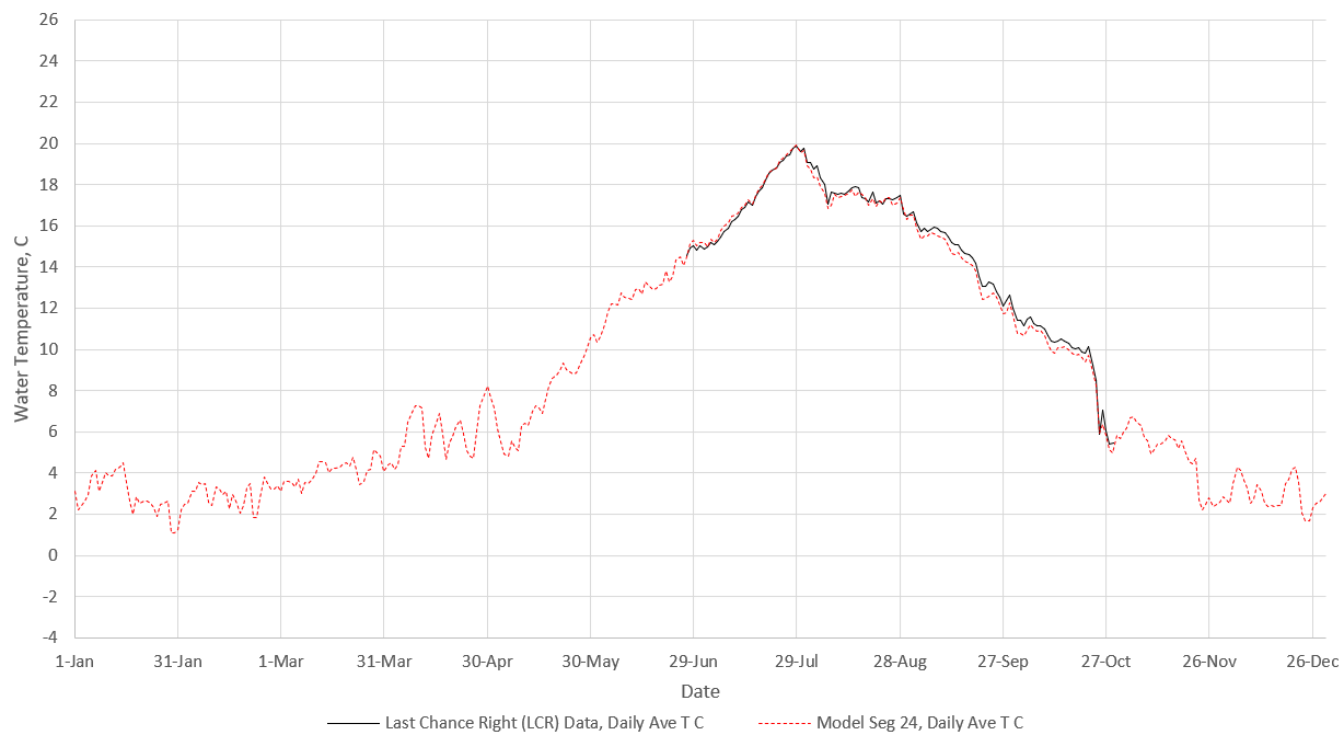


Figure 76. Henry's Fork River, model-data daily average water temperature comparison at model segment 24 with data from Last Chance Right, 2023.

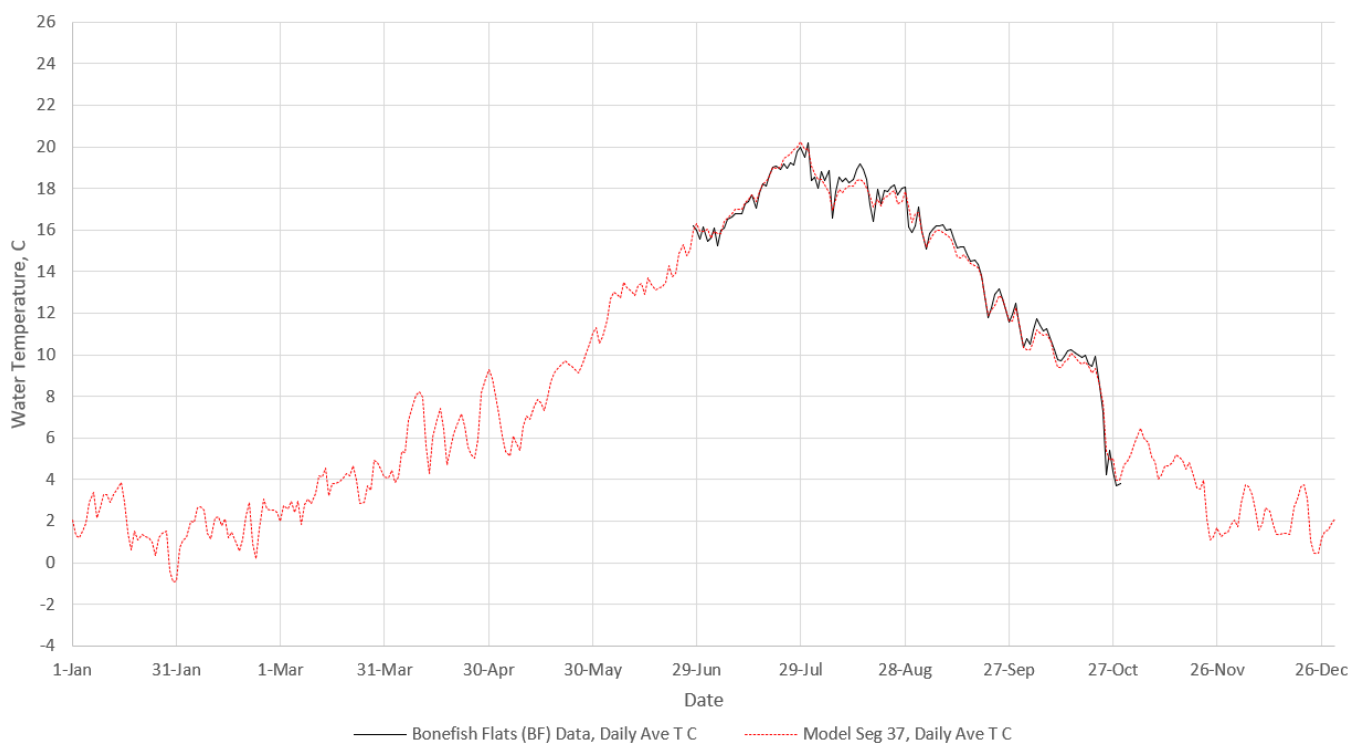


Figure 77. Henry's Fork River, model-data daily average water temperature comparison at model segment 37 with data from Bonefish Flats, 2023.

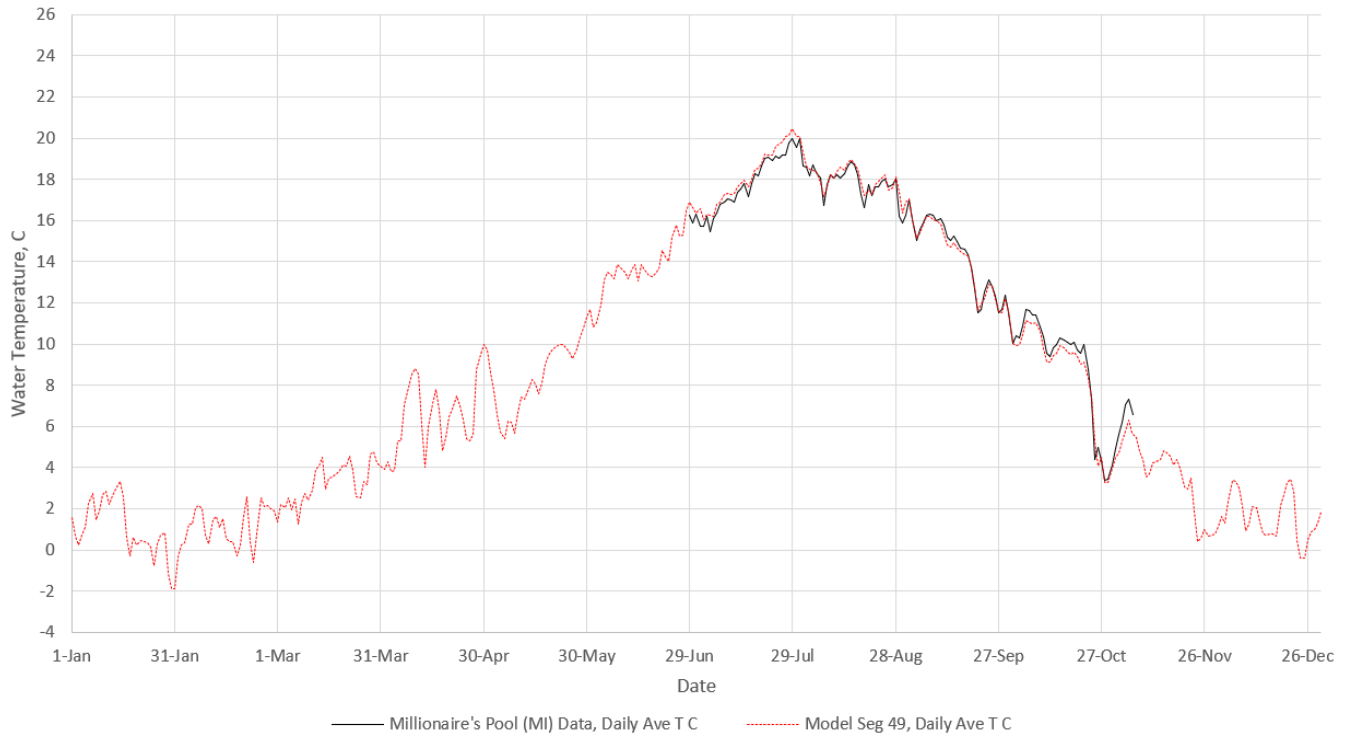


Figure 78. Henry's Fork River, model-data daily average water temperature comparison at model segment 49 with data from Millionaire's Pool, 2023.

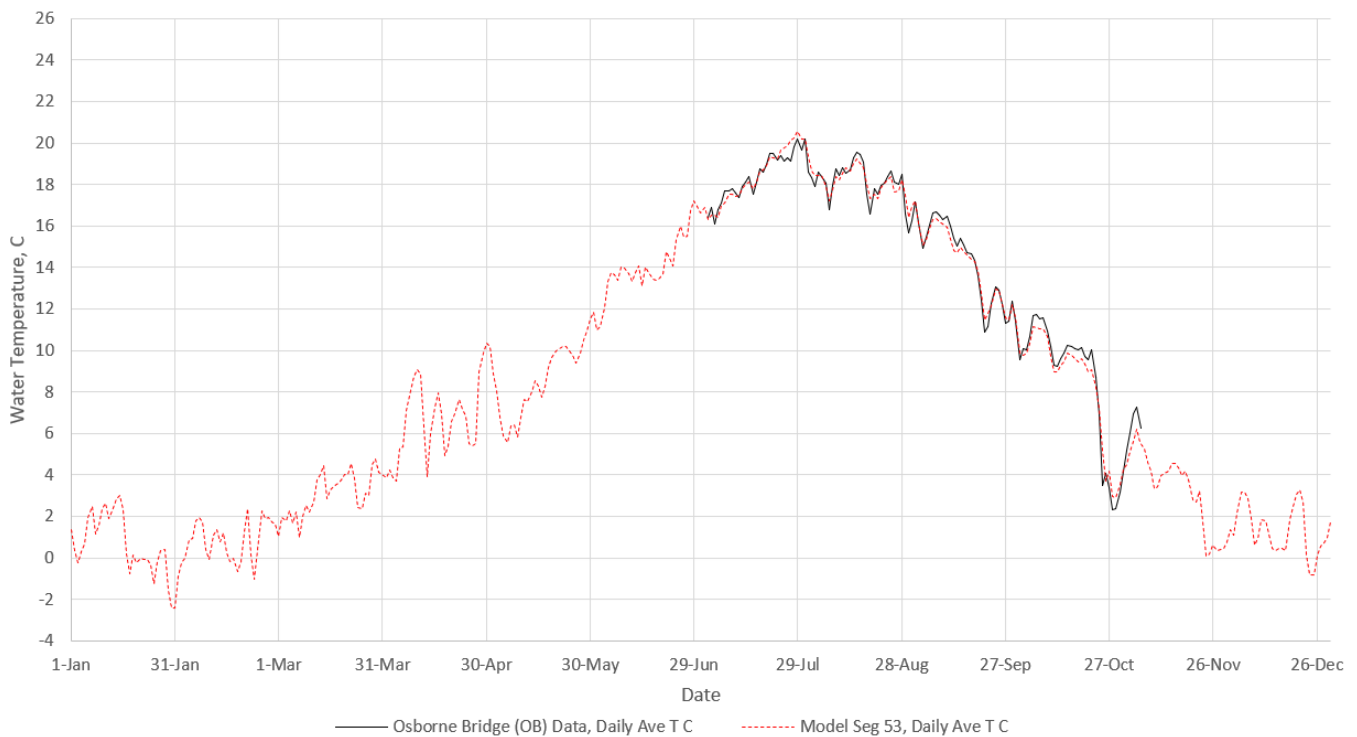


Figure 79. Henry's Fork River, model-data daily average water temperature comparison at model segment 53 with data from Osborne Bridge, 0.9 miles downstream of the model domain, 2023.

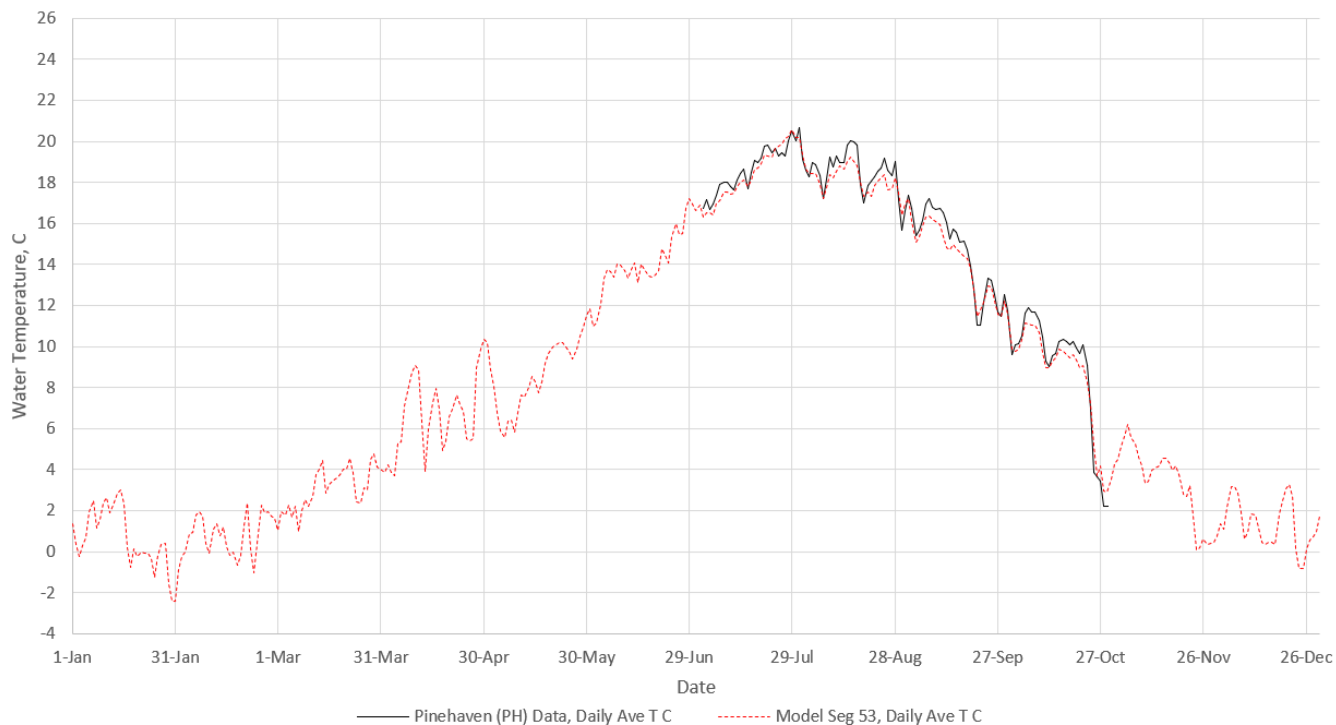


Figure 80. Henry's Fork River, model-data daily average water temperature comparison at model segment 53 with data from Pinehaven (1), 4.6 miles downstream of the model domain, 2023.

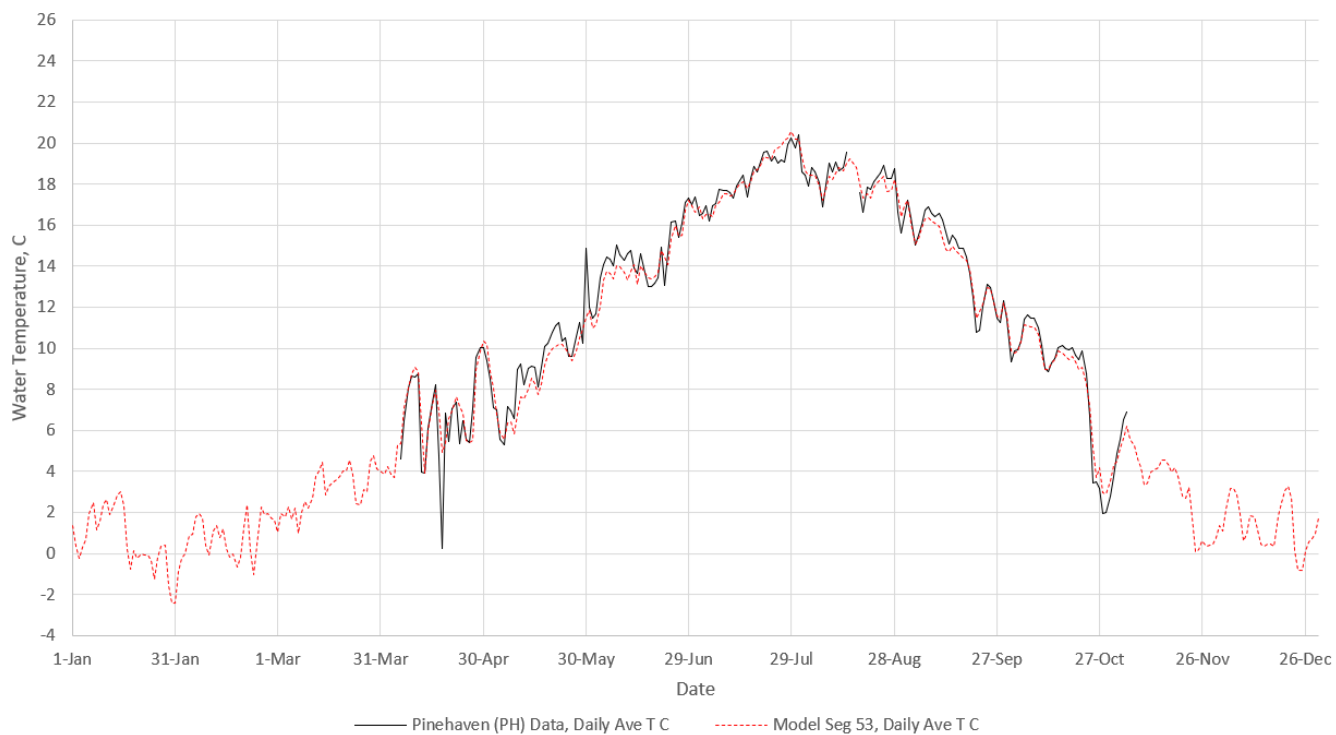


Figure 81. Henry's Fork River, model-data daily average water temperature comparison at model segment 53 with data from Pinehaven (2), 4.6 miles downstream of the model domain, 2023.

Preliminary Model Scenarios

Three preliminary model scenarios were developed for the Island Park Reservoir and Henry's Fork River CE-QUAL-W2 models to understand how the magnitude and frequency of water temperature standards violations occur in different management and operational scenarios. Reservoir output flows and temperatures from the Island Park Reservoir model were used as the upstream boundary condition for the Henry's Fork River model to better simulate the compounding impact to stream temperatures for each scenario. These scenarios are detailed below:

- **2°C Change in Air Temperature**
 - This scenario simulates the effects of a 2°C increase and a 2°C decrease in air temperature on Island Park Reservoir and Henry's Fork River water temperatures in 2023.
 - In developing the scenario, the air temperature parameter [TAIR] in the input meteorology file [met.csv] for the Island Park Reservoir and Henry's Fork River models was modified by +/- 2°C. No other changes were made to the models.
- **Restoration Effort (Riparian Shading)**
 - This scenario simulates potential restoration efforts along the banks of the reservoir and river with trees planted along the banks of both water bodies.
 - To simulate the increase in tree cover (and resulting surface water shading), the dynamic shade parameter [DYNOSH] in the input shade file [shade.npt] for each model was modified as follows:
 - Island Park Reservoir: Increase [DYNOSH] from 0 to 0.1.
 - DYNOSH = 0.0 (0%): 100% of incoming solar radiation reaches the water surface.
 - DYNOSH = 0.1 (10%): 90% of incoming solar radiation reaches the water surface.
 - Henry's Fork River: increase [DYNOSH] from 0 to 0.75.
 - DYNOSH = 0.75 (75%): 25% of incoming solar radiation reaches the water surface.
- **Conservation of Reservoir Cold Water for Summer Release**
 - This scenario simulates a cold-water conservation program that preserves cold Island Park Reservoir bottom depth temperatures for later summer release.
 - Water is withdrawn from a new proposed withdrawal structure between January 1, 2023 and May 31, 2023 while surface temperatures are below 16°C (~68 degrees Fahrenheit).
 - The proposed structure is collocated with the FRREC Power and USBR Gate withdrawals at Segment 99 in the model. The withdrawal elevation was set to 3 m (9.8 ft.) below the average elevation of the Island Park Reservoir in 2023 (1,920.1 m AMSL), or 1,917.1 m AMSL.
 - Total daily withdrawals from the Island Park Reservoir remain consistent with the calibrated model. Figure 82 shows the modified outflow time series from the Island Park Reservoir with the proposed structure.

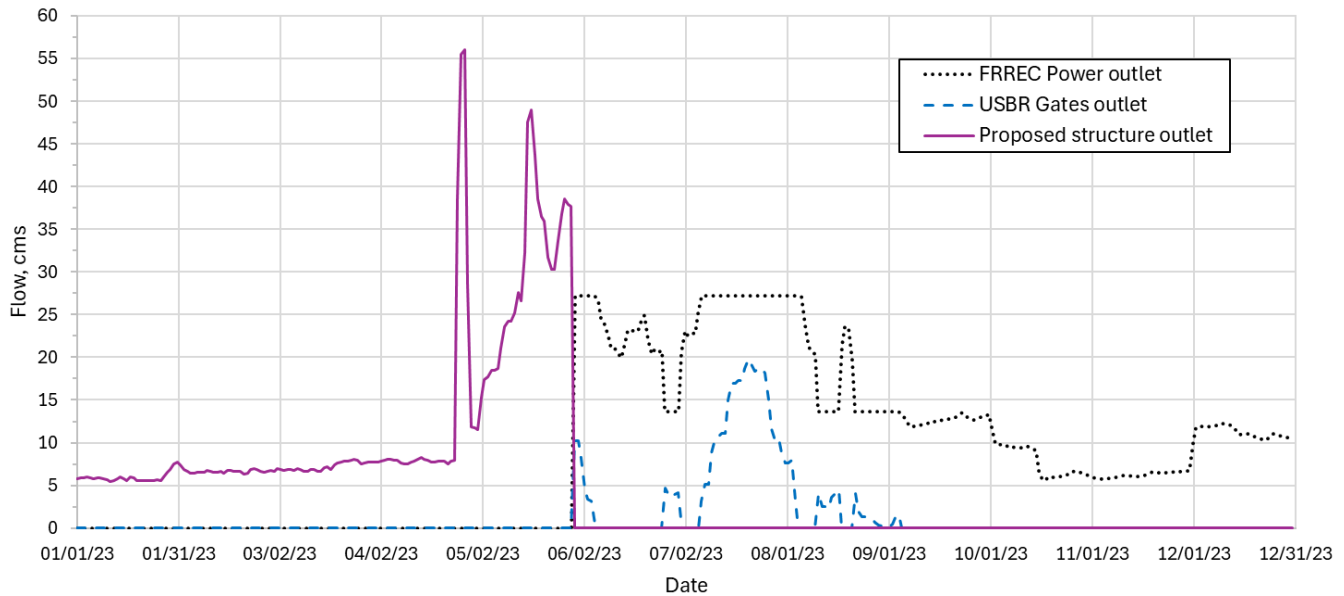


Figure 82. Modified Island Park Reservoir model outflows for the cold-water conservation scenario.

Island Park Reservoir

Table 20 through Table 22 present comparisons of the calibrated model to the preliminary model scenarios, with references to the Cold-Water Aquatic Life and Salmonid Spawning criteria, for continuous, daily average, and daily maximum time series of the reservoir outflow water temperatures. Outflow temperature was calculated as the flow-weighted average of the gate outflow temperatures. Figure 83 through Figure 91 show time series of the calibrated model alongside preliminary model scenarios.

The cold-water conservation scenario results in the greatest reduction in outflow water temperatures and features the lowest water temperatures across the preliminary model scenarios. However, the implementation of the restoration effort, a 2°C reduction in air temperature, and the implementation of a cold-water conservation program (and supporting infrastructure) result in similar changes in average outflow temperature.

Compared to the calibrated model, the preliminary model scenarios result in incremental variations in outflow water temperature (less than 5% of outflow temperatures under baseline conditions). Similarly, exceedance of the Cold-Water Aquatic Life and Salmonid Spawning temperature thresholds remains fairly consistent across these scenarios.

Table 20. Comparison of continuous temperature statistics at the outflow of the Island Park Reservoir model.

Preliminary Model Scenario (2023 Model Run)	Continuous Temperature (°C)			
	Min	Max	Avg.	Change from calibrated average (%)
Calibrated model	3.74	18.64	8.62	n/a
2°C increase in air temperature	3.62	19.17	9.03	+0.40 (4.66%)
2°C decrease in air temperature	3.56	17.99	8.32	-0.30 (3.52%)
Restoration	3.50	17.99	8.40	-0.22 (2.60%)
Cold water conservation	1.75	18.63	8.31	-0.31 (3.58%)

Table 21. Comparison of daily average temperature statistics at the outflow of the Island Park Reservoir model.

Preliminary Model Scenario (2023 Model Run)	Daily Average Temperature (°C)					
	Min	Max	Avg.	Change from calibrated avg (%)	No. of days CWAL* (19°C) is exceeded	No. of days Salmonid Spawning (9°C) is exceeded
<i>Entire Year</i>						
Calibrated model	3.74	18.51	8.61	n/a	0	157
2°C increase in air temperature	3.66	19.10	9.01	+0.40 (4.65%)	4	168
2°C decrease in air temperature	3.72	17.86	8.31	-0.30 (3.52%)	0	146
Restoration	3.71	17.84	8.39	-0.22 (2.60%)	0	149
Cold water conservation	1.88	18.49	8.30	-0.31 (3.57%)	0	162
<i>June</i>						
Calibrated model	11.37	13.75	12.81	n/a	0	30
2°C increase in air temperature	12.20	14.27	13.42	+0.61 (4.73%)	0	30
2°C decrease in air temperature	10.85	13.21	12.32	-0.49 (3.84%)	0	30
Restoration	10.99	13.35	12.44	-0.37 (2.85%)	0	30
Cold water conservation	9.76	13.69	12.21	-0.6 (4.68%)	0	30
<i>July</i>						
Calibrated model	14.04	18.51	16.45	n/a	0	31
2°C increase in air temperature	14.56	19.10	17.00	+0.55 (3.34%)	4	31
2°C decrease in air temperature	13.48	17.86	15.89	-0.56 (3.41%)	0	31
Restoration	13.62	17.84	15.94	-0.51 (3.09%)	0	31
Cold water conservation	13.98	18.49	16.44	-0.01 (0.06%)	0	31
<i>August</i>						
Calibrated model	16.32	18.38	17.08	n/a	0	31
2°C increase in air temperature	16.77	18.94	17.47	+0.39 (2.31%)	0	31
2°C decrease in air temperature	15.80	17.82	16.48	-0.60 (3.49%)	0	31
Restoration	15.88	17.82	16.57	-0.51 (2.98%)	0	31
Cold water conservation	16.32	18.41	17.02	-0.06 (0.36%)	0	31

* Cold Water Aquatic Life criteria (CWAL).

Table 22. Comparison of daily maximum temperature statistics at the outflow of the Island Park Reservoir model.

Preliminary Model Scenario (2023 Model Run)	Daily Maximum Temperature (°C)					
	Min	Max	Avg.	Change from calibrated avg (%)	No. of days CWAL (22°C) is exceeded	No. of days Salmonid Spawning (13°C) is exceeded
<i>Entire Year</i>						
Calibrated model	3.76	18.64	8.70	n/a	0	103
2°C increase in air temperature	3.69	19.17	9.11	+0.42 (4.78%)	0	111
2°C decrease in air temperature	3.76	17.99	8.39	-0.30 (3.50%)	0	95
Restoration	3.74	17.99	8.47	-0.23 (2.59%)	0	100
Cold water conservation	1.89	18.63	8.44	-0.26 (2.99%)	0	101
<i>June</i>						
Calibrated model	11.60	14.04	12.99	n/a	0	16
2°C increase in air temperature	12.42	14.60	13.59	+0.60 (4.62%)	0	24
2°C decrease in air temperature	11.07	13.50	12.49	-0.50 (3.88%)	0	10
Restoration	11.19	13.64	12.61	-0.38 (2.96%)	0	14
Cold water conservation	10.08	13.99	12.42	-0.57 (4.39%)	0	14
<i>July</i>						
Calibrated model	14.28	18.64	16.60	n/a	0	31
2°C increase in air temperature	14.80	19.17	17.14	+0.54 (3.27%)	0	31
2°C decrease in air temperature	13.74	17.99	16.04	-0.55 (3.34%)	0	31
Restoration	13.88	17.99	16.10	-0.50 (3.02%)	0	31
Cold water conservation	14.23	18.63	16.60	0.00 (0.00%)	0	31
<i>August</i>						
Calibrated model	16.40	18.40	17.16	n/a	0	31
2°C increase in air temperature	16.85	18.97	17.56	+0.40 (2.31%)	0	31
2°C decrease in air temperature	15.85	17.83	16.58	-0.58 (3.39%)	0	31
Restoration	15.94	17.84	16.66	-0.51 (2.94%)	0	31
Cold water conservation	16.38	18.43	17.11	-0.06 (0.33%)	0	31

±2°C Change in Air Temperature

Figure 83 through Figure 85 show the continuous, daily average, and daily maximum water temperatures from the reservoir outflow due to a ±2°C change in air temperature. As expected, the decrease in air temperature decreased the water temperature and the increase in air temperature increased the water temperature. However, the 2°C air temperature increase resulted in a greater change in reservoir outflow temperature than a decrease in air temperature.

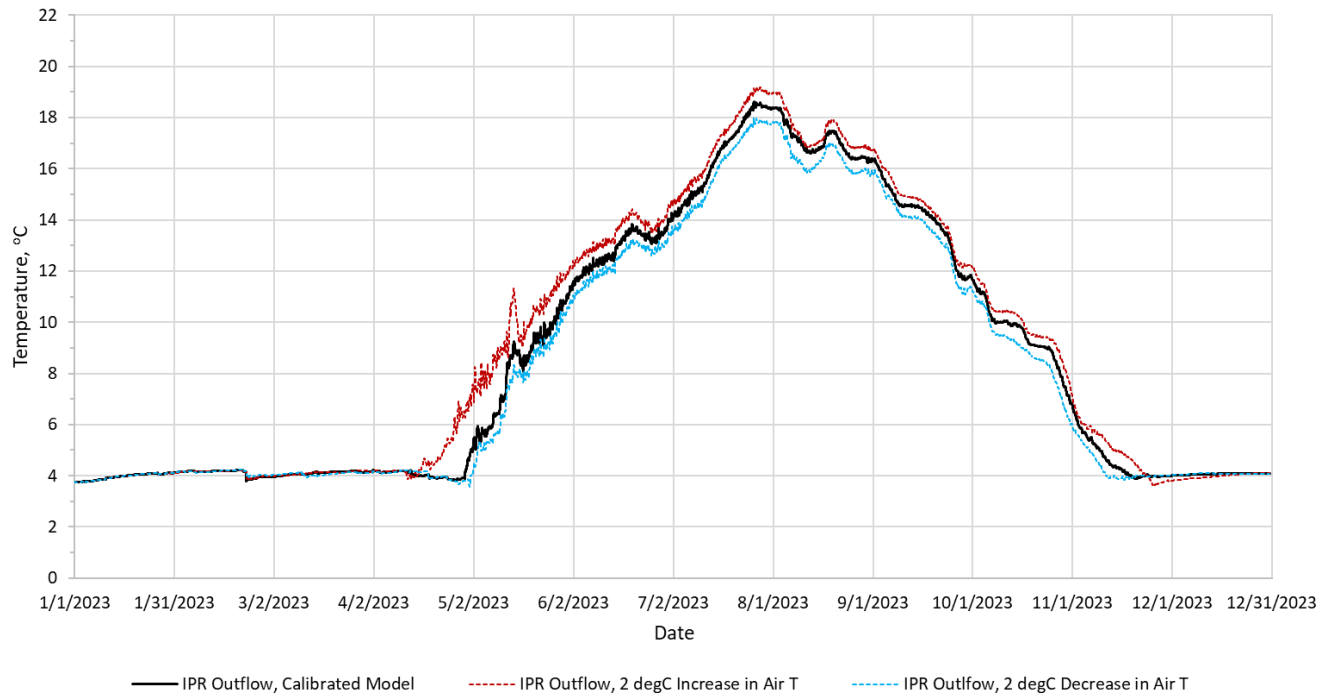


Figure 83. Continuous outflow temperature from Island Park Reservoir for the 2°C change in air temperature scenario.

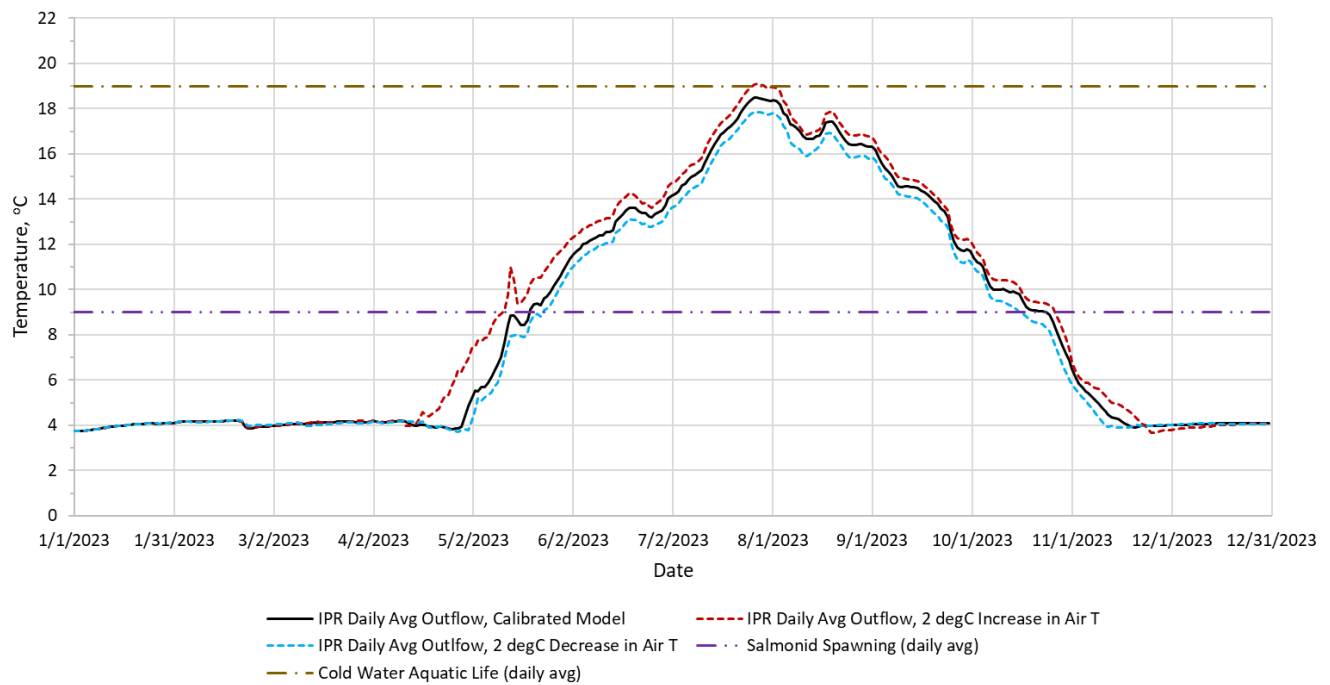


Figure 84. Average daily outflow temperature from Island Park Reservoir for the 2°C change in air temperature scenario.

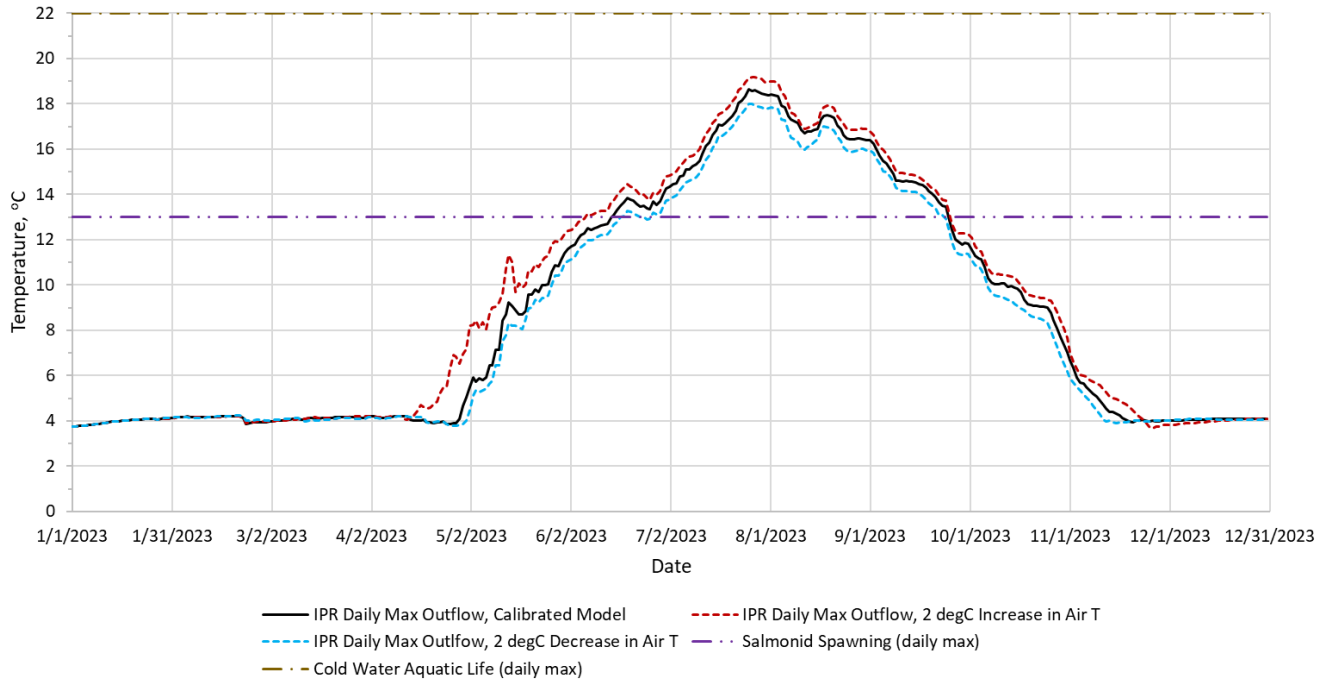


Figure 85. Maximum daily outflow temperature from Island Park Reservoir for the 2°C change in air temperature scenario.

Restoration Effort (Riparian Shading)

Figure 86 through Figure 88 show the continuous, daily average, and daily maximum water temperatures from the reservoir outflow following the implementation of a restoration (riparian planting) effort along the banks of the Island Park Reservoir and Henry's Fork River. Restoration decreased the water temperature leaving the Island Park Reservoir between May and late November when the reservoir is expected to be free of ice. The greatest apparent difference between water temperatures in the calibrated model and restoration scenario occurs in late July, when the reservoir is near its maximum water temperature.

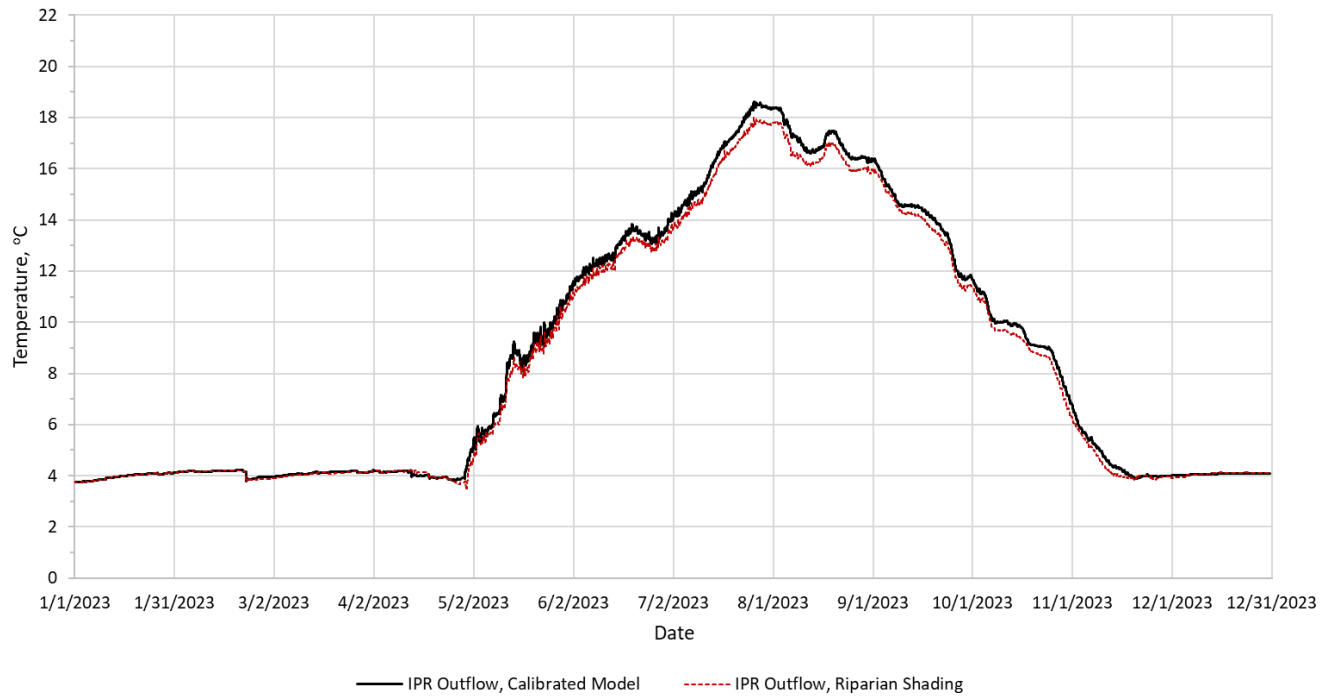


Figure 86. Continuous outflow temperature from Island Park Reservoir for the restoration (riparian planting) scenario.

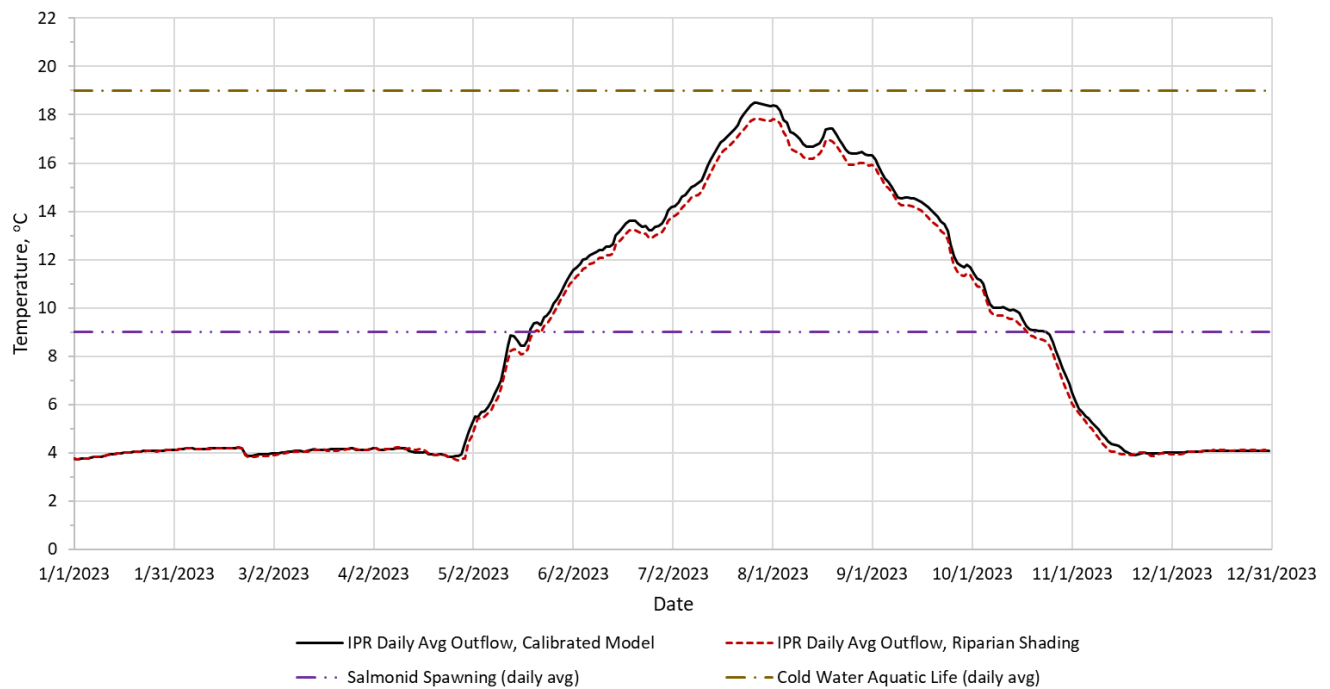


Figure 87. Average daily outflow temperature from Island Park Reservoir for the restoration (riparian planting) scenario.

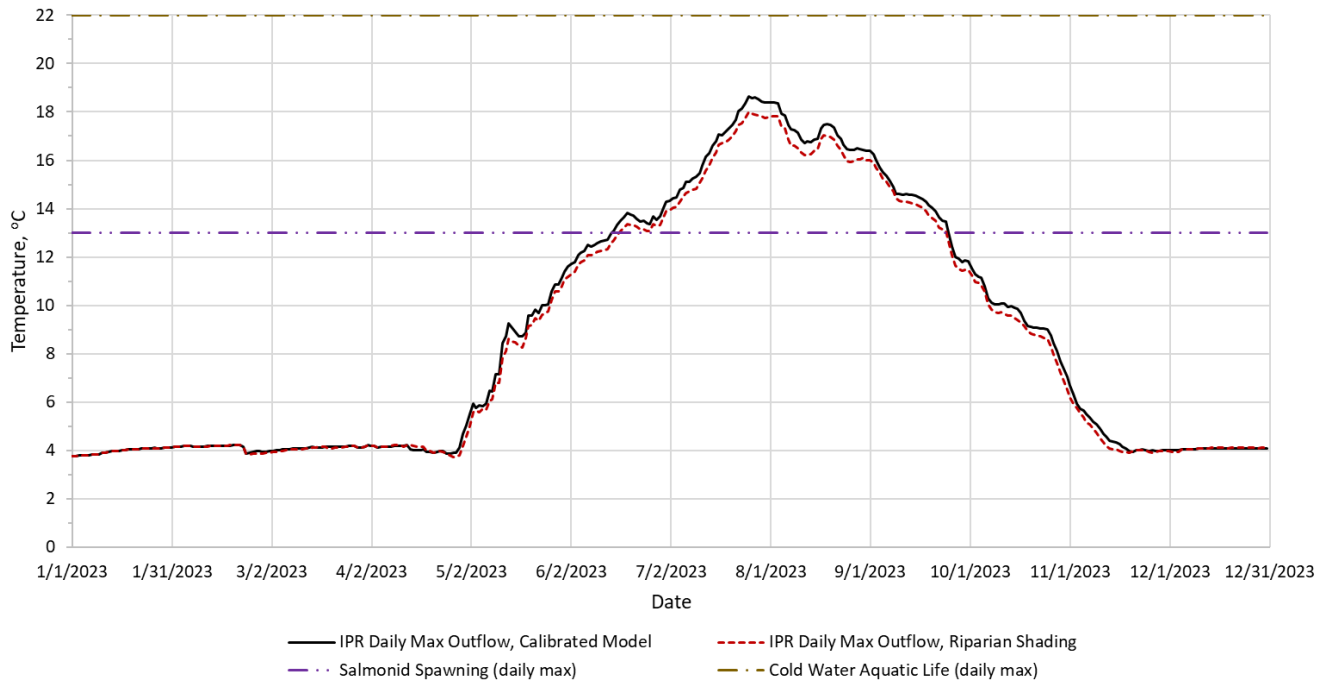


Figure 88. Maximum daily outflow temperature from Island Park Reservoir for the restoration (riparian planting) scenario.

Conservation of Cold-Water Temperatures

Figure 89 through Figure 91 show the continuous, daily average, and daily maximum water temperatures from the reservoir outflow following the implementation of a cold-water conservation program in the Island Park Reservoir. Water withdrawals from the proposed outlet located 3 m below the water surface results in lower outflow water temperatures while the reservoir is covered in ice (through late April). After the reservoir is free of ice, scenario water temperatures follow or exceed the outflow temperatures of the calibrated model until the normal operation of the Gates and Power outlets resumes. Leaving cold water in the bottom of the reservoir results in a short period of diminished outflow water temperatures through mid-June. Thereafter, water temperatures from the calibrated model and conservation scenario track closely.

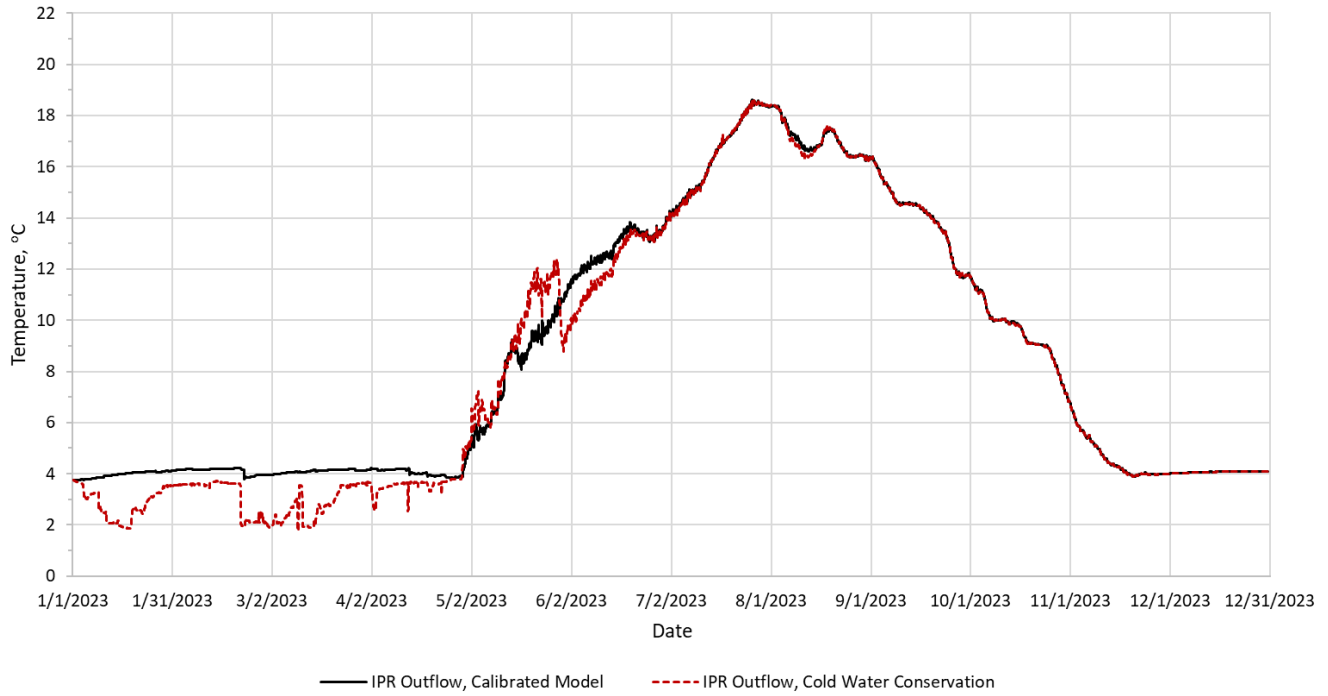


Figure 89. Continuous outflow temperature from Island Park Reservoir for the cold water conservation scenario.

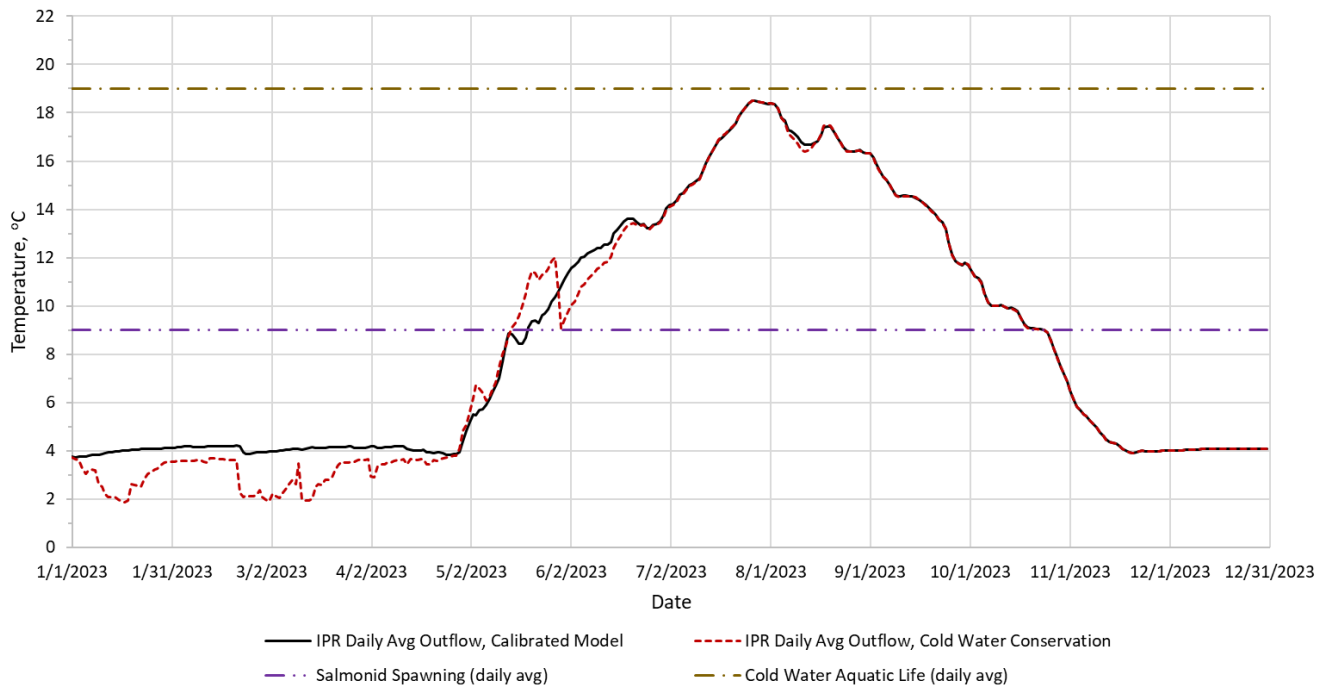


Figure 90. Average daily outflow temperature from Island Park Reservoir for the cold water conservation scenario.

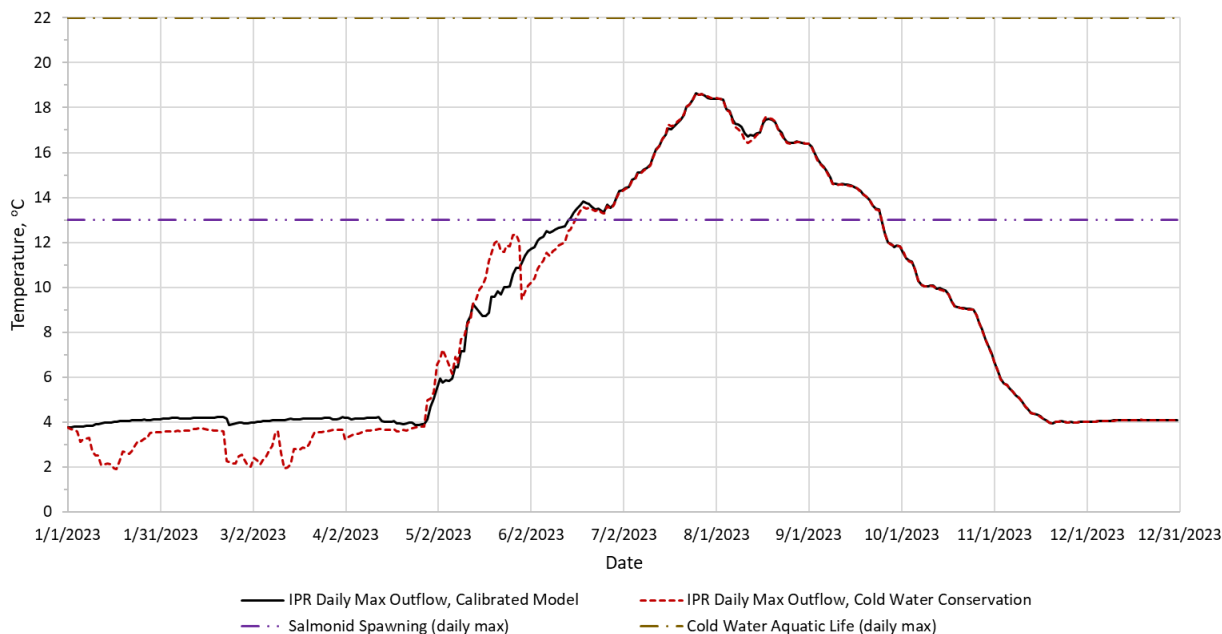


Figure 91. Maximum daily outflow temperature from Island Park Reservoir for the cold water conservation scenario.

Henry's Fork River

Table 23 through Table 25 present comparisons of the calibrated model to preliminary model scenarios, with references to the Cold-Water Aquatic Life and Salmonid Spawning criteria, for continuous, daily average, and daily maximum time series of Henry's Fork River water temperature. Water temperatures were derived from the furthest downstream segment of the Henry's Fork River model grid (segment 53), representing the temperature of the Henry's Fork River at the river's confluence with Thurmon Creek. Figure 83 through Figure 91 show time series of the calibrated model alongside preliminary model scenarios.

Cold water conservation results in the lowest reduction in outflow temperatures (0.02°C) in stark contrast to the results of the Island Park Reservoir scenario model runs. The implementation of a restoration effort involving riparian planting resulted in a 2.75°C reduction in the daily maximum temperature, the greatest simulated reduction across the preliminary model scenarios. Riparian planting also reduced the number of days the maximum and average daily water temperature exceeded the Salmonid Spawning temperature threshold by 26 days (a reduction of 16%) and 46 days (a reduction of 35%), respectively. Riparian planting was more effective at reducing stream temperatures than even a 2°C reduction in air temperature.

Table 23. Comparison of continuous temperature statistics at the outflow of the Henry's Fork River model.

Preliminary Model Scenario (2023 Model Run)	Continuous Temperature (°C)			
	Min	Max	Avg.	Change from calibrated average (%)
Calibrated model	-3.08	22.28	8.29	n/a
2°C increase in air temperature	-2.75	22.90	8.77	+0.48 (5.77%)
2°C decrease in air temperature	-3.36	21.77	7.88	-0.41 (4.97%)
Restoration	-3.30	18.28	6.71	-1.58 (19.09%)
Cold water conservation	-3.29	22.31	8.17	-0.12 (1.49%)

Table 24. Comparison of daily average temperature statistics at the outflow of the Henry's Fork River model.

Preliminary Model Scenario (2023 Model Run)	Daily Average Temperature (°C)					
	Min	Max	Avg.	Change from calibrated avg (%)	No. of days CWAL (19°C) is exceeded	No. of days Salmonid Spawning (9°C) is exceeded
<i>Entire Year</i>						
Calibrated model	-1.56	19.30	8.27	n/a	5	162
2°C increase in air temperature	-1.29	19.93	8.75	+0.48 (5.78%)	13	172
2°C decrease in air temperature	-1.82	18.71	7.86	-0.41 (4.97%)	0	149
Restoration	-2.50	17.25	6.69	-1.58 (19.11%)	0	136
Cold water conservation	-1.79	19.33	8.15	-0.12 (1.49%)	6	164
<i>June</i>						
Calibrated model	12.40	16.74	14.37	n/a	0	30
2°C increase in air temperature	13.11	17.27	14.97	+0.60 (4.17%)	0	30
2°C decrease in air temperature	11.86	16.20	13.86	-0.52 (3.60%)	0	30
Restoration	11.25	13.72	12.27	-2.11 (14.67%)	0	30
Cold water conservation	11.35	16.71	13.98	-0.39 (2.71%)	0	30
<i>July</i>						
Calibrated model	15.98	19.30	17.70	n/a	4	31
2°C increase in air temperature	16.49	19.93	18.27	+0.57 (3.20%)	11	31
2°C decrease in air temperature	15.42	18.71	17.14	-0.57 (3.21%)	0	31
Restoration	13.55	17.25	15.60	-2.10 (11.86%)	0	31
Cold water conservation	15.95	19.33	17.70	-0.01 (0.04%)	5	31
<i>August</i>						
Calibrated model	15.59	19.19	17.63	n/a	1	31
2°C increase in air temperature	16.12	19.78	18.12	+0.50 (2.82%)	2	31
2°C decrease in air temperature	15.08	18.58	17.02	-0.60 (3.42%)	0	31
Restoration	12.72	17.07	15.27	-2.35 (13.35%)	0	31
Cold water conservation	15.60	19.23	17.59	-0.03 (0.19%)	1	31

Table 25. Comparison of daily maximum temperature statistics at the outflow of the Henry's Fork River model.

Preliminary Model Scenario (2023 Model Run)	Daily Maximum Temperature (°C)					
	Min	Max	Avg.	Change from calibrated avg (%)	No. of days CWAL (19°C) is exceeded	No. of days Salmonid Spawning (9°C) is exceeded
<i>Entire Year</i>						
Calibrated model	-0.21	22.28	10.09	n/a	6	132
2°C increase in air temperature	0.04	22.90	10.57	+0.49 (4.82%)	14	145
2°C decrease in air temperature	-1.82	18.70	9.67	-0.42 (4.18%)	0	124
Restoration	-1.27	18.28	7.33	-2.76 (27.36%)	0	86
Cold water conservation	-0.47	22.31	9.96	-0.13 (1.28%)	6	133
<i>June</i>						
Calibrated model	13.58	19.95	16.81	n/a	0	30
2°C increase in air temperature	14.30	20.50	17.41	+0.61 (3.61%)	0	30
2°C decrease in air temperature	13.04	19.41	16.28	-0.52 (3.11%)	0	30
Restoration	11.61	14.46	12.89	-3.92 (23.31%)	0	13
Cold water conservation	12.58	19.92	16.42	-0.39 (2.31%)	0	28
<i>July</i>						
Calibrated model	18.46	22.26	20.53	n/a	3	31
2°C increase in air temperature	18.99	22.90	21.11	+0.58 (2.81%)	9	31
2°C decrease in air temperature	17.92	21.64	19.95	-0.58 (2.81%)	0	31
Restoration	14.21	18.28	16.47	-4.06 (19.77%)	0	31
Cold water conservation	18.43	22.27	20.52	-0.01 (0.04%)	3	31
<i>August</i>						
Calibrated model	18.18	22.28	20.21	n/a	3	31
2°C increase in air temperature	18.69	22.74	20.72	+0.51 (2.55%)	5	31
2°C decrease in air temperature	17.58	21.77	19.59	-0.61 (3.03%)	0	31
Restoration	13.58	17.95	16.09	-4.11 (20.35%)	0	31
Cold water conservation	18.20	22.31	20.18	-0.03 (0.14%)	3	31

±2°C Change in Air Temperature

Figure 92 through Figure 94 show the continuous, daily average, and daily maximum water temperatures in the river due to a ±2°C change in air temperature. As expected, the decrease in air temperature decreased the water temperature and the increase in air temperature increased the water temperature. However, the 2°C air temperature increase resulted in a marginally greater change in river water temperatures than a decrease in air temperature.

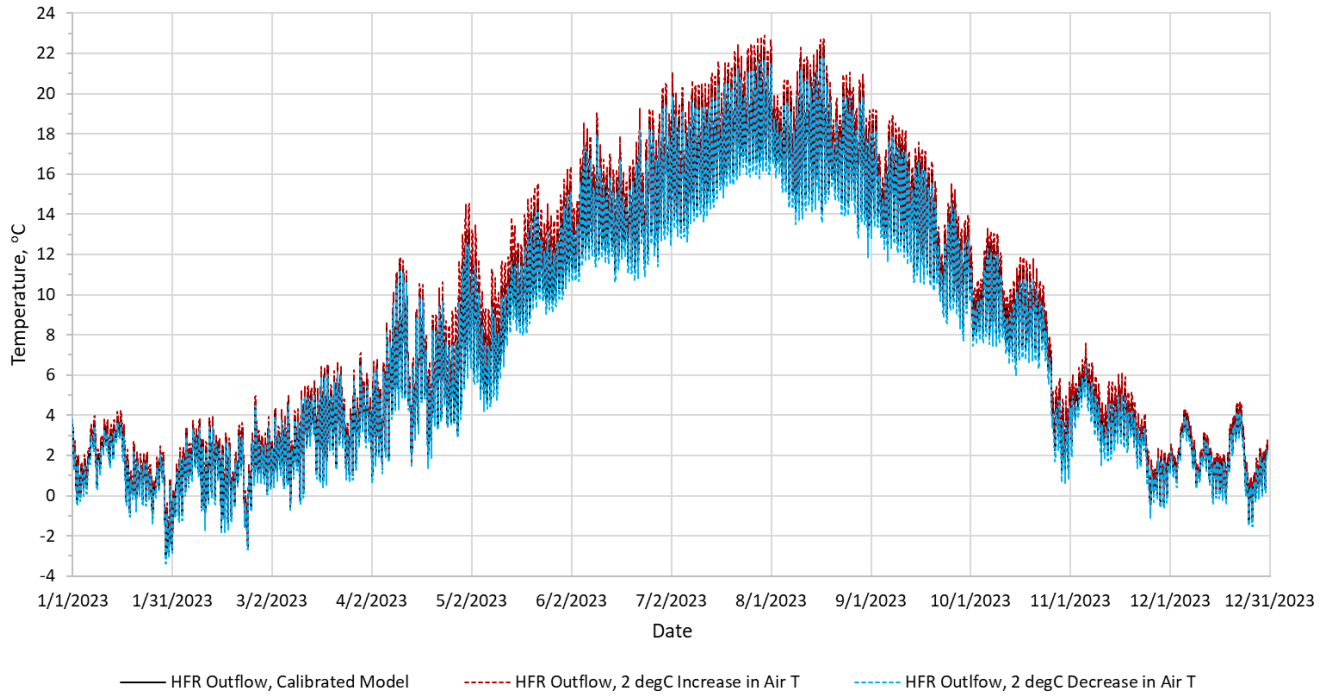


Figure 92. Continuous outflow temperature from the Henry's Fork River for the 2°C change in air temperature scenario.

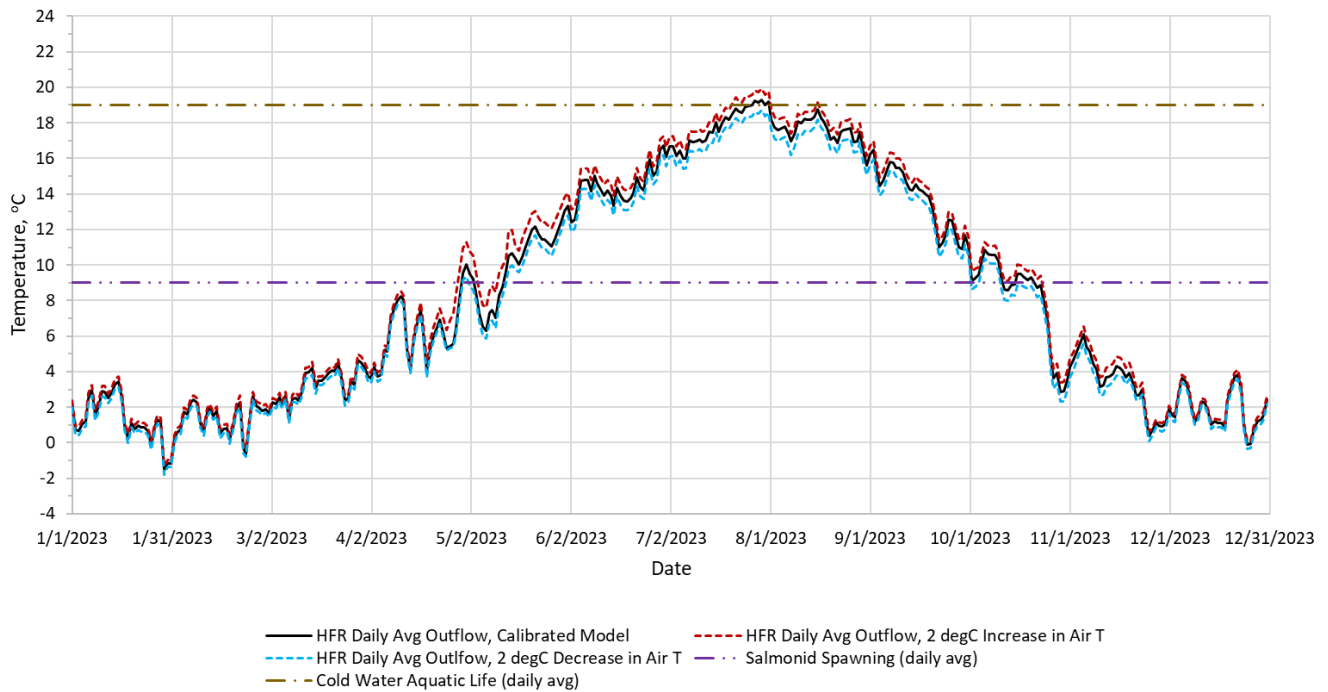


Figure 93. Daily average outflow temperature from the Henry's Fork River for the 2°C change in air temperature scenario.

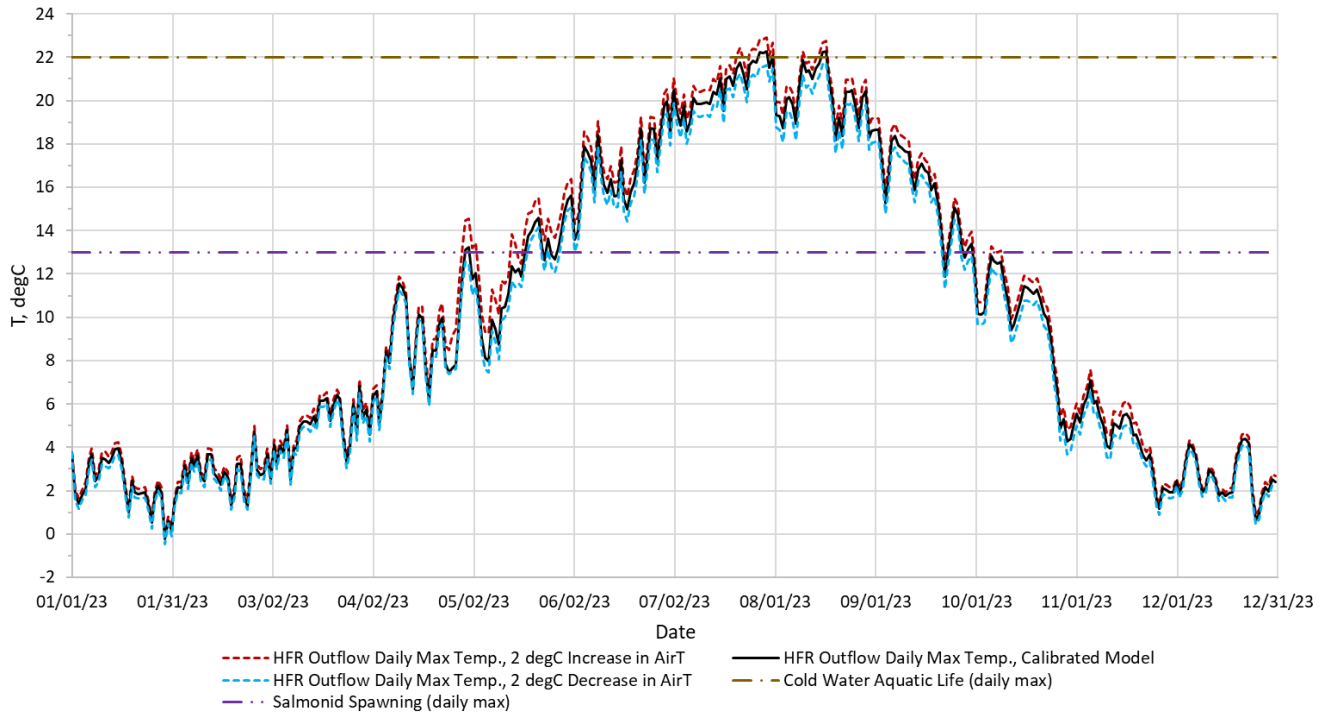


Figure 94. Daily maximum outflow temperature from the Henry's Fork River for the 2°C change in air temperature scenario.

Restoration Effort (Riparian Shading)

Figure 95 through Figure 97 show the continuous, daily average, and daily maximum water temperatures in the river following the implementation of a restoration (riparian planting) effort along the banks of the Island Park Reservoir and Henry's Fork River. Restoration substantially decreased the water temperature leaving the Henry's Fork River across the entire model simulation, with the greatest apparent difference between water temperatures in the calibrated model and restoration scenario occurring over the summer.

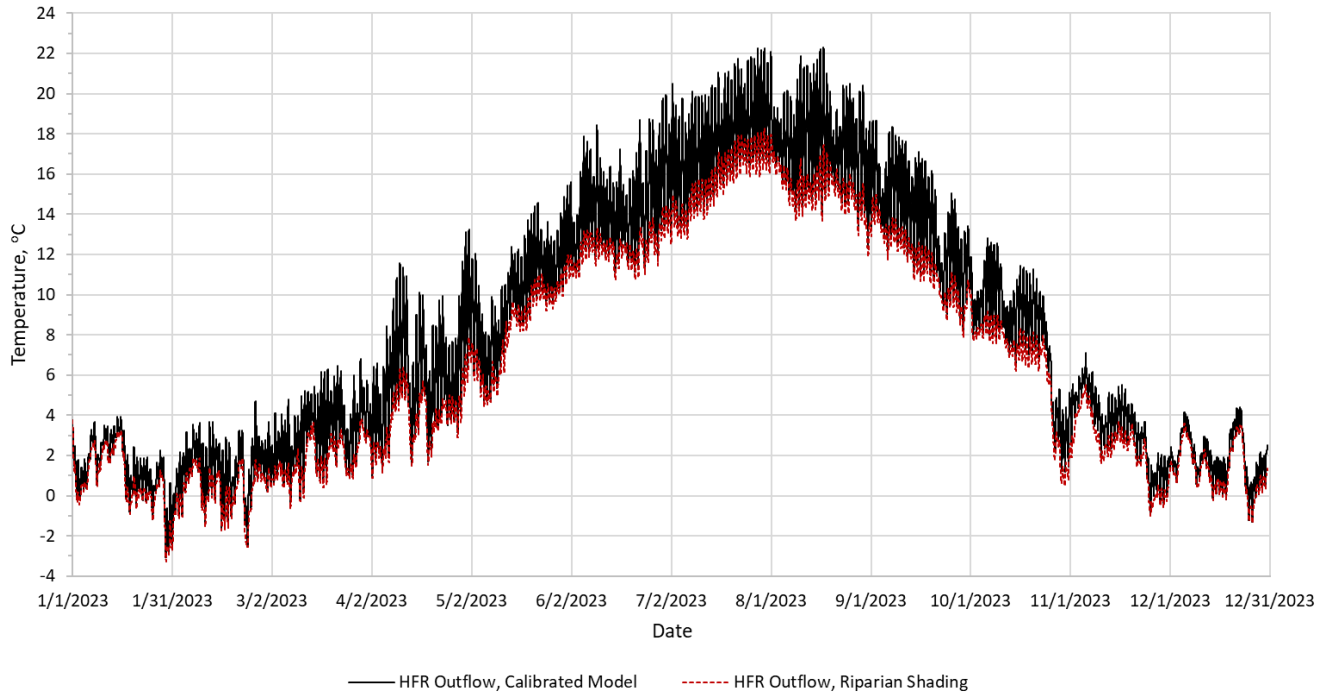


Figure 95. Continuous outflow temperature from the Henry's Fork River for the restoration (riparian shading) scenario.

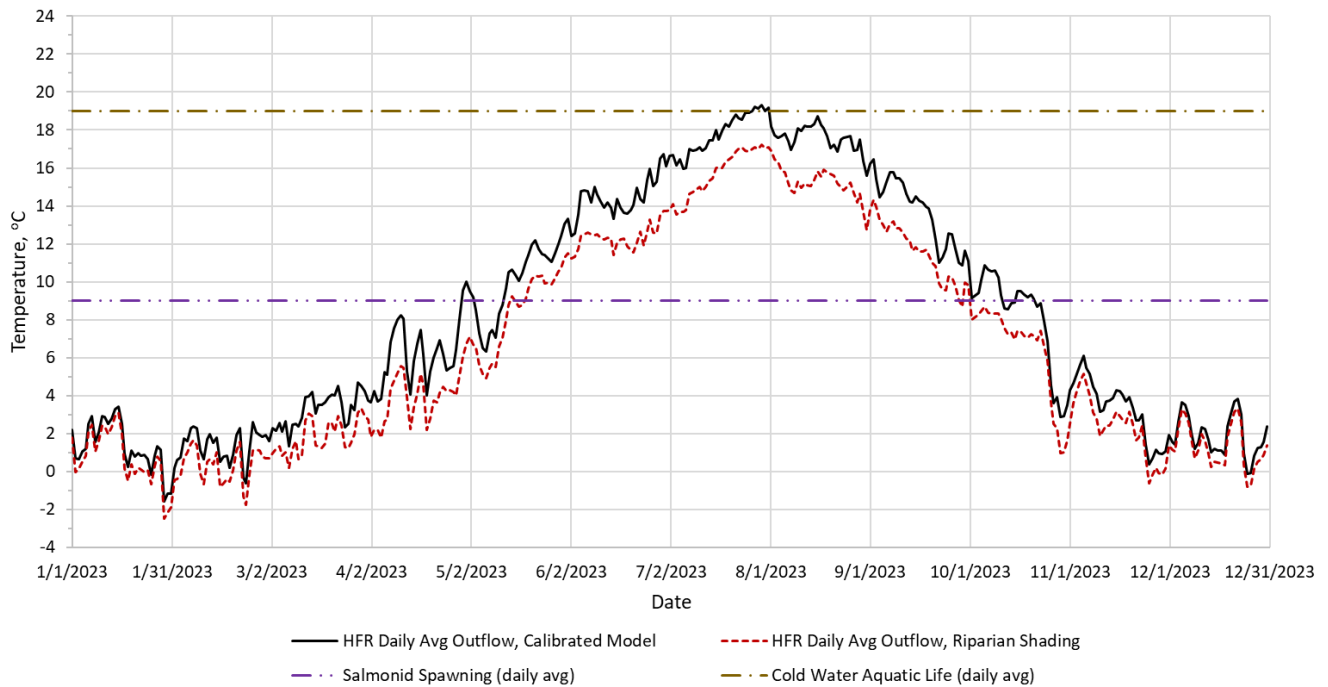


Figure 96. Daily average outflow temperature from the Henry's Fork River for the restoration (riparian shading) scenario.

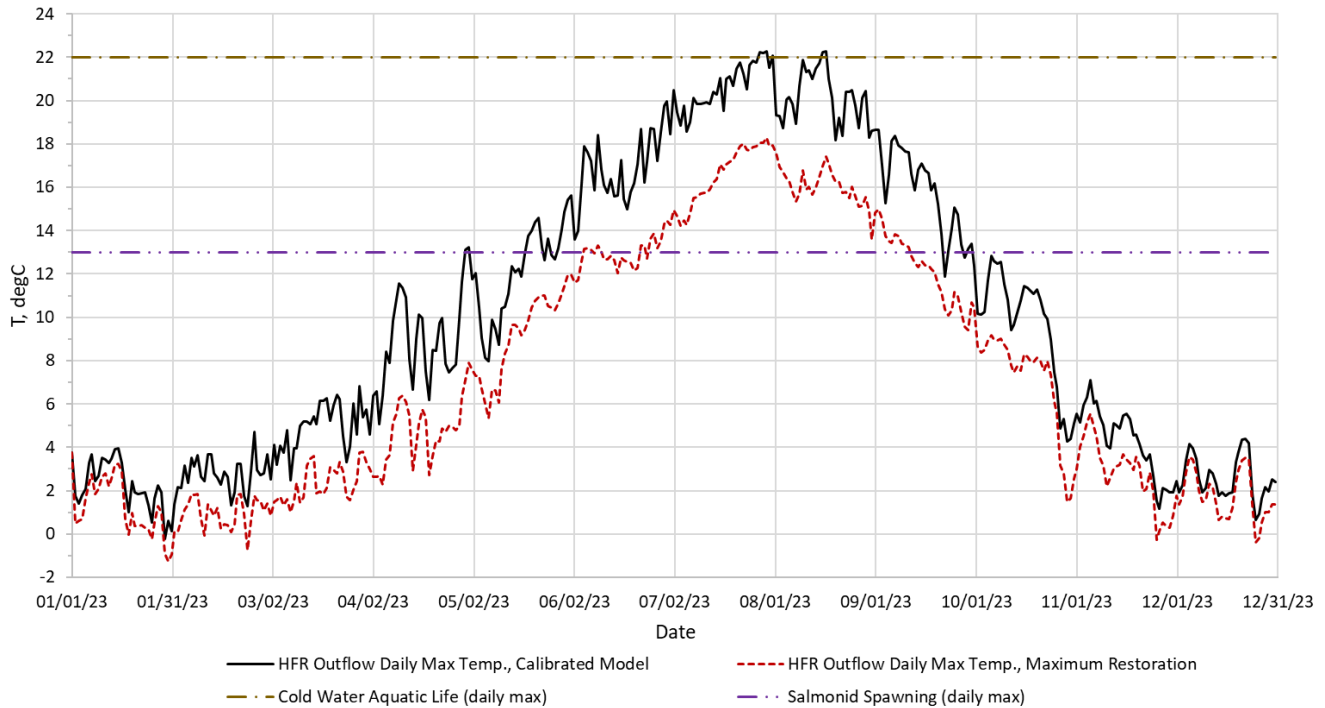


Figure 97. Daily maximum outflow temperature from the Henry's Fork River for the restoration (riparian shading) scenario.

Conservation of Cold-Water Temperatures

Figure 98 through Figure 100 show the continuous, daily average, and daily maximum water temperatures in the river following the implementation of a cold-water conservation program in the Island Park Reservoir. Water withdrawals from the proposed outlet located 3 m below the water surface results in lower Henry's Fork River outflow water temperatures while the reservoir is covered in ice (through late April). After the reservoir is free of ice, scenario water temperatures follow or exceed the river water temperatures of the calibrated model until the normal operation of the Gates and Power outlets resumes. Leaving cold water in the bottom of the reservoir results in a short period of diminished outflow water temperatures in mid-June that go to the river. Thereafter, water temperatures from the calibrated model and conservation scenario track closely.

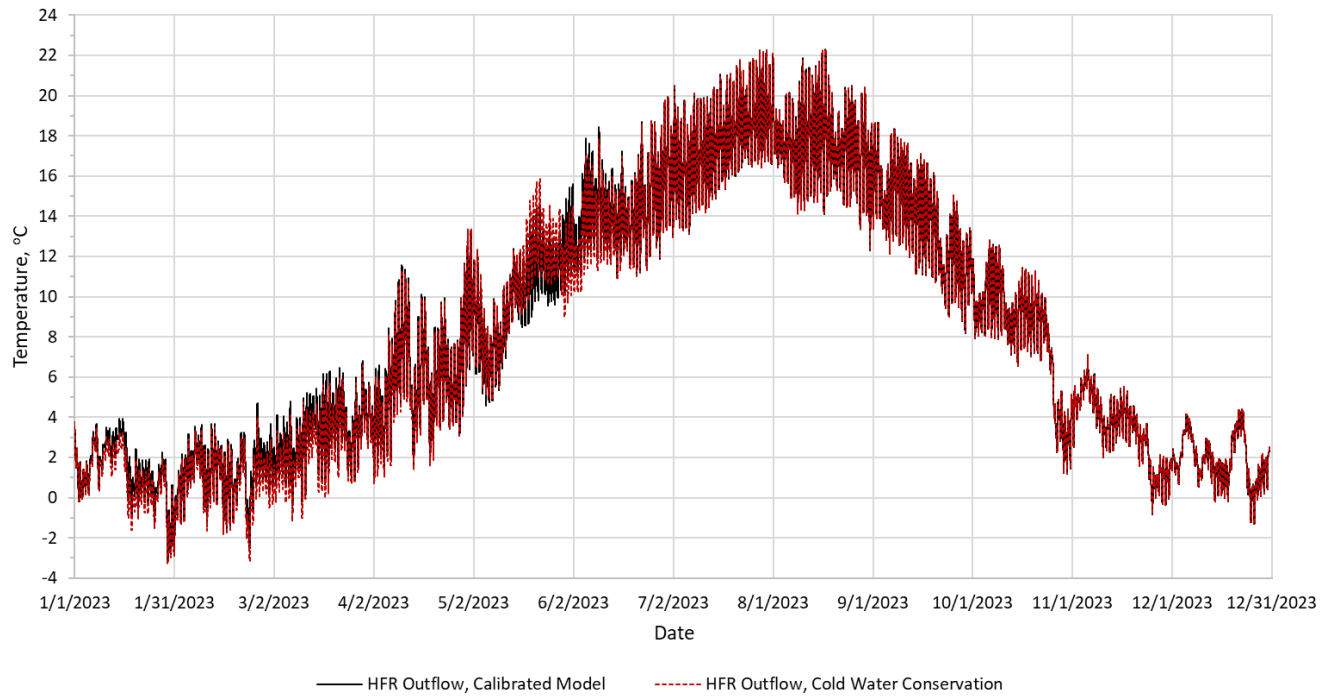


Figure 98. Continuous outflow temperature from the Henry's Fork River for the cold water conservation scenario.

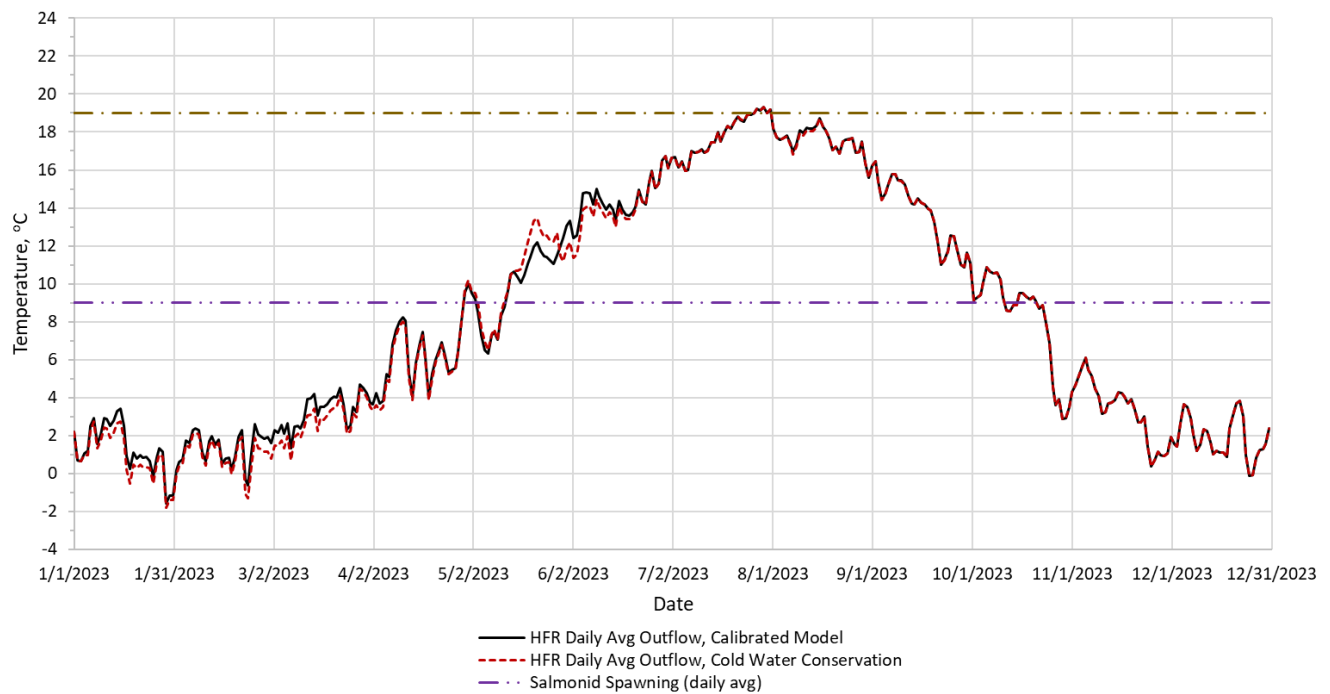


Figure 99. Daily average outflow temperature from the Henry's Fork River for the cold water conservation scenario

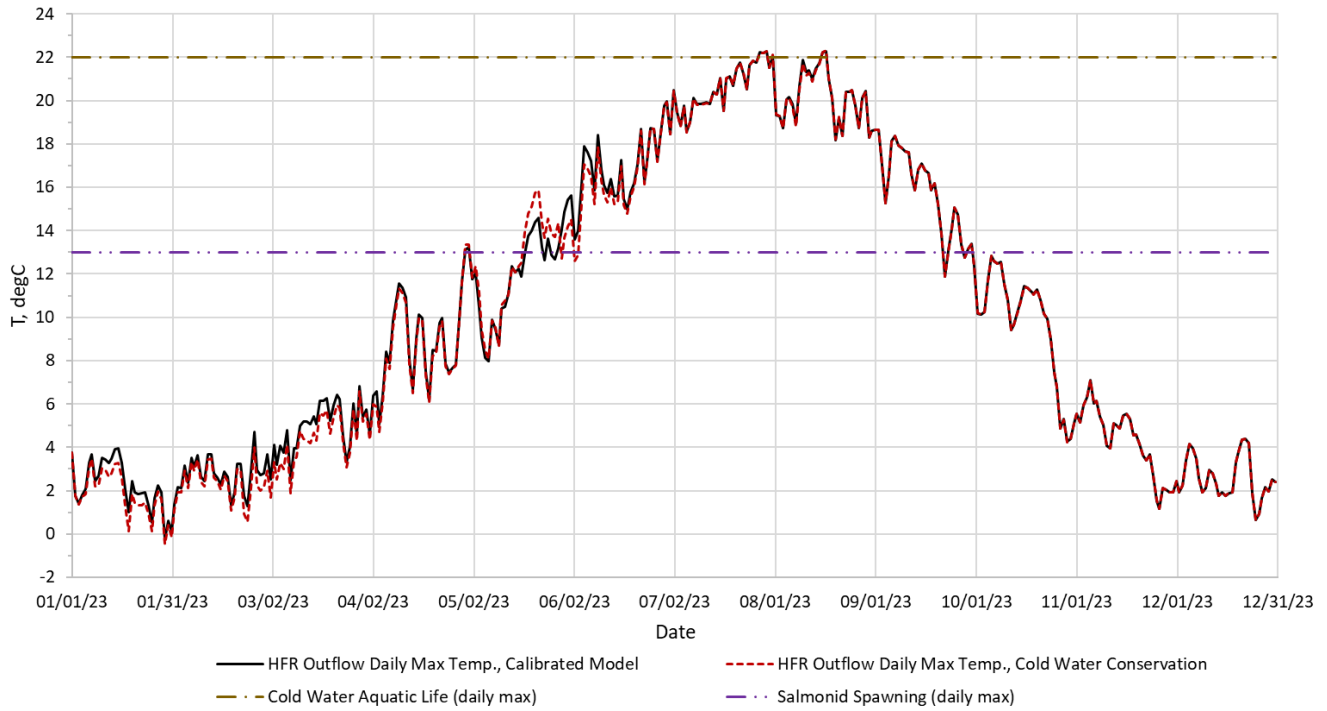


Figure 100. Daily maximum outflow temperature from the Henry's Fork River for the cold water conservation scenario.

Summary

This report summarizes the development, calibration, and initial testing of the Island Park Reservoir and Henry's Fork River CE-QUAL-W2 hydrodynamic and temperature models. The models were developed using a combination of data provided by the Henry's Fork Foundation (HFF) and time series data retrieved from local meteorological and streamflow monitoring stations. Gaps in hydrodynamic, meteorologic, and stream temperature records were filled using interpolation or correlation with other continuous datasets.

The models were calibrated using time series and vertical profile data supplied by the HFF to simulate conditions in the reservoir and river reach between January 1 and December 31, 2023. The models capture overarching processes regulating the volume and temperature of water leaving the water bodies, though some localized processes are obscured. Opportunities for further model refinement are outlined throughout the report. The existing models, however, sufficiently represent the hydrodynamics (with a mean absolute error less than 0.75 cms) and temperature dynamics (with a mean absolute error less than 1°C) of the two water bodies. Combined, the linked models could support the development of TMDL for the Henry's Fork River above the confluence with Thurmon Creek.

Three preliminary model scenarios were developed for the Island Park Reservoir and Henry's Fork River CE-QUAL-W2 models to understand how the magnitude and frequency of water temperature standards violations occur in different management and operational scenarios. Reservoir output flows and temperatures from the Island Park Reservoir model were used as the upstream boundary condition for the Henry's Fork River model to better simulate the compounding impact to stream temperatures for each scenario. The restoration scenario, simulating an intensive riparian planting effort along the banks of the Island Park Reservoir and Henry's Fork River, resulted in the greatest diminishment of stream temperatures, exceeding observed changes under the 2°C decrease in air temperature scenario, but this preliminary model scenario utilized gross assumptions on much shade these trees would provide. This scenario should be revisited with refined information. In general, changes in stream temperatures across scenarios were more pronounced in the Henry's Fork River than the Island Park Reservoir.

A training manual providing an overview of the CE-QUAL-W2 input and control files, post-processor, and accompanying utilities was also develop to support future development of the model and model scenarios. The training manual is attached to this report as an appendix.

References

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Appendix – Training Manual

To: Alex Bell, Idaho Department of Environmental Quality

July 9, 2025

From: Rob Annear, Ph.D., P.E. and Noah Benitez-Nelson, E.I.T.,
Annear Water Resources, LLC

Subject: CE-QUAL-W2 Training Manual for IDEQ

Overview

Annear Water Resources, LLC (AWR) has prepared the following training manual to supplement the two-dimensional, laterally averaged, hydrodynamic and water quality CE-QUAL-W2 (W2) Version 4.5 (Wells, 2023) models developed on behalf of the Idaho Department of Environmental Quality (DEQ). Two W2 models were developed to simulate streamflow and stream temperature dynamics in the Island Park Reservoir and downstream sections of the Henry's Fork River. The development and calibration of the models is described in the main report. This document provides an overview of the Shareable Model file package containing the linked W2 models, an introduction to W2 input and control files, and a review of the post-processor to support future development of the models and model scenarios.

File Organization

The following folders (**bolded**) and files (*italicized*) are included in the W2 Shareable Model package:

CE-QUAL-W2_Manual_v4.5: Contains Version 4.5 of the W2 model, available for download from the Portland State University Water Quality Research Group CE-QUAL-W2 website (<https://www.ce.pdx.edu/w2/>). This folder is included for user reference; it does not affect the operation of the developed Island Park Reservoir or Henry's Fork River models. Additional details concerning folder contents may be found on the W2 model website at <https://www.cee.pdx.edu/w2/download.html>. Highlighted folders and files are detailed below:

- Executables
 - Contains the preprocessor (*preW2-v45_64.exe*) and model executable (*w2-v45_64.exe*) files. Both files should be co-located with the control and input files for a given model to function properly. Copies of both the preprocessor and model executables have already been copied to the Henry's Fork River and Island Park Reservoir model folders.
- User Manual
 - Contains a series of PDFs documenting the theory and development of the W2 model as well as guides for developing model input files, examples of previous W2 projects, and overviews of included W2 utilities.
- W2tools post-processor
 - Contains the installation files for the W2 post-processor graphical user interface (GUI). A brief user manual detailing the operation of the post-processor is also included.

HenrysForkReservoir: Contains the executable, control, and input files for the Henry's Fork River W2 model.

- InputFiles

- Contains the input files for the calibrated model and model scenarios. Files were named following established W2 naming conventions (refer to CE-QUAL-W2_Manual_v4.5/User Manual/W2manual45_Part3_InputOutputFiles_rev8.pdf for additional details).
- *preW2-v45_64.exe*:
 - The preprocessor executable for the W2 model, used to identify errors and potential problems in the model control file prior to execution.
- *w2_con4.5_HenrysForkRiver_CalibratedModel*
 - The control file for the Henry's Fork River calibrated model.
- *w2_con4.5_HenrysForkRiver_ColdWaterRetention*
 - The control file for the Henry's Fork River cold-water conservation (retention) scenario, simulating a cold-water conservation program that preserves cold Island Park Reservoir bottom temperatures for later summer release.
- *w2_con4.5_HenrysForkRiver_minus2degC*
 - The control file for the Henry's Fork River 2°C increase in air temperature scenario.
- *w2_con4.5_HenrysForkRiver_plus2degC*
 - The control file for the Henry's Fork River 2°C decrease in air temperature scenario model.
- *w2_con4.5_HenrysForkRiver_RiparianShading*
 - The control file for the Henry's Fork River the restoration effort scenario, simulating potential restoration efforts along the banks of the reservoir and river with trees planted along the banks of both water bodies.
- *w2_v45_64.exe*
 - The W2 version 4.5 model executable file.

IslandParkReservoir: Contains the executable, control, and input files for the Island Park Reservoir W2 model.

- InputFiles
 - Contains the input files for the calibrated model and model scenarios. Files were named using common W2 naming conventions (refer to CE-QUAL-W2_Manual_v4.5/User Manual/W2manual45_Part3_InputOutputFiles_rev8.pdf for additional details).
- *preW2-v45_64.exe*
 - The preprocessor executable for the W2 model, used to identify errors and potential problems in the model control file prior to execution.
- *w2_con4.5_IslandParkReservoir_CalibratedModel*
 - The control file for the Island Park Reservoir calibrated model.
- *w2_con4.5_IslandParkReservoir_ColdWaterRetention*
 - The control file for the Island Park Reservoir cold-water conservation (retention) scenario, simulating a cold-water conservation program that preserves cold Island Park Reservoir bottom temperatures for later summer release.
- *w2_con4.5_IslandParkReservoir_minus2degC*
 - The control file for the Island Park Reservoir 2°C increase in air temperature scenario.
- *w2_con4.5_IslandParkReservoir_plus2degC*
 - The control file for the Island Park Reservoir 2°C decrease in air temperature scenario.
- *w2_con4.5_IslandParkReservoir_RiparianShading*

- The control file for the Island Park Reservoir restoration effort scenario, simulating potential restoration efforts along the banks of the reservoir and river with trees planted along the banks of both water bodies.
 - w2_v45_64.exe
- The W2 version 4.5 model executable file.

Operating the Model

Operating the W2 model is a three-step process:

1. Prepare the calibrated model or model scenario control file using the macro-enabled Excel control file converter.
2. Validate the control file using the W2 pre-processor (preW2_v4_64.exe) and review models/warnings.
3. Run the model executable file (w2_v45_64.exe) to generate the model output.

This section expands upon each of these steps in detail and provides insights into common errors that may arise during normal model development and operation

Generating a control file

Distinct macro-enabled Excel files (w2_con4.5_{model}_{scenario}.xlsx) have been developed for the calibrated models and each model scenario. These Excel files generate the w2_con.csv control file read by the preprocessor and model executables. Section 3 in Part 5 of the user manual (W2manual45_Part5_ModelUtilities_rev9.pdf) provides additional details concerning the development and utility of the Excel file.

Figure 101 shows the Excel file corresponding to the Island Park Reservoir calibrated model. The “w2_con.csv” sheet is primarily used to modify the model setup and execution; the remaining sheets promote the development of ancillary input files that were not used in the model development.

CE-QUAL-W2 Version									
1	Note COL A and B are not written out to w2_con.csv	2	w2_con.csv file format	3	CE-QUAL-W2 Version	4	4.5	5	
4	Fixed length of file except when more than 5 algae, 5 zooplankton,	5	TITLE C	6	Control File version	7	4.5	8	w2_con45.csv
5	5 macrophytes, 5 structures, 5 periphyton groups.	6	Any comment - this is written only to the SNP file	7	Title comments: next 10 lines	8		9	
6	The # of rows though changes with the # of active water quality constituents.	7	Do not change the file tab name for this sheet since the output file name is tied to the name of the tab	8	"Version 4.1 model Island Park Reservoir, Idaho"	9		10	
7	NWB: # of waterbodies	8		9	"Reservoir System with 4 branches, 1 waterbody"	10		11	
8	NBR: number of branches	9		10	"Model run with true input data"	11		12	
9	IMX: maximum number of segments including inactive segments	10		11		12		13	
10	KMX: maximum number of vertical layers including inactive layers (top and bottom)	11		12		13		14	
11	NPROC: # of processors (INACTIVE at this time)	12		13		14		15	
12	CLOSEC: close dialog box after executing if =ON	13		14		15		16	
13	NTR: number of tributaries	14		15		16		17	
14	NST: maximum # of structures in a branch	15		16		17		18	
15	NW: # of internal weirs	16		17		18		19	
16	NWD: # of withdrawals	17		18		19		20	
17	NGT: # of gates	18		19		20		21	
18	NSP: # of spillways	19		20		21		22	
19	NPI: # of pipes	20		21		22		23	
20	NPU: # of pumps or water level control rules	21		22		23		24	
21	NGC: # of generic water quality constituents	22		23		24		25	
22	Do not change bolded headers in COL C - these are checked by the program	23		24		25		26	
23	NDAY: Maximum number of output dates or timestep related changes	24		25		26		27	
24	SELECTC: Turn ON/OFF USGS automatic point selection from a multiple outlet structure	25		26		27		28	
25	HABITATC: Turn ON/OFF habitat analyses for fish and eutrophication variables	26		27		28		29	
26	ENVIRPC: Turn ON/OFF environmental performance criteria	27		28		29		30	
27	AERATEC: Turn ON/OFF aeration to waterbody with dissolved oxygen probe control	28		29		30		31	
28	INTUWIL: Turn ON/OFF initial water surface slope and velocity calculation for a	29		30		31		32	
29	ORGC: simulates the organic matter as C rather than organic matter; SED_DIAG	30		31		32		33	
30	Fill in these with real dates and the Julian dates will be filled in automatically	31		32		33		34	
31	TMSTRT	32		33		34		35	
32	1/1/2023 0:00	33		34		35		36	
33	TMEND	34		35		36		37	
34	12/31/2023 23:59	35		36		37		38	
35	1,000	36		37		38		39	
36	365,999	37		38		39		40	
37	Year	38		39		40		41	
38	2023	39		40		41		42	
39	Go to Index of Sheets:	40		41		42		43	
40	Index of Sheets: 1A1	41		42		43		44	
41		42		43		44		45	
42		43		44		45		46	
43		44		45		46		47	
44		45		46		47		48	
45	This is a new stability check in case water level rises or falls too quickly, it low	46		47		48		49	

Figure 101. View of the macro-enabled Excel control file converter for the Island Park Reservoir calibrated model.

Cells highlighted in yellow are read and converted into the model control file and can be modified to change the input parameters, input files, and overall model functionality. Variable names and explanations are included in Column A and B. Part 3 of the user manual (W2manual45_Part3_InputOutputFiles_rev8.pdf) provides additional details concerning each variable and, as applicable, the corresponding model input files.

Once the model variables and input files have been defined, users can export the contents of the sheet using the “Export to CSV file” button at the top of the page, generating the w2_con.csv control file. Figure 102 shows the normal termination of the macro-enabled spreadsheet.

A	B	C	D	E
1 Note COL A and B are not written out to w2_con.csv	w2_con.csv file format	CE-QUAL-W2 Version		4.5
2		Control File version		4.5 w2_con45.cs
3 Fixed length of file except when more than 5 algae, 5 zooplankton,	TITLE C	Title comments: next 10 lines		
4 5 macrophytes, 5 structures, 5 periphyton groups.	Any comment - this is written only to the SNP file	"Version 4.1 model Island Park Reservoir, Idaho"		
5 The # of rows though changes with the # of active water quality constituents.		"Reservoir System with 4 branches, 1 waterbody"		
6 Do not change the file tab name for this sheet since the output file name is tied to the name of the tab		"Model run with true input data"		
7 NWB: # of waterbodies				
8 NBR: number of branches				
9 IMX: maximum number of segments including inactive segments				
10 KMX: maximum number of vertical layers including inactive layers (top and bottom)				
11 NPROC: # of processors (INACTIVE at this time)				
12 CLOSEC: close dialog box after executing if =ON				
13 NTR: number of tributaries				
14 NST: maximum # of structures in a branch				
15 NIW: # of internal weirs				
16 NWD: # of withdrawals				
17 NGT: # of gates				
18 NSP: # of spillways				
19 NPI: # of pipes				
20 NPU: # of pumps or water level control rules				
21 NGC: # of generic water quality constituents				
22 Do not change bolded headers in COL C - these are checked by the program				
23 NDAY: Maximum number of output dates or timestep related changes				
24 SELECTC: Turn ON/OFF USGS automatic port selection from a multiple outlet structure where	MISCELLANEOUS	NDAY	SELECTC	HABTATC
25 HABTATC: Turn ON/OFF habitat analyses for fish and eutrophication variables		100 OFF	OFF	OFF
26 ENVIRPC: Turn ON/OFF environmental performance criteria				
27 AERATEC: Turn ON/OFF aeration to waterbody with dissolved oxygen probe control	TIME CON	TMSTRT	TMEND	YEAR
28 INITUWL: Turn ON/OFF initial water surface slope and velocity calculation for a river system	These are computed from formula in Column A-->	1.00	365.00	2023
29 ORGCC: simulates the organic matter as C rather than organic matter; SED_DIAG: turns ON/OFF sediment diagenesis				
30 Fill in these with real dates and the Julian dates will be filled in automatically	DLT CON	NDLT	DLTMIN	DLTINTER
31 TMSTRT	Time step control parameters	2	0.1 OFF	
32 1/1/2023 0:00	DLT DATE	DLTD	DLTD	DLTD
33 12/31/2023 23:59	Date of time step change in JDAY	1	3	
34 1.000	DLT MAX	DLTMAX	DLTMAX	DLTMAX
35 365.999		5	60	
36 Year	Maximum time step in seconds			
37 2023				
38				

Figure 102. Normal termination of the macro-enabled Excel control file converter for the Island Park Reservoir calibrated model.

Using the preprocessor

The model preprocessor executable should be run immediately following the development of the w2_con.csv file to flag sources of potential error in the model setup. To run the preprocessor, double click the preW2_v4_64.exe file. A terminal will open as the executable runs through the w2_con.csv control file. The normal termination of the preprocessor is depicted in Figure 103.

Model warnings and errors are summarized in the output pre.wrn and pre.err text files, respectively. If the preprocessor terminates normally, the model executable may be run despite flagged model warning and errors. Output warnings and errors are generated to identify divergence from expected values and highlight potential instabilities in the model. Common warnings and errors are detailed below:

“Ice formation temperature [ICET2=6.000] > 4.0 for waterbody 1”

- Ice formation temperatures above 4.0°C are flagged by the preprocessor in the pre.err file. This error is common to all Island Park Reservoir calibrated and scenario model set ups and reflects the extreme effort to extend the duration of modeled ice cover in the reservoir.

“Julian day 244.000: WSC(I) AT SEG(I)=57 < 0.5 in .\InputFiles\wsc.csv”

- Wind sheltering coefficients less than 0.5 inches are flagged in the pre.wrn file. This warning is common to all Island Park Reservoir calibrated and scenario model set ups but does not affect the operation of the model.

“Cell width [B(29,2) = 9.000] < or > 10X width [B(29,3) = 163.000]”

- Differences in cells widths greater than 10x the magnitude of each other are flagged in the pre.wrn file. This warning does not affect model operations.

“No structures defined [NSTR=0] for downstream flow boundary in branch 1”

- This warning is common across all Island Park Reservoir calibrated and scenario model set ups. Outflows from the outlet structures located at Island Park Dam were added as withdrawals to the model instead of structures. The added spillway similarly does not classify as a model structure.
- Similarly, this warning appears in all Henry’s Fork Reservoir model set ups.
- This warning, appearing in the pre.wrn file, may be ignored.

“Water surface elevation is below bottom elevation at segment 1”

- This warning appears in all Island Park Reservoir calibrated and scenario model set ups. Not all segments in the model grid are submerged over the duration of the model simulation. This warning, appearing in the pre.wrn file, does not impact model performance and may be ignored.

“Minimum timestep [DLTMIN=.001] < 0.1”

- Minimum timesteps less than 0.1 seconds are flagged by the preprocessor but do not impact the operations of the model. Minimum timesteps 0.1 seconds or less are common for representing periods of extremely high river flows.

“Longitudinal eddy diffusivity [DX= 1.000] 10x > DX-theory = 0.0984 for waterbody. 1: Model may be unstable”

- Differences exceeding a magnitude between user-specified and model-derived theoretical longitudinal eddy diffusivity result in warnings output to the pre.wrn model file. In this case, however, the difference between user-specified and theoretical longitudinal eddy diffusivity barely exceeds the 10x criteria, the model is unlikely to be unstable and the warning may be ignored.

“Water surface elevation difference of 2.43m between segment 9 and segment 10”

- This warning appears in the Henry’s Fork River model setup and should be considered. It should be reviewed and thought about but in this case it’s likely and artifact of the how the segments are connected together and their adjacent geometries.

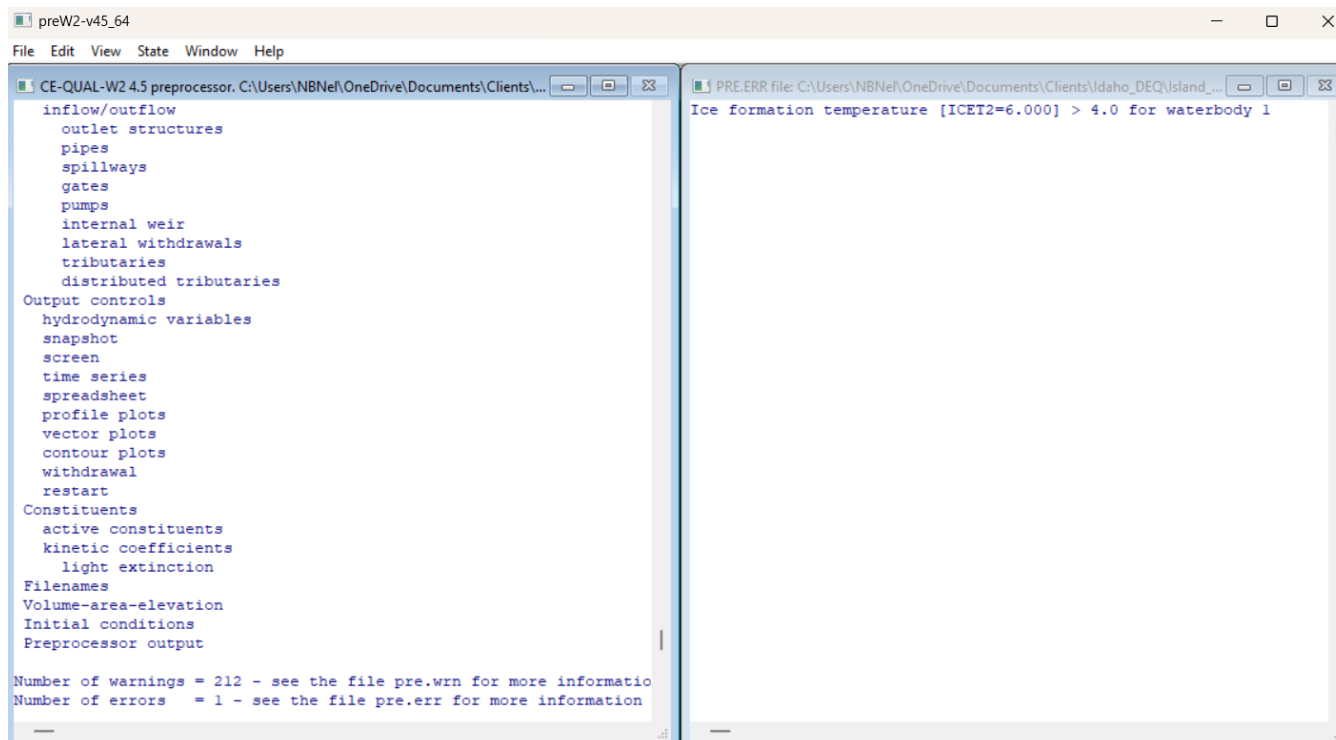


Figure 103. Normal termination of the W2 preprocessor. The number of flagged warnings and errors are summarized at the bottom of the left panel; model errors are detailed in the right panel.

Running the model executable

Following the preprocessor, the model executable w2_v45_64.exe may be run by double clicking on the executable file. Figure 104 shows the GUI that appears when users run the executable.

The model executable GUI displays select parameters detailing simulated conditions. The [SCR PRINT] parameters in the macro-enabled Excel control file can be adjusted to increase or decrease the refresh rate of the GUI. A progress bar at the bottom of the GUI displays the current progress of the model execution. When the model has successfully completed, the “Executing” label in the status bar will be replaced by a note describing the “Normal Execution” of the model and providing the datetime when the model finished running.

CE-QUAL-W2 V4.5 Run Status

Time Parameters		Meteorological Parameters		Run Times	
Gregorian date	January 14, 2023	Air temperature	-1.76 deg C	Start	13:12:31
Julian date	14 days .00 hours	Dew point temperature	1.30 deg C	Current	13:15:16
Elapsed time	13 days .00 hours	Wind speed	2.72 m/s	End	
Timestep	24 sec at (1,1) (k,i)	Wind direction	3.35 radians	CPU	2.72 min
Minimum timestep	5 sec at (1,1) (k,i)	Cloud cover	8.80 0-10		
at	0 days .00 hours	Equilibrium temperature	.0 deg C		
Average timestep	21 sec	Surface heat exchange	.0 W/m ² /deg C		
# of iterations	51368	Solar radiation	.1 W/m ²		
# of timestep violations	0 = .00 %				

Water Surface	
Surface layer	55 k
Water surface elevation	1919.71 m
Minimum deviation	-.30 m
at segment	110 i

Inflow/Outflow	
Branch flow, m ³ /s	.00 7.50 .00 .00 .26
Branch temperature, deg C	.79 3.69 .79 .79 .79
Distributed tributary flow, m ³ /s	1.32 .04 .06 .00 .00
Distributed tributary temperature, deg C	.79 .79 .79 .51 .00
Tributary flow, m ³ /s	.410 .000 .000 .000 .000
Tributary inflow temperature, deg	11.26 .00 .00 .00 .00
Spillway flow, m ³ /s	.00
Gate flow, m ³ /s	
Pump flow, m ³ /s	
Pipe flow, m ³ /s	
Outlet structure flow,	.00 .00 .00 .00 .00
Withdrawal flow,	5.95 .00 .00

Model run directory: C:\Users\NBNe\OneDrive\Documents\Clients\Idaho_DEQ\Island_Park_Reservoir\ShareableModels\IslandParkReservoir

Status: Executing

Priority: Idle Lowest Low Normal High Highest

Figure 104. View of the model executable GUI. The priority of the model executable (specified in the lower right-hand corner) has been set to the “Highest” possible setting to decrease the model runtime.

Model Output and Evaluation

Output Files

Part 3 of the user manual (W2manual45_Part3_InputOutputFiles_rev8.pdf) describes the output files generated by W2 in detail. The following files are likely to be of interest to users of the linked Island Park Reservoir and Henry’s Fork River models:

Island Park Reservoir

- qwo_99.csv
 - The total volume of flow leaving the Island Park Reservoir at the Island Park Dam, corresponding to segment 99 of the model grid. Reservoir outflow was used as the upstream flow boundary condition of the Henry’s Fork River model.
 - Individual outflows from the spillway and each outlet are detailed in the qwo_sp1_seg99.csv, qwo_wd1_seg99.csv, and qwo_wd2_seg99.csv output files.

- two_seg 99
 - The sum of the temperature of outflows leaving the Island Park Reservoir at the Island Park Dam, corresponding to segment 99 of the model grid.
 - The temperature of individual outflows from the spillway and each outlet are detailed in the two_sp1_seg99.csv, two_wd1_seg99.csv, and two_wd2_seg99.csv output files. The flow-weighted average temperature of these individual outflows was used as the upstream inflow temperature boundary condition of the Henry's Fork River model.
- spr.csv
 - Modelled reservoir temperature profiles laterally averaged across segment 99. The dates of the spr.csv output correspond to the dates of vertical temperature profiles collected by the Henry's Fork Foundation in 2023.

Henry's Fork River

- qwo_53
 - The total volume of flow leaving the furthest downstream extent of the model, corresponding to segment 53 of the model grid located immediately above the confluence of the Henry's Fork River and Thurmon Creek.
- two_53
 - The temperature of outflow leaving the furthest downstream extent of the model, corresponding to segment 53 of the model grid located immediately above the confluence of the Henry's Fork River and Thurmon Creek.
- tsr_{number}_seg{segment}
 - Output time series of stream flow temperature, shading, and other parameters corresponding to each segment of the model grid.

In addition to the above files, the model executable generates a linkage file for the post-processor (with the file type ".w2l"). The utility of the W2 post-processor is described in the following section.

Using the W2 post-processor

The W2 post-processor hosts a range of plotting and processing tools to help users interpret and refine model results. W2_Post_Quick_guide (Rev03).pdf, located in the CE-QUAL-W2_Manual_v4.5 /W2tools post-processor folder, provides an overview of the tool's functionality. The installation executable for the post-processing tool is located in the same folder. This section highlights specific components of the post-processor likely to be relevant to users of the Island Park Reservoir and Henry's Fork River models.

Identifying and loading the W2 model linkage file

The Island Park Reservoir and Henry's Fork River models and model scenarios have been set up to generate a W2 linkage file upon termination. This linkage file, denoted by the file type ".w2l", can be loaded into the post-processor using the "Browse" button on the GUI's default landing page (Figure 105).

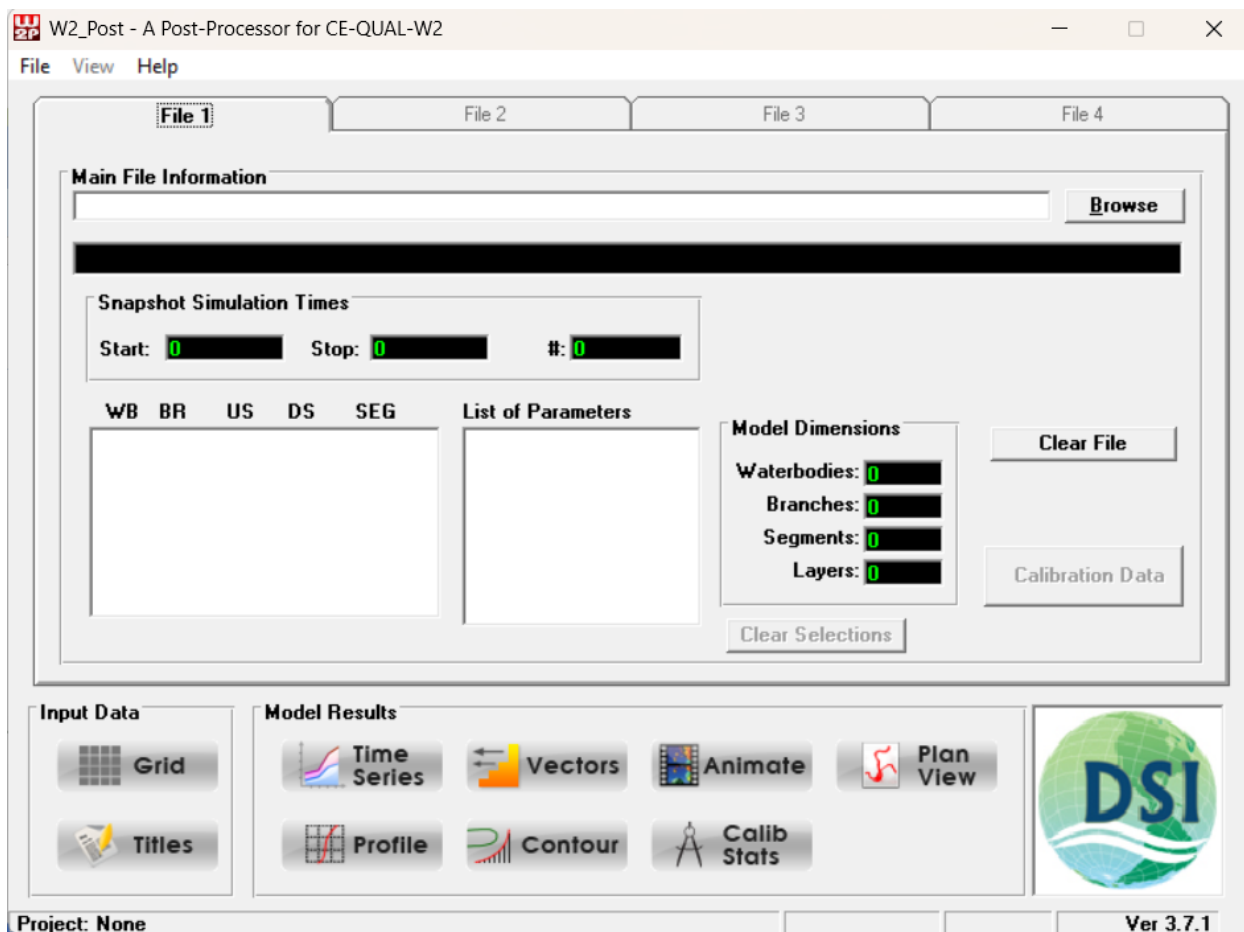


Figure 105. The default landing page of the W2 post-processor. The “Browse” button at the top right of the screen can be used to load the W2 linkage file. The “Time Series” and “Profile” functionalities are located at the bottom center of the screen under “Model Results”.

Vertical profiles

The W2 post-processor allows users to generate vertical profiles of any segment at any time (over the model duration) for modeled parameters. To navigate to the tool, select the “Profile” option under “Model Results” on the GUI landing page (Figure 105).

Figure 106 shows the generated vertical temperature profile of the Island Park Reservoir model at segment 99 (corresponding to Island Park Dam) on June 1, 2023 (Julian date 151). To view a segment in another branch, users would need to first select the corresponding branch under “Profiling Selections” before navigating to the segment of interest using the “Segment” drop down selector. The plotting space can be modified using the settings under the “Options” header button and exported using the “File” header button.

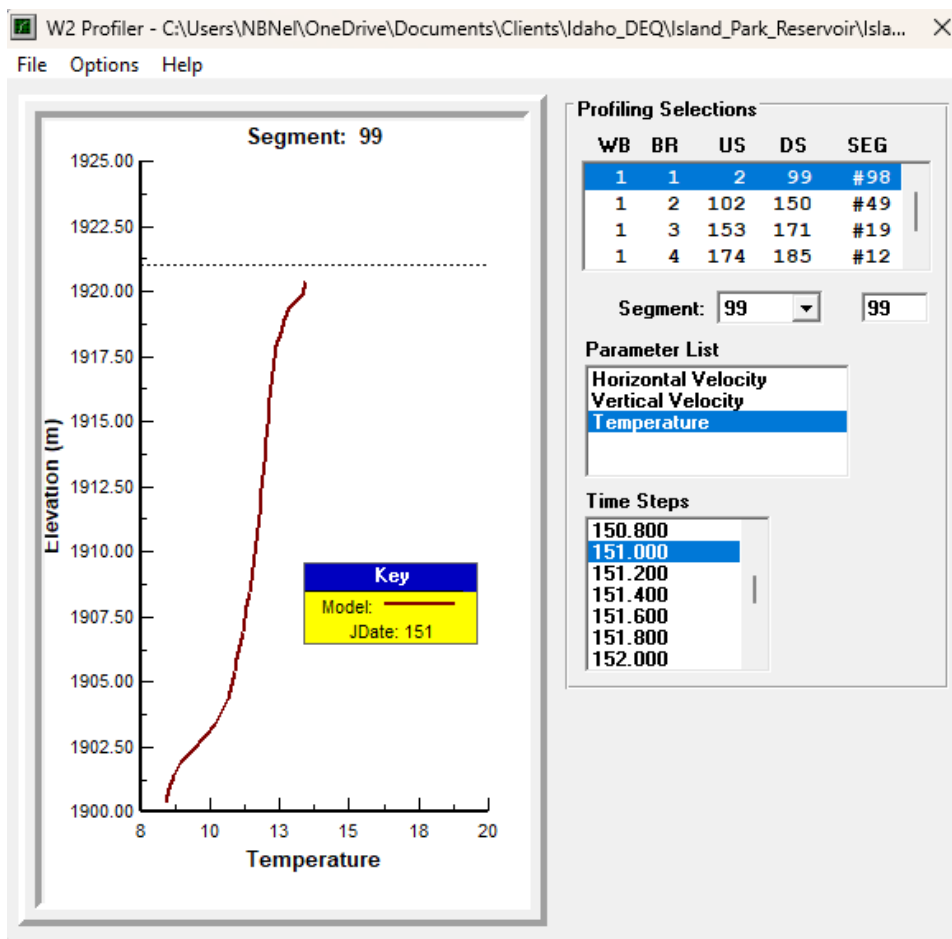


Figure 106. View of the W2 “Profile” tool, showing the vertical temperature profile of the Island Park Reservoir at segment 99 (Island Park Dam) on June 1, 2023 (Julian date 151).

Time Series

The W2 post-processor allows users to create timeseries of any model cell at any time (over the model duration) for modeled parameters. To navigate to the tool, select the “Time Series” option under “Model Results” (Figure 105).

Figure 107 shows the cell selection page that first appears when users first open the tool. Users can select one or more cells in the model grid, navigating between branches using the slider at the top of the page. Once the user has selected the model cells for output (highlighted in red), the “OK” button at the top of the page will become actionable. Pressing the “OK” button will lead users to a secondary page where they can define plotting options and select from a list of available parameters. Note, only those cells that are inundated (contain water) will output parameter timeseries.

Figure 108 shows the temperature timeseries for the bottom grid cell of the Henry’s Fork River model at segment 53, the lowest downstream segment of the model corresponding to the river just above its confluence with Thurmon Creek. For this example, the “Multiple Cells/Single Parameter” option was selected alongside the “Temperature” parameter.

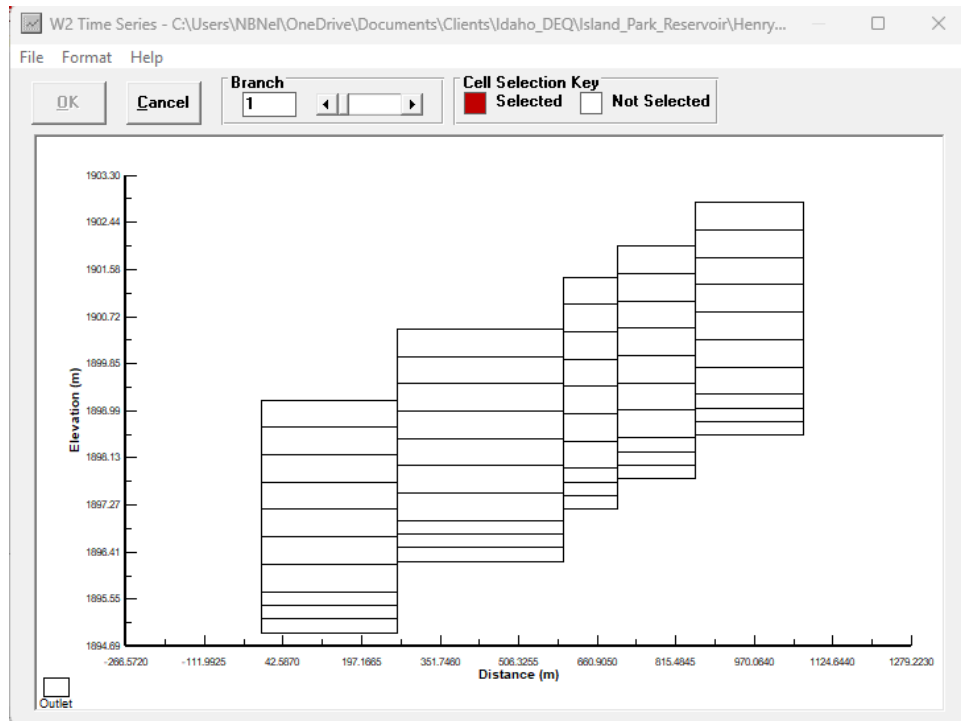


Figure 107. Cell selection screen of the W2 post-processor “Time Series” tool. Branch 1 of the Henry’s Fork River calibrated model depicted.

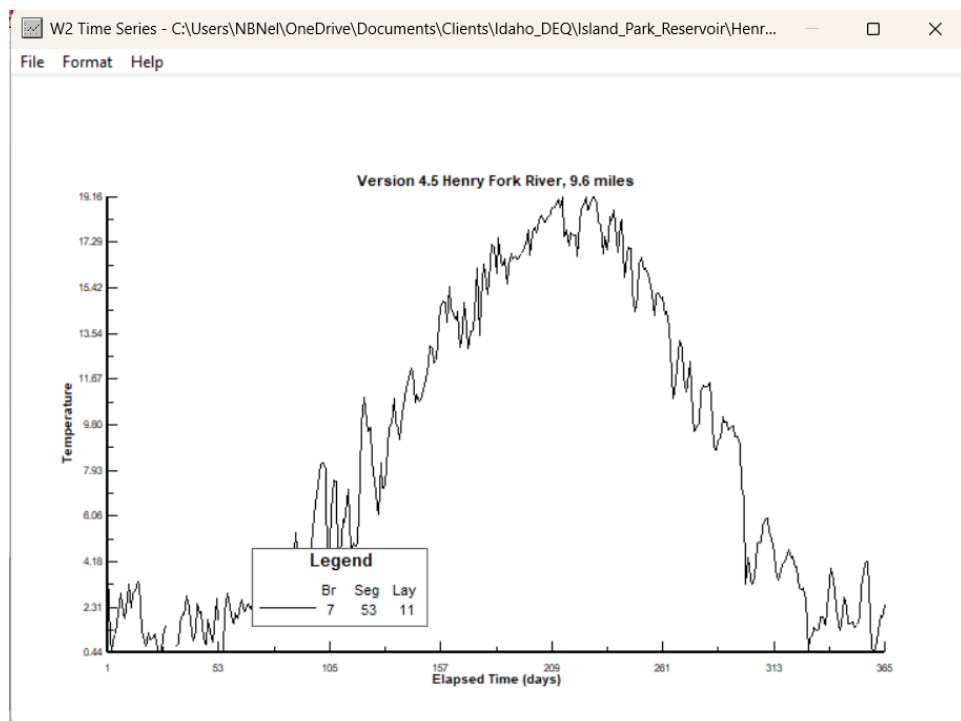


Figure 108. Timeseries of temperature at the bottom of the Henry’s Fork River model grid at segment 53, corresponding to the river just above its confluence with Thurmon Creek. The plotting space was created using the W2 post-processor “Time Series” tool.

References

Wells, S. A. 2023. CE-QUAL-W2: A Two-Dimensional, Later-ally Averaged, Hydrodynamic and Water Quality Model, Version 4.5, User Manual, Department of Civil and Environmental Engineering, Portland State University, 1,106 pp.