Draft Final

Chelan River Stream Network Temperature Model
Lake Chelan Hydroelectric Project
FERC Project No. 637

Prepared for

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EXECUTIVE SUMMARY

As part of relicensing the Lake Chelan Hydroelectric Project, FERC No. 637, a stream temperature modeling study was applied to the 3.9-mile long bypassed section of the Chelan River between Lake Chelan Dam and the confluence with the Columbia River. Using the Stream Network Temperature Model (SNTEMP), stream temperatures within the bypass were simulated under variable conditions of flow, weather, and channel configuration. The purpose of this study was to generate information useful in the evaluation of alternative project management scenarios for enhancement of fish populations.

The StreamTemp computer model (a variation of SNTEMP) was calibrated and validated with measured hydrological and meteorological data from June 19 to August 20, 2002. In these temperature model analyses, calibration of the temperature model utilized one-half of a partial year of data followed by validation testing of the calibrated model with the second half of the data. The available data set allowed for a reasonable calibration and validation of the model. Temperature predictions and conclusions for simulation runs (gaming scenarios) can be viewed as approximating conditions during similar flow, weather and seasonal parameters.

The gaming scenario data consisted of 425 days from May though September, 2000 to 2002, plus an extreme hot-weather pattern from July 24 to August 6, 1998. Weather data originated from the U.S. Forest Service Chelan Ranger Station, and flows and water temperatures were taken from forebay, penstock and powerhouse data sensors.

Results show that downstream mean daily water temperatures will either cool or warm depending on ambient weather conditions, lower flow releases are more responsive to weather than higher flows, and maximum daily water temperatures are generally higher with lower flows. A comparison of the air temperature with the upstream water temperatures within the calibration data file shows that the mean daily input water temperatures in the forebay of Lake Chelan are already approaching equilibrium with the air temperature, even prior to entering the Chelan River channel. This is likely because the top surface of Lake Chelan (and hence the channel input water) has had time to acclimate to the weather regime. Consequently, on hot days, relatively hot water is entering the channel.

The predicted average daily water temperatures at downstream locations did not vary significantly under a wide range of flows. Generally, on warmer days, larger discharges of cooler water kept the stream from warming as much as smaller volumes. However, on some cooler days and at higher flows, the downstream water was actually warmer than at lower flows because the thermal mass of the larger volume of water was less capable of cooling as quickly.

While 24-hour average temperatures generally followed the input water temperatures over a wide range of flows, the calculated maximum temperatures followed a pattern where the smaller flows had a much greater diurnal range of temperatures than larger flows. Average 24-hour temperatures rarely exceeded 24 degrees, but maximum 24-hour temperatures often exceeded 24 degrees in low flow scenarios.

Prediction results followed the same patterns but were more exaggerated under extremely hot weather. Chelan River water warms through the bypassed reach even under very high flows. A seasonal trend is evident when the model is applied using late spring (May) to early fall (September) data for the three modeled years, with lower flows warming more (both mean daily and maximum daily) prior to mid

August, and cooling more than higher flows thereafter. Temperature simulation by study reach within the Chelan River bypass showed that the greatest temperature increases occur within the uppermost reach. However, the temperature of water released at the dam into the uppermost reach in the summer is already consistently higher than standard temperature criteria for salmonids.

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1. INTRODUCTION

The Lake Chelan Hydroelectric Project (FERC No. 637) is located on the Chelan River near the City of Chelan in Chelan County, Washington. The Project is licensed to the Public Utility District No. 1 of Chelan County whose central offices are 32 miles south, in Wenatchee, Washington. The existing FERC license is due to expire at the end of March 2004 and this water temperature modeling study is being completed as a requirement for the environmental portion of the relicensing process.

1.1 LOCATION

From the dam that maintains Lake Chelan at its current elevation, 3.9 miles of the Chelan River is bypassed down to a powerhouse near the confluence with the Columbia River. Water is diverted at the dam through a 2.2-mile long tunnel and penstock and returned to the Chelan River approximately 400 feet upstream of the Columbia River at the project powerhouse.

1.2 BACKGROUND

In most years, the bypassed section of the Chelan River is generally dry as a result of project operations and lake level management under the FERC license. Only during wet years or during project maintenance does the river channel receive substantial flow. When flow is not being released into the river below the dam, fish habitat is restricted to a few isolated pools in the gorge section of the bypassed reach and a short section of river below the powerhouse tailrace. Summer and fall chinook salmon (*Oncorhynchus tshawytscha*) have been observed utilizing the tailrace and lower river for spawning under the right conditions, while smallmouth bass (*Micropterus dolomieu*) and suckers (*Catostomus* spp.) use the available habitat for rearing.

If flow releases are specified under a new license, additional fish habitat could be created and maintained within river bypassed reach in most years. Depending on flow, channel configuration, weather, and water temperatures, various fish species might occupy the habitat. Given the proper conditions (primarily suitable water temperature), even stream habitat necessary for the West Slope cutthroat trout (*Salmo clarki*) might be achieved in the Chelan River. Providing suitable habitat in the upper three miles of the river for this species is a primary desired beneficial use designated by the Natural Sciences Working Group, a project re-licensing committee.

This study was performed to provide an evaluation of flow release alternatives and possible habitat enhancement options. The process-oriented temperature model StreamTemp (based on SNTEMP, Theurer et al. 1984) was used to predict water temperatures in this reach under various simulated flow regimes and weather conditions. This model has the benefit of being peer-reviewed, published, and widely applied. Measurements of stream temperature, flow, geometry, and localized meteorology were used in the construction and calibration of the temperature model. StreamTemp incorporates (1) a complete solar model that includes both topographic and riparian vegetation shade; (2) a meteorological correction model to account for the change in air temperature, relative humidity, and atmospheric pressure as a function of elevation; (3) a complete set of heat flux components to account for all significant heat sources; (4) a heat transport model to determine longitudinal water temperature changes; (5) regression models to smooth or complete known water temperature data sets; (6) a flow mixing model at tributary junctions; and (7) calibration equations to help eliminate bias and reduce errors at calibration nodes (Theurer et al. 1984). The StreamTemp program, running under Microsoft Windows, enhances the usability of the SNTEMP algorithms by providing simplified data input into a single data file, and multiple graphs and tables for ease in checking data and results.

Development of an accurate temperature model for a river such as the Chelan involves acquiring as much real, measured data as available for calibration. Hogan et al. (1973) found that analysis of data for a period of two years leads to the same general distribution of equilibrium temperatures as does a ten year period. However, with the Chelan River, there is no required minimum flow below the dam and there has been a recent sequence of dry years. Consequently, prior to 2002, no calibration data were available except for a brief period (13 days) in 1999. A rough, un-validated temperature model based on these 13 days was developed in 2001. In 2002, from June through August, various test flows were passed below the dam to specifically allow stream temperature data collection. The previous model was discarded after collection of this larger data set from which a more rigorous temperature model was developed. Following model calibration and validation from this data set, other months and years of weather and forebay water temperatures were added for gaming simulations. As with any other model, daily temperature predictions at specific locations should not be considered as absolutes, but as comparative temperatures for use in evaluating potential management alternatives.

1.3 SALMONID TEMPERATURE THRESHOLD

A threshold of 20ºC (68ºF) is identified in this report as the approximate upper temperature limit of suitable salmonid habitat, according to standard guidelines for thermal tolerance of salmonid species (McAfee 1966, Reiser and Bjornn 1979, Raleigh et al. 1984 and 1986, Armour 1991). The ultimate upper incipient lethal temperature (UUILT) above which 50% mortality is expected to occur, ranges between 23ºC to 25ºC for chinook salmon, cutthroat and rainbow trout (Bell 1986, Eaton et al. 1995). These salmonid temperature criteria are noted only as reference points and are considered relative indexes rather than absolute limits due to other factors that may control suitability. These factors include the range of diurnal temperature variation, availability of thermal refuges (e.g. deep pools or springs), water quality, fish size, sex, life cycle stage, and possible genetic variation in thermal tolerance of salmonid species and strains.

2. STUDY AREA

2.1 STUDY REACHES

For the purpose of this and other related environmental studies, the Chelan River has been segmented into four study reaches based on gradient, channel confinement, and fluvial geomorphologic characteristics (Figure 1a). A more detailed description of the reaches is available in the Bypass Reach (Gorge) Flow Releases Study Report (R2 Resource Consultants and Ichthyological Associates, Inc. 2000).

Reach 1 – Starting from the dam and extending down 2.29 miles, the river channel in this 1% gradient reach is generally wide (averaging 85 feet), is partially confined by the glacial moraine hillsides, and has little or no riparian vegetation. The upper section of Reach 1 is more confined to a single channel while the lower section widens into one or two very shallow braided channels. Since reach azimuth is important for the shading algorithm, unlike the remaining reaches, Reach 1 was broken into twelve sections corresponding to section azimuth.

Reach 2 – Even lower gradient than Reach 1, this 0.75 miles of river is more confined by steep, non-vegetated hillsides with a narrower average channel width of less than 50 feet. Stream shading is provided by the steep hillsides.

Reach 3 – Varying between 5 to 10% gradient, this gorge section is 0.38 miles long and has a channel width of only about 35 feet. Steep bedrock walls confine and shade this portion of the river when the sun is low in the south (fall, winter and spring.) The east-west aspect of the reach allows much greater solar radiation during mid summer.

Reach 4 – Ending at the confluence with the powerhouse tailrace, this 0.49 mile long reach is generally less than 2% in gradient and has an average stream channel width of 108 feet. Minimum shading is provided by the topography with little or no established riparian vegetation.

Figure 1b is a topographic map of the study area, identifying azimuth section nodes within each reach. Table 1 lists the latitude, longitude and upstream distance (from end of Reach 4 near Chelan Powerhouse) for each study node.

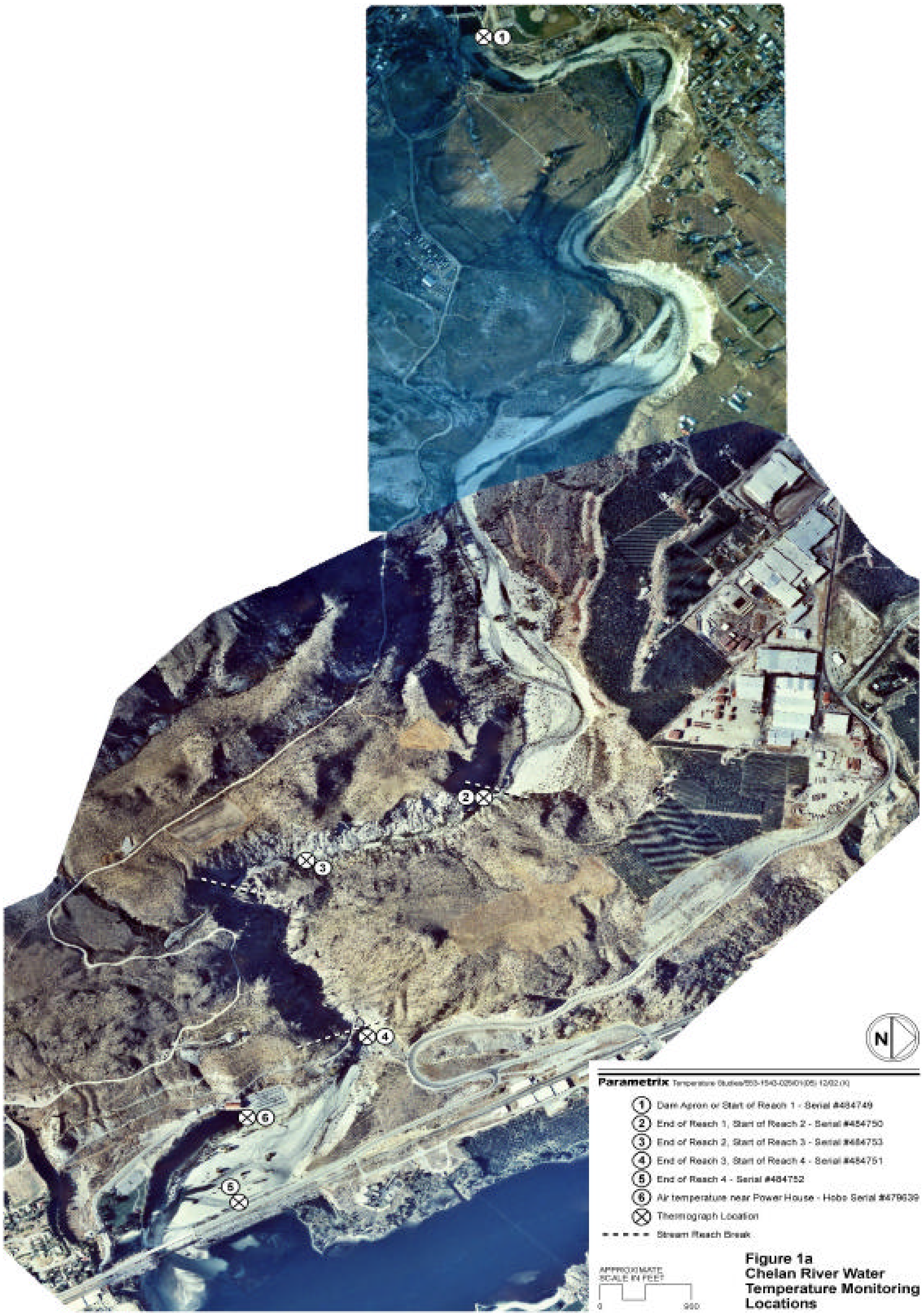


Figure 1A Chelan River Water Temperature Monitoring Locations

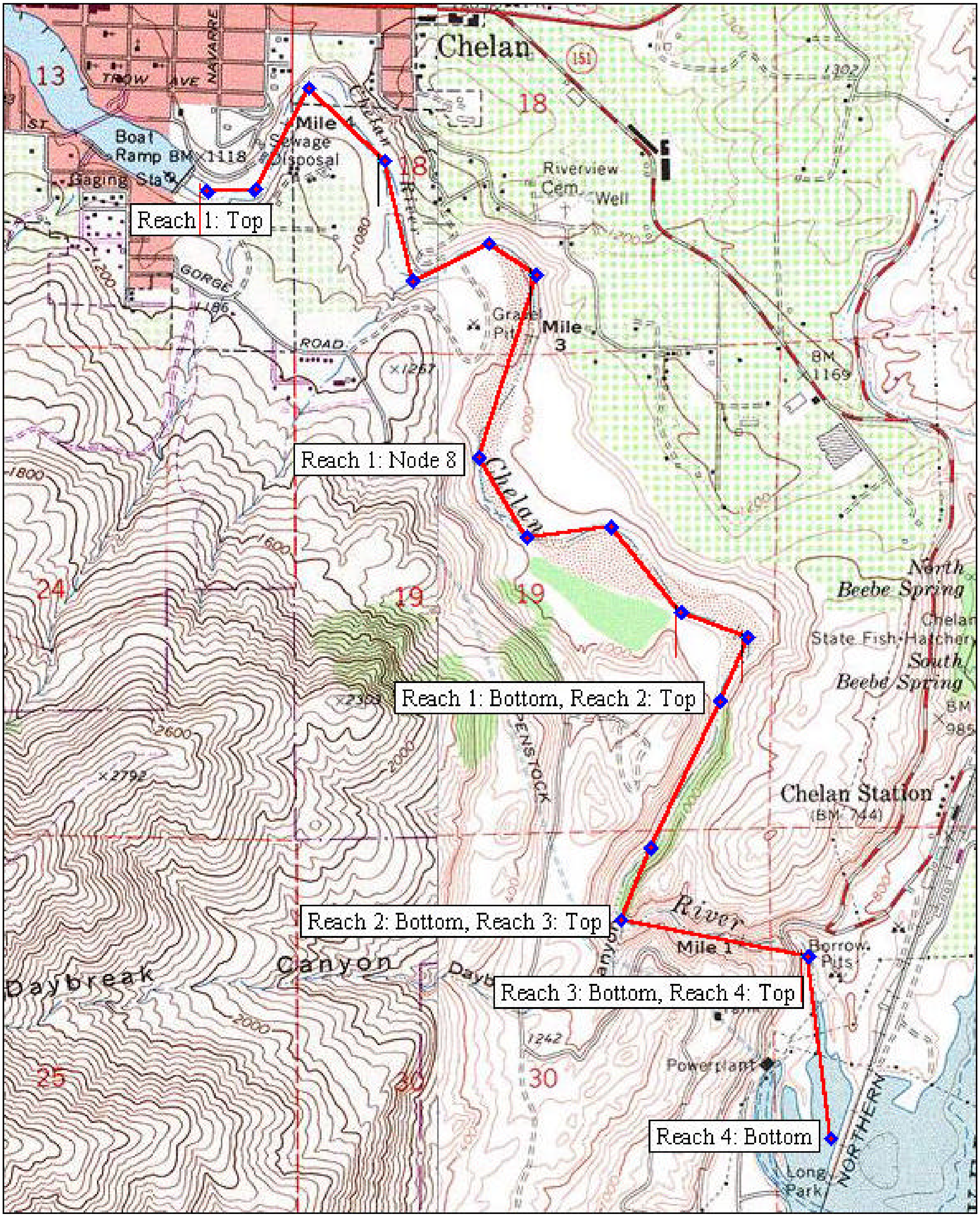


Figure 1B. Topographic Map of Study Area

Table 1. Locations of Study Nodes

Chelan River Study Locations					
Node	**Title**	**Latitude**	**Longitude**	**Upstream Distance (km)**	**Azimuth Downstream**
1	Reach 1, Top of Study, dam apron	47.83408	-120.011	6.10	85.8
2	Reach 1, Node 2	47.83413	-120.009	5.90	25.8
3	Reach 1, Node 3	47.83715	-120.007	5.50	131.5
4	Reach 1, Node 4	47.83500	-120.003	5.10	164.5
5	Reach 1, Node 5	47.83149	-120.002	4.68	62.3
6	Reach 1, Node 6	47.83256	-119.999	4.41	126.2
7	Reach 1, Node 7	47.83164	-119.997	4.22	199.2
8	Reach 1, Node 8	47.82622	-119.999	3.59	150.6
9	Reach 1, Node 9	47.82392	-119.997	3.29	86.7
10	Reach 1, Node 10	47.82416	-119.994	3.01	142.1
11	Reach 1, Node 11	47.82167	-119.990	2.65	113.2
12	Reach 1, Node 12	47.82094	-119.988	2.43	205.1
13	End of Reach 1, Top of Reach 2	47.81909	-119.989	2.20	207.2
14	Reach 2, Node 2	47.81469	-119.992	1.61	204.9
15	End of Reach 2, Top of Reach 3, top of gorge	47.81259	-119.993	1.35	103.1
16	End of Reach 3, Top of Reach 4, bottom of gorge	47.81152	-119.985	0.60	175.0
17	End of Reach 4, near Powerhouse	47.80615	-119.984	0.00	

3. CALIBRATION PROCESS

3.1 INPUT DATA: STREAM TEMP MODEL DATA ACQUISITION

3.1.1 Water Temperature and Recording Thermographs

StowAway® TidbiT® thermographs, manufactured by Onset Computer Corporation, were used in the water temperature study. The operating temperature of these thermographs is -4° to + 37°C to, with a stated accuracy of ± 0.2° C and resolution of 0.16° C. They are waterproof to 1000 feet and can be set to record in intervals of 0.5 seconds to 9 hours. The internal battery will operate for 5 years but length of deployment depends on the time interval selected for recording temperature measurements.

An Onset Computer Corporation HOBO® measuring device was used to record ambient air temperature and relative humidity in the area of the bypassed reach. The HOBO thermograph has a measurement range of –30°C to +50°C. Manufacturer specifications report an accuracy of ±0.2°C for this thermograph in high-resolution mode (resolution = 0.02°C) and an accuracy of 0.4°C in standard resolution mode (resolution = 0.38°C).

Each thermograph was triggered prior to deployment and deployed on June 11or 12, 2002. The actual time the thermographs were installed was recorded in the field notes. The thermographs recorded water temperature every 30 minutes. For protection against debris that might be carried by the current and damage during deployment and retrieval, each thermograph was fastened inside a copper pipe cap (1½ in) with holes drilled in it to allow free access to the river water. The caps with the thermographs and radio tags inside were then mounted on small boulders in the riverbed. A single hole was drilled in the boulders with a rechargeable drill and masonry bits. Stainless steel anchor bolts were driven into the holes and used to secure the thermograph packages to the boulders. The copper caps were mounted with the open end against the boulders, thus encapsulating the thermographs and radio tags. This anchoring method also provided stability in the high velocity currents of the bypassed reach and helped camouflage the thermographs against tampering.

The Onset HOBO® was installed on the underside of a birdhouse that had been modified to permit free airflow around the device while protecting it from rainfall. The HOBO was mounted on a tree, about 1.5 meters above ground and 2 meters into the riparian zone from the edge of the tailrace pool, and in a location shaded from direct sunlight.

3.1.2 Thermograph Installation Locations

The thermographs locations were recorded in the field notebook with sketches and descriptions of the area to aid in relocating the units. GPS coordinates were also recorded for some of the units (Table 2). Unfortunately, some locations in the gorge were not open enough to the sky to allow an adequate GPS fix. All temperature-monitoring locations, indicated on the aerial photograph of the Chelan Bypass Reach (Figure 1a), are approximate (+or- 50 feet in any direction). The Onset HOBO® was located just below the powerhouse on the east bank of the tailrace pool.

Table 2. Chelan River Bypass - Parametrix Hobo and Tidbit Temperature Monitoring Locations

Monitoring Locations	Latitude	Longitude
Air temperature near Power House - Hobo Serial # 479639	NO Data	
End Of Reach 4 - Serial # 484752	NO Data	
End of Reach 3, Start of Reach 4 - Serial # 484751	47°48.687'	119°59.085'
End of Reach 2, Start of Reach 3 - Serial # 484753	47°48.804'	119°59.430'
End of Reach 1, Start of Reach 2 - Serial # 484750	47°49.167'	119°59.234'
Dam Apron or Start of Reach 1 - Serial # 484749	NO Data	
	(WGS 1984)	

3.1.3 Temperature Data Handling And Reduction

The raw data files collected by the StowAway® TidbiT® thermographs were exported into Excel (Microsoft? , 1985-1999). Raw data collected from any fixed temperature monitoring station during two or more sequential sampling events were then combined into a single data set. Each data set (one per thermograph) was examined for outliers that were recorded during retrieval, download, and re-deployment periods. These outlier values were not removed from their respective data sets but were marked with color blocks and comments in a column adjacent to the temperature values. The resulting data files were saved in Excel workbooks, ready for reporting and/or analysis.

Discharge and spill data and additional forebay temperature data for the Chelan River dam and powerhouse were received from the Chelan County PUD. These data were added to the worksheets containing the thermograph data. The temperature data for each thermograph and reach were matched to the discharge/spill data and forebay temperature data by date and time. Each resulting data set was marked, with color blocks and comments, to highlight suspect data that might need to be removed prior to inclusion of the data sets in the model. Examples of questionable data include temperature extremes that may have resulted from exposure of the thermograph to air during retrieval and downloading or during no-spill periods. The modeler made the final decision on the validity and use of thermograph data.

Site-specific water temperature data in the study reaches were obtained through the placement of temperature loggers. From June 19 through August 20, 2002, OnSet Computer Corporation Optic Stowaway temperature loggers were deployed at the end of each primary reach and at the top of Reach 1 (dam apron) to monitor water temperatures hourly. A water temperature sensor was also placed in the forebay of Lake Chelan. Since the model requires daily average input temperatures and the top of Reach 1 sensor missed some data (due to exposure to air, and times when the sensor was removed for downloading) the forebay temperatures were used as input temperatures to the model to maximize the number of days for calibration. Figure 2 shows the average daily temperature pattern for the forebay input water temperatures in 2002.

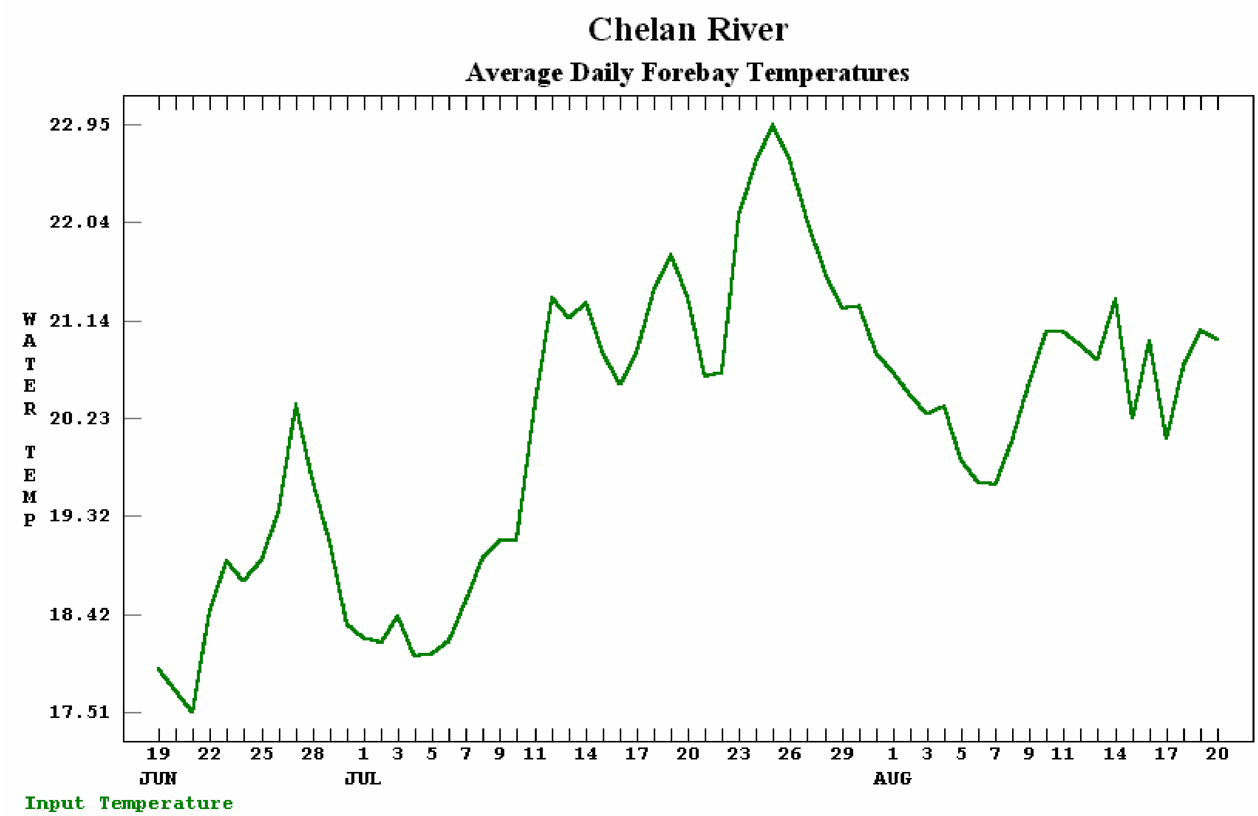


Figure 2. Average Daily Forebay Water Temperatures in °C in 2002

3.1.4 Hydrology

Various test flows were passed below the dam from June 19 through August 20, 2002, to specifically allow stream temperature data collection. Data on flow releases from Chelan Dam were provided by the Chelan PUD (Figure 3). These flow data, together with the recorded temperature data, served as the basis for the hydrology data input file within the SNTEMP model. No lateral accretion flows were included.

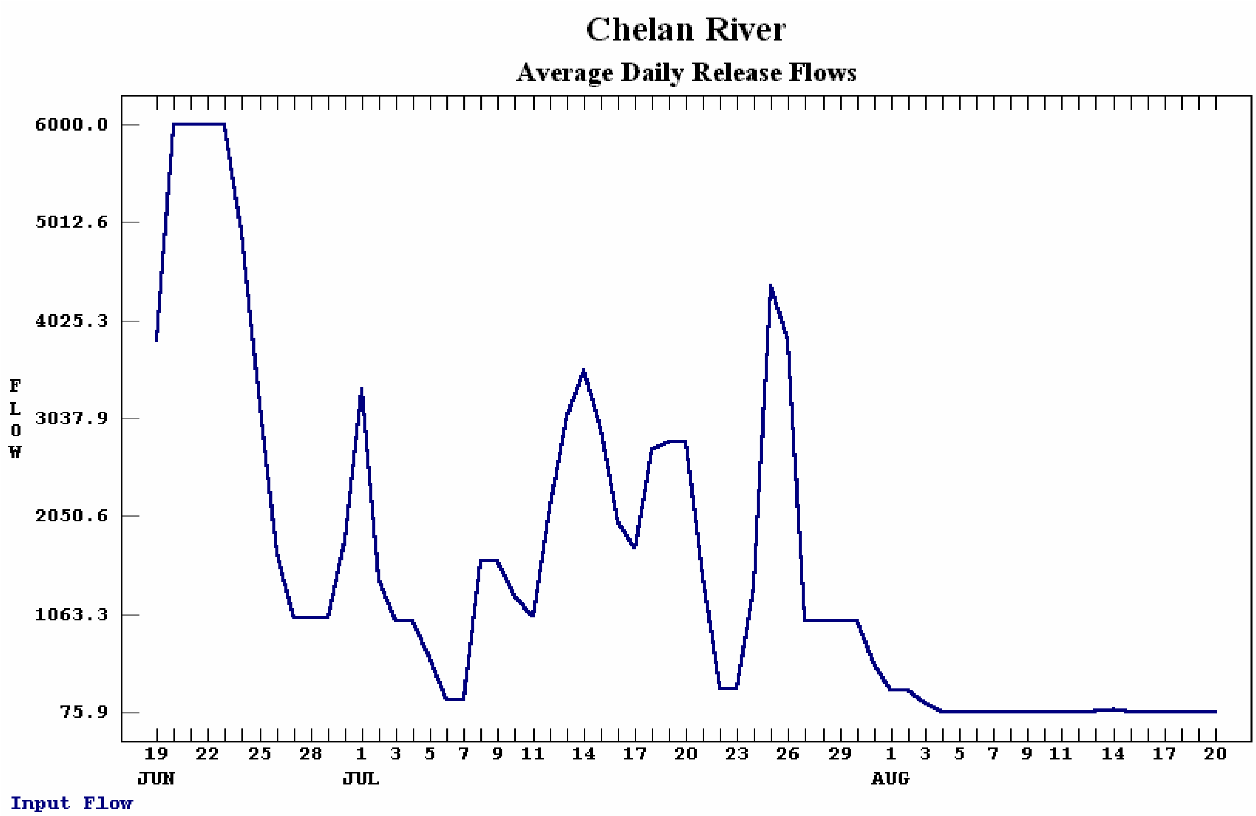


Figure 3. Average Daily Release Flows in Cubic Feet per Second from Lake Chelan in 2002

3.1.5 Meteorology

Daily air temperature data were obtained from the National Oceanographic and Atmospheric Agency meteorological station at Chelan. Relative humidity was measured at the powerhouse. These values served as the meteorological database for the temperature model (Figure 4). Wind speed was set to an average constant of 1.788 meters per second since the local microclimates along the Chelan River reaches are likely different from the nearest available weather station (Wenatchee.) Solar radiation was calculated using the StreamTemp model algorithm and adjusted by modifying percent sunshine, when known cloudy or rainy days occurred at Chelan and Wenatchee.

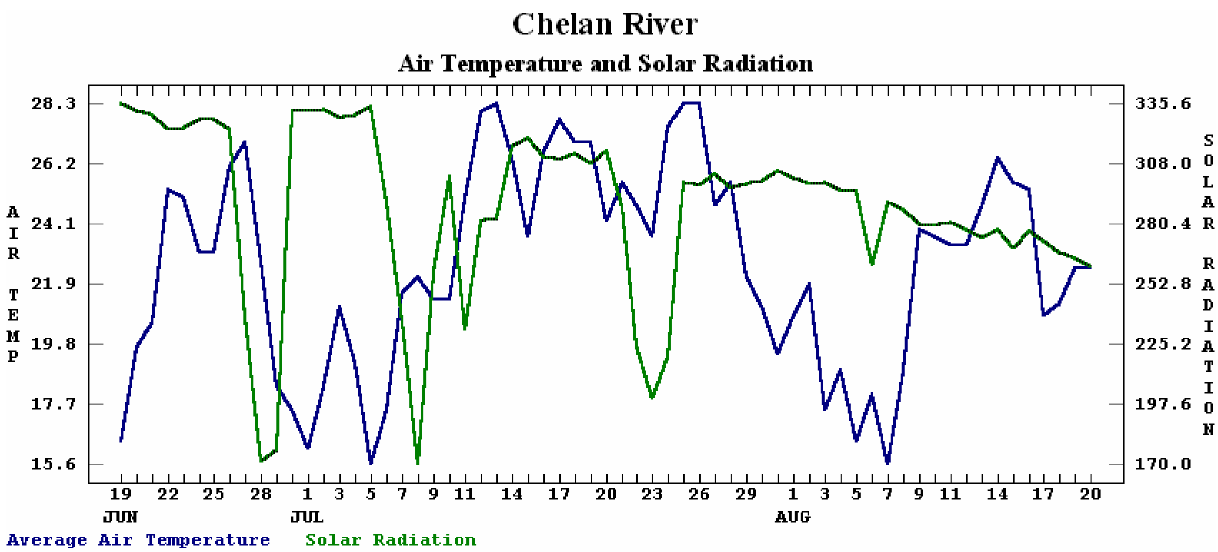


Figure 4. Air Temperature in °C and Solar Radiation in Kilojoules/square meter/second

Air temperatures were measured at the Chelan Powerhouse, but only during the 2002 season. Consequently, they were not used in the calibration since the simulation runs included 2000 and 2001, in addition to 2002. Instead, only the Chelan weather station data was used in the calibration and simulation process. As a quality control measure, for the period of overlap, Chelan and powerhouse air temperatures were compared (Figure 5.). For this period of time, Chelan data is an average of -0.43 degrees Celsius cooler than that of the powerhouse (this difference reflects the adiabatic lapse rate based upon the difference in elevation between the two meteorological station locations).

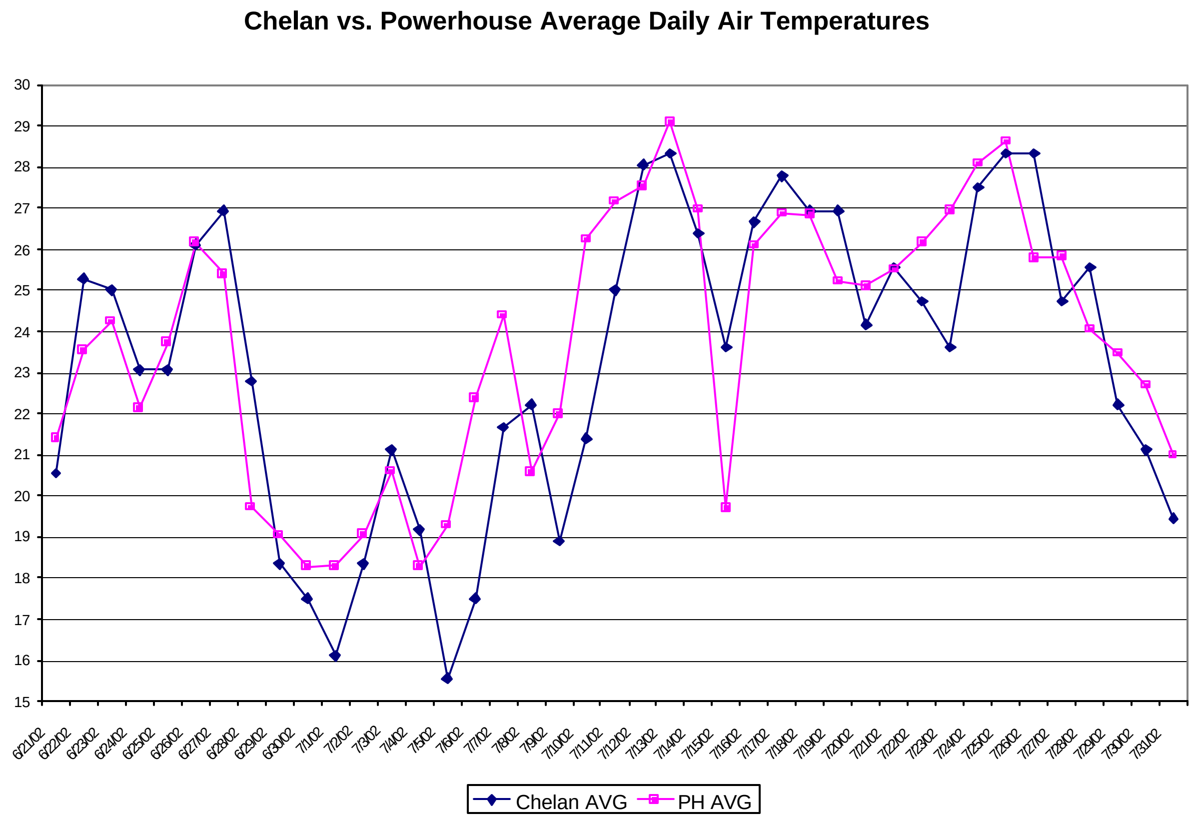


Figure 5. Air Temperatures at Town of Chelan and the Chelan Powerhouse, 2002

3.1.6 Shade Measurements

An insignificant amount of shading is provided to the Chelan River by streamside vegetation within the bypass reach. Topographic shading varies from minimal shading in the open valley to extensive shading in the gorge during winter months. Initial shade values were obtained in the field on June 9, 2001. Readings of topographic altitude were also made using the seamless USGS topographic map software program TOPO! (National Geographic Holdings, 2000). Numerous readings of rise over run were used to generate an average value of topographic altitude for each bank of the four reaches (east and west banks are fixed by convention based on river segment azimuth). These readings compared favorably to those measured on site using a hand-held clinometer. The mean topographic altitude values for each reach used in the shade sub-component portion of the StreamTemp model are as follows:

Reach 1 – North bank 15° to 20° (avg = 16.8°), South bank 16.57° to 25° (avg = 18.6°)

Reach 2 – West bank 40°, East bank 30°

Reach 3 – North bank 55°, South bank 50°

Reach 4 – East bank 21°, West bank 25°

Using these angles and reach azimuths, the model calculated daily shade percentages. Table 3 shows the range of shading for the reaches from the beginning of the study (June 19) until the end (August 20).

Since shading increases dramatically during the autumn, included are calculated shade values for September 30 (the end of the simulation period.)

Table 3. Calculated Shade by Study Reach on Selected Dates – Chelan River

Reach	% Shade June 19	% Shade August 20	% Shade September 30
1	3.84	4.56	7.25
2	19.45	22.63	28.59
3	7.56	3.18	91.69
4	12.46	14.87	18.97

Note that calculated shade for Reach 3 (the gorge) is rather low through the calibration period, but then increases dramatically by the end of the simulation period. This is due to the east-west orientation of the reach that allows sunlight to enter in the summer, but blocks sun after the declination of the sun lowers below the 50° horizon.

3.1.7 Stream Geometry

Stream elevations and distances are fundamental stream geometry measurements required in StreamTemp. Elevation and distance values for the Chelan River model were derived from the TOPO! program. Stream width can be a very sensitive parameter in modeling stream temperatures (Bartholow 1989). StreamTemp employs width as a function of discharge in the form:

$$W = a\,Q^{b}$$

where W = width (meters), Q = discharge (cms), and a and b are empirically derived coefficients. This allows the model to increase or decrease the width of the river as the flow increases or decreases.

The following are the reach a and b coefficients used in the study

Reach 1 a = 5.0 to 10.0, b = 0.30 to 0.35

Reach 2 a = 6.0, b = 0.3

Reach 3 a = 6.0, b = 0.2

Reach 4 a = 8.0, b = 0.3

Derived wetted widths (in meters) for these coefficients for selected flows are shown in Table 4.

Table 4. Derived wetted widths (meters) at selected flows

Reach	40 c.f.s.	~350 c.f.s.	1000 c.f.s.
Upper Reach 1	8.35	18.03	25.78
Lower Reach 1	10.44	22.54	32.23
Reach 2	6.22	12.04	16.36
Reach 3	6.15	9.55	11.71
Reach 4	8.35	18.03	25.78

3.2 CALIBRATION AND VALIDATION PROCEDURES

Calibration of the temperature model is the process by which certain parameters are adjusted to allow the model to more accurately predict observed water temperatures. Adjustments are often needed to correct for differences in physical conditions between the water surface where temperature change occurs and the sites of data collection. For instance, the air temperature data were collected near the bypassed reach at the City of Chelan. Even with the air temperature location being as close as Chelan, the city is located on the shore of a lake and may have slightly different air temperatures than the Chelan River canyon. A global modification of a particular meteorological parameter such as air temperature might allow for a more accurate prediction model.

Any differences in conditions could affect the ability of the model to reproduce observed water temperatures and warrant calibration adjustments. These calibrations should be within reasonable limits, as defined in the documentation for the models (Bartholow 1989). The input data to these parameters are modified globally (the entire input data set of the specified parameter) by the application of a constant and coefficient modifier to each daily input value. The global calibration factors were used in the computer program to modify the meteorological parameters according to the general form of:

$$Y = a_0 + a_1 y$$

where:

Y is the modified meteorological parameter
y is the original input meteorological parameter
a_0 is the calibration constant factor
a_1 is the calibration coefficient factor.

3.2.1 Data Sets

The Chelan Bypass Temperature Model was calibrated by first dividing the available data (June 19, 2002 through August 20, 2002) into two sets. Set 2 was comprised of 124 data pairs (observed versus predicted water temperatures at the bottom of four reaches for 31 days) when stream flows were less than or equal to 1,000 c.f.s.. This set of data was used for model calibration. Set 1 was comprised of 124 data pairs when stream flows exceeded 1,000 c.f.s., and was reserved for a test of model validation.

3.2.2 Calibration

Through the process of iterative gaming, no global calibration constants and coefficients were deemed necessary to enhance model prediction accuracy. However, some less critical input data were not available for all of the period or only available from distant sources. Because of this, certain data were set to a constant as follows:

Percent Sunshine: Set to 90% for all dates except where rainfall and cloud cover data warranted adjustment down.

Humidity: Calibration (and validation) data used mean daily values measured by the Hobo sensor at the Chelan Powerhouse. (Simulation-run data were set to 30% for all dates except where rainfall and cloud cover data warranted upward adjustment.)

Wind Speed: Set to 1.788 meters per second as a global average.

Dust Coefficient: Set to 10. (Note - a value of 20 produced slightly better calibration statistics, possibly due to generally smoky air during the calibration period – a period of extensive wildfires in the locale. However, this higher number was not appropriate for the "normal" simulation period.)

Ground Reflectivity: Set to 20%.

Table 5 shows the summary calibration statistics of the Chelan River Temperature Model's performance at the four downstream Chelan River calibration nodes for the 31 days.

Table 5. Calibration and Validation Statistics – Chelan Stream Temperature Model

Data Set	Correlation Coefficient (R^2)	Mean Error (^0C)	Probable Error (+/-^0C)	Maximum Error (^0C)	Bias (+/-^0C)	% Errors >1.0
#2 - Calibration	0.9326	0.2404	0.1888	1.0154	0.0170	0.8
#1 - Validation	0.9907	0.0586	0.1095	0.5774	0.0098	0.0

3.2.3 Validation

Typically, to have confidence that a calibrated stream temperature model will predict accurately over a wide range of flows and climate conditions, the model will be validated. Validation is generally accomplished by applying the global calibration factors to another independent set of data, or by splitting the available data set into two equal-sized sets, and running the model as a test of the calibration. Statistics for the validation data that are comparable to those for the initial calibration provide confidence in the calibration.

The second set of available data (Set 1) was modeled under the same calibration criteria applied to Set 2 data in the calibration of the model. Table 5 shows the validation statistics for this simulation.

3.2.4 Goodness-of-fit

As a test of the predictive capabilities of the calibrated model, the observed temperatures are predicted under those conditions in which they were observed. Figures 6 through 9 illustrate the mean daily temperatures predicted, together with the mean daily observed water temperatures at the ends of Reach 1 through 4, respectively. Since not all variables affecting the water temperature are accounted for in any model, and because measurement error almost always exists, all models predict with some error. In a well calibrated model, this error is minimal and is randomly distributed. For a calibrated StreamTemp model, the rule-of-thumb goodness-of-fit criteria for an acceptable calibration are as follows (Bartholow 1989):

1 - Simultaneously maximizing the R^2 value while minimizing the mean error to near zero.

2 - No more than 10% of the simulated temperatures are greater than 1^0C from measured temperatures.

3 - No single simulated temperature is greater than 1.5^0C from measured temperatures.

4 - The mean of the absolute values of measured minus simulated is less than 0.5^0C.

5 - There is no trend in spatial, temporal, or "temperature" error.

3.3 CALIBRATION RESULTS

3.3.1 24-Hour Average Temperatures

Model runs showed a high degree of correlation between observed and calculated 24-hour daily average temperatures. The following graphs show the results at the end of each reach.

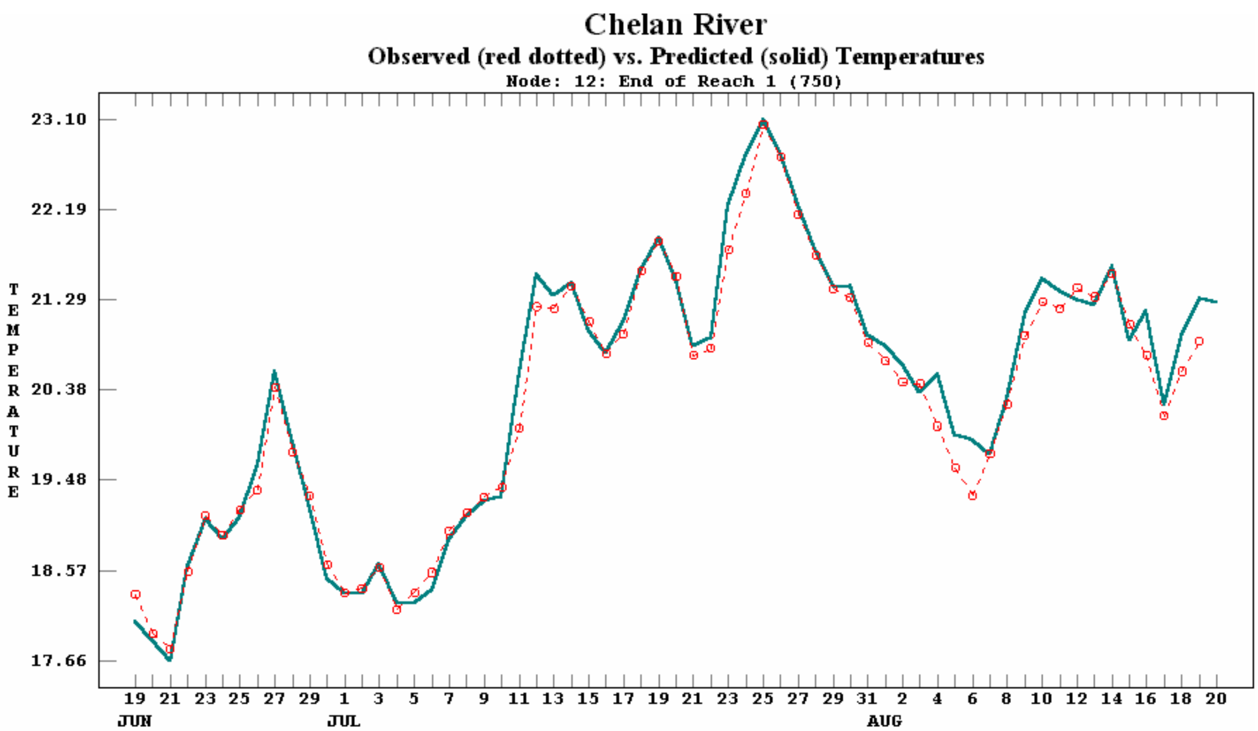


Figure 6. Graph of Observed vs. Predicted Temperatures in °C, End of Reach 1, in 2002

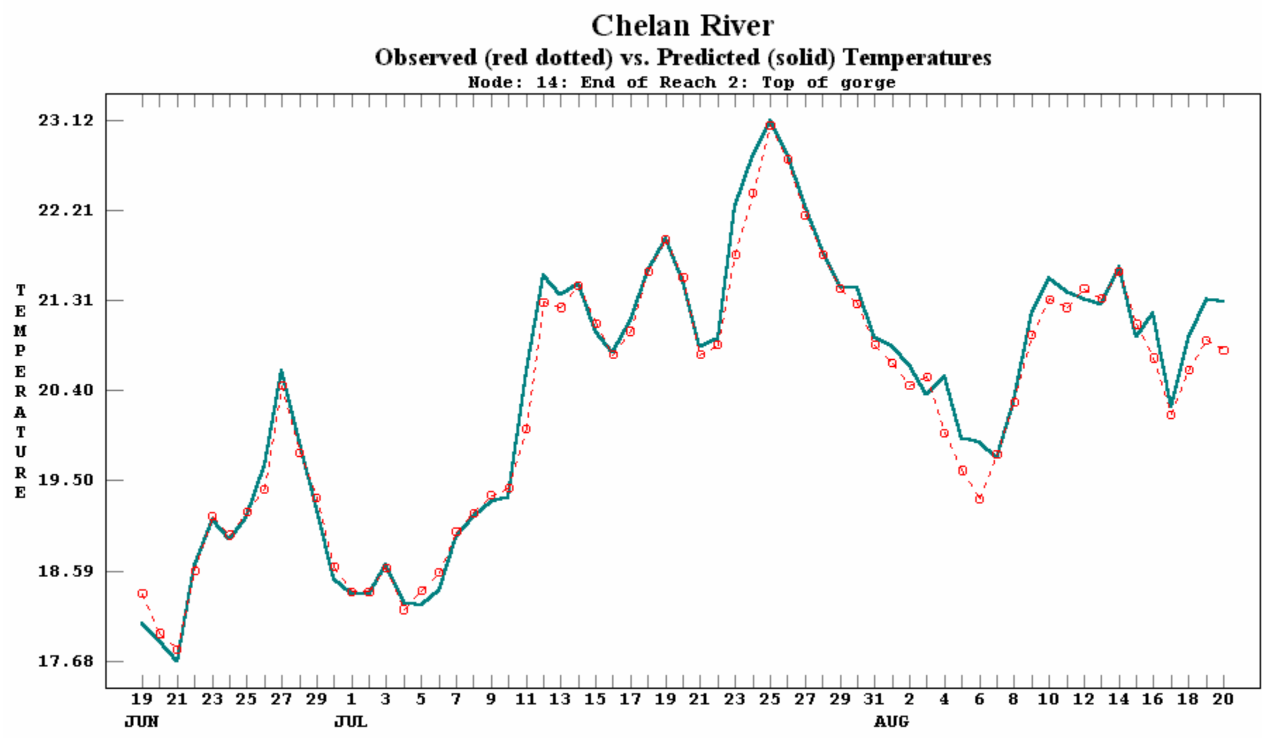


Figure 7. Graph of Observed vs. Predicted Temperatures in °C, End of Reach 2, in 2002

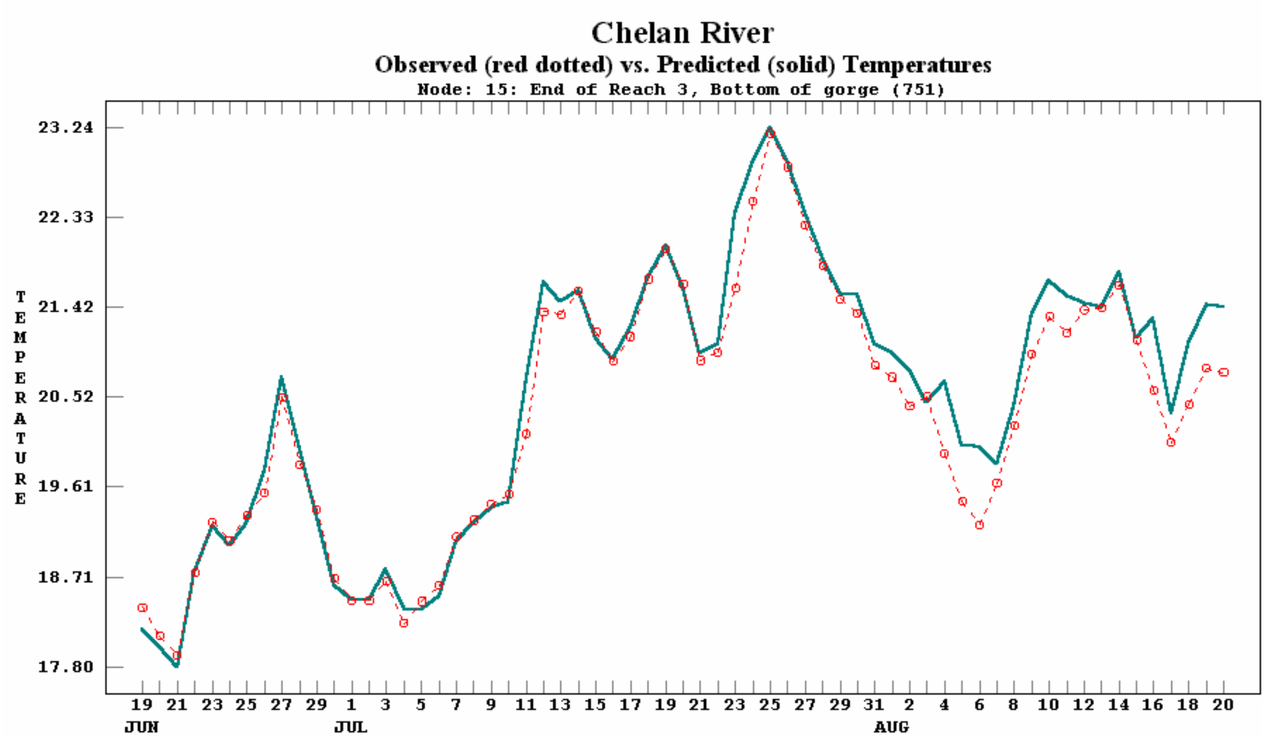


Figure 8. Graph of Observed vs. Predicted Temperatures in °C, End of Reach 3, in 2002

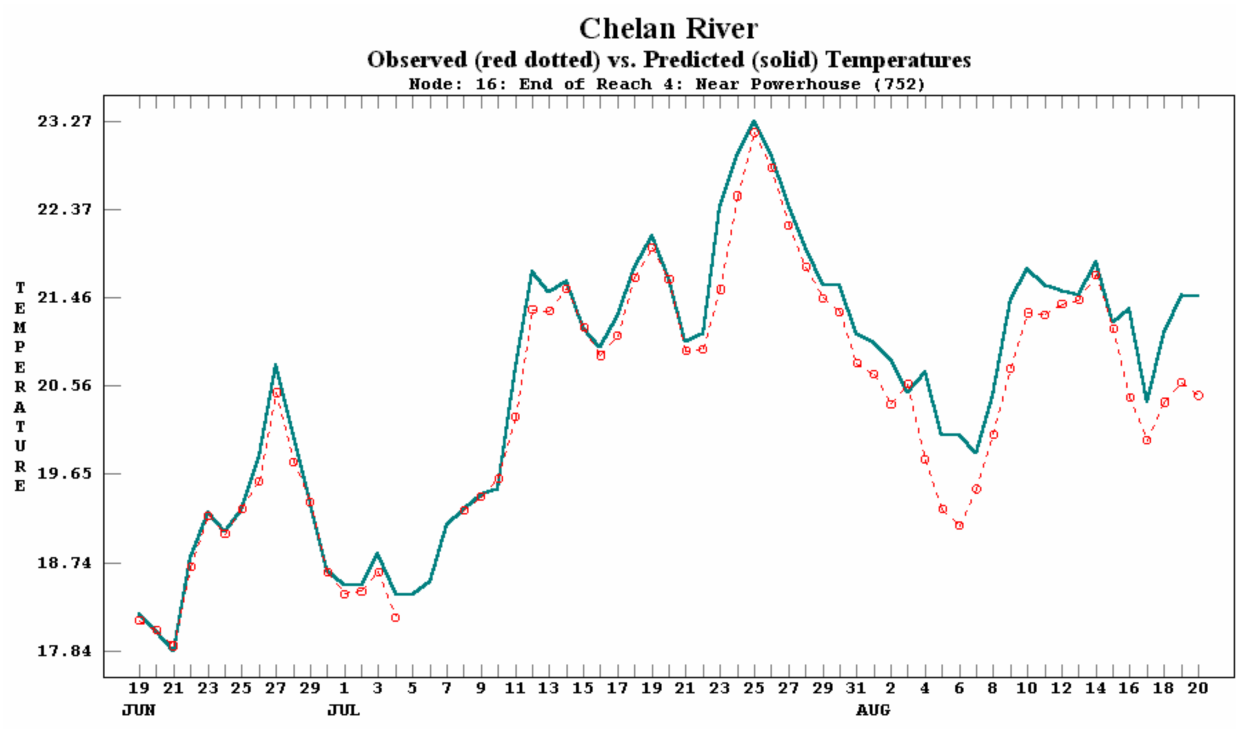


Figure 9. Graph of Observed vs. Predicted Temperatures in °C, End of Reach 4, in 2002

Figures 10 through 13 show the scatterplots of observed vs. predicted temperatures. No systematic error is in evidence that might suggest a problem with the model calibration.

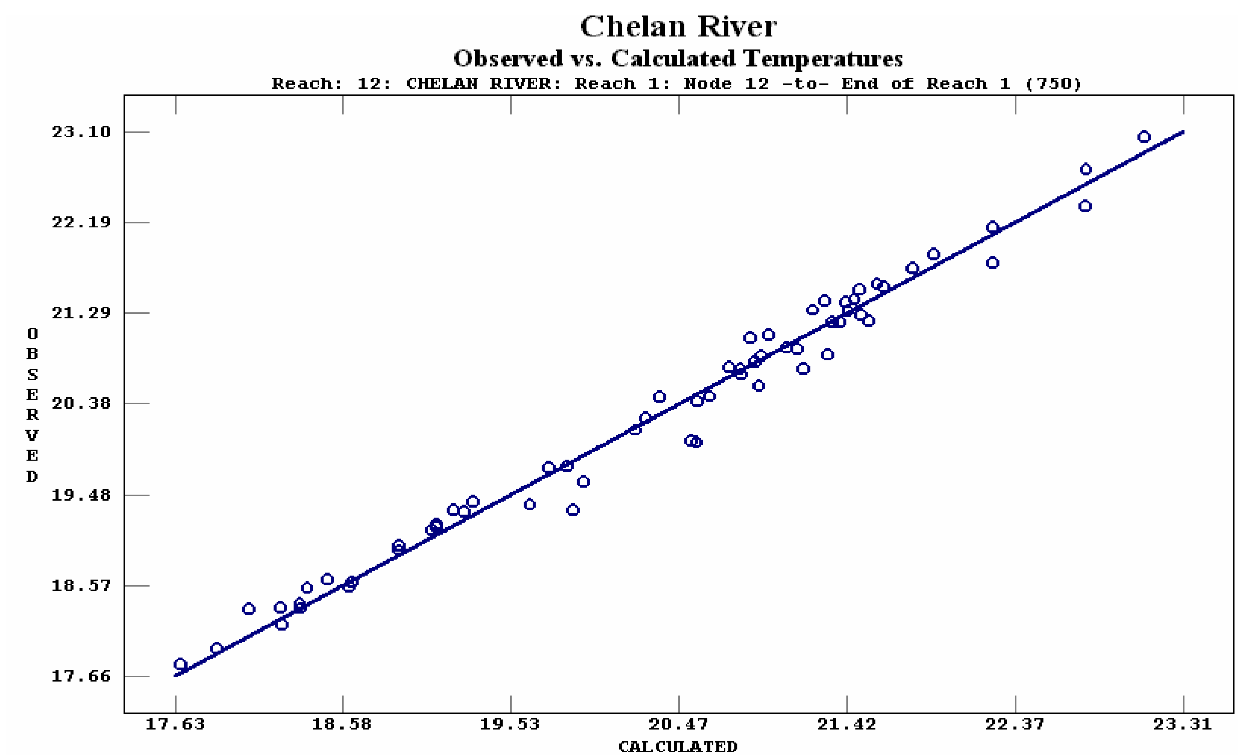


Figure 10. Scatterplot of Observed vs. Predicted Temperatures in °C, End of Reach 1

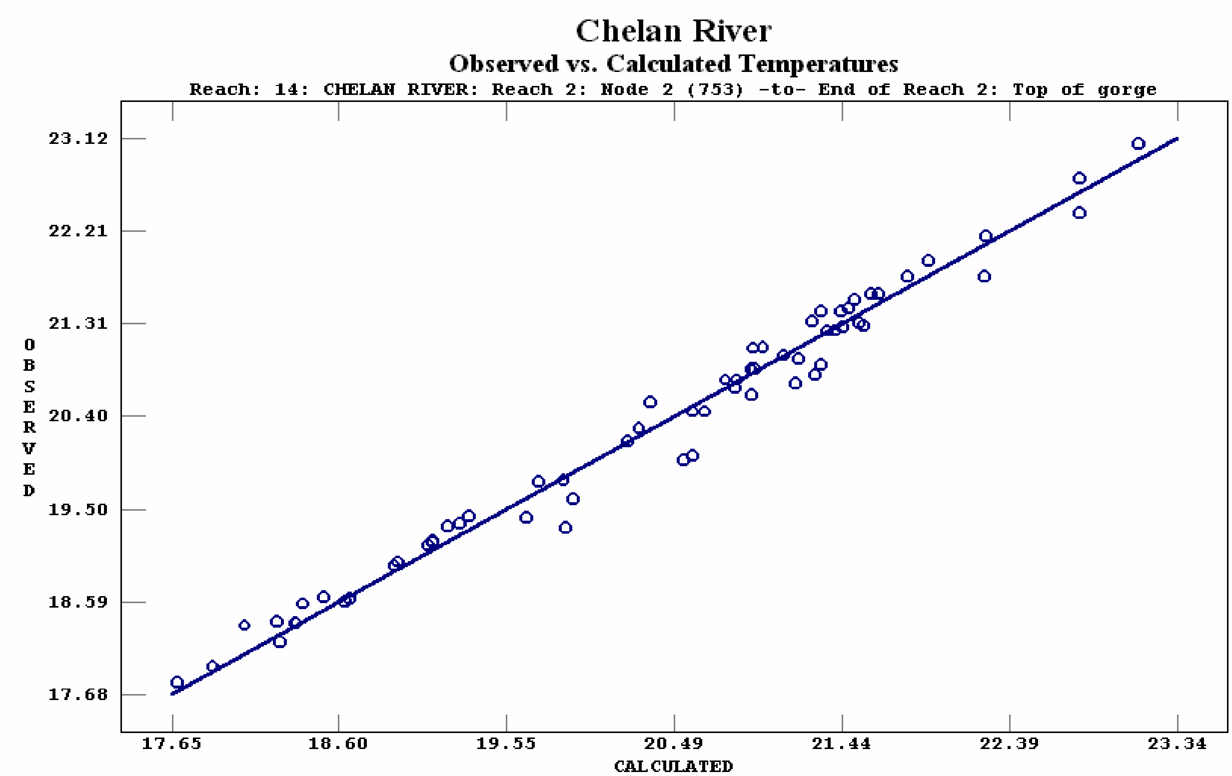


Figure 11. Scatterplot of Observed vs. Predicted Temperatures in °C, End of Reach 2

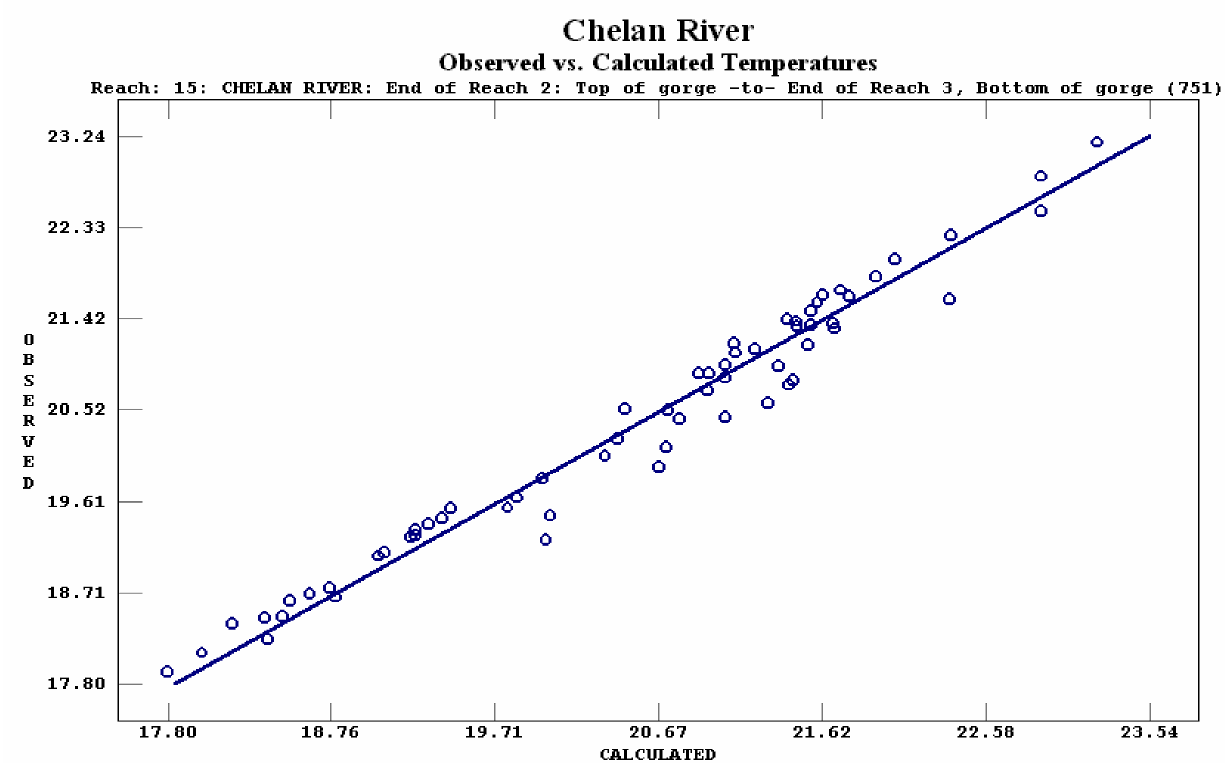


Figure 12. Scatterplot of Observed vs. Predicted Temperatures in °C, End of Reach 3

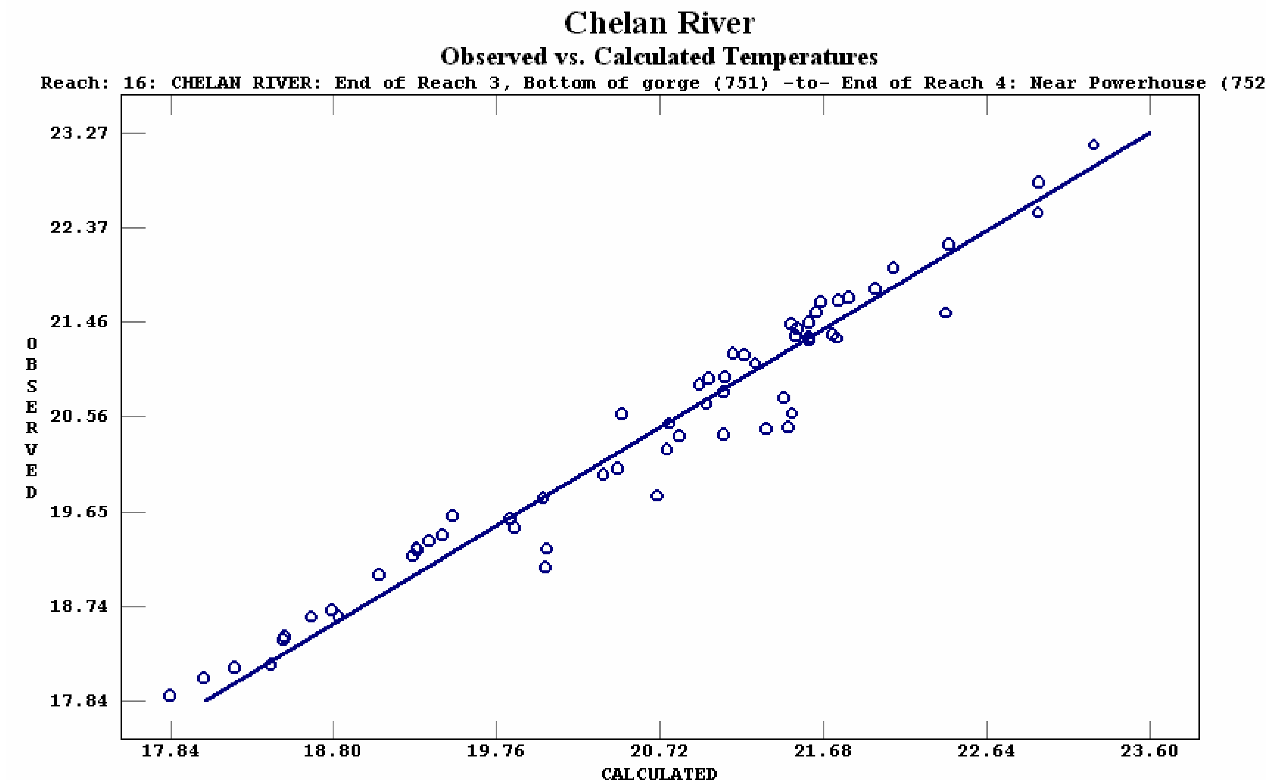


Figure 13. Scatterplot of Observed vs. Predicted Temperatures in °C, End of Reach 4

3.3.2 Maximum Daily Water Temperature Calibration

The StreamTemp model was written to simulate mean daily temperatures well, but it uses an empirical simplification rather than a theoretical calculation in predicting maximum daily water temperatures. For this reason and others (Bartholow 1989), StreamTemp may not simulate daily maximum water temperatures as well as daily mean. To calibrate maximum daily water temperatures, the Reach Manning N (and hence travel time) is varied iteratively until the predicted temperatures match the pattern of the observed maximum daily stream temperatures. Changes to Reach Manning N do not affect mean daily computations.

Figure 14 shows the optimized model for estimating maximum daily stream temperatures. Although the predicted maximum temperatures do not exactly fit the observed stream temperatures, the overall pattern follows and the maximum temperature calibration is judged acceptable within its acknowledged limits.

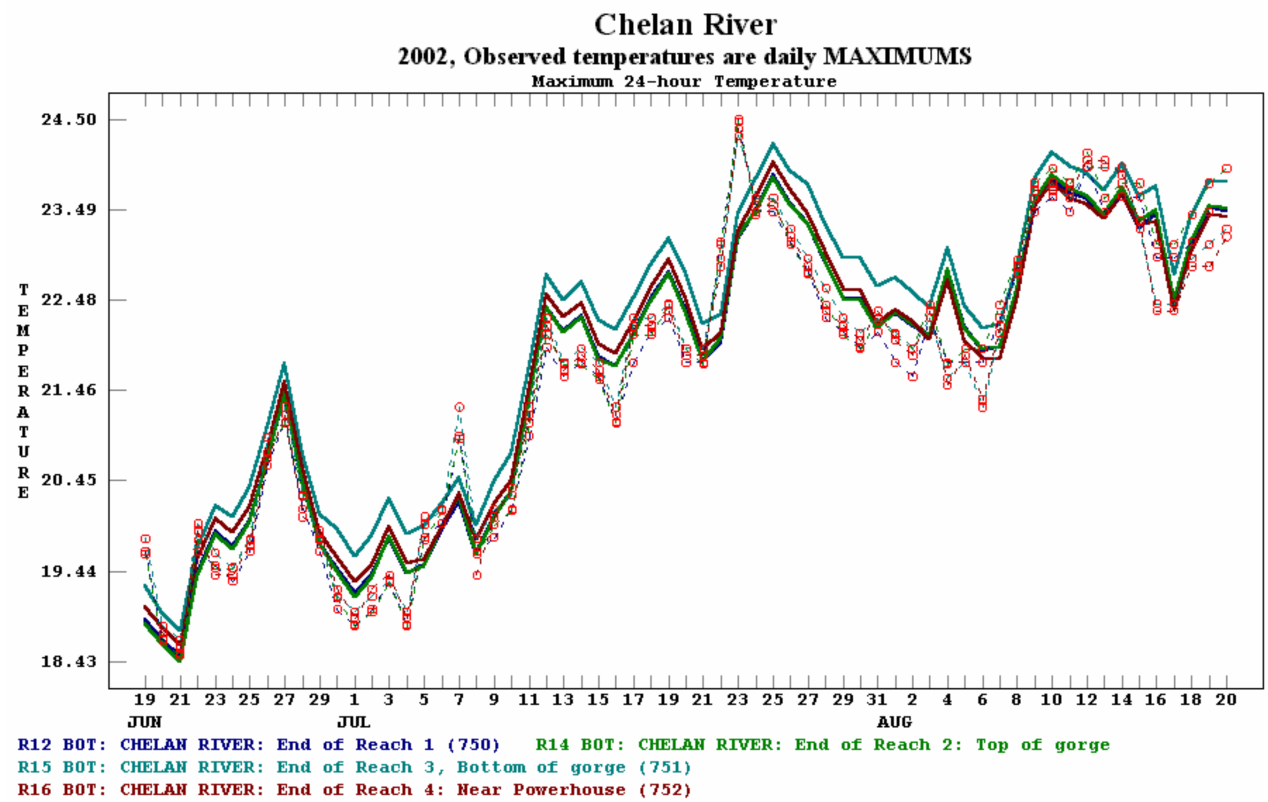


Figure 14. Maximum Temperature Calibration – Observed Versus Predicted in °C, 2002

The following graph (Figure 15) summarizes the final 24-hour average and maximum temperatures at the end of the four Chelan River study reaches. The pattern of increasing divergence between the mean daily stream temperature and the daily maximum temperatures toward the end of the study period (August) are likely due to the lower flows in that time period, rather than weather conditions.

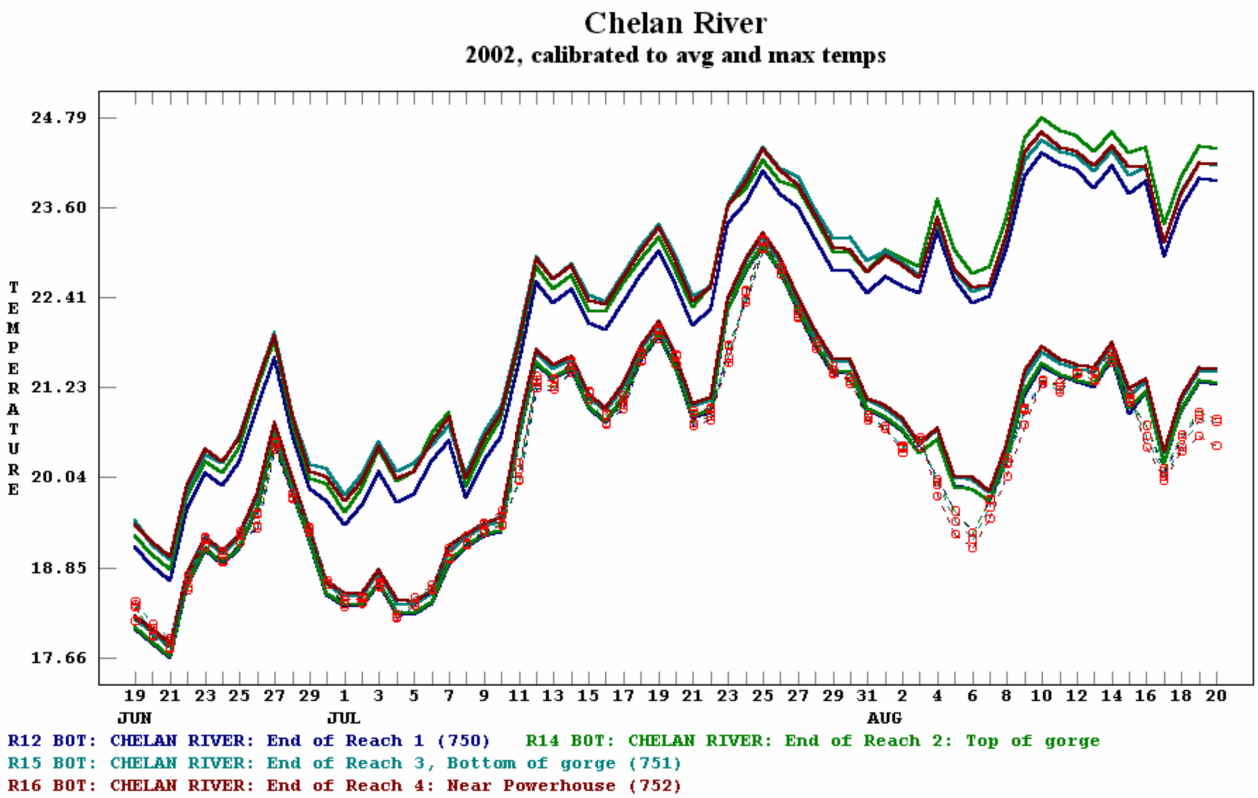


Figure 15. Observed and Predicted Mean Daily and Predicted Maximum Temperatures in °C, 2002

3.4 CALIBRATION CONCLUSIONS

1) The calibration was successful in closely matching the observed and calculated mean daily stream temperatures for the study period.

2) The calibration was moderately successful in matching the observed and calc ulated maximum daily temperatures for the study period.

3) The average daily temperatures at the calibration sites (ends of reaches) was similar to the daily average input temperatures over a wide range of flows due to the input temperatures having already being warmed/cooled by the weather conditions.

4) Daily temperature fluctuations (average vs. maximum temperatures) were greater during low flows, especially at the downstream end of the study (i.e., higher flows = lower maximum temperatures on very warm days.)

4. GAMING SIMULATIONS

4.1 SIMULATION INPUT DAT A

The calibrated StreamTemp file was expanded to include data from three years, 2000, 2001 and 2002 and the months of May through September. An extreme weather scenario was added from the Manson weather station (located on the north shore of Lake Chelan seven miles from the dam) from July 24 – August 6, 1998. A total of 425 days were included in the model, with simulation of varying amounts of stream flow released below the dam. In addition to mean daily stream temperature, maximum daily stream temperatures were also predicted for the end of each reach under the same set of flow releases and climate conditions.

4.1.1 Meteorology

Air temperatures were obtained from the Chelan Ranger Station (except for the extreme weather scenario). For dates with precipitation, humidity was increased above the 30% default, and percent sunshine was reduced below the 90% default. Wind was set at a default of 1.788 m.p.s.

4.1.2 Hydrology

Input water temperatures were obtained from the Chelan Powerhouse cooling water and penstock monitors.

To assess the effect of increased flows in the bypass reach, the model was gamed by altering the amount of flow in the river while leaving all other parameters unchanged. The following flows were gamed: 40 c.f.s., 80 c.f.s., 100 c.f.s., 200 c.f.s., 300 c.f.s., 400 c.f.s., 600 c.f.s., 800 c.f.s., 1000 c.f.s., 1500 c.f.s., 2,000 c.f.s., and 4000 c.f.s..

4.2 GAMING RESULTS

Figures 16 through 27 are scatterplots of average daily and maximum temperatures for each of the gaming flow scenarios at the end of each reach, plus Node 8 near the middle of Reach 1 (five total locations. Since up to four years (2000, 2001, 2002 and two weeks of extreme weather in 1998) of data are included, each date may have up to 20 values for each temperature.

Generally, the higher flow releases result in slightly lower mean daily temperatures, with less daily fluctuation. For example, 19.464 ^{0}C is the mean of the 425 days 24-hr average temperature predicted at the bottom of Reach 4 (near Chelan Powerhouse) under a release of 40 c.f.s.. For a release of 4000 c.f.s., 19.258 ^{0}C is the mean for the 425 predicted days modeled. The single greatest 24-hr average value under the 40 c.f.s. release is 24.405 ^{0}C with 24.046 ^{0}C under the 4000 c.f.s. release (Figure 27 and Appendix D).

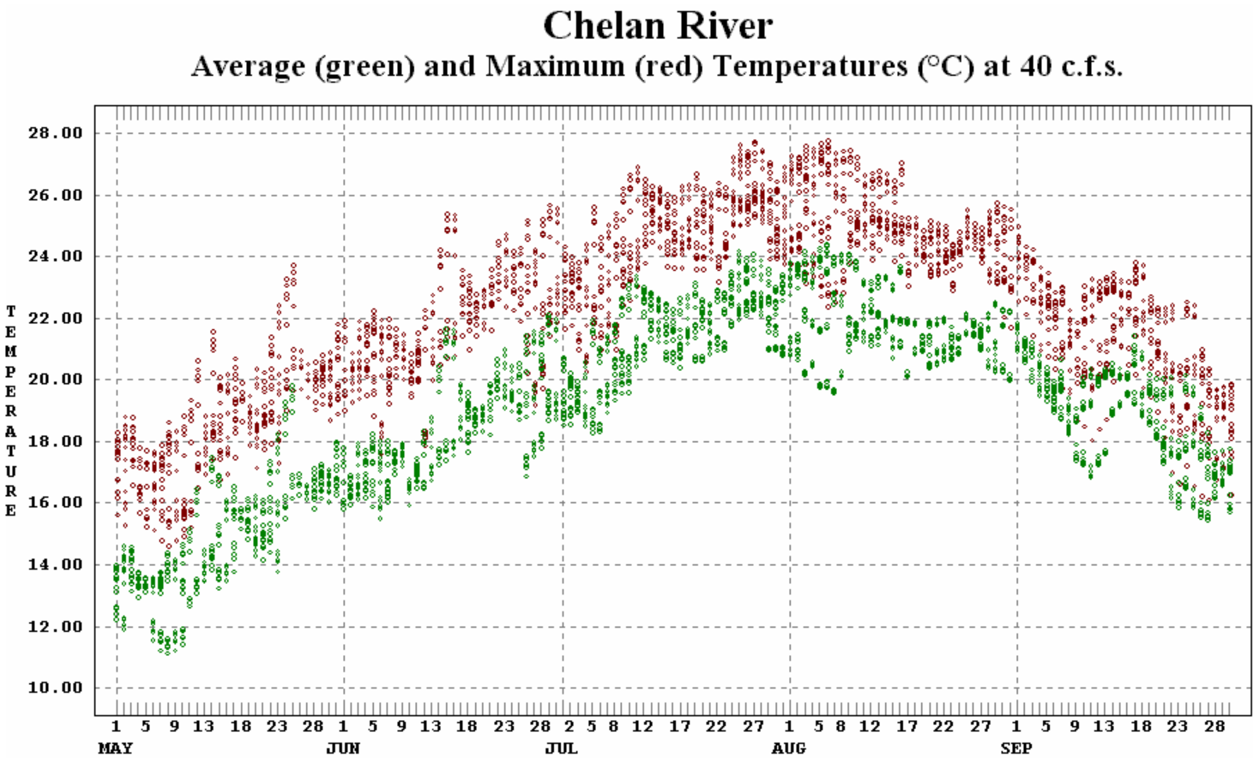


Figure 16. Gamed Daily Average (green) and Maximum (red) Temperatures in °C at 40 c.f.s.

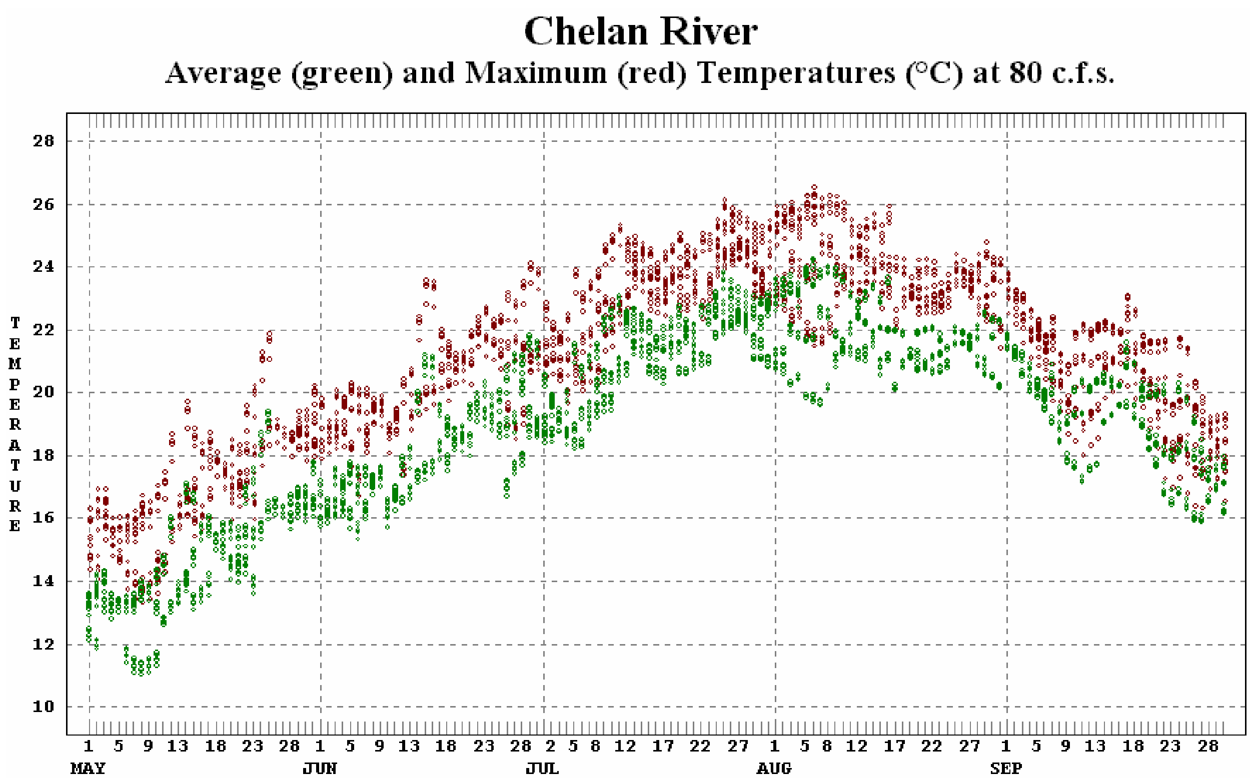


Figure 17. Gamed Daily Average (green) and Maximum (red) Temperatures in °C at 80 c.f.s.

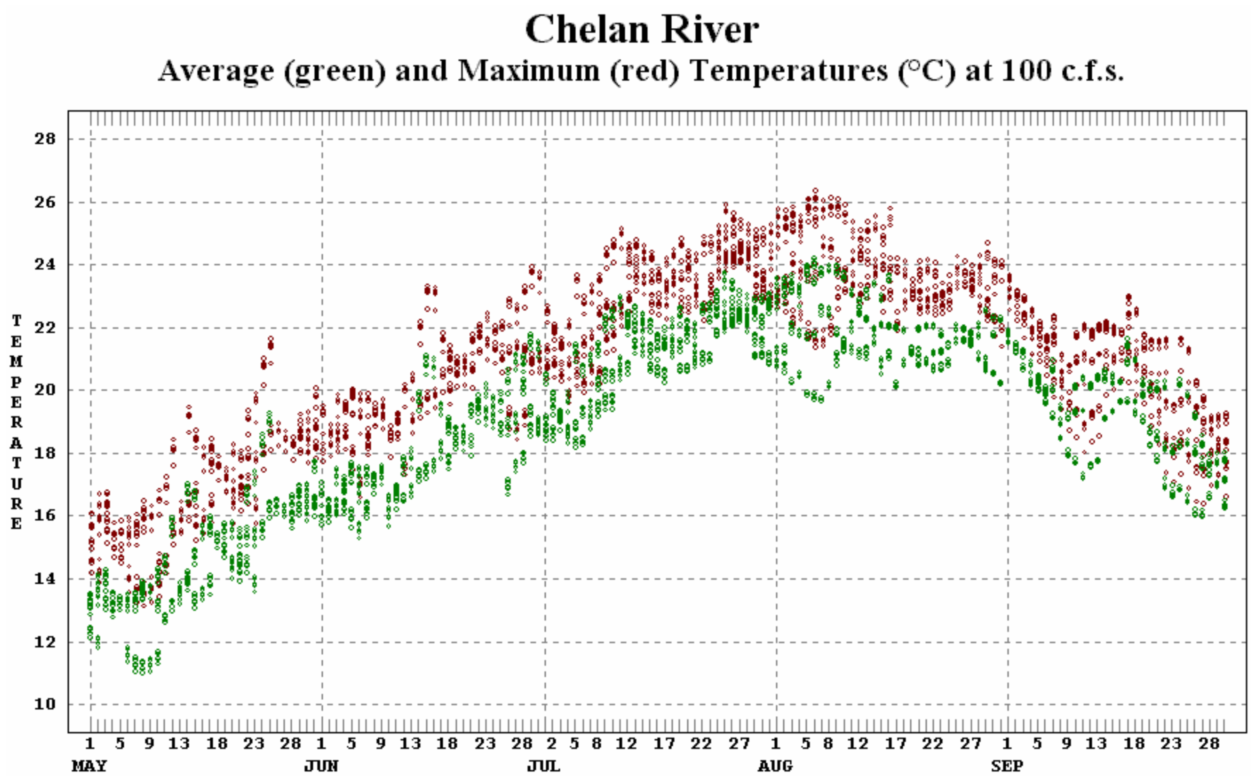


Figure 18. Gamed Daily Average (green) and Maximum (red) Temperatures in °C at 100 c.f.s.

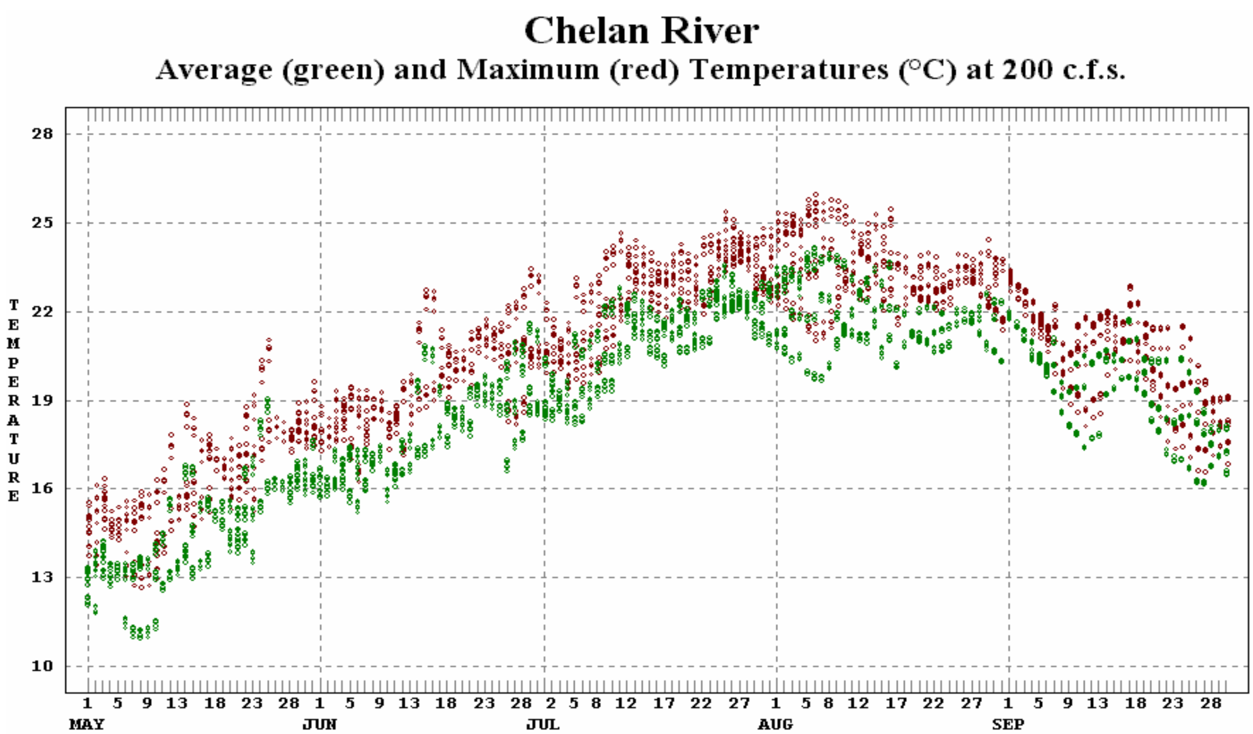


Figure 19. Gamed Daily Average (green) and Maximum (red) Temperatures in °C at 200 c.f.s.

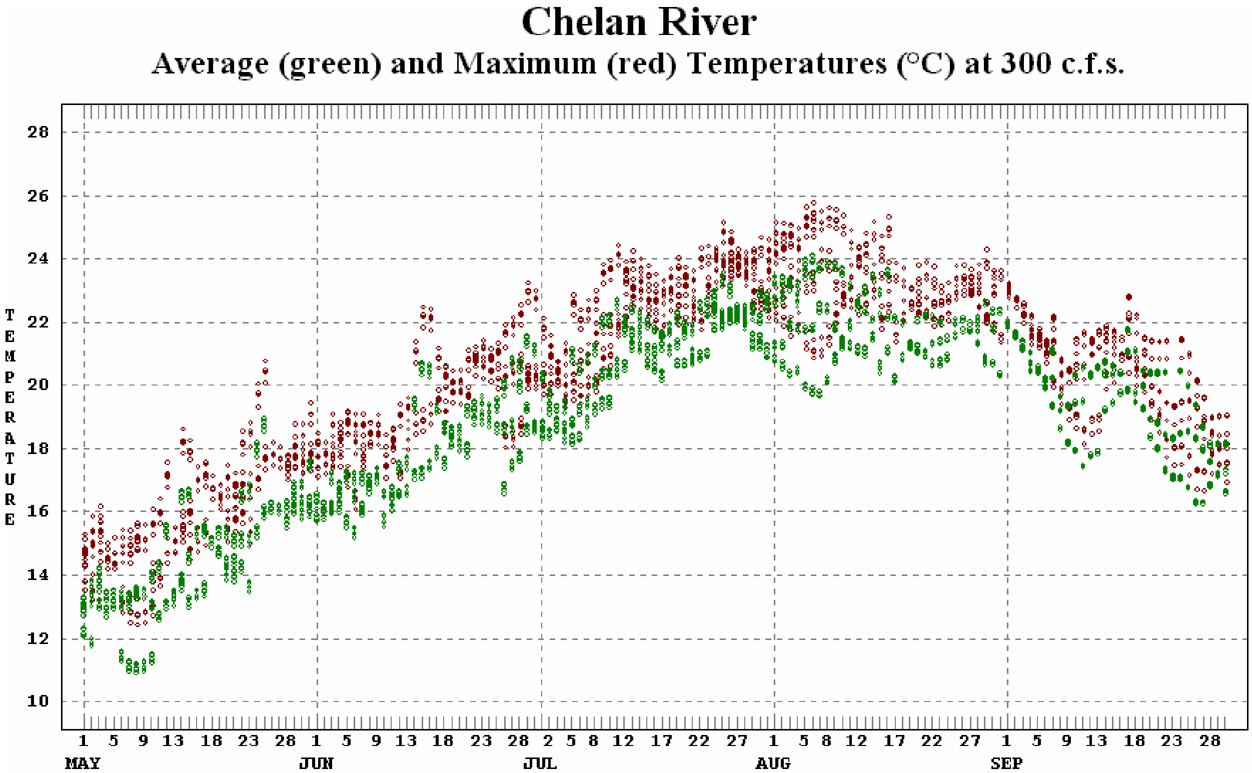


Figure 20. Gamed Daily Average (green) and Maximum (red) Temperatures in °C at 300 c.f.s.

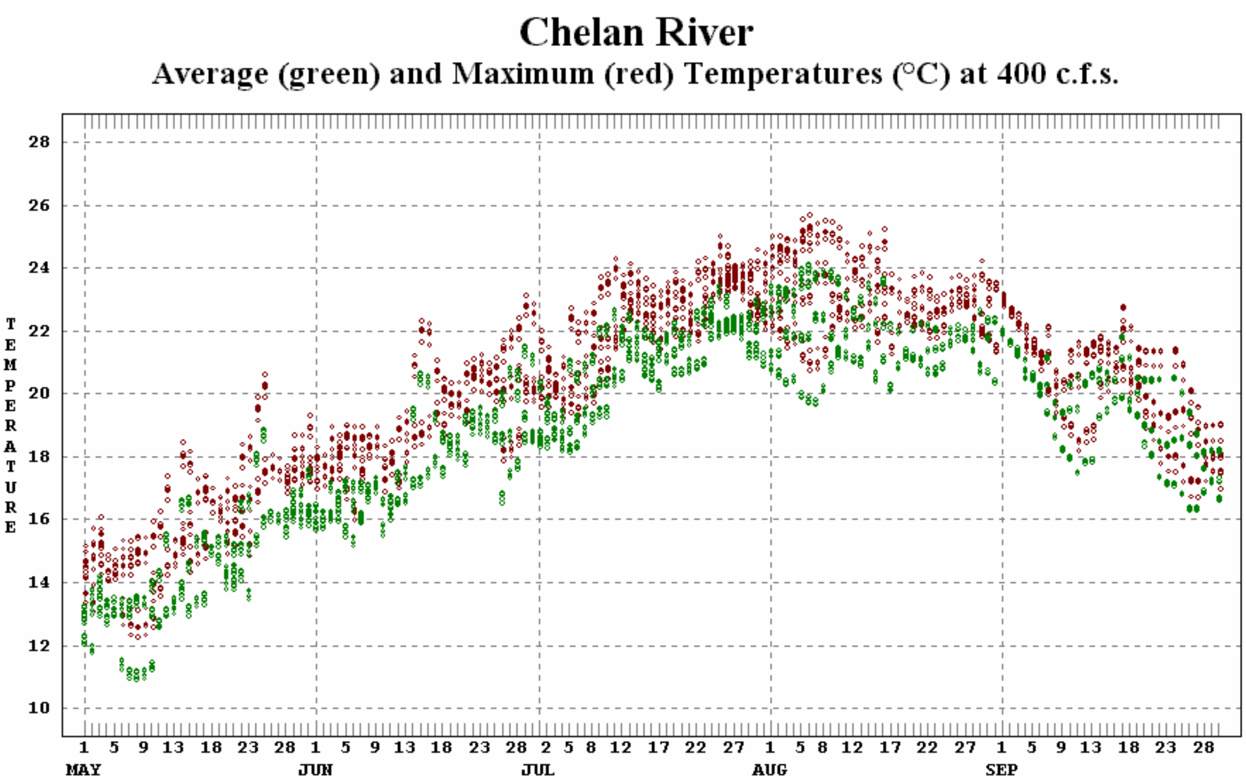


Figure 21. Gamed Daily Average (green) and Maximum (red) Temperatures in °C at 400 c.f.s.

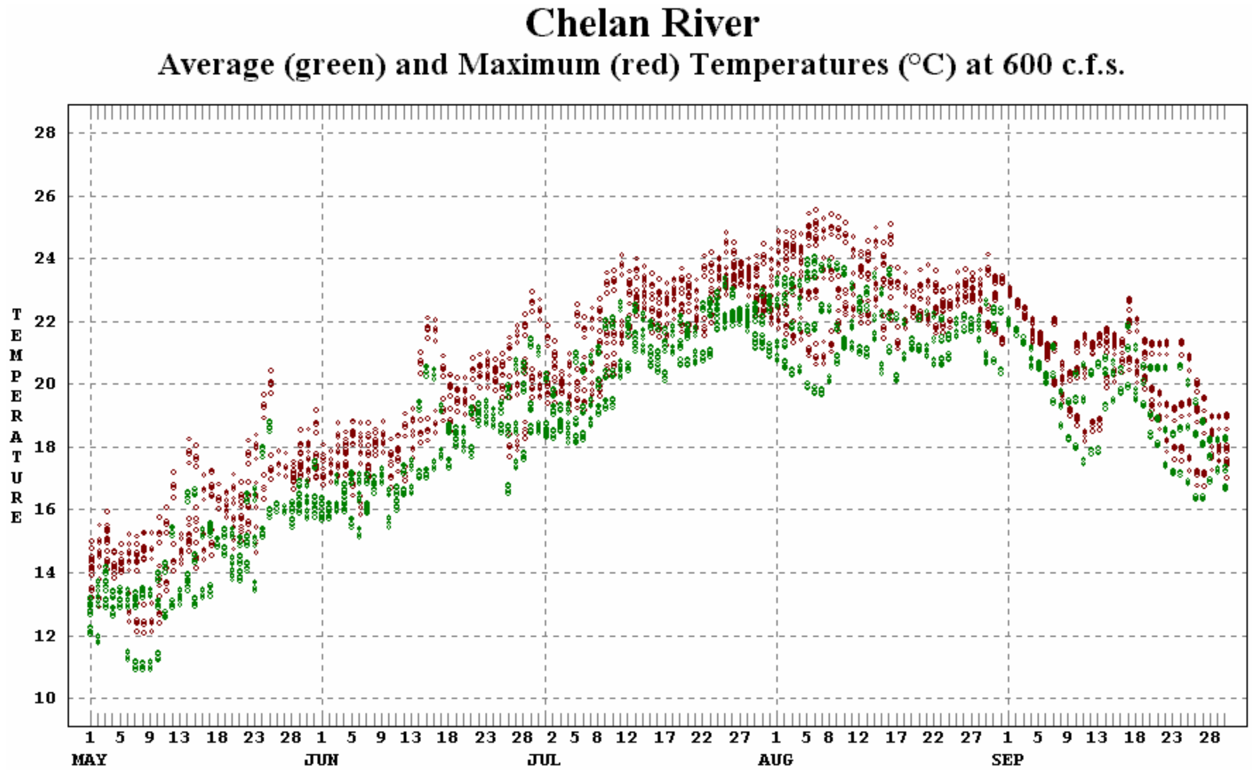


Figure 22. Gamed Daily Average (green) and Maximum (red) Temperatures in °C at 600 c.f.s.

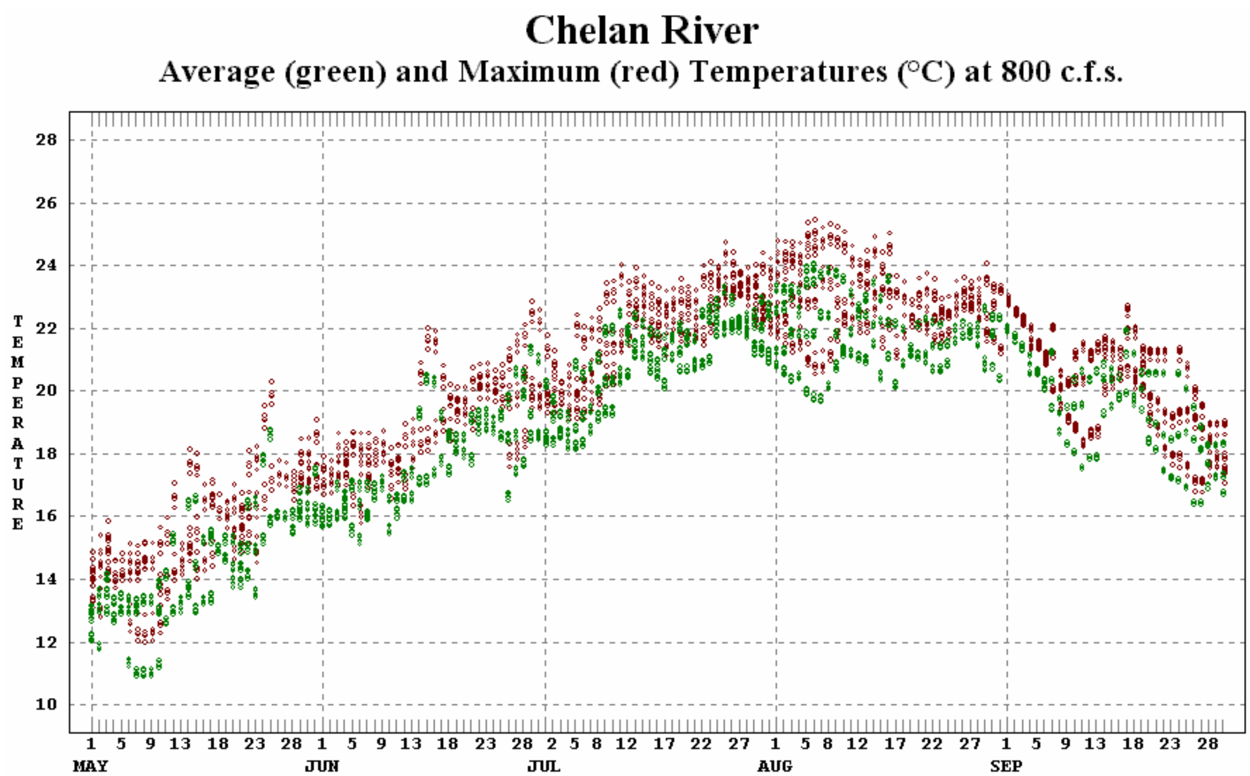


Figure 23. Gamed Daily Average (green) and Maximum (red) Temperatures in °C at 800 c.f.s.

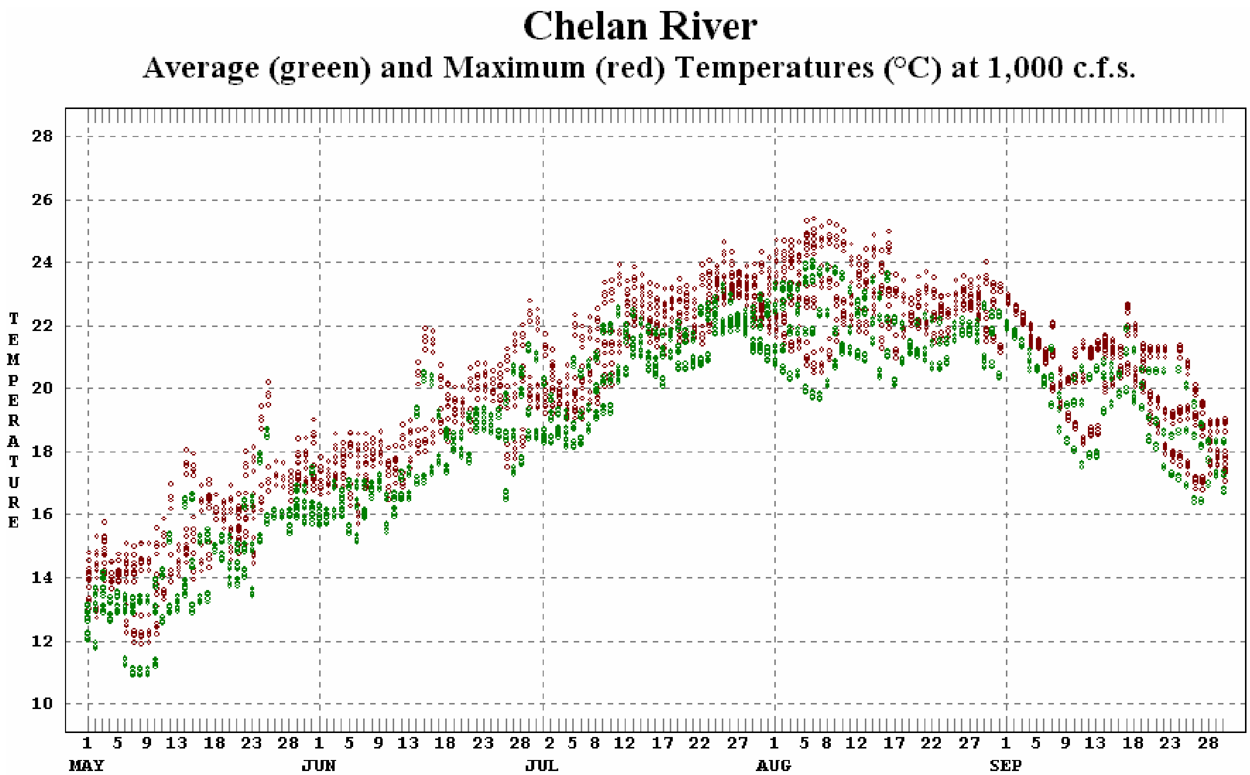


Figure 24. Gamed Daily Average (green) and Maximum (red) Temperatures in °C at 1000 c.f.s.

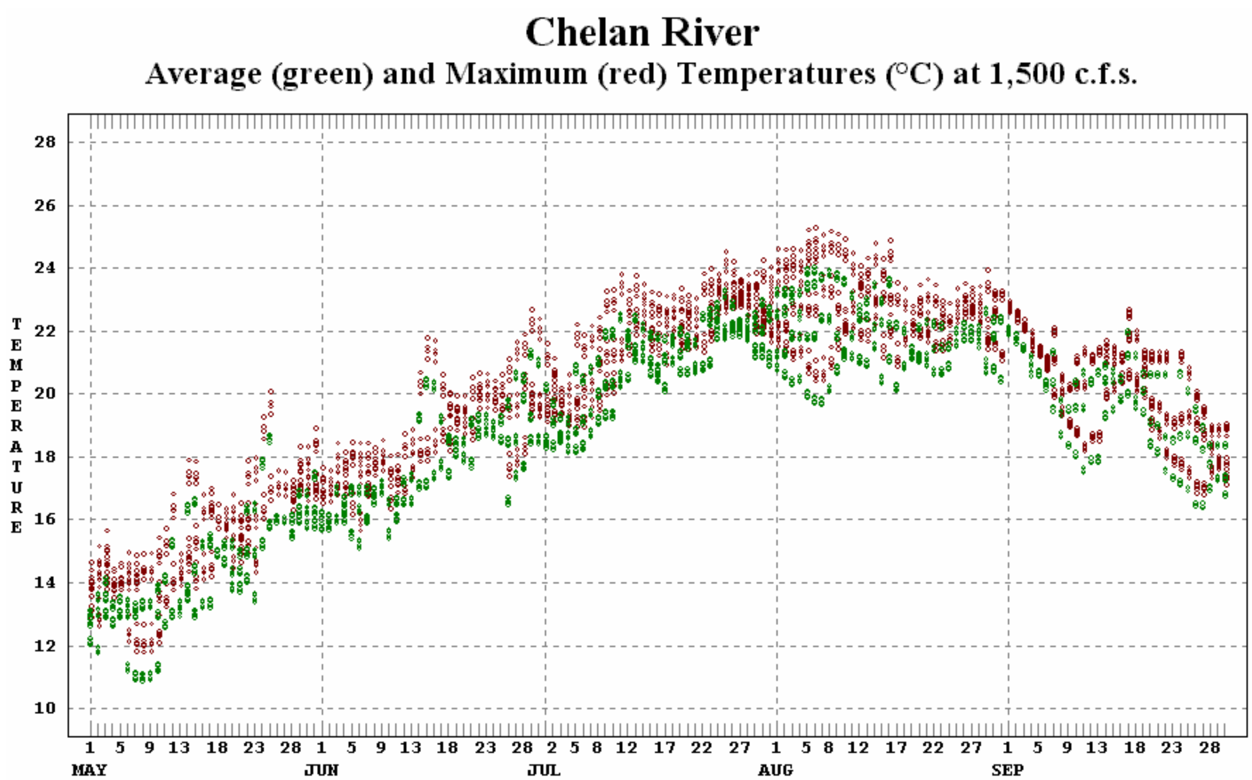


Figure 25. Gamed Daily Average (green) and Maximum (red) Temperatures in °C at 1500 c.f.s.

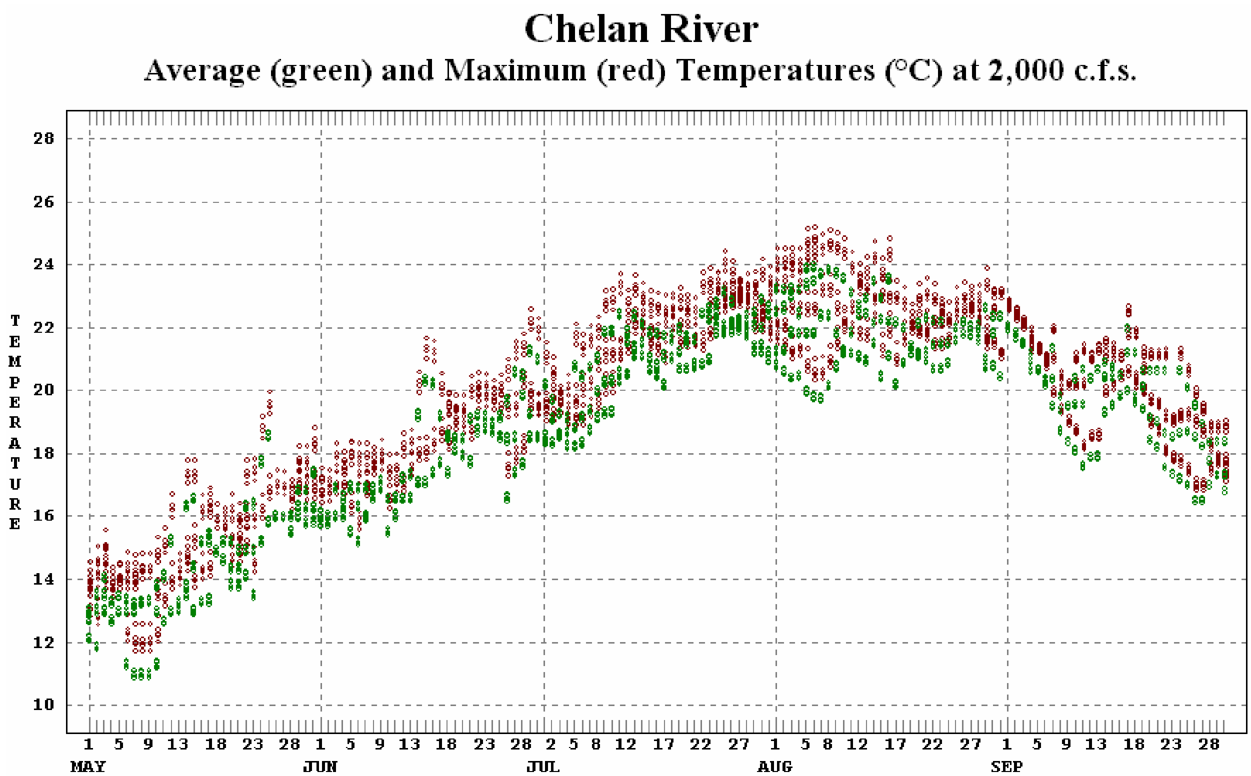


Figure 26. Gamed Daily Average (green) and Maximum (red) Temperatures in °C at 2000 c.f.s.

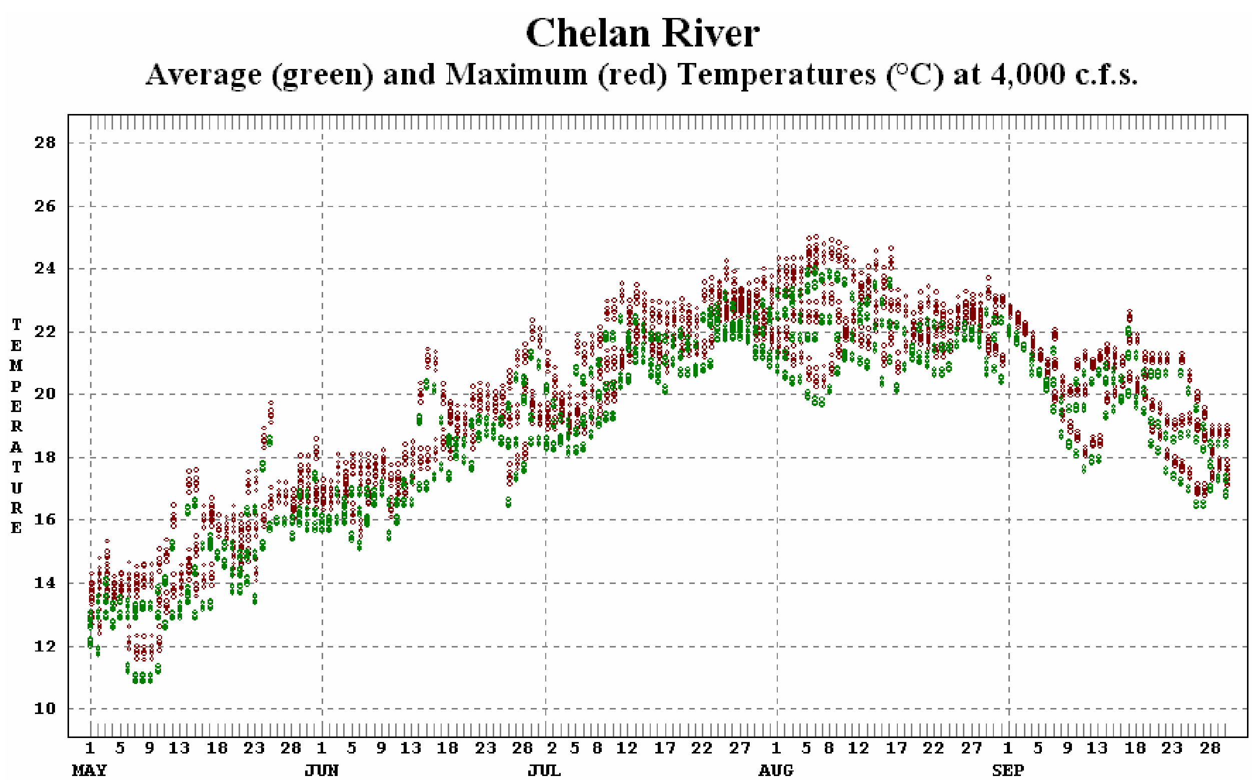


Figure 27. Gamed Daily Average (green) and Maximum (red) Temperatures in °C at 4000 c.f.s.

While the differences between average daily water temperatures were minimal at a range of flows (due to the channel input water temperatures being already warmed or cooled by the prevalent weather conditions), the maximum daily water temperatures showed a greater degree of divergence. In general, lower flows had a stronger reaction to the daily high air temperatures, while higher flows fluctuated less. The following graphs illustrate the reaction of the daily maximum temperatures to flow levels and weather. The scale for the graphs has been set from 20 to 28 degrees (C) to better view the differences during hot weather conditions.

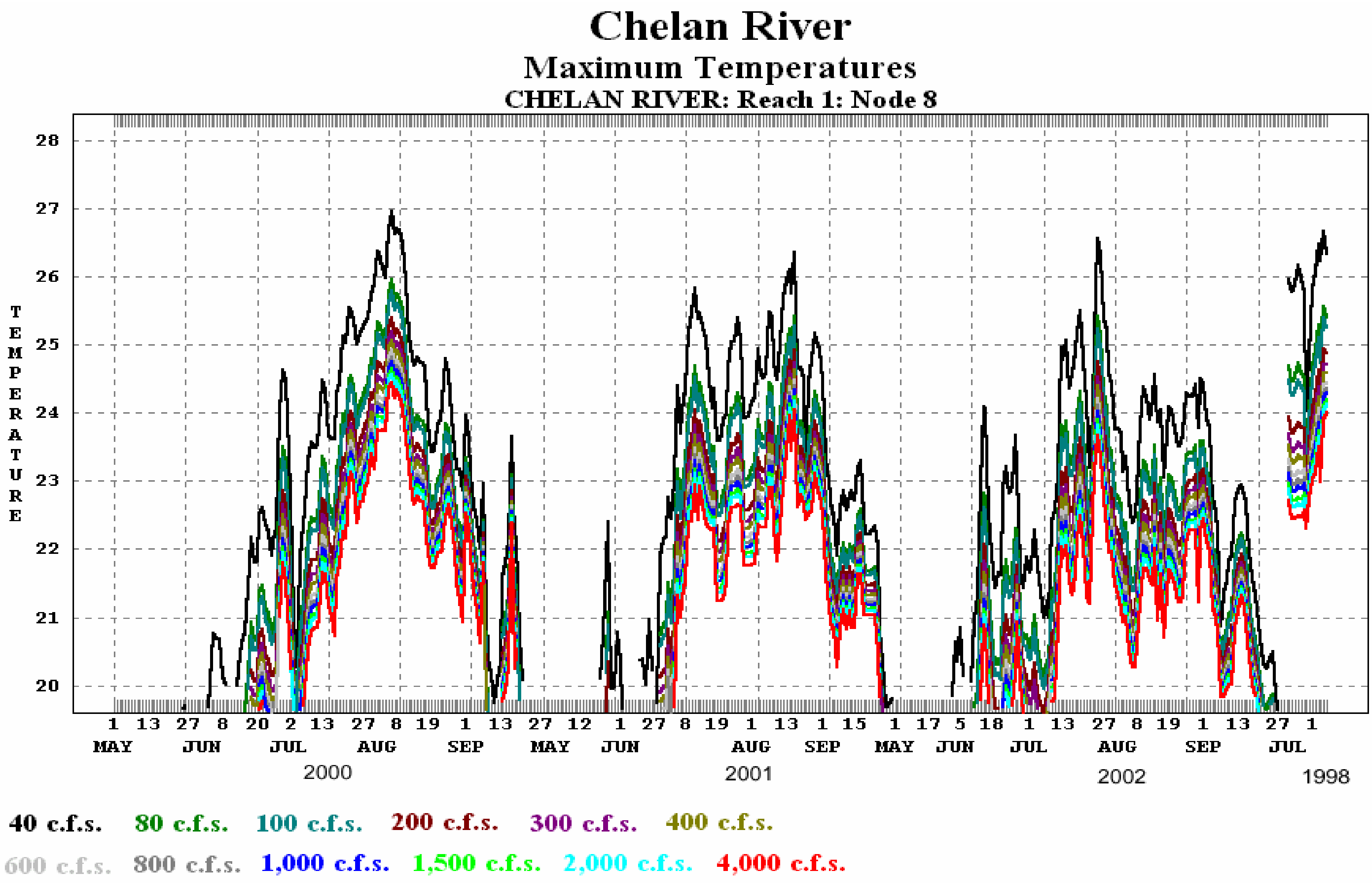


Figure28a. Maximum Daily Temperatures in ^{0}C, Node 8 (near middle of Reach 1.)

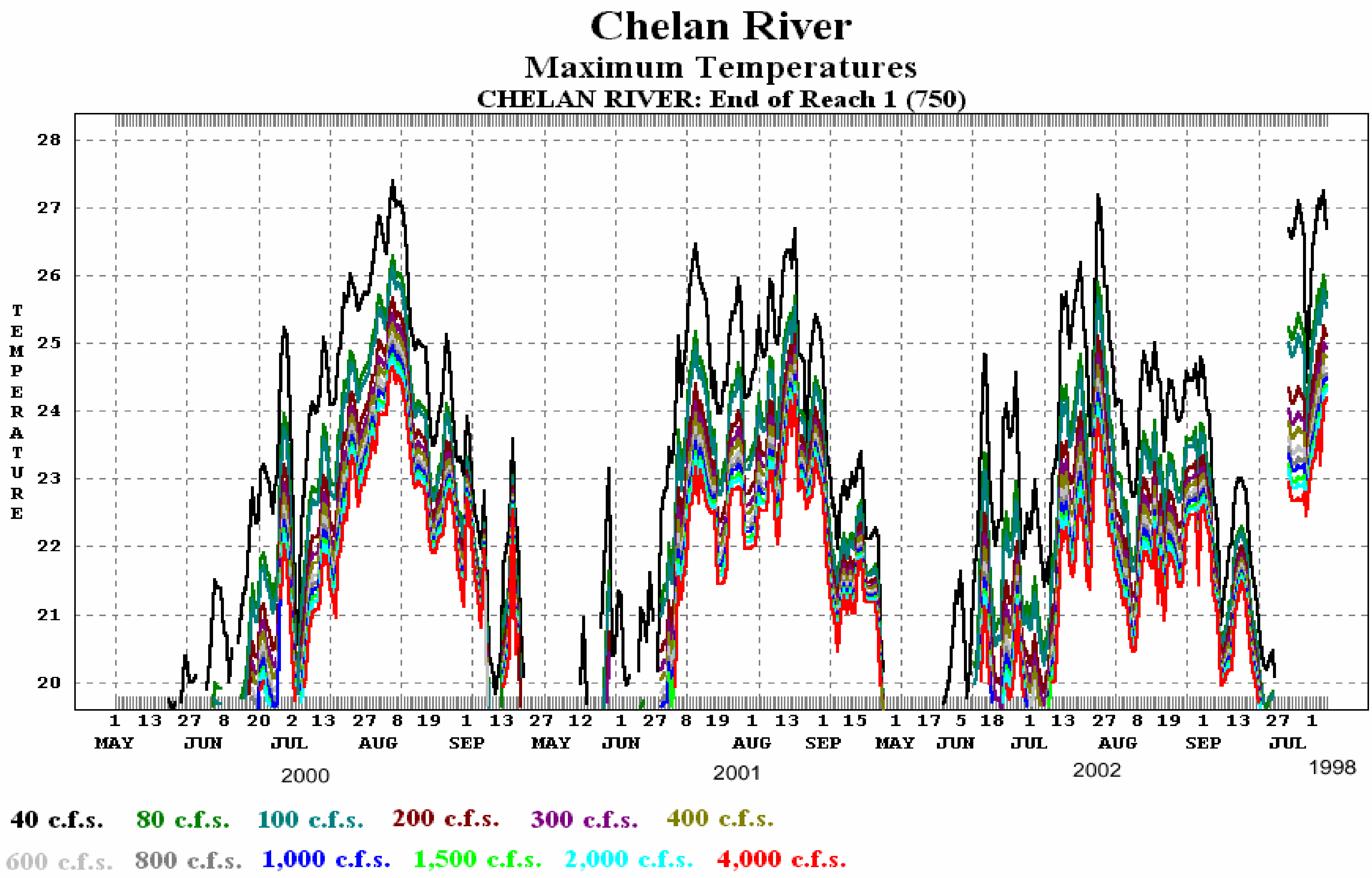


Figure 28b. Maximum Daily Temperatures in ^{0}C, End of Reach 1.

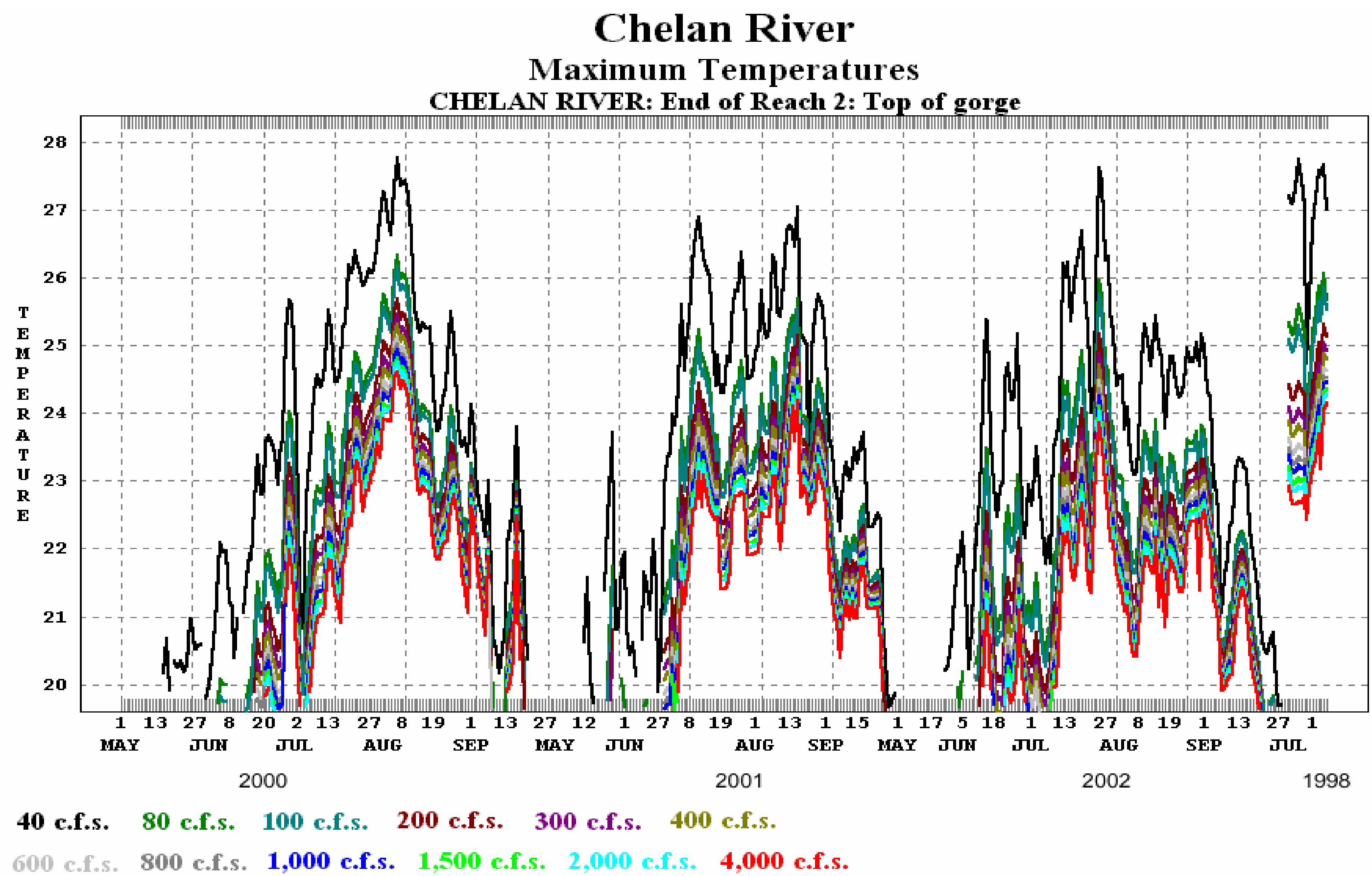


Figure 29. Maximum Daily Temperatures in ^{0}C, End of Reach 2.

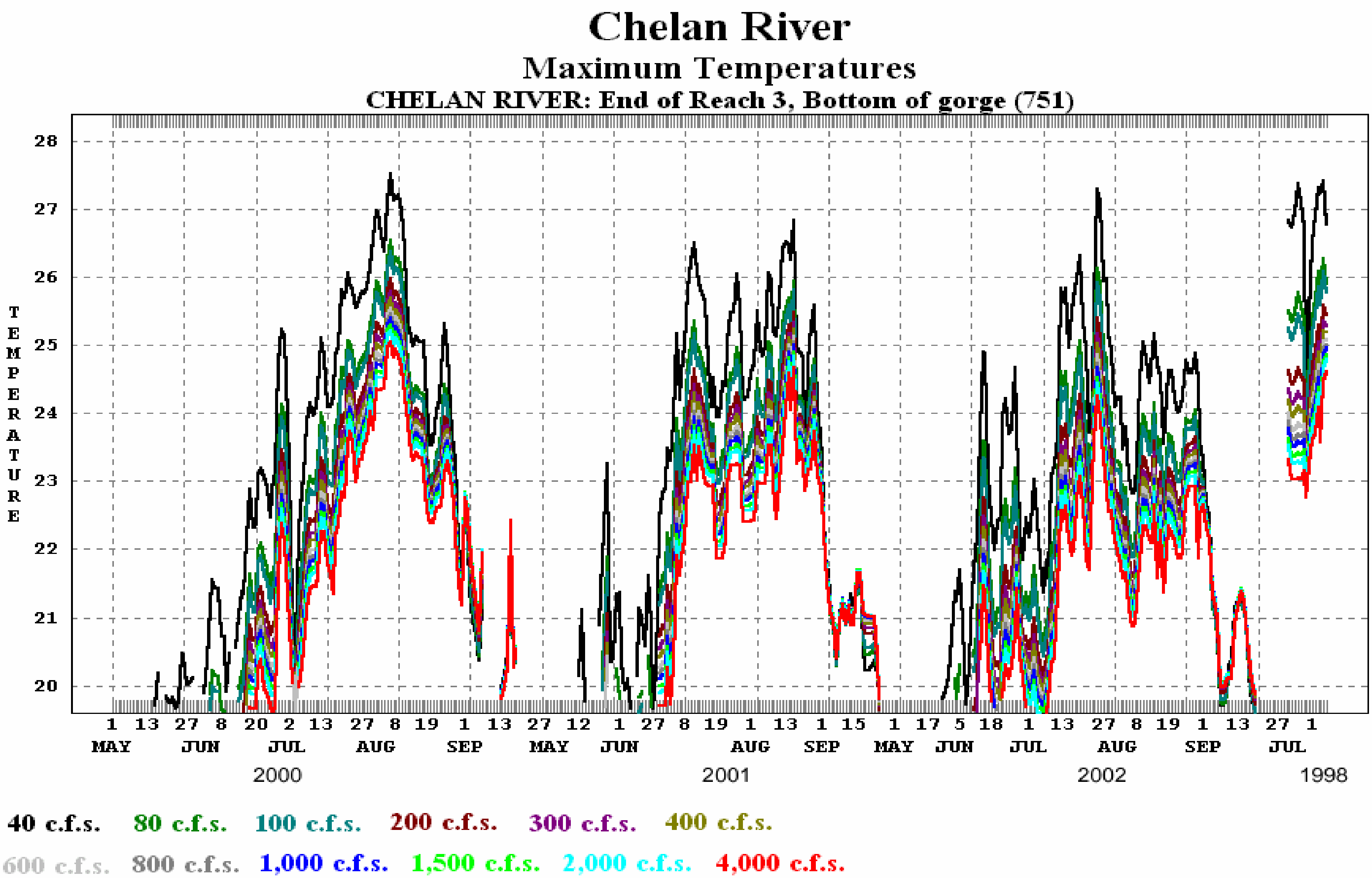


Figure 30. Maximum Daily Temperatures in ^{0}C, End of Reach 3.

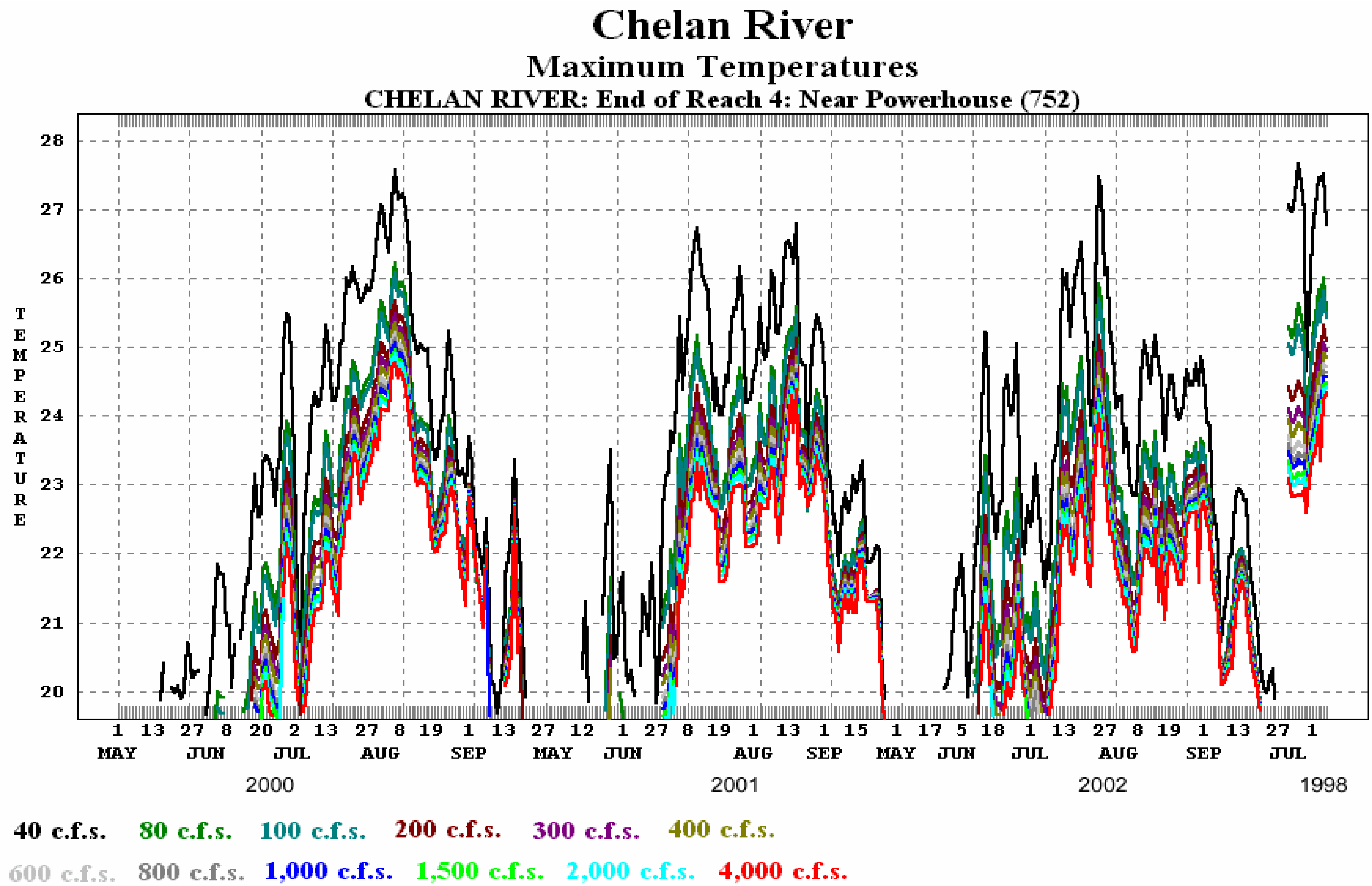


Figure 31. Maximum Daily Temperatures in ^{0}C, End of Reach 4.

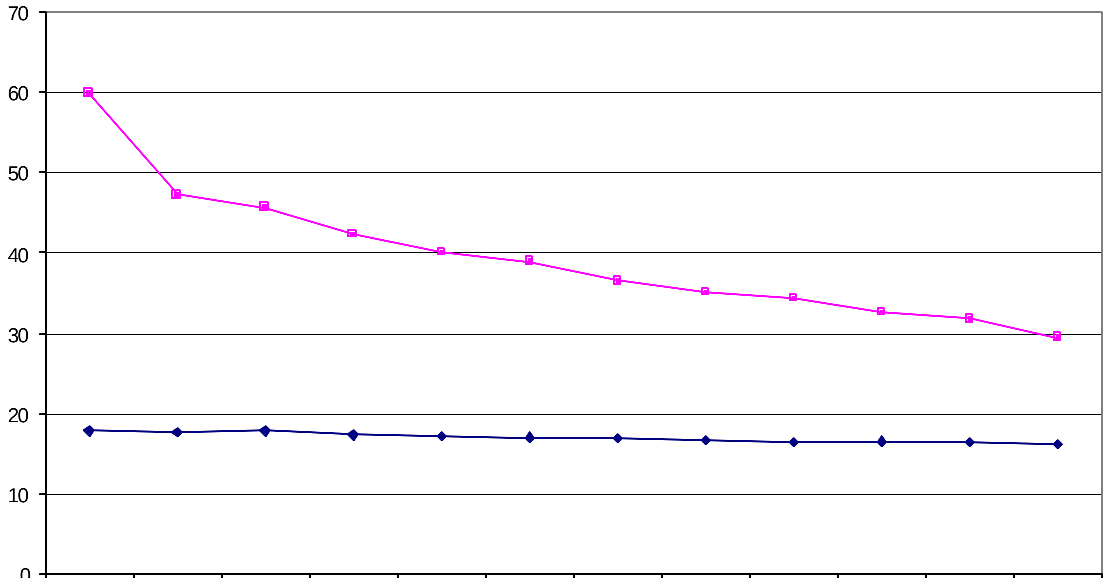
4.3 THRESHOLD TEMPERATURE ANALYSIS

Threshold temperature analysis for temperatures of 22, 23 and 24 (^{0}C) were conducted.

Figures 32 to 34 show the percent exceedance for each of the temperatures, while Figures 35 to 37 show the Degree Day results. Degree Days are similar to National Weather Service Cooling Degree Days, (daily maximum temperature – threshold temperature) * time period. For example, with a threshold temperature of 24 degrees, a value of 24.5 would equal 0.5 Degree Days, while a value of 26.5 would equal 2.5 Degree Days for that date. These daily values are summed to provide the final result.

Data from five nodes were used in the threshold temperature analyses. These were Node 8 (approximately half way down Reach 1), and the bottoms of Reaches 1, 2, 3, & 4 (Figure 1b). Node 8 was included to result in more balanced results by distance because Reach 1 is by far the longest. A total of 2125 data points were included in the analyses (5 nodes times 425 days.)

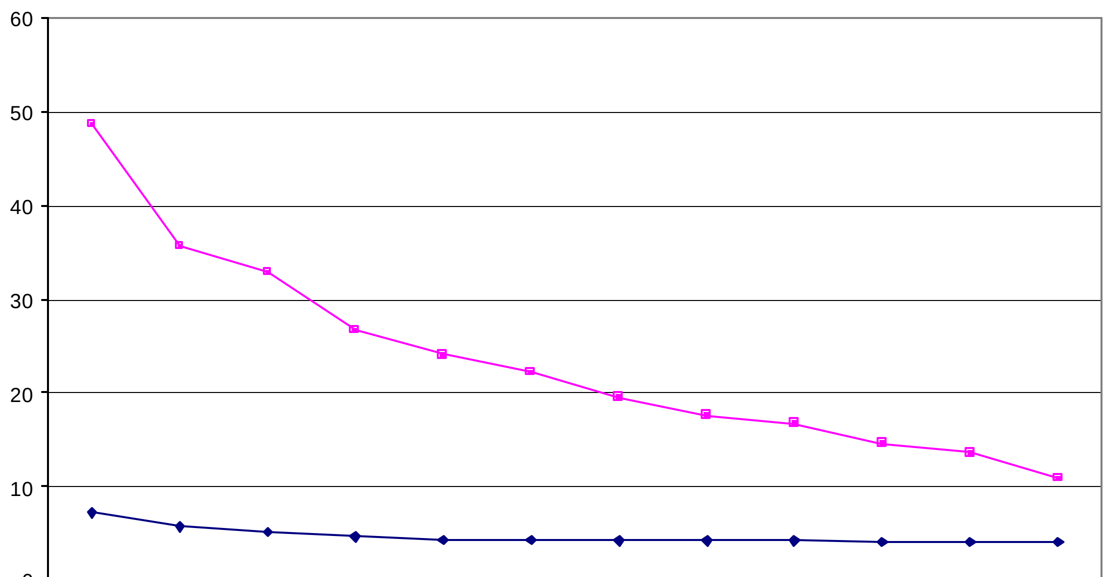
Percent Exceedence
Threshold Temperature 22°



	40 c.f.s.	80 c.f.s.	100 c.f.s.	200 c.f.s.	300 c.f.s.	400 c.f.s.	600 c.f.s.	800 c.f.s.	1000 c.f.s.	1500 c.f.s.	2000 c.f.s.	4000 c.f.s.
Avg Temp	17.882	17.741	17.882	17.412	17.224	17.082	17.035	16.753	16.471	16.565	16.518	16.235
MaxTemp	59.859	47.247	45.694	42.353	40.141	38.965	36.518	35.106	34.4	32.612	31.812	29.506

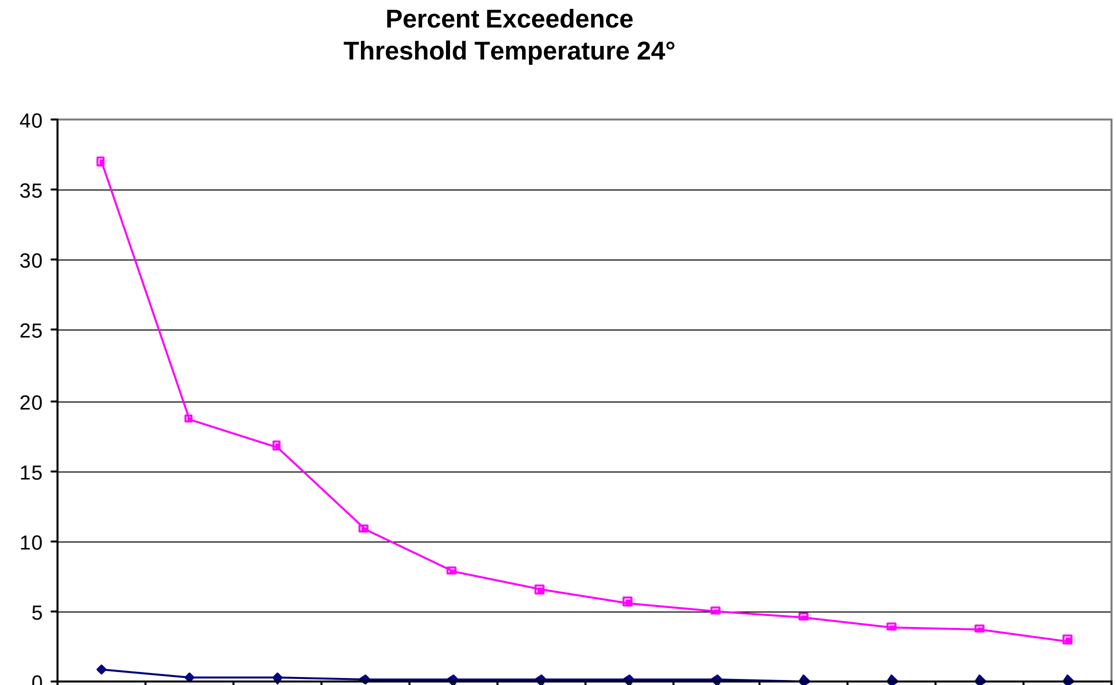
Figure 32. Percent Exceedance, Threshold Temperature of 22 °C

Percent Exceedence
Threshold Temperature 23°



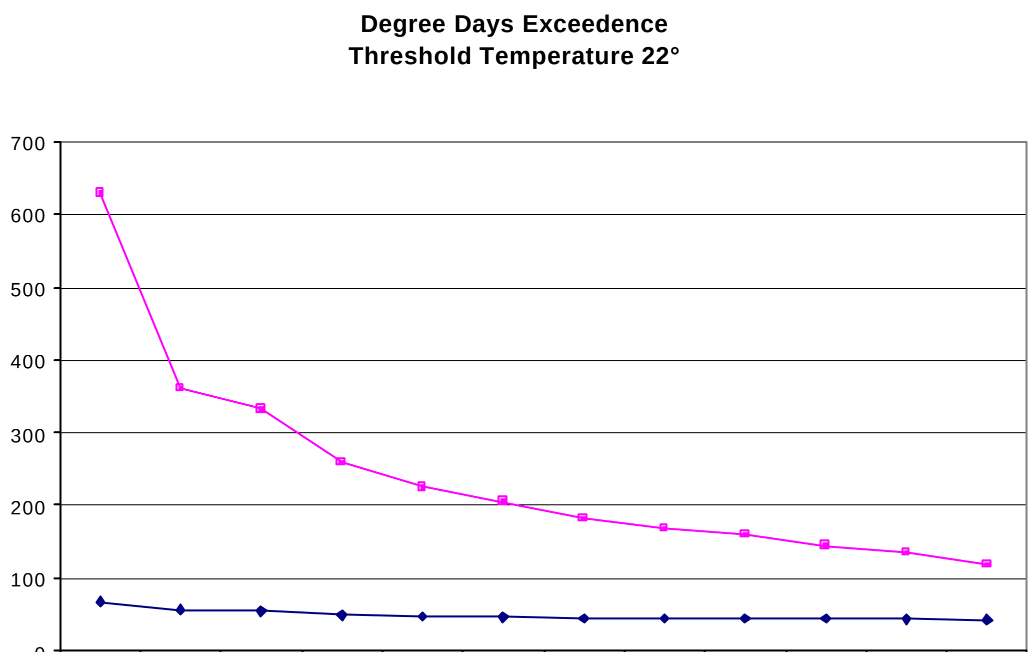
	40 c.f.s.	80 c.f.s.	100 c.f.s.	200 c.f.s.	300 c.f.s.	400 c.f.s.	600 c.f.s.	800 c.f.s.	1000 c.f.s.	1500 c.f.s.	2000 c.f.s.	4000 c.f.s.
Avg Temp	7.247	5.741	5.224	4.659	4.329	4.329	4.282	4.235	4.235	4.094	4.094	4.094
Max Temp	48.659	35.671	32.941	26.682	24.047	22.259	19.529	17.6	16.8	14.635	13.647	10.918

Figure 33. Percent Exceedance, Threshold Temperature of 23 °C



	40 c.f.s.	80 c.f.s.	100 c.f.s.	200 c.f.s.	300 c.f.s.	400 c.f.s.	600 c.f.s.	800 c.f.s.	1000 c.f.s.	1500 c.f.s.	2000 c.f.s.	4000 c.f.s.
Avg Temp	0.894	0.329	0.282	0.188	0.141	0.141	0.141	0.141	0.094	0.094	0.094	0.094
Max Temp	36.941	18.635	16.706	10.824	7.859	6.541	5.647	4.988	4.565	3.859	3.718	2.918

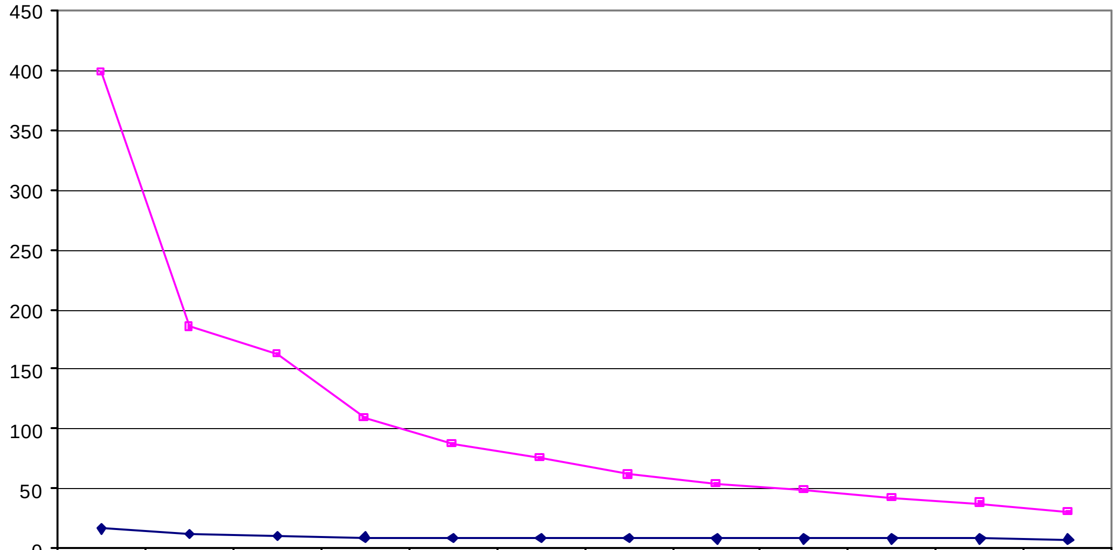
Figure 34. Percent Exceedance, Threshold Temperature of 24 °C



	40 c.f.s.	80 c.f.s.	100 c.f.s.	200 c.f.s.	300 c.f.s.	400 c.f.s.	600 c.f.s.	800 c.f.s.	1000 c.f.s.	1500 c.f.s.	2000 c.f.s.	4000 c.f.s.
Avg Temp	67.73	56.87	54.43	49.13	47.22	46.21	45.14	44.57	44.22	43.77	43.54	43.15
Max Temp	629.39	361.82	332.26	258.42	225.12	205.32	182.34	168.71	159.39	144.88	136.12	119.11

Figure 35. Degree Days, Threshold Temperature of 22 °C

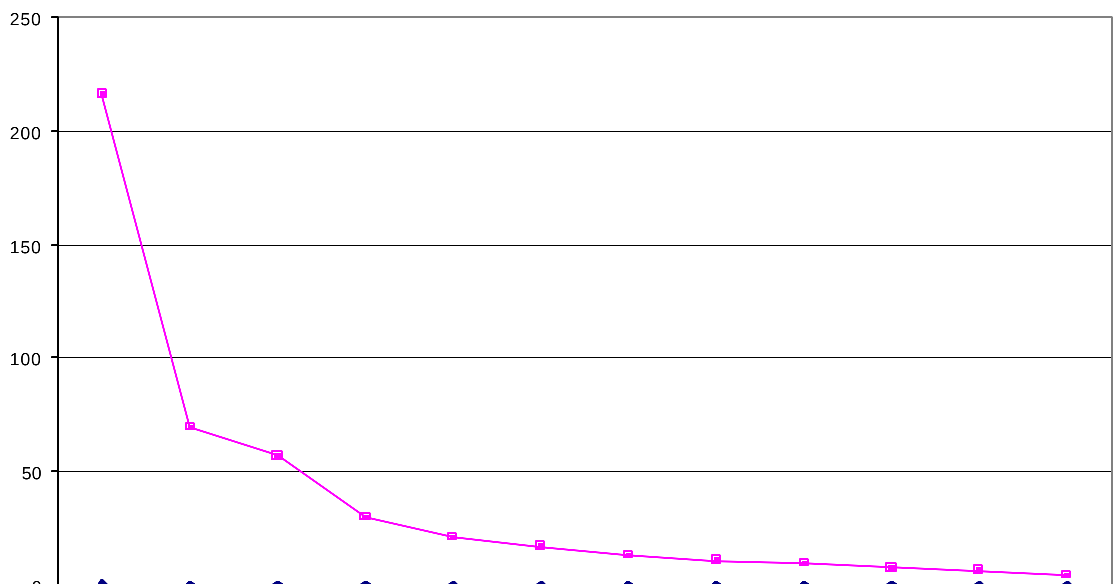
Degree Days Exceedence
Threshold Temperature 23°



	40 c.f.s.	80 c.f.s.	100 c.f.s.	200 c.f.s.	300 c.f.s.	400 c.f.s.	600 c.f.s.	800 c.f.s.	1000 c.f.s.	1500 c.f.s.	2000 c.f.s.	4000 c.f.s.
Avg Temp	16.58	11.71	10.85	9.43	8.95	8.72	8.46	8.31	8.21	8.08	8.01	7.89
Max Temp	397.35	185.07	162.23	108.97	87.41	75.34	61.72	54.14	49.23	41.95	37.83	30.28

Figure 36. Degree Days, Threshold Temperature of 23 °C

Degree Days Exceedence
Threshold Temperature 24°



	40 c.f.s.	80 c.f.s.	100 c.f.s.	200 c.f.s.	300 c.f.s.	400 c.f.s.	600 c.f.s.	800 c.f.s.	1000 c.f.s.	1500 c.f.s.	2000 c.f.s.	4000 c.f.s.
Avg Temp	0.51	0.15	0.12	0.06	0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.01
Max Temp	215.97	69.76	56.9	29.83	21.11	17.14	13.15	11.02	9.68	7.75	6.67	4.72

Figure 37. Degree Days, Threshold Temperature of 24 °C

4.4 EXCEEDANCE PERCENTILES

Exceedance percentiles (at increments of 5 percent) were calculated for daily average and maximum temperatures for each set of flows. Figure 38 shows the Average Temperature Exceedance Percentiles with Table 6 showing the data. Figure 39 shows the Maximum Temperature Exceedance Percentiles with Table 7 showing the data.

Table 6. Average Temperature Exceedance Percentiles

Percentile	40 c.f.s.	80 c.f.s.	100 c.f.s.	200 c.f.s.	300 c.f.s.	400 c.f.s.	600 c.f.s.	800 c.f.s.	1000 c.f.s.	1500 c.f.s.	2000 c.f.s.	4000 c.f.s.
0.05	24.40	24.28	24.25	24.17	24.14	24.12	24.10	24.08	24.08	24.06	24.06	24.05
5.04	23.31	23.09	23.04	22.91	22.87	22.86	22.84	22.82	22.81	22.81	22.81	22.78
10.02	22.64	22.50	22.47	22.40	22.37	22.35	22.33	22.33	22.32	22.32	22.32	22.32
15.01	22.24	22.16	22.14	22.10	22.09	22.09	22.08	22.08	22.08	22.07	22.06	22.06
20.00	21.87	21.87	21.88	21.87	21.87	21.86	21.86	21.86	21.85	21.86	21.85	21.84
25.04	21.60	21.57	21.55	21.55	21.58	21.56	21.56	21.55	21.55	21.56	21.55	21.56
30.02	21.27	21.25	21.24	21.24	21.23	21.22	21.22	21.22	21.22	21.22	21.21	21.22
35.01	20.99	20.97	20.97	20.98	20.98	20.97	20.96	20.95	20.95	20.95	20.94	20.94
40.00	20.67	20.67	20.68	20.67	20.67	20.66	20.66	20.66	20.67	20.68	20.69	20.68
45.04	20.23	20.31	20.31	20.38	20.42	20.45	20.46	20.46	20.45	20.45	20.45	20.46
50.02	19.86	19.95	19.97	20.00	20.04	20.04	20.03	20.05	20.06	20.07	20.07	20.09
55.01	19.53	19.49	19.45	19.43	19.41	19.40	19.41	19.40	19.39	19.38	19.39	19.39
60.00	19.09	19.06	19.04	18.94	18.90	18.87	18.85	18.83	18.84	18.82	18.82	18.81
65.04	18.56	18.48	18.49	18.47	18.49	18.48	18.48	18.48	18.47	18.46	18.47	18.48
70.02	17.75	17.74	17.75	17.81	17.83	17.84	17.81	17.81	17.80	17.82	17.81	17.79
75.01	17.25	17.16	17.15	17.10	17.09	17.08	17.09	17.07	17.05	17.04	17.03	17.00
80.00	16.71	16.64	16.62	16.56	16.53	16.51	16.48	16.49	16.48	16.47	16.46	16.44
85.04	16.19	16.10	16.06	16.01	15.97	15.95	15.92	15.90	15.90	15.89	15.88	15.87
90.02	15.02	14.74	14.69	14.54	14.49	14.46	14.42	14.40	14.39	14.37	14.36	14.34
95.01	13.65	13.49	13.45	13.35	13.30	13.28	13.26	13.24	13.22	13.20	13.19	13.18
100.00	11.12	11.03	11.01	10.96	10.94	10.92	10.91	10.90	10.90	10.89	10.88	10.88
Minimum	11.12	11.03	11.01	10.96	10.94	10.92	10.91	10.90	10.90	10.89	10.88	10.88
Maximum	24.40	24.28	24.25	24.17	24.14	24.12	24.10	24.08	24.08	24.06	24.06	24.05
Mean	19.33	19.27	19.25	19.21	19.19	19.19	19.17	19.17	19.16	19.16	19.15	19.15
Median	19.86	19.95	19.98	20.00	20.04	20.04	20.04	20.05	20.07	20.08	20.07	20.09

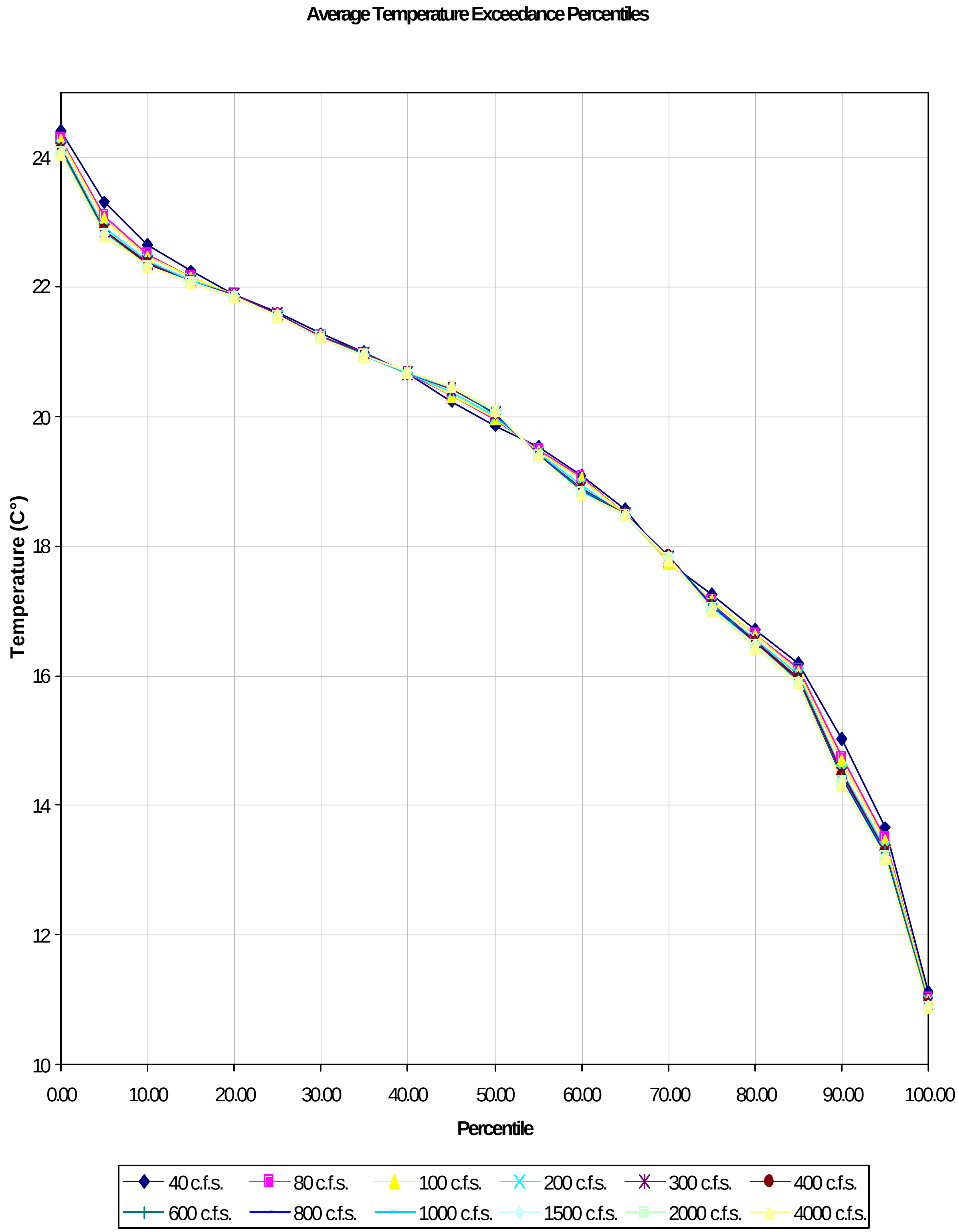


Figure 38. Average Temperature Exceedance Percentiles

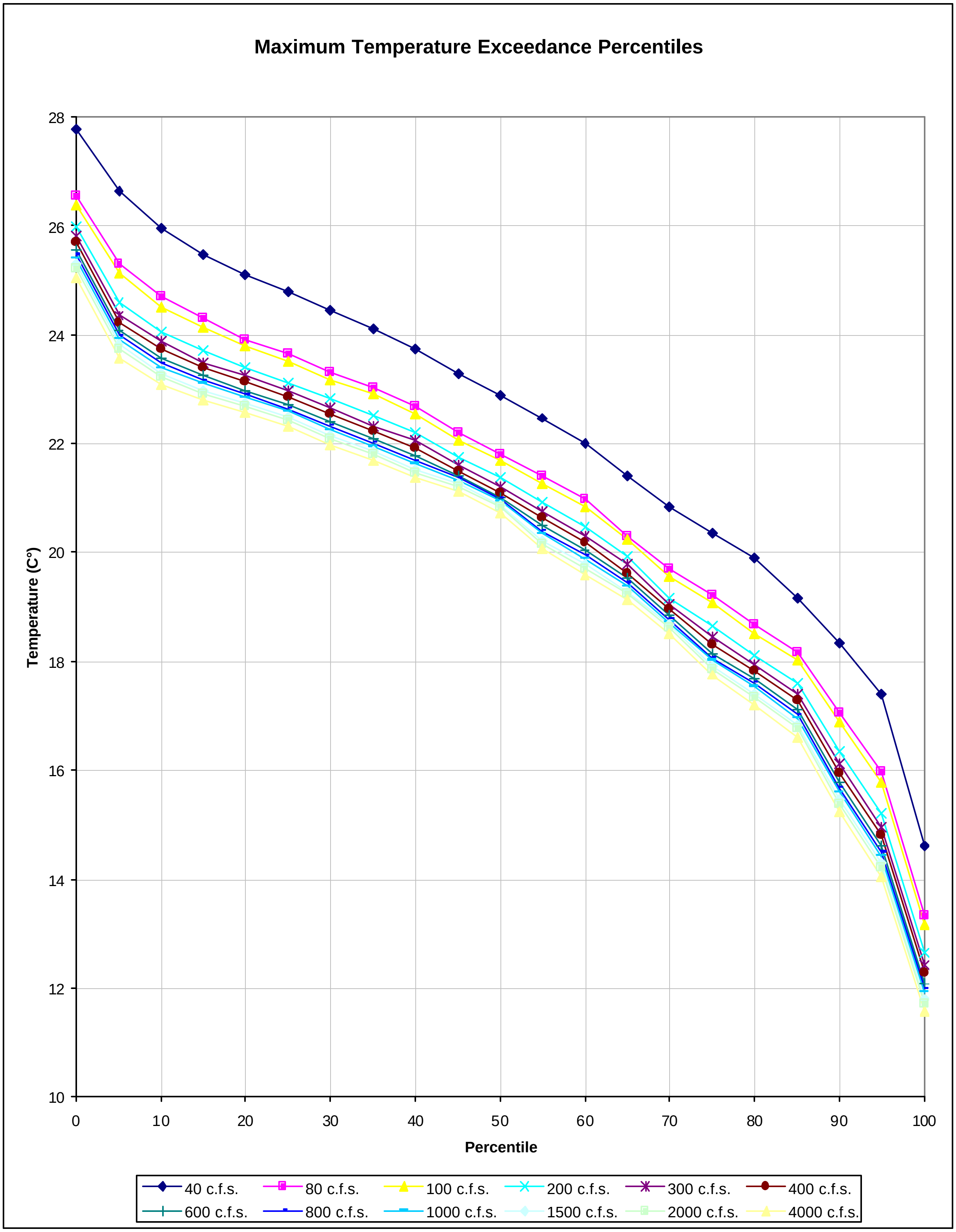


Figure 39. Maximum Temperature Exceedance Percentiles

Table 7. Maximum Temperature Exceedance Percentiles

Percentile	40 c.f.s.	80 c.f.s.	100 c.f.s.	200 c.f.s.	300 c.f.s.	400 c.f.s.	600 c.f.s.	800 c.f.s.	1000 c.f.s.	1500 c.f.s.	2000 c.f.s.	4000 c.f.s.
0.05	27.78	26.55	26.38	25.98	25.80	25.69	25.55	25.47	25.40	25.29	25.22	25.04
5.04	26.62	25.31	25.12	24.60	24.35	24.23	24.07	23.98	23.92	23.82	23.75	23.58
10.02	25.95	24.69	24.51	24.06	23.87	23.74	23.57	23.47	23.38	23.28	23.22	23.08
15.01	25.47	24.31	24.14	23.71	23.49	23.38	23.26	23.16	23.11	22.98	22.92	22.80
20.00	25.09	23.92	23.78	23.41	23.24	23.13	22.98	22.90	22.84	22.74	22.68	22.57
25.04	24.78	23.64	23.50	23.11	22.96	22.85	22.71	22.64	22.59	22.49	22.43	22.30
30.02	24.46	23.32	23.17	22.82	22.65	22.54	22.41	22.32	22.25	22.14	22.08	21.97
35.01	24.11	23.03	22.90	22.51	22.32	22.23	22.09	22.01	21.95	21.87	21.81	21.68
40.00	23.73	22.68	22.55	22.20	22.05	21.92	21.77	21.68	21.63	21.53	21.47	21.36
45.04	23.28	22.19	22.05	21.74	21.61	21.50	21.41	21.36	21.31	21.25	21.20	21.11
50.02	22.89	21.80	21.68	21.37	21.21	21.09	21.01	20.98	20.94	20.87	20.83	20.72
55.01	22.47	21.40	21.27	20.92	20.76	20.63	20.48	20.39	20.34	20.22	20.16	20.06
60.00	22.00	20.97	20.84	20.47	20.31	20.18	20.03	19.94	19.88	19.78	19.70	19.58
65.04	21.41	20.31	20.23	19.93	19.77	19.61	19.52	19.44	19.38	19.28	19.24	19.12
70.02	20.85	19.69	19.57	19.16	19.05	18.96	18.85	18.77	18.72	18.67	18.63	18.50
75.01	20.35	19.22	19.07	18.66	18.46	18.31	18.15	18.06	18.02	17.92	17.86	17.75
80.00	19.89	18.67	18.50	18.12	17.95	17.82	17.68	17.61	17.54	17.41	17.33	17.19
85.04	19.16	18.17	18.03	17.60	17.41	17.27	17.13	17.03	16.95	16.84	16.76	16.61
90.02	18.33	17.05	16.88	16.36	16.11	15.95	15.77	15.67	15.60	15.45	15.37	15.25
95.01	17.41	15.99	15.77	15.22	14.95	14.80	14.61	14.50	14.42	14.30	14.22	14.05
100.00	14.61	13.33	13.15	12.66	12.43	12.28	12.10	11.99	11.92	11.79	11.72	11.58
Minimum	14.61	13.33	13.15	12.66	12.43	12.28	12.10	11.99	11.92	11.79	11.72	11.58
Maximum	27.78	26.55	26.38	25.98	25.80	25.69	25.55	25.47	25.40	25.29	25.22	25.04
Mean	22.48	21.32	21.17	20.78	20.59	20.48	20.33	20.24	20.18	20.08	20.02	19.89
Median	22.90	21.80	21.68	21.38	21.21	21.10	21.01	20.98	20.95	20.87	20.83	20.73

5. DISCUSSION AND CONCLUSIONS

The end-of-reach mean daily temperatures simulated under the different flow regimes produced results that differed by weather and by reach. Some days showed a relatively large response to weather and flow while others showed very little. The pattern of heating or cooling also changed, depending on whether the air temperature (primarily) was warmer or colder than the starting water temperature for each reach. Lower flow releases generally responded more strongly to the meteorology than higher flow releases, whether heating or cooling. Still, since input water temperatures had nearly approached equilibrium with the prevalent weather conditions (primarily air temperature) due to the effect of Lake Chelan, the range of daily average stream temperatures was quite similar for low and high flows.

The end-of-reach maximum daily temperatures simulated under the different flow regimes were more consistent in response, with the lower flows producing higher daily maxima on warm days. This result would be expected because the higher daily maximum air temperatures would cause the lower flows to respond and warm more quickly, without the offset of nighttime cooling.

During mid-summer, ending temperatures are generally higher in all years under the lower flow release. This condition begins to change, however, in August, when lower flows result in lower daily mean water temperatures downstream. The crossover occurs when the weather starts to cool and the temperature of flow released from Lake Chelan starts out high and drops more rapidly at lower flow levels. If the objective of flow management in the Chelan bypass is to maintain the lowest possible summer mean daily temperatures, then this would be accomplished with higher flows early in the season and lower flows later.

5.1 SALMONID TEMPERATURE THRESHOLD IMPLICATIONS

Application of the standard salmonid temperature thresholds discussed earlier to the Chelan River bypass indicates unsuitable water temperatures under any combination of weather or release flow during mid- and late-summer. Dam release temperatures start out higher than 20°C between early- to mid-July and persist until about mid-September in both years. Any amount of exposure to the prevalent meteorological conditions in the area will either maintain or increase these temperatures until late summer. Lower release flows will warm to a greater extent, while flows of 1,500 cfs or even higher would warm slightly and still remain above the threshold.

Only putting the Chelan River in a closed riparian canopy to enable development of a localized evaporative microclimate is likely to create cooling in the bypass, and recurring high scouring flow events through the bypass eliminate this option. If establishment of a salmonid population is to remain a management goal, success would most likely require a combination of staged flow release targets, channel morphology management, selection of temperature tolerant fish stocks, and acceptance of cold water temperature standard excursions.

6. LITERATURE CITED

Anchor Environmental. 2000. Lake Chelan 1999 water quality monitoring report. Report prepared for Public Utility District No. 1 of Chelan County, Wenatchee, Washington.

Armour, C.L. 1991. Guidance for evaluating and recommending temperature regimes to protect fish. Instream Flow Paper 28. United States Fish and Wildlife Service Biological Report 90(22). Washington, D.C. 13 pp.

Bartholow, J.M. 1989. Stream temperature investigations: field and analytical methods. Instream Flow Information Paper No. 13. U.S. Fish and Wildlife Service Biological Report 89 (17). 139 pp.

Bell, M.C. 1986. Fisheries handbook of engineering requirements and biological criteria. Contract #DACW57-80-M-0567. Fish Passage Development and Evaluation Program, United States Army Corps of Engineers, Portland, Oregon. 326pp.

Eaton, J.G., J.H. McCormick, B.E. Goodno, D.G. O'Brien, H.G. Stefany, M. Hondzo, and R.M. Scheller. 1995. A field information-based system for estimating fish temperature tolerances. Fisheries 20(4)10-18.

Hogan, C.M., L.C. Patmore, and H. Seidman. 1973. Statistical prediction of equilibrium temperature from standard meteorological data bases. Environmental Protection Technology Series. EPA-600/2-73-003. USEPA, Washington, D.C. 271 pp.

McAfee, W.R. 1966. Rainbow trout. Pages 192-215 in A. Calhoun, editor. Inland fisheries management. California Department of Fish and Game. Sacramento, California. 546 pp.

National Geographic Holdings. 2000. Washington. Seamless USGS Topographic Maps on CD-ROM. National Geographics Maps, San Francisco, CA. Part number: 110-600-001.

Raleigh, R.F., T. Hickman, R.C. Solomon, and P.C. Nelson. 1984. Habitat suitability information: Rainbow trout. United States Fish and Wildlife Service FWS/OBS-82/10.60. 64 pp.

Raleigh, R.F., W.J. Miller, and P.C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: Chinook salmon. United States Fish and Wildlife Service, Biological Report 82(10.122). 64 pp.

Reiser, D.W., and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. Volume 1 in W.R. Meehan, editor. Influence of forest and rangeland management on anadromous fish habitat in western North America. United States Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-96. Portland, Oregon.

R2 Resource Consultants, and Ichthyological Associates, Inc.. 2000. Bypass Reach(Gorge) Flow Releases Study Report. (Final) Lake Chelan Hydroelectric Project, FERC Project No. 637. Report prepared for Public Utility District No. 1 of Chelan County, Wenatchee, Washington.

Theurer, F.D., K.A. Voos, and W.J. Miller. 1984. Instream water temperature model. Instream Flow Information Paper 16. Cooperative Instream Flow and Aquatic System Group, U.S. Fish and Wildlife Service. Fort Collins, Colorado.

APPENDIX A

Calibration Input Data

INPUT FLOWS AND TEMPERATURES: TOP OF STUDY

Flows are c.f.s, Temperatures are Centigrade

MO	DY	TOP Flow	TOP Temp
6	19	3814	17.91
6	20	6000	17.72
6	21	6000	17.51
6	22	6000	18.44
6	23	6000	18.92
6	24	4917	18.73
6	25	3175	18.93
6	26	1687	19.39
6	27	1025	20.36
6	28	1025	19.65
6	29	1025	19.09
6	30	1803	18.33
7	1	3333	18.20
7	2	1417	18.16
7	3	1000	18.40
7	4	1000	18.03
7	5	633	18.06
7	6	200	18.18
7	7	200	18.54
7	8	1600	18.94
7	9	1600	19.10
7	10	1256	19.12
7	11	1050	20.38
7	12	2144	21.34
7	13	3070	21.16
7	14	3516	21.30
7	15	2935	20.83
7	16	2000	20.55
7	17	1733	20.86
7	18	2725	21.42
7	19	2800	21.74
7	20	2800	21.35
7	21	1449	20.62
7	22	325	20.66
7	23	314	22.11
7	24	1350	22.60
7	25	4380	22.95
7	26	3833	22.61
7	27	1000	22.07
7	28	1000	21.57
7	29	1000	21.24
7	30	1000	21.28
7	31	563	20.83
8	1	300	20.66
8	2	300	20.44

8	3	179	20.27
8	4	77	20.34
8	5	76	19.85
8	6	76	19.65
8	7	76	19.62
8	8	76	20.03
8	9	77	20.56
8	10	77	21.03
8	11	77	21.03
8	12	77	20.91
8	13	103	20.77
8	14	113	21.33
8	15	77	20.23
8	16	78	20.95
8	17	78	20.04
8	18	78	20.71
8	19	78	21.05
8	20	78	20.96

WEATHER DATA

Daily Data at Chelan Weather Station

Temperature is Centigrade, Wind Speed is Meters per second, Solar Radiation is Julians per Square Meter per Second.

MO	DAY	Day Length	High Air Temp	Low Air Temp	AVG Air Temp	% Humidity	Wind Speed	% Sun	SOLAR RAD.
6	19	15.815	19.44	13.33	16.39	41.8	1.8	90.0	335.64
6	20	15.817	27.78	11.67	19.72	42.1	1.8	90.0	332.20
6	21	15.818	27.78	13.33	20.56	44.5	1.8	90.0	330.09
6	22	15.817	33.33	17.22	25.28	43.6	1.8	90.0	324.02
6	23	15.815	31.67	18.33	25.00	42.9	1.8	90.0	324.77
6	24	15.812	28.89	17.22	23.05	41.4	1.8	90.0	328.22
6	25	15.807	30.00	16.11	23.06	40.1	1.8	90.0	328.73
6	26	15.801	35.56	16.67	26.11	40.4	1.8	90.0	324.08
6	27	15.793	35.00	18.89	26.94	35.6	1.8	50.0	237.64
6	28	15.784	28.33	17.22	22.78	60.1	1.8	25.0	171.53
6	29	15.774	21.11	15.56	18.33	53.8	1.8	25.0	176.57
6	30	15.762	21.11	13.89	17.50	43.0	1.8	90.0	332.14
7	1	15.749	21.11	11.11	16.11	44.5	1.8	90.0	332.53
7	2	15.735	23.33	13.33	18.33	36.4	1.8	90.0	333.17
7	3	15.719	27.78	14.44	21.11	38.0	1.8	90.0	329.21
7	4	15.702	25.00	13.33	19.17	37.9	1.8	90.0	330.73
7	5	15.684	20.56	10.56	15.56	35.0	1.8	90.0	334.29
7	6	15.665	24.44	10.56	17.50	30.5	1.8	70.0	290.31
7	7	15.644	28.89	14.44	21.67	44.1	1.8	50.0	235.82
7	8	15.622	28.89	15.56	22.22	57.8	1.8	25.0	170.00

7	9	15.599	28.89	13.89	21.39	42.9	1.8	60.0	258.36
7	10	15.574	28.33	14.44	21.39	41.3	1.8	80.0	302.21
7	11	15.549	33.33	16.67	25.00	41.0	1.8	50.0	231.65
7	12	15.522	36.11	20.00	28.06	41.2	1.8	75.0	281.72
7	13	15.494	35.56	21.11	28.33	36.7	1.8	75.0	283.31
7	14	15.465	31.67	21.11	26.39	36.1	1.8	90.0	316.09
7	15	15.435	28.89	18.33	23.61	34.1	1.8	90.0	319.64
7	16	15.404	35.00	18.33	26.67	39.8	1.8	90.0	311.45
7	17	15.372	35.56	20.00	27.78	38.1	1.8	90.0	309.90
7	18	15.339	31.67	22.22	26.94	34.4	1.8	90.0	312.45
7	19	15.304	32.78	21.11	26.94	39.2	1.8	90.0	308.32
7	20	15.269	28.33	20.00	24.17	33.9	1.8	90.0	313.88
7	21	15.233	32.78	18.33	25.56	38.8	1.8	80.0	288.56
7	22	15.196	32.78	16.67	24.72	39.1	1.8	50.0	224.62
7	23	15.158	29.44	17.78	23.61	44.5	1.8	40.0	200.37
7	24	15.119	36.11	18.89	27.50	41.0	1.8	50.0	219.14
7	25	15.079	35.00	21.67	28.33	38.2	1.8	90.0	299.78
7	26	15.039	35.00	21.67	28.33	38.9	1.8	90.0	298.00
7	27	14.997	29.44	20.00	24.72	35.2	1.8	90.0	303.67
7	28	14.955	31.11	20.00	25.56	43.1	1.8	90.0	296.81
7	29	14.912	26.67	17.78	22.22	45.5	1.8	90.0	298.61
7	30	14.868	25.56	16.67	21.11	41.8	1.8	90.0	300.13
7	31	14.824	25.56	13.33	19.44	31.2	1.8	90.0	304.67
8	1	14.778	28.89	12.78	20.84	32.6	1.8	90.0	301.43
8	2	14.733	29.44	14.44	21.94	32.2	1.8	90.0	299.06
8	3	14.686	23.33	11.67	17.50	35.4	1.8	90.0	299.71
8	4	14.639	25.00	12.78	18.89	39.0	1.8	90.0	295.60
8	5	14.591	22.22	10.56	16.39	40.0	1.8	90.0	295.63
8	6	14.543	24.44	11.67	18.06	48.9	1.8	75.0	261.24
8	7	14.494	20.56	10.56	15.56	48.2	1.8	90.0	290.23
8	8	14.444	26.11	11.67	18.89	43.0	1.8	90.0	287.22
8	9	14.394	30.56	17.22	23.89	42.6	1.8	90.0	280.23
8	10	14.343	30.00	17.22	23.61	41.1	1.8	90.0	279.49
8	11	14.292	30.00	16.67	23.34	34.9	1.8	90.0	280.93
8	12	14.241	31.11	15.56	23.34	37.1	1.8	90.0	278.01
8	13	14.189	33.33	16.11	24.72	38.0	1.8	90.0	274.15
8	14	14.136	35.56	17.22	26.39	24.2	1.8	90.0	277.99
8	15	14.083	35.00	16.11	25.56	38.0	1.8	90.0	269.36
8	16	14.030	33.33	17.22	25.28	20.3	1.8	90.0	276.97
8	17	13.976	29.44	12.22	20.83	31.8	1.8	90.0	272.73
8	18	13.922	30.00	12.50	21.25	38.5	1.8	90.0	267.61
8	19	13.868	31.11	13.89	22.50	38.5	1.8	90.0	264.40
8	20	13.813	28.89	16.11	22.50	41.9	1.8	90.0	260.87

APPENDIX B

Calibration Data Statistics

```
Filename: C:\DLG\STRMTEMP\CHELAN\STRMTEMP\DONE\C2002C.STR
Chelan River
2002, calibrated to avg and max temps
Temperatures: Centigrade
----------------------------------------------------------------------
Dam Apron: TOP OF STUDY (749) -to- Reach 1: Node 2

                             Input  Avg24hr  Max24hr
                  MEAN:     20.153   20.161   21.171

               MINIMUM:     17.510   17.516   18.086
                  DATE:       6/21     6/21     6/21

               MAXIMUM:     22.950   22.956   23.518
                  DATE:       7/25     7/25     7/25

----------------------------------------------------------------------
Reach 1: Node 2 -to- Reach 1: Node 3

                             Input  Avg24hr  Max24hr
                  MEAN:     20.161   20.177   21.188

               MINIMUM:     17.516   17.528   18.127
                  DATE:       6/21     6/21     6/21

               MAXIMUM:     22.956   22.968   23.554
                  DATE:       7/25     7/25     7/25

----------------------------------------------------------------------
Reach 1: Node 3 -to- Reach 1: Node 4

                             Input  Avg24hr  Max24hr
                  MEAN:     20.177   20.194   21.231

               MINIMUM:     17.528   17.541   18.151
                  DATE:       6/21     6/21     6/21

               MAXIMUM:     22.968   22.980   23.580
                  DATE:       7/25     7/25     7/25

----------------------------------------------------------------------
Reach 1: Node 4 -to- Reach 1: Node 5


                             Input  Avg24hr  Max24hr
                  MEAN:     20.194   20.216   21.531

               MINIMUM:     17.541   17.558   18.318
                  DATE:       6/21     6/21     6/21

               MAXIMUM:     22.980   22.997   23.746
```

```
             DATE:       7/25     7/25     7/25

---------------------------------------------------------------------
Reach 1: Node 5 -to- Reach 1: Node 6

                          Input  Avg24hr  Max24hr
             MEAN:       20.216   20.233   21.720

          MINIMUM:       17.558   17.569   18.390
             DATE:       6/21     6/21     6/21

          MAXIMUM:       22.997   23.008   23.896
             DATE:       7/25     7/25     8/10

---------------------------------------------------------------------
Reach 1: Node 6 -to- Reach 1: Node 7

                          Input  Avg24hr  Max24hr
             MEAN:       20.233   20.245   21.691

          MINIMUM:       17.569   17.576   18.372
             DATE:       6/21     6/21     6/21

          MAXIMUM:       23.008   23.015   23.853
             DATE:       7/25     7/25     8/10

---------------------------------------------------------------------
Reach 1: Node 7 -to- Reach 1: Node 8

                          Input  Avg24hr  Max24hr
             MEAN:       20.245   20.282   21.703

          MINIMUM:       17.576   17.602   18.397
             DATE:       6/21     6/21     6/21

          MAXIMUM:       23.015   23.040   23.870
             DATE:       7/25     7/25     8/10

---------------------------------------------------------------------
Reach 1: Node 8 -to- Reach 1: Node 9

                          Input  Avg24hr  Max24hr
             MEAN:       20.282   20.296   21.588

          MINIMUM:       17.602   17.613   18.331
             DATE:       6/21     6/21     6/21

          MAXIMUM:       23.040   23.051   23.765
             DATE:       7/25     7/25     7/25

---------------------------------------------------------------------
```

Reach 1: Node 9 -to- Reach 1: Node 10

	Input	Avg24hr	Max24hr
MEAN:	20.296	20.314	21.789
MINIMUM:	17.613	17.625	18.434
DATE:	6/21	6/21	6/21
MAXIMUM:	23.051	23.062	24.061
DATE:	7/25	7/25	8/10

Reach 1: Node 10 -to- Reach 1: Node 11

	Input	Avg24hr	Max24hr
MEAN:	20.314	20.335	21.783
MINIMUM:	17.625	17.640	18.448
DATE:	6/21	6/21	6/21
MAXIMUM:	23.062	23.076	24.036
DATE:	7/25	7/25	8/10

Reach 1: Node 11 -to- Reach 1: Node 12

	Input	Avg24hr	Max24hr
MEAN:	20.335	20.350	21.938
MINIMUM:	17.640	17.650	18.560
DATE:	6/21	6/21	6/21
MAXIMUM:	23.076	23.087	24.290
DATE:	7/25	7/25	8/10

Reach 1: Node 12 -to- End of Reach 1 (750)

	Input	Avg24hr	Max24hr
MEAN:	20.350	20.367	21.997
MINIMUM:	17.650	17.664	18.682
DATE:	6/21	6/21	6/21
MAXIMUM:	23.087	23.101	24.318
DATE:	7/25	7/25	8/10

End of Reach 1 (750) -to- Reach 2: Node 2

	Input	Avg24hr	Max24hr

	Input	Avg24hr	Max24hr
MEAN:	20.367	20.380	22.215
MINIMUM:	17.664	17.677	18.761
DATE:	6/21	6/21	6/21
MAXIMUM:	23.101	23.113	24.712
DATE:	7/25	7/25	8/10

Reach 2: Node 2 -to- End of Reach 2: Top of gorge (753)

	Input	Avg24hr	Max24hr
MEAN:	20.380	20.387	22.280
MINIMUM:	17.677	17.683	18.833
DATE:	6/21	6/21	6/21
MAXIMUM:	23.113	23.119	24.786
DATE:	7/25	7/25	8/10

End of Reach 2: Top of gorge -to- End of Reach 3, Bottom of gorge (751)

	Input	Avg24hr	Max24hr
MEAN:	20.387	20.512	22.293
MINIMUM:	17.683	17.801	18.948
DATE:	6/21	6/21	6/21
MAXIMUM:	23.119	23.237	24.499
DATE:	7/25	7/25	8/10

End of Reach 3, Bottom of gorge (751) -to- End of Reach 4: Near Powerhouse (752)

	Input	Avg24hr	Max24hr
MEAN:	20.512	20.553	22.277
MINIMUM:	17.801	17.838	18.998
DATE:	6/21	6/21	6/21
MAXIMUM:	23.237	23.273	24.592
DATE:	7/25	7/25	8/10

STUDY SUMMARY STATISTICS
Data Points: 1008

	Input	Avg24hr	Max24hr
MEAN:	20.288	20.313	21.775
MINIMUM:	17.510	17.516	18.086
DATE:	6/21	6/21	6/21
MAXIMUM:	23.237	23.273	24.786
DATE:	7/25	7/25	8/10

APPENDIX C

Simulation Run Input Data

MO	DAY	YEAR	Input Water Temp	AVG Air Temp	% Humidity	Wind Speed	% Sun	SOLAR RAD.
5	1	2000	12.80	14.44	30.0	1.8	90.0	292.40
5	2	2000	13.30	16.67	30.0	1.8	90.0	293.03
5	3	2000	13.30	16.39	30.0	1.8	90.0	295.02
5	4	2000	13.10	11.67	60.0	1.8	50.0	212.69
5	5	2000	12.80	11.39	30.0	1.8	90.0	301.14
5	6	2000	12.80	11.11	30.0	1.8	90.0	303.00
5	7	2000	12.80	10.56	30.0	1.8	90.0	304.95
5	8	2000	13.10	13.06	30.0	1.8	90.0	305.49
5	9	2000	13.10	13.61	30.0	1.8	90.0	306.85
5	10	2000	12.80	11.11	70.0	1.8	40.0	196.61
5	11	2000	12.50	8.61	50.0	1.8	60.0	246.35
5	12	2000	12.80	10.00	30.0	1.8	90.0	313.24
5	13	2000	13.10	11.94	30.0	1.8	90.0	313.89
5	14	2000	13.60	12.78	30.0	1.8	90.0	314.95
5	15	2000	14.20	15.83	40.0	1.8	70.0	270.59
5	16	2000	15.00	16.39	30.0	1.8	90.0	315.76
5	17	2000	15.00	19.44	30.0	1.8	90.0	315.04
5	18	2000	14.70	15.83	30.0	1.8	90.0	318.77
5	19	2000	15.00	16.39	60.0	1.8	50.0	225.51
5	20	2000	15.00	17.22	30.0	1.8	90.0	320.41
5	21	2000	14.70	17.78	30.0	1.8	90.0	321.24
5	22	2000	14.70	18.33	30.0	1.8	90.0	322.02
5	23	2000	14.70	17.22	30.0	1.8	90.0	323.90
5	24	2000	15.00	16.67	30.0	1.8	90.0	325.35
5	25	2000	15.60	18.33	30.0	1.8	90.0	325.27
5	26	2000	15.80	17.22	30.0	1.8	90.0	327.05
5	27	2000	15.80	14.44	30.0	1.8	90.0	329.75
5	28	2000	15.30	16.94	30.0	1.8	90.0	329.14
5	29	2000	15.80	15.00	30.0	1.8	90.0	331.26
5	30	2000	16.10	15.28	60.0	1.8	50.0	234.70
5	31	2000	16.10	14.72	50.0	1.8	60.0	261.28
6	1	2000	15.60	11.67	30.0	1.8	90.0	335.53
6	2	2000	15.60	14.44	30.0	1.8	90.0	334.79
6	3	2000	15.80	16.67	30.0	1.8	90.0	334.12
6	4	2000	16.40	19.17	30.0	1.8	90.0	333.00
6	5	2000	16.70	20.28	30.0	1.8	90.0	332.74
6	6	2000	16.70	19.44	30.0	1.8	90.0	333.98
6	7	2000	16.70	19.44	30.0	1.8	90.0	334.52
6	8	2000	16.70	16.39	40.0	1.8	80.0	312.20
6	9	2000	16.70	17.50	50.0	1.8	70.0	286.01
6	10	2000	16.40	10.56	30.0	1.8	90.0	341.33
6	11	2000	16.40	14.44	30.0	1.8	90.0	339.67
6	12	2000	16.40	13.33	80.0	1.8	20.0	161.70
6	13	2000	16.40	15.00	30.0	1.8	90.0	339.99
6	14	2000	16.90	16.11	30.0	1.8	90.0	339.55
6	15	2000	16.90	18.33	30.0	1.8	90.0	338.23
6	16	2000	17.20	16.67	30.0	1.8	90.0	339.58
6	17	2000	17.50	20.56	30.0	1.8	90.0	336.80
6	18	2000	18.30	21.67	30.0	1.8	90.0	335.93
6	19	2000	18.30	18.06	30.0	1.8	90.0	338.91
6	20	2000	18.30	18.61	30.0	1.8	90.0	338.52
6	21	2000	18.90	20.56	30.0	1.8	90.0	336.95
6	22	2000	19.03	20.56	30.0	1.8	90.0	336.89

6	23	2000	18.58	21.67	30.0	1.8	90.0	335.82
6	24	2000	18.50	21.11	30.0	1.8	90.0	336.17
6	25	2000	18.35	18.89	30.0	1.8	90.0	337.79
6	26	2000	18.24	21.94	30.0	1.8	90.0	335.03
6	27	2000	18.29	23.33	30.0	1.8	90.0	333.46
6	28	2000	20.26	25.00	30.0	1.8	90.0	331.45
6	29	2000	21.07	24.72	30.0	1.8	90.0	331.41
6	30	2000	20.77	25.28	30.0	1.8	90.0	330.44
7	1	2000	20.02	20.83	30.0	1.8	90.0	334.30
7	2	2000	19.55	18.33	30.0	1.8	90.0	335.82
7	3	2000	19.12	16.39	60.0	1.8	40.0	213.73
7	4	2000	18.51	15.83	80.0	1.8	30.0	184.90
7	5	2000	18.64	16.39	30.0	1.8	90.0	335.54
7	6	2000	18.98	18.89	30.0	1.8	90.0	333.17
7	7	2000	19.21	19.17	30.0	1.8	90.0	332.30
7	8	2000	19.79	21.94	30.0	1.8	90.0	329.31
7	9	2000	20.08	22.22	30.0	1.8	90.0	328.34
7	10	2000	20.14	20.83	30.0	1.8	90.0	328.78
7	11	2000	20.12	21.94	30.0	1.8	90.0	327.01
7	12	2000	20.33	22.50	30.0	1.8	90.0	325.67
7	13	2000	20.93	24.72	30.0	1.8	90.0	322.64
7	14	2000	20.93	23.06	30.0	1.8	90.0	323.36
7	15	2000	20.49	20.28	30.0	1.8	90.0	324.81
7	16	2000	20.32	21.11	30.0	1.8	90.0	323.14
7	17	2000	19.98	23.61	30.0	1.8	90.0	319.87
7	18	2000	20.86	23.61	30.0	1.8	90.0	318.81
7	19	2000	21.06	23.61	30.0	1.8	90.0	317.71
7	20	2000	21.52	26.67	30.0	1.8	90.0	313.41
7	21	2000	21.42	26.39	30.0	1.8	90.0	312.56
7	22	2000	22.28	25.28	30.0	1.8	90.0	312.55
7	23	2000	22.45	23.89	30.0	1.8	90.0	312.69
7	24	2000	22.28	23.89	30.0	1.8	90.0	311.41
7	25	2000	21.67	24.72	30.0	1.8	90.0	309.30
7	26	2000	22.01	24.17	30.0	1.8	90.0	308.49
7	27	2000	22.02	25.00	30.0	1.8	90.0	306.30
7	28	2000	22.25	23.89	30.0	1.8	90.0	305.96
7	29	2000	22.33	24.17	30.0	1.8	90.0	304.25
7	30	2000	22.74	24.44	30.0	1.8	90.0	302.51
7	31	2000	22.45	28.06	30.0	1.8	90.0	297.19
8	1	2000	23.06	28.06	30.0	1.8	90.0	295.66
8	2	2000	23.04	28.06	30.0	1.8	90.0	294.10
8	3	2000	23.08	26.11	30.0	1.8	90.0	294.62
8	4	2000	23.08	24.72	30.0	1.8	90.0	294.36
8	5	2000	23.73	26.67	30.0	1.8	90.0	290.75
8	6	2000	23.76	28.89	30.0	1.8	90.0	286.58
8	7	2000	23.54	27.50	30.0	1.8	90.0	286.45
8	8	2000	23.67	27.50	30.0	1.8	90.0	284.70
8	9	2000	23.57	28.06	30.0	1.8	90.0	282.31
8	10	2000	23.41	27.50	30.0	1.8	90.0	281.12
8	11	2000	22.98	25.83	30.0	1.8	90.0	280.98
8	12	2000	22.64	20.56	30.0	1.8	90.0	283.54
8	13	2000	22.34	21.67	30.0	1.8	90.0	280.79
8	14	2000	22.03	21.39	30.0	1.8	90.0	279.05
8	15	2000	22.15	21.94	30.0	1.8	90.0	276.65
8	16	2000	22.08	21.94	30.0	1.8	90.0	274.65
8	17	2000	22.07	21.94	30.0	1.8	90.0	272.63

8	18	2000	21.86	23.06	30.0	1.8	90.0	269.71
8	19	2000	21.33	19.44	30.0	1.8	90.0	270.24
8	20	2000	21.14	16.67	30.0	1.8	90.0	269.78
8	21	2000	21.15	17.22	30.0	1.8	90.0	267.32
8	22	2000	21.35	19.44	30.0	1.8	90.0	263.83
8	23	2000	21.37	20.56	30.0	1.8	90.0	260.93
8	24	2000	21.38	23.06	30.0	1.8	90.0	256.94
8	25	2000	21.85	25.56	30.0	1.8	90.0	252.69
8	26	2000	22.06	22.50	30.0	1.8	90.0	252.92
8	27	2000	21.85	18.06	30.0	1.8	90.0	253.53
8	28	2000	21.48	15.83	30.0	1.8	90.0	252.41
8	29	2000	20.96	17.78	30.0	1.8	90.0	249.09
8	30	2000	20.68	20.00	30.0	1.8	90.0	245.47
8	31	2000	20.33	20.00	30.0	1.8	90.0	243.14
9	1	2000	22.00	18.06	30.0	1.8	90.0	241.91
9	2	2000	21.80	16.67	30.0	1.8	90.0	240.25
9	3	2000	21.40	14.17	30.0	1.8	90.0	239.00
9	4	2000	20.90	13.89	30.0	1.8	90.0	236.70
9	5	2000	20.60	14.44	30.0	1.8	90.0	234.03
9	6	2000	20.10	14.72	30.0	1.8	90.0	231.47
9	7	2000	21.30	15.00	30.0	1.8	90.0	228.90
9	8	2000	18.60	18.06	30.0	1.8	90.0	225.01
9	9	2000	18.30	13.61	30.0	1.8	90.0	224.53
9	10	2000	18.00	14.44	30.0	1.8	90.0	221.71
9	11	2000	17.50	14.44	30.0	1.8	90.0	219.22
9	12	2000	17.80	15.83	30.0	1.8	90.0	216.14
9	13	2000	17.80	18.61	30.0	1.8	90.0	212.35
9	14	2000	19.20	20.28	30.0	1.8	90.0	208.99
9	15	2000	19.40	21.11	30.0	1.8	90.0	206.03
9	16	2000	19.70	22.22	30.0	1.8	90.0	202.90
9	17	2000	21.90	20.28	30.0	1.8	90.0	201.51
9	18	2000	19.70	22.22	30.0	1.8	90.0	197.93
9	19	2000	20.00	21.39	30.0	1.8	90.0	195.92
9	20	2000	18.30	20.56	30.0	1.8	90.0	193.87
9	21	2000	18.10	16.11	30.0	1.8	90.0	193.40
9	22	2000	17.50	11.11	30.0	1.8	90.0	192.61
9	23	2000	17.30	10.00	30.0	1.8	90.0	190.39
9	24	2000	17.10	16.11	30.0	1.8	90.0	185.86
9	25	2000	16.90	12.78	30.0	1.8	90.0	184.52
9	26	2000	16.40	13.61	30.0	1.8	90.0	181.74
9	27	2000	16.40	13.06	30.0	1.8	90.0	179.41
9	28	2000	16.90	15.56	30.0	1.8	90.0	176.08
9	29	2000	17.20	17.22	30.0	1.8	90.0	172.98
9	30	2000	17.20	19.17	40.0	1.8	70.0	145.12
5	1	2001	11.94	9.72	30.0	1.8	90.0	294.52
5	2	2001	11.67	8.33	30.0	1.8	90.0	296.92
5	3	2001	13.89	11.67	30.0	1.8	90.0	297.43
5	4	2001	12.50	13.61	30.0	1.8	90.0	298.32
5	5	2001	13.33	8.61	60.0	1.8	40.0	194.15
5	6	2001	13.20	8.61	30.0	1.8	90.0	304.01
5	7	2001	13.06	11.11	30.0	1.8	90.0	304.71
5	8	2001	13.06	15.83	30.0	1.8	90.0	304.01
5	10	2001	13.61	14.44	30.0	1.8	90.0	308.02
5	11	2001	13.89	16.39	30.0	1.8	90.0	308.47
5	12	2001	15.00	19.44	30.0	1.8	90.0	307.97
5	14	2001	16.11	20.56	30.0	1.8	90.0	310.07

5	15	2001	16.39	12.78	60.0	1.8	70.0	267.62
5	17	2001	15.28	12.22	30.0	1.8	90.0	319.41
5	19	2001	14.44	14.17	30.0	1.8	90.0	321.01
5	20	2001	14.17	11.67	30.0	1.8	90.0	323.53
5	21	2001	14.17	13.06	30.0	1.8	90.0	324.05
5	22	2001	16.11	18.89	30.0	1.8	90.0	321.62
5	23	2001	16.11	24.72	30.0	1.8	90.0	317.68
5	24	2001	17.50	24.44	30.0	1.8	90.0	319.03
5	25	2001	18.33	23.89	30.0	1.8	90.0	320.62
5	29	2001	16.67	12.50	30.0	1.8	90.0	332.64
5	30	2001	16.67	13.06	30.0	1.8	90.0	333.21
5	31	2001	17.22	16.67	30.0	1.8	90.0	331.90
6	1	2001	15.83	22.78	30.0	1.8	90.0	327.86
6	2	2001	15.83	16.39	30.0	1.8	90.0	333.60
6	3	2001	15.83	13.61	30.0	1.8	90.0	335.96
6	4	2001	15.83	14.72	30.0	1.8	90.0	335.99
6	5	2001	15.28	17.22	50.0	1.8	70.0	284.51
6	6	2001	15.00	15.83	70.0	1.8	40.0	211.58
6	7	2001	15.83	15.00	30.0	1.8	90.0	337.57
6	8	2001	16.39	18.89	30.0	1.8	90.0	335.44
6	9	2001	16.94	16.94	40.0	1.8	80.0	312.17
6	11	2001	16.39	15.28	30.0	1.8	90.0	339.17
6	18	2001	17.22	18.33	30.0	1.8	90.0	338.65
6	26	2001	16.39	17.50	30.0	1.8	90.0	338.59
6	27	2001	17.22	15.83	80.0	1.8	30.0	186.53
6	28	2001	17.50	16.39	70.0	1.8	40.0	212.71
6	29	2001	18.33	18.89	30.0	1.8	90.0	336.66
6	30	2001	18.33	21.39	30.0	1.8	90.0	334.25
7	1	2001	18.33	21.94	30.0	1.8	90.0	333.33
7	2	2001	18.89	23.06	30.0	1.8	90.0	331.84
7	3	2001	18.33	24.17	30.0	1.8	90.0	330.25
7	4	2001	18.89	25.44	30.0	1.8	90.0	328.37
7	5	2001	20.56	26.28	30.0	1.8	90.0	326.87
7	6	2001	20.28	21.67	30.0	1.8	90.0	330.90
7	7	2001	20.56	23.06	30.0	1.8	90.0	328.98
7	8	2001	20.83	24.31	30.0	1.8	90.0	327.06
7	9	2001	21.67	25.83	30.0	1.8	90.0	324.72
7	10	2001	21.67	28.33	30.0	1.8	90.0	321.00
7	11	2001	22.22	27.78	30.0	1.8	90.0	320.90
7	12	2001	21.67	27.50	30.0	1.8	90.0	320.41
7	13	2001	22.22	24.44	30.0	1.8	90.0	322.92
7	14	2001	21.94	24.72	30.0	1.8	90.0	321.73
7	15	2001	21.67	25.00	30.0	1.8	90.0	320.49
7	16	2001	21.67	19.44	30.0	1.8	90.0	324.46
7	17	2001	21.67	15.00	30.0	1.8	90.0	326.39
7	18	2001	21.67	18.06	30.0	1.8	90.0	323.36
7	19	2001	20.56	19.17	30.0	1.8	90.0	321.45
7	20	2001	20.56	19.17	30.0	1.8	90.0	320.31
7	21	2001	20.56	22.50	30.0	1.8	90.0	316.42
7	23	2001	20.83	21.11	30.0	1.8	90.0	315.15
7	24	2001	21.67	21.67	30.0	1.8	90.0	313.40
7	25	2001	21.94	23.33	30.0	1.8	90.0	310.62
7	26	2001	21.94	23.33	30.0	1.8	90.0	309.27
7	27	2001	21.94	26.67	30.0	1.8	90.0	304.55
7	28	2001	21.94	23.89	30.0	1.8	90.0	305.96
7	29	2001	21.11	18.89	30.0	1.8	90.0	308.58

7	30	2001	21.11	19.17	30.0	1.8	90.0	306.88
7	31	2001	21.11	19.44	30.0	1.8	90.0	305.15
8	1	2001	21.11	21.67	30.0	1.8	90.0	301.89
8	2	2001	21.11	22.50	30.0	1.8	90.0	299.62
8	3	2001	21.67	25.00	30.0	1.8	90.0	295.73
8	4	2001	21.67	22.78	30.0	1.8	90.0	296.11
8	5	2001	21.67	21.11	30.0	1.8	90.0	295.78
8	6	2001	21.67	22.22	30.0	1.8	90.0	293.18
8	7	2001	22.22	26.39	30.0	1.8	90.0	287.62
8	8	2001	22.22	25.83	30.0	1.8	90.0	286.43
8	9	2001	21.67	23.89	30.0	1.8	90.0	286.46
8	10	2001	21.11	25.56	30.0	1.8	90.0	283.10
8	11	2001	21.67	26.67	30.0	1.8	90.0	280.15
8	12	2001	22.22	28.89	30.0	1.8	90.0	275.89
8	13	2001	22.78	27.50	30.0	1.8	90.0	275.53
8	14	2001	23.33	25.28	30.0	1.8	90.0	275.81
8	15	2001	22.78	26.11	30.0	1.8	90.0	273.06
8	16	2001	23.40	27.22	30.0	1.8	90.0	269.99
8	20	2001	22.00	22.22	30.0	1.8	90.0	266.19
8	21	2001	22.20	21.11	30.0	1.8	90.0	264.87
8	22	2001	22.10	21.67	40.0	1.8	80.0	241.71
8	23	2001	22.10	18.33	60.0	1.8	30.0	146.35
8	27	2001	21.94	22.22	30.0	1.8	90.0	250.87
8	28	2001	21.94	25.56	30.0	1.8	90.0	246.00
8	29	2001	22.50	25.28	30.0	1.8	90.0	243.97
8	30	2001	22.22	25.83	30.0	1.8	90.0	241.22
8	31	2001	22.22	25.56	30.0	1.8	90.0	239.15
9	1	2001	21.94	23.61	30.0	1.8	90.0	238.36
9	4	2001	21.11	19.44	30.0	1.8	90.0	233.97
9	5	2001	20.56	20.83	30.0	1.8	90.0	230.74
9	6	2001	20.28	18.33	30.0	1.8	90.0	229.75
9	7	2001	20.28	18.89	30.0	1.8	90.0	227.02
9	8	2001	19.72	17.50	30.0	1.8	90.0	225.28
9	10	2001	20.28	20.56	30.0	1.8	90.0	218.73
9	11	2001	20.56	21.11	30.0	1.8	90.0	215.94
9	12	2001	20.28	20.83	30.0	1.8	90.0	213.63
9	13	2001	20.56	21.39	30.0	1.8	90.0	210.84
9	14	2001	20.28	24.17	30.0	1.8	90.0	206.61
9	15	2001	20.28	23.06	30.0	1.8	90.0	204.87
9	17	2001	21.11	21.94	30.0	1.8	90.0	200.58
9	18	2001	21.11	23.33	30.0	1.8	90.0	197.26
9	19	2001	20.56	19.72	30.0	1.8	90.0	196.80
9	20	2001	20.56	17.50	30.0	1.8	90.0	195.34
9	21	2001	20.56	17.78	30.0	1.8	90.0	192.70
9	22	2001	20.56	18.61	30.0	1.8	90.0	189.82
9	24	2001	20.56	20.00	30.0	1.8	90.0	184.17
9	25	2001	20.00	21.94	30.0	1.8	90.0	180.70
9	26	2001	19.44	17.78	50.0	1.8	60.0	140.13
9	27	2001	18.89	14.17	30.0	1.8	90.0	179.05
9	28	2001	18.33	12.22	30.0	1.8	90.0	177.17
9	29	2001	18.33	13.33	30.0	1.8	90.0	174.34
9	30	2001	18.33	14.44	30.0	1.8	90.0	171.50
5	1	2002	12.50	16.94	30.0	1.8	90.0	291.01
5	2	2002	12.80	16.94	30.0	1.8	90.0	292.87
5	3	2002	12.80	12.22	30.0	1.8	90.0	297.18
5	6	2002	11.10	10.83	30.0	1.8	90.0	303.12

5	7	2002	10.80	9.72	30.0	1.8	90.0	305.30
5	8	2002	10.80	7.78	30.0	1.8	90.0	307.72
5	9	2002	10.80	9.44	30.0	1.8	90.0	308.74
5	10	2002	11.10	8.06	30.0	1.8	90.0	310.88
5	13	2002	12.80	17.50	30.0	1.8	90.0	310.80
5	14	2002	13.30	15.56	30.0	1.8	90.0	313.45
5	15	2002	12.80	12.50	30.0	1.8	90.0	316.52
5	16	2002	13.10	11.67	30.0	1.8	90.0	318.31
5	17	2002	13.10	16.94	30.0	1.8	90.0	316.77
5	20	2002	13.60	17.78	50.0	1.8	60.0	249.98
5	21	2002	13.60	15.56	30.0	1.8	90.0	322.66
5	22	2002	13.90	15.00	30.0	1.8	90.0	324.16
5	23	2002	13.30	13.33	30.0	1.8	90.0	326.21
5	28	2002	15.80	18.33	50.0	1.8	60.0	256.18
5	29	2002	16.10	17.78	50.0	1.8	60.0	257.39
5	30	2002	15.60	16.11	30.0	1.8	90.0	331.44
5	31	2002	15.60	20.00	30.0	1.8	90.0	329.48
6	3	2002	16.70	19.17	30.0	1.8	90.0	332.34
6	4	2002	16.10	20.83	30.0	1.8	90.0	331.66
6	5	2002	16.70	21.11	30.0	1.8	90.0	332.04
6	6	2002	16.10	18.89	30.0	1.8	90.0	334.40
6	7	2002	15.80	12.22	30.0	1.8	90.0	339.12
6	10	2002	15.30	18.33	30.0	1.8	90.0	336.73
6	11	2002	15.80	20.28	30.0	1.8	90.0	335.60
6	12	2002	17.00	20.00	30.0	1.8	90.0	336.17
6	13	2002	17.10	22.50	30.0	1.8	90.0	334.29
6	14	2002	19.00	23.89	30.0	1.8	90.0	333.19
6	15	2002	20.10	26.39	30.0	1.8	90.0	330.70
6	16	2002	20.00	26.67	30.0	1.8	90.0	330.54
6	17	2002	19.00	20.00	30.0	1.8	90.0	337.26
6	18	2002	18.40	18.61	30.0	1.8	90.0	338.44
6	19	2002	17.91	16.39	41.8	1.8	90.0	335.64
6	20	2002	17.72	19.72	42.1	1.8	90.0	332.20
6	21	2002	17.51	20.56	44.5	1.8	90.0	330.09
6	22	2002	18.44	25.28	43.6	1.8	90.0	324.02
6	23	2002	18.92	25.00	42.9	1.8	90.0	324.77
6	24	2002	18.73	23.06	41.4	1.8	90.0	328.22
6	25	2002	18.93	23.06	40.1	1.8	90.0	328.73
6	26	2002	19.39	26.11	40.4	1.8	90.0	324.08
6	27	2002	20.36	26.94	35.6	1.8	50.0	237.64
6	28	2002	19.65	22.78	60.1	1.8	25.0	171.53
6	29	2002	19.09	18.33	53.8	1.8	50.0	238.73
6	30	2002	18.33	17.50	43.0	1.8	90.0	332.14
7	1	2002	18.20	16.11	44.5	1.8	90.0	332.53
7	2	2002	18.16	18.33	36.4	1.8	90.0	333.17
7	3	2002	18.40	21.11	38.0	1.8	90.0	329.21
7	4	2002	18.03	19.17	37.9	1.8	90.0	330.73
7	5	2002	18.06	15.56	35.0	1.8	90.0	334.29
7	6	2002	18.18	17.50	30.5	1.8	70.0	290.31
7	7	2002	18.54	21.67	44.1	1.8	50.0	235.82
7	8	2002	18.94	22.22	57.8	1.8	25.0	170.00
7	9	2002	19.10	21.39	42.9	1.8	75.0	291.50
7	10	2002	19.12	21.39	41.3	1.8	80.0	302.21
7	11	2002	20.38	25.00	41.0	1.8	50.0	231.65
7	12	2002	21.34	28.06	41.2	1.8	75.0	281.72
7	13	2002	21.16	28.33	36.7	1.8	75.0	283.31

7	14	2002	21.30	26.39	36.1	1.8	90.0	316.09
7	15	2002	20.83	23.61	34.1	1.8	90.0	319.64
7	16	2002	20.55	26.67	39.8	1.8	90.0	311.45
7	17	2002	20.86	27.78	38.1	1.8	90.0	309.90
7	18	2002	21.42	26.94	34.4	1.8	90.0	312.45
7	19	2002	21.74	26.94	39.2	1.8	90.0	308.32
7	20	2002	21.35	24.17	33.9	1.8	90.0	313.88
7	21	2002	20.62	25.56	38.8	1.8	80.0	288.56
7	22	2002	20.66	24.72	39.1	1.8	50.0	224.62
7	23	2002	22.11	23.61	44.5	1.8	40.0	200.37
7	24	2002	22.60	27.50	41.0	1.8	50.0	219.14
7	25	2002	22.95	28.33	38.2	1.8	90.0	299.78
7	26	2002	22.61	28.33	38.9	1.8	90.0	298.00
7	27	2002	22.07	24.72	35.2	1.8	90.0	303.67
7	28	2002	21.57	25.56	43.1	1.8	90.0	296.81
7	29	2002	21.24	22.22	45.5	1.8	90.0	298.61
7	30	2002	21.28	21.11	41.8	1.8	90.0	300.13
7	31	2002	20.83	19.44	31.2	1.8	90.0	304.67
8	1	2002	20.66	20.84	32.6	1.8	90.0	301.43
8	2	2002	20.44	21.94	32.2	1.8	90.0	299.06
8	3	2002	20.27	17.50	35.4	1.8	90.0	299.71
8	4	2002	20.34	18.89	39.0	1.8	90.0	295.60
8	5	2002	19.85	16.39	40.0	1.8	90.0	295.63
8	6	2002	19.65	18.06	48.9	1.8	75.0	261.24
8	7	2002	19.62	15.56	48.2	1.8	90.0	290.23
8	8	2002	20.03	18.89	43.0	1.8	80.0	268.84
8	9	2002	20.56	23.89	42.6	1.8	80.0	262.29
8	10	2002	21.03	23.61	41.1	1.8	90.0	279.49
8	11	2002	21.03	23.34	34.9	1.8	90.0	280.93
8	12	2002	20.91	23.34	37.1	1.8	80.0	260.21
8	13	2002	20.77	24.72	38.0	1.8	90.0	274.15
8	14	2002	21.33	26.39	24.2	1.8	90.0	277.99
8	15	2002	20.23	25.56	38.0	1.8	90.0	269.36
8	16	2002	20.95	25.28	20.3	1.8	90.0	276.97
8	17	2002	20.04	20.83	31.8	1.8	90.0	272.73
8	18	2002	20.71	21.50	38.5	1.8	90.0	267.38
8	19	2002	21.05	22.50	38.5	1.8	90.0	264.40
8	20	2002	20.96	22.50	41.9	1.8	90.0	260.87
8	21	2002	20.84	22.50	30.0	1.8	90.0	263.86
8	22	2002	20.56	22.50	30.0	1.8	90.0	261.72
8	23	2002	20.56	23.34	30.0	1.8	90.0	258.91
8	24	2002	20.73	23.62	30.0	1.8	90.0	256.51
8	25	2002	21.46	23.89	30.0	1.8	90.0	254.09
8	26	2002	21.67	22.22	30.0	1.8	90.0	253.13
8	27	2002	21.67	22.23	30.0	1.8	90.0	250.87
8	28	2002	21.67	24.17	30.0	1.8	90.0	247.15
8	29	2002	20.56	26.39	30.0	1.8	90.0	243.01
8	30	2002	21.67	25.28	30.0	1.8	90.0	241.68
9	1	2002	21.84	23.89	30.0	1.8	90.0	238.15
9	2	2002	21.56	21.39	30.0	1.8	90.0	237.55
9	3	2002	21.39	21.67	30.0	1.8	90.0	235.00
9	4	2002	20.56	16.95	30.0	1.8	90.0	235.31
9	5	2002	20.56	17.78	30.0	1.8	90.0	232.47
9	6	2002	20.28	16.39	30.0	1.8	90.0	230.72
9	7	2002	19.42	16.39	50.0	1.8	50.0	162.44
9	8	2002	19.30	15.28	30.0	1.8	90.0	226.32

9	9	2002	19.44	16.39	30.0	1.8	90.0	223.35
9	10	2002	19.44	19.72	30.0	1.8	90.0	219.20
9	11	2002	19.44	20.56	30.0	1.8	90.0	216.27
9	12	2002	20.28	21.95	30.0	1.8	90.0	212.97
9	13	2002	20.56	21.94	30.0	1.8	90.0	210.51
9	14	2002	20.79	21.11	30.0	1.8	90.0	208.52
9	15	2002	20.64	21.11	30.0	1.8	90.0	206.03
9	16	2002	20.37	22.50	30.0	1.8	90.0	202.73
9	17	2002	19.90	19.45	30.0	1.8	90.0	201.94
9	18	2002	19.52	18.89	30.0	1.8	90.0	199.71
9	19	2002	19.35	18.06	30.0	1.8	90.0	197.60
9	20	2002	19.05	16.67	30.0	1.8	90.0	195.69
9	21	2002	18.95	15.28	30.0	1.8	90.0	193.73
9	22	2002	18.58	15.28	30.0	1.8	90.0	191.21
9	23	2002	18.45	15.56	30.0	1.8	90.0	188.59
9	24	2002	18.58	16.67	30.0	1.8	90.0	185.64
9	25	2002	18.63	17.50	30.0	1.8	90.0	182.80
9	26	2002	18.45	15.83	30.0	1.8	90.0	180.96
9	27	2002	18.18	12.78	30.0	1.8	90.0	179.50
9	28	2002	17.68	15.83	30.0	1.8	90.0	175.98
9	29	2002	17.22	15.28	50.0	1.8	70.0	147.27
9	30	2002	16.74	13.34	30.0	1.8	90.0	171.86
7	24	1998	21.94	28.23	38.0	1.8	98.0	313.65
7	25	1998	21.67	26.71	50.0	1.8	98.0	307.02
7	26	1998	21.67	27.48	53.0	1.8	97.0	301.44
7	27	1998	21.67	30.76	45.0	1.8	95.0	296.48
7	28	1998	21.67	29.86	46.0	1.8	92.0	291.33
7	29	1998	21.83	27.41	50.0	1.8	90.0	288.39
7	30	1998	21.83	23.54	62.0	1.8	41.0	190.69
7	31	1998	22.22	22.88	68.0	1.8	59.0	225.46
8	1	1998	22.32	24.53	50.0	1.8	93.0	293.91
8	2	1998	22.41	24.58	60.0	1.8	96.0	291.54
8	3	1998	22.78	25.52	59.0	1.8	96.0	288.74
8	4	1998	22.22	27.40	54.0	1.8	96.0	286.43
8	5	1998	23.19	26.48	49.0	1.8	93.0	284.96
8	6	1998	23.33	23.14	43.0	1.8	97.0	296.94

APPENDIX D

Simulation Run Statistics

AVERAGE 24-hour Temperatures Summary:
Differences are comparisons with 40 c.f.s.

CHELAN RIVER: Reach 1: Node 7 -to- Reach 1: Node 8

Flows	Mean Temp	Max Temp	Min Diff	Max Diff	Mean Diff
40 c.f.s.	19.174	24.021	---	---	---
80 c.f.s.	19.128	23.952	0.001	-0.345	-0.046
100 c.f.s.	19.117	23.936	0.001	-0.429	-0.057
200 c.f.s.	19.091	23.896	0.001	-0.628	-0.083
300 c.f.s.	19.080	23.879	0.002	-0.710	-0.094
400 c.f.s.	19.074	23.870	0.002	-0.757	-0.100
600 c.f.s.	19.067	23.859	0.002	-0.810	-0.107
800 c.f.s.	19.063	23.853	0.002	-0.840	-0.111
1000 c.f.s.	19.061	23.849	0.002	-0.860	-0.113
1500 c.f.s.	19.057	23.843	0.002	-0.889	-0.117
2000 c.f.s.	19.055	23.840	0.002	-0.906	-0.119
4000 c.f.s.	19.051	23.834	0.002	-0.935	-0.123

AVERAGE 24-hour Temperatures Summary:
Differences are comparisons with 40 c.f.s.

CHELAN RIVER: Reach 1: Node 12 -to- End of Reach 1 (750)

Flows	Mean Temp	Max Temp	Min Diff	Max Diff	Mean Diff
40 c.f.s.	19.295	24.184	---	---	---
80 c.f.s.	19.224	24.076	-0.001	-0.549	-0.071
100 c.f.s.	19.206	24.050	-0.002	-0.686	-0.089
200 c.f.s.	19.164	23.985	-0.002	-1.013	-0.131
300 c.f.s.	19.146	23.958	-0.003	-1.150	-0.149
400 c.f.s.	19.136	23.943	-0.003	-1.228	-0.159
600 c.f.s.	19.125	23.925	-0.003	-1.317	-0.170
800 c.f.s.	19.118	23.915	-0.003	-1.368	-0.177
1000 c.f.s.	19.114	23.908	-0.004	-1.402	-0.181
1500 c.f.s.	19.108	23.899	-0.004	-1.451	-0.188
2000 c.f.s.	19.104	23.893	-0.004	-1.480	-0.191
4000 c.f.s.	19.098	23.883	-0.004	-1.530	-0.198

AVERAGE 24-hour Temperatures Summary:
Differences are comparisons with 40 c.f.s.

CHELAN RIVER: Reach 2: Node 2 (753) -to- End of Reach 2: Top of gorge

Flows	Mean Temp	Max Temp	Min Diff	Max Diff	Mean Diff
40 c.f.s.	19.302	24.202	---	---	---
80 c.f.s.	19.234	24.095	0.001	-0.604	-0.067
100 c.f.s.	19.217	24.068	0.001	-0.755	-0.084
200 c.f.s.	19.177	24.003	0.001	-1.119	-0.125
300 c.f.s.	19.159	23.975	0.001	-1.272	-0.142

400 c.f.s.	19.150	23.959	0.001	-1.359	-0.152
600 c.f.s.	19.138	23.941	0.000	-1.459	-0.163
800 c.f.s.	19.132	23.931	0.000	-1.515	-0.170
1000 c.f.s.	19.128	23.924	0.000	-1.553	-0.174
1500 c.f.s.	19.121	23.914	-0.000	-1.608	-0.180
2000 c.f.s.	19.118	23.908	-0.000	-1.640	-0.184
4000 c.f.s.	19.112	23.898	0.000	-1.696	-0.190

AVERAGE 24-hour Temperatures Summary:
Differences are comparisons with 40 c.f.s.

CHELAN RIVER: End of Reach 2: Top of gorge -to- End of Reach 3, Bottom of gorge (751)

Flows	Mean Temp	Max Temp	Min Diff	Max Diff	Mean Diff
40 c.f.s.	19.424	24.354	---	---	---
80 c.f.s.	19.355	24.234	-0.001	-0.671	-0.070
100 c.f.s.	19.337	24.203	-0.001	-0.839	-0.087
200 c.f.s.	19.294	24.130	0.002	-1.242	-0.130
300 c.f.s.	19.276	24.099	0.002	-1.410	-0.148
400 c.f.s.	19.266	24.081	0.002	-1.506	-0.158
600 c.f.s.	19.254	24.061	0.002	-1.615	-0.170
800 c.f.s.	19.248	24.050	0.002	-1.677	-0.176
1000 c.f.s.	19.243	24.042	0.002	-1.718	-0.181
1500 c.f.s.	19.237	24.031	0.001	-1.778	-0.187
2000 c.f.s.	19.233	24.025	0.001	-1.812	-0.191
4000 c.f.s.	19.227	24.014	0.001	-1.872	-0.198

AVERAGE 24-hour Temperatures Summary:
Differences are comparisons with 40 c.f.s.

CHELAN RIVER: End of Reach 3, Bottom of gorge (751) -to- End of Reach 4: Near Powerhouse (752)

Flows	Mean Temp	Max Temp	Min Diff	Max Diff	Mean Diff
40 c.f.s.	19.464	24.405	---	---	---
80 c.f.s.	19.393	24.280	-0.001	-0.719	-0.072
100 c.f.s.	19.374	24.248	-0.002	-0.901	-0.090
200 c.f.s.	19.330	24.170	-0.004	-1.339	-0.135
300 c.f.s.	19.311	24.137	-0.005	-1.524	-0.154
400 c.f.s.	19.300	24.119	-0.005	-1.629	-0.164
600 c.f.s.	19.288	24.097	-0.006	-1.749	-0.177
800 c.f.s.	19.281	24.085	-0.006	-1.818	-0.184
1000 c.f.s.	19.276	24.077	-0.007	-1.862	-0.188
1500 c.f.s.	19.269	24.065	-0.007	-1.929	-0.195
2000 c.f.s.	19.265	24.058	-0.007	-1.967	-0.199
4000 c.f.s.	19.258	24.046	-0.008	-2.034	-0.206

MAXIMUM 24-hour Temperatures Summary:

Differences are comparisons with 40 c.f.s.
CHELAN RIVER: Reach 1: Node 7 -to- Reach 1: Node 8

Flows	Mean Temp	Max Temp	Min Diff	Max Diff	Mean Diff
40 c.f.s.	22.091	26.962	---	---	---
80 c.f.s.	21.081	25.952	-0.316	-1.517	-1.010
100 c.f.s.	20.937	25.803	-0.343	-1.757	-1.154
200 c.f.s.	20.549	25.398	-0.426	-2.389	-1.542
300 c.f.s.	20.359	25.200	-0.473	-2.689	-1.732
400 c.f.s.	20.240	25.075	-0.505	-2.875	-1.851
600 c.f.s.	20.092	24.919	-0.546	-3.104	-1.999
800 c.f.s.	20.000	24.822	-0.573	-3.245	-2.091
1000 c.f.s.	19.936	24.753	-0.593	-3.343	-2.156
1500 c.f.s.	19.832	24.643	-0.625	-3.499	-2.259
2000 c.f.s.	19.768	24.575	-0.645	-3.595	-2.323
4000 c.f.s.	19.645	24.442	-0.685	-3.780	-2.447

MAXIMUM 24-hour Temperatures Summary:
Differences are comparisons with 40 c.f.s.

CHELAN RIVER: Reach 1: Node 12 -to- End of Reach 1 (750)

Flows	Mean Temp	Max Temp	Min Diff	Max Diff	Mean Diff
40 c.f.s.	22.518	27.406	---	---	---
80 c.f.s.	21.407	26.301	-0.273	-1.773	-1.111
100 c.f.s.	21.242	26.129	-0.284	-2.074	-1.276
200 c.f.s.	20.801	25.665	-0.328	-2.862	-1.717
300 c.f.s.	20.590	25.441	-0.358	-3.230	-1.928
400 c.f.s.	20.460	25.302	-0.378	-3.454	-2.059
600 c.f.s.	20.301	25.131	-0.406	-3.725	-2.218
800 c.f.s.	20.204	25.027	-0.423	-3.889	-2.314
1000 c.f.s.	20.138	24.955	-0.436	-4.001	-2.381
1500 c.f.s.	20.034	24.841	-0.455	-4.177	-2.484
2000 c.f.s.	19.972	24.773	-0.467	-4.281	-2.546
4000 c.f.s.	19.856	24.643	-0.489	-4.480	-2.662

MAXIMUM 24-hour Temperatures Summary:
Differences are comparisons with 40 c.f.s.

CHELAN RIVER: Reach 2: Node 2 -to- End of Reach 2: Top of gorge (753)

Flows	Mean Temp	Max Temp	Min Diff	Max Diff	Mean Diff
40 c.f.s.	22.938	27.776	---	---	---
80 c.f.s.	21.431	26.331	-0.438	-2.344	-1.507
100 c.f.s.	21.268	26.161	-0.440	-2.657	-1.670
200 c.f.s.	20.822	25.695	-0.467	-3.482	-2.116
300 c.f.s.	20.603	25.464	-0.491	-3.872	-2.335
400 c.f.s.	20.467	25.319	-0.510	-4.112	-2.471
600 c.f.s.	20.297	25.139	-0.537	-4.404	-2.641

800 c.f.s.	20.193	25.027	-0.556	-4.582	-2.745
1000 c.f.s.	20.120	24.949	-0.570	-4.704	-2.818
1500 c.f.s.	20.005	24.825	-0.593	-4.897	-2.933
2000 c.f.s.	19.936	24.749	-0.608	-5.013	-3.002
4000 c.f.s.	19.806	24.605	-0.635	-5.233	-3.132

MAXIMUM 24-hour Temperatures Summary:
Differences are comparisons with 40 c.f.s.

CHELAN RIVER: End of Reach 2: Top of gorge -to- End of Reach 3, Bottom of gorge (751)

Flows	Mean Temp	Max Temp	Min Diff	Max Diff	Mean Diff
40 c.f.s.	22.213	27.526	---	---	---
80 c.f.s.	21.375	26.545	0.002	-1.636	-0.838
100 c.f.s.	21.245	26.384	-0.002	-1.940	-0.967
200 c.f.s.	20.924	25.977	-0.002	-2.704	-1.289
300 c.f.s.	20.783	25.796	-0.001	-3.056	-1.429
400 c.f.s.	20.699	25.686	-0.002	-3.266	-1.514
600 c.f.s.	20.593	25.552	0.007	-3.517	-1.619
800 c.f.s.	20.525	25.467	0.008	-3.670	-1.688
1000 c.f.s.	20.473	25.404	0.006	-3.778	-1.740
1500 c.f.s.	20.379	25.294	-0.006	-3.955	-1.833
2000 c.f.s.	20.313	25.218	-0.004	-4.069	-1.900
4000 c.f.s.	20.150	25.038	0.004	-4.316	-2.063

MAXIMUM 24-hour Temperatures Summary:
Differences are comparisons with 40 c.f.s.

CHELAN RIVER: End of Reach 3, Bottom of gorge (751) -to- End of Reach 4: Near Powerhouse (752)

Flows	Mean Temp	Max Temp	Min Diff	Max Diff	Mean Diff
40 c.f.s.	22.653	27.675	---	---	---
80 c.f.s.	21.313	26.239	-0.303	-2.177	-1.340
100 c.f.s.	21.174	26.087	-0.277	-2.481	-1.479
200 c.f.s.	20.802	25.681	-0.216	-3.266	-1.851
300 c.f.s.	20.624	25.485	-0.177	-3.627	-2.029
400 c.f.s.	20.513	25.363	-0.159	-3.847	-2.140
600 c.f.s.	20.377	25.214	-0.143	-4.111	-2.276
800 c.f.s.	20.294	25.122	-0.136	-4.270	-2.359
1000 c.f.s.	20.237	25.058	-0.132	-4.378	-2.416
1500 c.f.s.	20.147	24.957	-0.127	-4.548	-2.506
2000 c.f.s.	20.093	24.896	-0.124	-4.650	-2.560
4000 c.f.s.	19.990	24.779	-0.119	-4.842	-2.663
