Appendix R

Water Temperatures in the Battle Creek Restoration Area

Appendix R
Water Temperatures in the Battle Creek Restoration Area

Introduction

Water temperature directly affects the quality of habitat used by various life stages of stream-resident fish. In Battle Creek, water temperatures are influenced by seasonal hydrological and meteorological conditions, diversions and powerhouse discharges (into South Fork), instream flow releases below diversion dams, and the diversion of cold spring water from the stream channel (Kier Associates 1999; Thomas R. Payne and Associates 1998a, 1998b). Effects on fish populations are determined by the distribution of water temperatures within the stream habitat.

In this appendix, water temperatures are evaluated under the existing and No Action conditions and for the four steelhead and salmon restoration alternatives. The habitat flows and hydroelectric power diversions have been simulated using a monthly flow model that is described in Appendix J of this report, "Results from Monthly Flow and Power Generation Model." The monthly temperatures at the upstream end of the North Fork (i.e., at Feeder Dam) and South Fork (i.e., at South Diversion Dam) have been estimated on the basis of field measurements. Warming estimates for each reach of Battle Creek, which depend on the streamflow and monthly assumed equilibrium temperature, have been developed to approximate the measured temperatures obtained by the California Department of Water Resources (DWR) during the last 5 years (1998–2002) and data collected by Thomas R Payne & Associates in 1989.

The distribution of water temperature within the habitat of stream-resident fish affects their ability to use that habitat effectively. Natural temperature conditions in Central Valley streams vary along a continuum from mountain headwaters to lowland rivers (CALFED 2000), and populations of fishes have adapted to this natural continuum. Hydroelectric power diversions that divert relatively cool water from North Fork Battle Creek North Fork Battle Creek to South Fork Battle Creek may provide cooling in South Fork Battle Creek, but may also disrupt the temperature continuum along South Fork Battle Creek. Habitat in these artificially cooled areas is considered to be of lower quality during months when it is disconnected from contiguous cool habitat.

Water diverted from North Fork Battle Creek will continue to flow into the South Fork Battle Creek and provide cooling under alternatives that do not include connectors between the South and Inskip powerhouse tailraces and the Inskip and Coleman Canals. Fish residing in these artificially cooled areas are at risk of exposure to suboptimal water temperatures during planned or unplanned disruptions in the hydropower conveyance system. The normal Pacific Gas and Electric Company (PG&E) practice in the Battle Creek system is to continue the diversions and canal flows and allow the canal flow to bypass the powerhouse and flow into the river whenever the power plants are shut down. However, a canal outage would lead to increased water temperatures below the powerhouses.

Water temperatures are an important aspect of the Battle Creek aquatic habitat that should be monitored and evaluated on a long-term adaptive management framework. This appendix presents initial measurements and understandings about the relationship between flows and water temperatures in each reach of Battle Creek.

Water temperature measurements and local meteorological data are both elements in the Adaptive Management Plan (AMP). An accurate hourly water temperature model, similar to the stream network temperature model (SNTEMP), should be developed and incorporated into the AMP so that the measured temperatures can be compared to aquatic habitats with other flow conditions; this comparison would allow the benefits of restoration flows to be quantified, and would allow target flows to be adjusted if temperature conditions are suitable with reduced flows.

Methods

Optimal Water Temperatures

Water temperatures are considered optimal when a number of physiological functions, including growth, swimming, feeding, and spawning, are not limited. Optimal temperatures provide for normal feeding activity, normal physiological response, and normal behavior (McCullough 1999). The monthly fish life stage production model considers the optimal temperatures for spawning (and emerging fry) and the optimal rearing temperatures for steelhead and for Chinook salmon. Monthly survival rates for these two life stages (spawning and rearing) are then estimated using the monthly average temperature. Figure R-1 shows the assumed relationships between monthly temperature and monthly survival.

For steelhead, optimal water temperatures for spawning and for emerging fry are less than 53˚F. The monthly survival of incubating eggs is assumed to be less than 80% at a temperature of 56˚F. Because steelhead eggs incubate for at least 2 months, temperatures above 56˚F will result in much lower survival of fry. For Chinook salmon, the optimal spawning temperature is slightly warmer, with 100% survival below 55˚F, and less than 80% survival at 58˚F. For steelhead rearing, the optimal temperature is less than 66˚F, with less than 80% monthly survival at a temperature of 70˚F. Because juvenile steelhead remain in the stream for an entire year, only a few months above 70˚F can be tolerated. Optimal rearing temperatures for Chinook salmon are assumed to be less than 65˚F, which is slightly cooler than for steelhead. The Chinook salmon monthly rearing survival is assumed to be less than 80% at a temperature of 69˚F.

For comparing the measured water temperatures in Battle Creek, ideal spawning temperatures would be less than 55˚F, and ideal rearing temperatures would be less than 65˚F. A few months of up to 70˚F can be tolerated, but temperatures above 70˚F are considered to be unsuitable for steelhead or Chinook salmon rearing. These are relatively cool temperatures for streams flowing from the Sierra Nevada or Cascade Mountains into the Central Valley of California in the summer. Battle Creek is somewhat unique because of the large number of cool springs that feed North Fork Battle Creek and South Fork Battle Creek, and the relatively deep canyon that provides shade on North Fork Battle Creek.

Measured Water Temperatures

Water temperatures have been measured in Battle Creek during the Instream Flow Incremental Methodology (IFIM) studies in 1989 and 1995 (Thomas R. Payne and Associates 1996a, 1996b) and during recent years by the DWR Northern District Office. These measured temperatures are shown and described in this appendix to provide an accurate description of water temperature patterns in North Fork Battle Creek and South Fork Battle Creek. Measurements from the diversion canals and powerhouse tailwater also are available, and from the mainstem of Battle Creek below the confluence. Water temperature measurements have been collected at selected springs (e.g., year-round temperature at the Eagle Canyon spring complex of 52°F) and were used to the extent possible in the SNTEMP simulation. Additional water temperature monitoring will be required to determine the temperature effects caused by other springs (e.g., spring water entering South Fork Battle Creek from Soap and Ripley Creeks).

The temperature measurements have been used to develop warming estimates for each reach of Battle Creek. The warming estimates are based on the difference between the upstream water temperature and the assumed monthly equilibrium temperature. Warming is expected to be reduced at higher flows. The warming estimates were used in the monthly fish production model to estimate the likely future production of fish in each reach for each baseline and restoration alternative.

As stated above, water temperature measurements were collected on Battle Creek using data loggers in 1989 by Thomas R. Payne & Associates (1996a, 1996b) and in 1998–2001 by the DWR Northern District Office. Hourly data were collected and then reported as daily minimum, mean, and maximum temperatures at several stations. Temperatures were analyzed to estimate the warming that took place as a function of streamflow in each reach of Battle Creek during the warmer months of June through September. During this period, flows in both North Fork Battle Creek and South Fork Battle Creek were generally less than about 30 cfs, and often were at the FERC required minimum flows, resulting in relatively high water temperatures. Warming in each reach is expected to be substantially less with higher flows compared to the warming observed at current Federal Energy Regulatory Commission (FERC) flows. The historical temperature records were evaluated to estimate the general influence of flow on Battle Creek temperatures.

1989 Temperatures

The 1989 monthly average temperatures and warming in North Fork Battle Creek and South Fork Battle Creek are summarized in Tables R-1a and R-1b, respectively. Estimates of the average flow in each reach are also given. These flow and temperature data were used to develop warming estimates for each reach for any specified monthly equilibrium temperature and with any flow.

Figure R-2 shows the daily average water temperatures in Battle Creek from May through October 1989. The top graph shows the upstream temperatures at Feeder Dam on North Fork Battle Creek and at South Diversion Dam on South Fork Battle Creek. The South Fork Battle Creek temperatures are generally about 3–5ºF warmer than the North Fork Battle Creek temperatures during the summer months.

The bottom graph of Figure R-2 shows the downstream temperatures in Battle Creek, above the Coleman powerhouse. There were no 1989 temperature data available for the confluence of North Fork Battle Creek and South Fork Battle Creek. The large drop in temperatures above the Coleman powerhouse in August was the result of the mainstem being cooled while the Coleman powerhouse was turned off and Coleman Canal diversions were reduced. The daily average air temperatures from Gerber (20 miles south of Red Bluff) are shown on the bottom graph of Figure R-2. Temperatures above the Coleman powerhouse generally remained slightly lower than the air temperatures. The daily average air temperatures can be used to approximate the equilibrium temperature for Battle Creek.

Figure R-3 shows the 1989 summer temperatures in North Fork Battle Creek and South Fork Battle Creek. The top graph shows water temperatures in North Fork Battle Creek. Temperatures in the first reach, from Feeder Dam to Eagle Canyon Diversion Dam, ranged from about 55 °F to 60 °F in June, July, August, and September. Flows were about 5 cfs in North Fork Battle Creek except in June, when higher flows were measured below Feeder Dam. Warming in this reach was about 3°F in June and rose gradually to about 5°F by September. The second reach is from Eagle Canyon Diversion Dam to Wildcat Diversion Dam. Warming in this reach was more notable. Beginning with about 2°F in May, it rose to about 10°F during July, then declined back to about 2°F in September.

The third reach is from Wildcat Diversion Dam to near the mouth of the North Fork Battle Creek confluence with South Fork Battle Creek. This reach experienced very little warming. Changes in temperature were less than 1°F.

The bottom graph of Figure R-3 shows water temperatures in the South Fork for the June–September period. Temperatures in the first reach, from South Diversion Dam to the South powerhouse, were about 60°F in June and July, then declined to less than 55ºF in September. Warming in this reach was about 6°F with a flow of 6–7 cfs. The next reach is from Inskip Diversion Dam to the Inskip powerhouse. There were no temperature data for Inskip Diversion Dam in 1989, but it was cooled by the South powerhouse discharge and would have been similar to the South powerhouse tailwater temperature. Temperatures above Inskip powerhouse were 70–75°F in July. The warming in July can be estimated as the difference between the above Inskip powerhouse temperature and the South powerhouse tailwater temperature, which was about 60ºF. Warming can be estimated to be about 10–15˚F. The third reach is from Coleman Diversion Dam to near the mouth of South Fork Battle Creek. There were no 1989 temperature data for Coleman Diversion Dam. Temperatures at the mouth were similar to temperatures above Inskip powerhouse. The Coleman powerhouse and canal were shut off during August, and temperatures at the mouth were cooled by the Inskip powerhouse discharge.

1998 Temperatures

Tables R-2a and R-2b summarize the monthly temperatures and warming in North Fork Battle Creek and South Fork Battle Creek, respectively, measured in 1998, along with the estimated flows for each reach.

Figure R-3 shows average daily water temperatures in Battle Creek in 1998, measured by DWR. The top graph shows the measured temperatures on North Fork Battle Creek at Feeder Dam and on South Fork Battle Creek at South Diversion Dam. North Fork Battle Creek temperatures remained below 55ºF, and South Fork Battle Creek temperatures remained below 60ºF.

The bottom graph of Figure R-4 shows the mainstem temperatures at the confluence of North Fork Battle Creek and South Fork Battle Creek and above the Coleman powerhouse. Temperatures below the confluence of North Fork Battle Creek and South Fork Battle Creek rose to about 65°F in early August. Warming in this mainstem reach was only about 5°F in July and August. The Gerber air temperatures are shown on the graph to indicate the seasonal trend in equilibrium temperature. Temperatures remained below 70ºF at the Coleman powerhouse because of the relatively high flows during 1998. This water temperature was considerably lower than the air temperature of about 80ºF in July and August.

Figure R-5 shows the North Fork Battle Creek and South Fork Battle Creek temperatures, air temperatures, and flows for the summer months of 1998. The bottom graph shows temperatures and flows in North Fork Battle Creek. Temperatures at the mouth of North Fork Battle Creek remained below 60°F for the entire year. Warming in the three North Fork Battle Creek reaches was very slight because of the generally high flows of more than 30 cfs (Table R-2a).

The top graph shows water temperatures and flows in South Fork Battle Creek. South Diversion Dam temperatures were about 60ºF in July and early August. Warming from South Diversion Dam to the confluence (mouth) was less than 5°F in July because of high flows (greater than 30 cfs) combined with the cooling effect of the powerhouse discharges from North Fork Battle Creek. Warming in the South and Inskip reaches were not measured during 1998. Warming in the Coleman reach was about 1°F in June and about 3–4°F in August.

1999 Temperatures

Table R-3a gives the measured monthly temperatures and warming estimates in North Fork Battle Creek in 1999. Table R-3b provides the measured monthly temperatures and warming estimates in South Fork Battle Creek in 1999.

The top graph of Figure R-6 shows the upstream temperatures at Feeder Dam and South Diversion Dam in 1999. Temperatures at the Feeder Dam were above 55ºF during most of June, July, and August, with a maximum of 60ºF measured on a few days in mid-July. South Diversion Dam temperatures were above 60ºF for the summer period, with a maximum of 65ºF during the same period in mid-July. These are relatively warm temperatures compared to other years. The graph indicates that South Diversion Dam temperatures responded to the same meteorological patterns as did temperatures in North Fork Battle Creek but remained about 5ºF warmer than the Feeder Dam temperatures during the summer.

The bottom graph of Figure R-6 shows water temperatures in the mainstem of Battle Creek. Temperatures below the confluence of North Fork Battle Creek and South Fork Battle Creek rose to about 65°F in July. Warming in the mainstem was about 1°F in June and about 3–5°F in September. Temperatures upstream of the Coleman powerhouse reached a maximum of about 70°F in July and August. North Fork Battle Creek and South Fork Battle Creek flows were each about 35 cfs (i.e., interim flows) at the confluence, so this observed warming corresponded to flow of about 80 cfs in the mainstem.

The top graph of Figure R-7 shows 1999 summer water temperatures and flows in North Fork Battle Creek and South Fork Battle Creek. Flows at Eagle Canyon Diversion Dam dropped to about 35 cfs in mid-June. Temperatures in the first reach, below Feeder Dam, rose to about 55°F in July. Warming in this reach varied from 1 to 2°F. Warming in the second reach, below Eagle Canyon Dam, was less than 3°F. Warming in the third reach, below Wildcat Dam, ranged from 1 to 3°F (Table R-3a).

The bottom graph of Figure R-7 shows summer water temperatures and flows in South Fork Battle Creek. After mid-June, flows in the fork dropped to less than 35 cfs. Temperatures in the first reach, below South Diversion Dam, rose to about 60°F by July. Warming in the South reach was about 4°F for most of the period of lower flows. Warming in the Inskip reach varied from about 2 to 12°F, with warming of more than about 8 °F for most of the period of lower flows. Warming in the Coleman reach varied from about 1 to 4°F, with warming of more than 3°F for most of the period of lower flows (30 cfs interim flow). The flows below South and Inskip Diversion Dams in June and July were above the highest flows reported (i.e., 10 cfs). The Inskip reach had the warmest temperatures of about 70ºF, and the warming was sometimes limited by relatively cool air temperatures. The temperatures at the mouth of South Fork Battle Creek were reduced because of the cool Inskip powerhouse releases and the higher interim flows below Coleman Diversion Dam in 1999.

2000 Temperatures

Table R-4a summarizes the 2000 monthly temperatures and warming in North Fork Battle Creek, as well as flow estimates. Table R-4b summarizes the 2000 monthly temperatures, flow estimates, and warming in South Fork Battle Creek.

The top graph of Figure R-8 shows the upstream temperatures at Feeder Dam and South Diversion Dam in 2000. Temperatures at the Feeder Dam were above 55ºF for most of June, July, and August, with a maximum of 60ºF measured during a few days at the end of June. South Diversion Dam temperatures were above 60ºF for the summer period, with a maximum of 65ºF during the same period at the end of June and at the beginning of August. The South Diversion Dam temperatures responded to the same meteorological patterns as North Fork Battle Creek temperatures but remained about 5ºF warmer than the Feeder Dam temperatures during the summer. The bottom graph of Figure R-8 shows 2000 water temperatures in the mainstem of Battle Creek. Temperatures below the confluence of North Fork Battle Creek and South Fork Battle Creek rose to about 65°F in July. Warming in the mainstem was about 2–5°F in June, about 4–6ºF in July, and about 3–6°F in August. There were no data for September. Temperatures upstream of the Coleman powerhouse reached a maximum of about 70°F in July. Measurement of temperatures near the mouth of Battle Creek began in 2000. These temperatures were very similar to those upstream of the Coleman powerhouse, and were 5–10ºF lower than the average air temperature. North Fork Battle Creek flows were higher than the 35 cfs target flow in June, and the flows in North Fork Battle Creek and South Fork Battle Creek were each about 35 cfs (i.e., interim flows) during the July–September period, so the observed warming corresponded to a flow of about 80 cfs in the mainstem. DWR installed a flow meter at the mouth of North Fork Battle Creek in September 2000, and the flows measured about 10 cfs more than below Eagle Canyon.

Figure R-9 shows North Fork Battle Creek and South Fork Battle Creek water temperatures and flows during summer 2000. The top graph shows water temperatures in North Fork Battle Creek. Flows at Eagle Canyon Diversion Dam dropped to about 30 cfs in late June. Temperatures in the first reach, below Feeder Dam, rose to about 60°F by the end of June. Warming in this reach varied from about 2.5 to 3°F. Warming in the Eagle reach began at about 2°F in mid-July and declined to about 0.5°F at the end of August. Warming in the Wildcat reach began at about 3°F in mid-July and declined to about 0.5°F by the end of August.

The bottom graph of Figure R-9 shows water temperatures and flows in South Fork Battle Creek. Near the end of June, flows in South Fork Battle Creek below Coleman Diversion Dam dropped to about 35 to 40 cfs. Temperatures in the first reach began at about 50°F and rose to about 65°F by July. Warming in the first reach, below South Diversion Dam, varied from about 4 to 5°F with a flow of 6–7 cfs. Warming in the Inskip reach was about 4–5°F in June and rose to 12–14°F in July and August, then dropped to about 8°F by the end of August. There were higher flows in June and July, but about 8 cfs in August and September. Warming in the Coleman reach varied from 1 to 2°F because of the relatively high flow of 30 cfs (i.e., interim flow).

2001 Temperatures

Table R-5a gives the monthly summary of 2001 temperatures and warming in North Fork Battle Creek, with flow estimates. A monthly summary of 2001 temperatures and warming in South Fork Battle Creek, as well as flow estimates, is given in Table R-5b.

The top graph of Figure R-10 shows the upstream 2001 temperatures at Feeder Dam and South Diversion Dam. Temperatures at the Feeder Dam were above 55ºF for most of the summer months, with a maximum of 58ºF measured for a few days in July and August. South Diversion Dam temperatures were above 60ºF for the summer period, with a maximum of 63ºF during the warmest days. The South Diversion Dam temperatures responded to the same meteorological patterns as North Fork Battle Creek temperatures , but remained about 3–5ºF warmer than the Feeder Dam temperatures during the summer.

The bottom graph of Figure R-10 shows 2001 water temperatures in the mainstem of Battle Creek for 2001. Temperatures below the confluence were about 60ºF in June and rose to about 70ºF in July. Warming in the mainstem was only about 1°F in June, because Coleman powerhouse and canal were shut off. Warming was about 4–6ºF in July. Warming peaked at 7–8ºF in early August, then gradually declined to 4–7ºF in September. Temperatures near the mouth of Battle Creek were similar to those upstream of the Coleman powerhouse, and remain 5–10ºF lower than the average air temperature.

Figure R-11 shows the water temperatures and flows in North Fork Battle Creek and South Fork Battle Creek for the summer months of 2001. The top graph shows the temperatures and flows for North Fork Battle Creek. Flows near the mouth of the fork were about 38–45 cfs for the period of June to September. Temperatures at the Feeder Dam remained below 58°F. Warming in the Feeder reach varied from about 2 to 3°F, with a flow of about 5 cfs. Warming in the Eagle reach was about 1–3°F in June, about 2–3°F in July and August, and about 1–2°F in September, with a flow of about 35 cfs. Warming in the Wildcat reach was about 1.5–3.5°F in June, about 2.5–3.5°F in July, declining to about 2–3°F in August and 1–2°F in September. North Fork Battle Creek temperatures remained below 65°F at the mouth.

The bottom graph of Figure R-11 shows water temperatures and flows in South Fork Battle Creek. For most of the period of June to September, flows in South Fork Battle Creek were about 6–8 cfs. Temperatures in the South reach rose to about 62°F by July. Warming in the South reach was about 5ºF. Warming in the Inskip reach were about 12°F in June, about 14°F in July, 12°F in August, and 9°F in September. Warming in the Coleman reach was 9°F in June and 10°F in July and the beginning of August. At the end of September, warming was about 7°F. South Fork Battle Creek temperatures at the mouth were 70–75°F during the summer. DWR installed a flow meter at the mouth of South Fork Battle Creek in 2001. Flows were about 7 cfs in summer 2001 because the interim flows were reduced to discourage anadromous fish from migrating up South Fork Battle Creek.

Summary of Measured Water Temperatures

The temperature measurements from the 5 years discussed above provide a very accurate description of water temperature conditions in Battle Creek. A wide range of flow conditions is represented in the measurements. Temperatures at the upstream end of the restoration area would not be affected by the restoration alternatives. Temperatures in the other reaches can be influenced by instream flows, diversions, and powerhouse tailwater discharges. The temperature measurements were used to develop warming estimates that were then used in fish production modeling. The warming estimates are described in the next section.

Water Temperature Modeling Methods

Water temperatures in Battle Creek were modeled using SNTEMP, a cross-sectional averaged, one-dimensional model that was applied to the Battle Creek system, including the natural stream channels and Hydroelectric Project canals. Development of the SNTEMP model for Battle Creek, including calibration and partial validation, was conducted primarily in the late 1980s by Thomas R. Payne & Associates (1996a, 1996b). Additional development of the model, including recalibration and validation, was conducted by PG&E staff (PG&E 2001) to evaluate temperatures under each of the Battle Creek Salmon and Steelhead Restoration Project alternatives.

The SNTEMP model simulated the Battle Creek temperature distribution, both spatially and temporally, using specified hydrology (dry, normal, and wet water years) and meteorology (hot, normal, and cold climate conditions). The graphical results for the different restoration alternatives, shown in Appendix K of this report, "Optimal Water Temperature Habitat in Battle Creek," indicate the simulated warming in each reach for the selected meteorology and flow conditions.

A simpler temperature modeling approach that would approximate the reach warming under any flow during the summer period was developed for use in the monthly fish production modeling. The development of this method and a comparison with the SNTEMP model output are described below.

SNTEMP Model Formulation

The SNTEMP model divides a steam into model segments, then specifies the upstream flow and any tributary inflows or accretions (i.e., springs). The upstream temperature and temperatures of the tributaries and accretions must also be specified. Meteorology data (daily average) is applied, and stream width and shading from topography and vegetation are specified to estimate the warming along the stream. Stream width, channel depth, and velocity all vary with flow, but only stream width is factored into the SNTEMP modeling. SNTEMP provides an accurate method of simulating steady-state longitudinal temperature profiles as a function of meteorology and flow.

Some of the most important uncertainties in the temperature modeling are the tributary flows and temperatures, the stream width (and depth) as a function of flow, and the shading parameters. SNTEMP allows the meteorology to be adjusted for each reach using a regression equation to allow for adjustments from a remote measurement station. The SNTEMP model calculates and reports all temperatures in Celsius units.

The advantage of a detailed temperature model is that the estimated stream parameters can be verified during calibration with measured flows and temperatures. Once the model is calibrated, it can be used to simulate the variations in temperatures that would result from fluctuations in meteorology and flow. The effects of managed flow alternatives on temperatures can also be compared for a standard range of meteorological conditions. This was the approach used by TRPA and PG&E in using the SNTEMP model for evaluating the Battle Creek flow alternatives.

Unfortunately, the TRPA reports do not show any measured temperatures, but they do report that most of the reach temperature calibrations were within about

1ºC of the measured 1989 and 1995 data. The PG&E report does show many of the calibration results for the 1999 data. Neither report gives the daily flows for each reach, and neither report shows comparisons of the predicted warming for a range of flows, because the summer flows were relatively constant at slightly above the FERC requirements in 1989 and at the FERC and interim flows in 1999.

Development of the Battle Creek SNTEMP Model

Water temperature measurements at 11 stations, and stream surveys of Battle Creek, were initiated by TRPA in 1988. The daily average temperatures from 1989 are printed in a table in a 1995 technical memorandum to the California Department of Fish and Game (DFG). The 1988 data does not appear in any of the TRPA reports and was not used in model calibration because it was not initiated until mid-July and not all stations were measured. Temperatures were also collected by TRPA in 1995, but none of this data is included in the model reports. The months of July through October were selected for modeling. The SNTEMP models were formulated with eight separate stream reaches and four canal sections. The models were run for the daily flow and meteorological conditions of the 4-month period and compared to the measured downstream temperatures. This gave a good calibration for the range of meteorology and relatively low flows that were observed in 1989 and 1995.

Calibration was accomplished by separately adjusting the meteorology data obtained from the Redding Airport for each individual reach. This approach may not be ideal for making adjustments for stream reaches located near each other, because other model parameters (such as stream shading, width, or inflow temperatures) should also be adjusted to obtain good calibration. The meteorology adjustments cause the equilibrium temperature of each reach to vary, giving different maximum temperatures at the downstream end of each reach. Although each reach may have different rates of warming and equilibrium temperatures that are governed by the flow and shading in the reach, the meteorology should have been held constant between reaches. The reports summarize the meteorology adjustments that were used, but do not report the assumed stream widths and shading fractions that were used. For most of the reaches, a similar adjustment was used that reduced the wind speed to 10% of that measured. This reduced the evaporation rate and increased the equilibrium temperatures considerably.

PG&E Adjustments in the SNTEMP Model

The PG&E SNTEMP modeling used 1999 data collected by DWR as part of the Battle Creek restoration project. PG&E found that the model was predicting mainstem temperatures above the Coleman powerhouse that were 2ºF warmer than the measured data from June and August, with a relatively high mainstem flow of about 60–70 cfs (i.e., interim flows). This discrepancy was similar to the 2.5ºF excess found for the 1989 data, with relatively low FERC flows of 12–15 cfs. No adjustments in the model parameters were made because the restoration emphasis is on the upstream reaches.

PG&E found that the model was estimating a warming of 10ºF for a flow of 5 cfs in the Feeder reach. Measurements in 2000 indicated that the warming in this reach was only 3ºF at a flow of 5 cfs. The shade assumptions were increased and the meteorological adjustments were changed (but not reported) so that the model now predicts a 3ºF warming for a flow of 5 cfs. The study cases that were run by PG&E used representative meteorology to represent each month. Cold, average, and warm meteorological conditions were simulated. The simulated monthly flows were generally set to the specified flow target for each alternative, although the actual flows simulated in each reach, and the accretions and spring flows, were not reported in either the TRPA or the PG&E reports. Figures R-12 through R-31 show the SNTEMP simulated stream temperature profiles for each project alternative during the months of June, July, August, and September. The figures present simulated water temperatures in both North Fork Battle Creek and South Fork Battle Creek that may occur during a normal water year with average meteorology. The SNTEMP report shows additional simulations of representative monthly temperature stream profiles for cold and warm meteorology. The stream temperature differences that are expected with each alternative can be evaluated by comparing these stream temperature profiles.

Measured Upstream Temperatures

The SNTEMP model (or any temperature evaluation) requires the upstream temperatures to be specified. South Fork Battle Creek temperatures at South Diversion Dam are always warmer than North Fork Battle Creek temperatures at Feeder Dam (see Figures R-2 to R-11). The Feeder Dam temperatures range from 55 to 58ºF during the warmest months (July and August). The South Diversion Dam temperatures are about 5ºF warmer than the Feeder Dam temperatures in these months. Temperatures are slightly cooler in June and September, with a difference of about 3ºF between dams. There is some daily variation in the pattern of warming and cooling, but these maximum summer average monthly temperatures of 58ºF at Feeder Dam and 63ºF at South Diversion Dam are surprisingly consistent. The PG&E SNTEMP modeling used a range of upstream temperatures that were matched with the cold, normal, and warm meteorology conditions. The temperatures selected for SNTEMP are given in Table R-6. The selected South Diversion Dam temperatures were generally 2–3ºF warmer than the Feeder Dam temperatures. In some years of measurements, the South Dam temperatures were 4–5ºF warmer.

SNTEMP-Simulated Warming Response to Increased Flows

The effects of flow management alternatives were investigated in the TRPA reports by comparing temperatures with a flow of 5 cfs on North Fork Battle Creek and 7 cfs on South Fork Battle Creek (i.e., 2 cfs above FERC flows) with higher releases of 25 cfs or 30 cfs. The 25 cfs releases on both forks cooled the Battle Creek temperatures upstream of the Coleman powerhouse (near the Coleman National Fish Hatchery) from about 25ºC (77ºF) with 12 cfs to about 22ºC (72ºF) with 50 cfs for July 1995 meteorology. The measured upstream temperatures at the Feeder Dam were about 14ºC (57ºF), and the South Diversion Dam temperatures were about 15ºC (59ºF). Similar results were obtained for 1988 and 1989 meteorology. The total warming that was simulated from Feeder Dam or South Diversion Dam to the Coleman powerhouse was therefore 10–11ºC with 12 cfs and 7–8ºC with 50 cfs. Thus, the modeled four-fold increase in flow did not result in a very large reduction in the warming.

One of the most important results of temperature modeling of Battle Creek is to show the minimum warming that could occur with higher flows and the maximum warming that could occur with reduced flows, assuming the same upstream temperatures. The response of water temperatures to flow, for a given initial temperature and maximum equilibrium temperature (derived from the meteorology), is a very important SNTEMP model result that should be determined and validated for each reach of Battle Creek.

Figure R-32 shows the simulated and measured temperatures below South Diversion Dam (5.8 miles) and below Inskip Diversion Dam (5.2 miles) for July 1989. The SNTEMP model does not appear to simulate any difference between flows of 5 cfs, 10 cfs, and 20 cfs. Only for flows of 40 cfs and 80 cfs was there any substantial reduction in downstream temperatures. Unfortunately, because there were never high flows with measured temperatures in these South Fork Battle Creek reaches, the actual warming response to increased flows in these reaches was not calibrated.

Table R-7 gives a summary of the SNTEMP warming estimates in the South and Inskip reaches for a range of flows. The SNTEMP results do not appear to match the generally expected warming pattern for a stream with relatively confined channel geometry. As flows increase, the travel time of water is reduced considerably but the surface area increases only slightly, so warming should be substantially reduced. In a canal, for example, temperature warming is expected to be inversely proportional to flow (i.e., warming = constant/flow). Doubling the flow should reduce warming to about half that of the warming that occurred with the initial flow.

Measurements of Warming in South Fork Battle Creek

Direct measurements of temperatures below Coleman Diversion Dam for a range of flows have now been made because the normal FERC flows of about 7 cfs were raised during 1998–2000 to the interim flow of about 35 cfs. However, the interim flows on South Fork Battle Creek were discontinued in 2001 to discourage Chinook salmon and steelhead from spawning in South Fork Battle Creek below Coleman Diversion Dam. Temperature measurements in 2001 indicate that the warming below Inskip Diversion Dam (5.2 miles) and below Coleman Diversion Dam (2.4 miles to the mouth) is similar, even though the Inskip reach is twice as long.

In July 2001, the Inskip warming was about 13ºF and the Coleman warming was about 10ºF (see Figure R-11 and Table R-5b). The initial temperatures at Inskip were slightly cooler, but the response to meteorology during the summer was nearly identical for the two reaches, as indicated by the downstream temperatures. In July 1999, the Inskip flows were about 7 cfs, but the Coleman flows were 35 cfs. The measured warming below Inskip was about 10ºF, but the warming below Coleman was reduced dramatically, to just 3.2ºF (see Figure R-7 and Table R-3b). This reduction appears to be more in line with the expected pattern of greatly reduced warming at higher flows. The five-fold flow increase resulted in a reduction of the warming to about 45% of that for the base flow of 7 cfs. This pattern follows the estimated general warming relationship of:

$$\text{Reach Warming} = \text{Reach Coefficient} / \text{Flow}^{0.5}$$

This basic relationship was used in the monthly flow and temperature assessment model that combined monthly flow estimates, for a range of expected hydrologic conditions, with the corresponding temperatures for these flows. The temperature effects of the increased flows expected under each restoration alternative are accurately estimated using this general relationship, adjusted to match measurements in each reach. Calibration of the coefficients for each reach was based on the measured warming at the relatively low FERC flows during 1998–2001.

Measurements of Warming in North Fork Battle Creek

Greatly reduced warming below Eagle Canyon Diversion Dam and below Wildcat Dam has been directly measured in the past 5 years with the interim flow of about 35 cfs. The warming between Eagle Canyon Diversion Dam and the mouth of North Fork Battle Creek has averaged about 4–5ºF when the flow was about 35 cfs. This average is slightly lower than the SNTEMP predicted warming of 5–6ºF that was simulated for the Anadromous Fish Restoration Program (AFRP) flow of 30 cfs with normal meteorology. The SNTEMP simulated warming of about 11–12ºF for the FERC flows of just 3 cfs are similar to the observed warming of 9–10ºF observed during 1989, with an assumed flow of about 5 cfs. This reduction in the warming that is already achieved in North Fork Battle Creek with the interim flow of 35 cfs below Eagle Canyon Diversion Dam (and with no Wildcat diversions) suggests that the North Fork Battle Creek temperatures remain very cold and suitable for most steelhead and Chinook salmon life stages.

The release of Eagle spring water to North Fork Battle Creek in recent years is not easily detectable because North Fork Battle Creek temperatures of less than 60ºF are similar to the assumed spring temperature of 50–55ºF, and the 10 cfs spring flow has a limited ability to cool the interim North Fork Battle Creek flow of 35 cfs. Additional cooling by higher flows is not expected unless the flows are increased substantially above interim flows. The cooling effect of Eagle spring water would be less effective at higher North Fork Battle Creek flows.

Battle Creek Monthly Warming Estimates

The upstream temperatures recorded at North Fork Feeder Dam and at South Diversion Dam have been fairly consistent from year to year. The restoration project would not influence the South Fork Battle Creek temperatures or flows upstream of South Diversion Dam. Also, the temperatures at North Battle Creek Feeder Diversion-Dam are assumed to be controlled by Bailey Creek and Rock Creek inflows. The restoration project does not include changing flows below the Keswick Diversion Dam, so it is assumed that North Battle Creek Feeder Diversion Dam temperatures would be unchanged by any restoration alternative. The monthly summer temperatures assumed for North Battle Creek Feeder Diversion Dam are 55˚F in June, 57.5˚F in July, 57.5˚F in August, and 55˚F in September. At the South Diversion Dam, the assumed monthly temperatures are higher. The South Diversion Dam summer temperatures are assumed to be 60˚F in June, 62.5˚F in July, 62.5˚F in August, and 60ºF in September.

The monthly warming estimates depend on the upstream temperatures in each reach, the assumed equilibrium temperatures, and the flow in each reach. The equilibrium temperatures are estimated from air temperatures and measured temperatures above the Coleman powerhouse and at the mouth of Battle Creek. The summer equilibrium temperatures are assumed to be 75ºF in June, 80ºF in July and August, and 75ºF in September. The warming estimates described below have been calibrated using the measured warming in each reach. All the monthly flows used in the monthly modeling can be reviewed in Appendix J of this report, “Results from Monthly Flow and Power Generation Model.”

Effects of Flow on Temperature Warming

Warming in the summer months is assumed to be a direct function of flow. Higher flows limit warming. The greatest possible effect of increased flow is a direct inverse relationship with temperature:

Temperature Warming (˚F) = Constant / Flow (cfs)

If this relationship holds, then doubling the flow will reduce warming to 50%. Increasing the flow by a factor of 10 will reduce warming to 10%. This reduction is the greatest possible effect because higher flows would also increase the volume and surface area of the stream reach and allow more heat exchange and a slightly longer travel time in which warming would occur. This theoretical relationship assigns the greatest benefit to the first increment of flow. For example, increasing the South Fork Battle Creek flow from 5 to 10 cfs would reduce the warming to 50% of existing warming. Increasing the flow to 20 cfs would reduce the warming to 25% of existing warming. Increasing the flow to 40 cfs would reduce the warming to 12.5% of existing warming. If the existing warming were 10ºF in July and August, the increase from 5 cfs to 10 cfs would reduce the warming by 5ºF. The increase in flow from 10 cfs to 20 cfs would reduce the warming by an additional 2.5ºF. Increasing the flow from 20 cfs to 40 cfs would reduce the warming only by an additional 1.25ºF.

A smaller estimated change in warming with flow was used in the monthly warming estimates. The warming in each reach was assumed to be proportional to the square root of flow:

Warming (˚F) = Constant / Flow (cfs) $^{0.5}$

If this relationship holds, a four-fold increase in flow (from 5 cfs to 20 cfs) would be required to reduce warming to 50% of existing warming. An increase in flow from 5 cfs to 80 cfs (16-fold increase) would be required to reduce the warming to 25% of existing warming. This assumed relationship “evens out” the potential temperature benefits of each increment of increased flow, and requires a greater increase in flow to achieve the same reduction in warming as was yielded by the earlier-described function.

The warming estimate was also assumed to be a function of the difference between the equilibrium temperature and the temperature at the upstream end of the reach:

Warming (˚F) = Constant * (Equilibrium – Upstream T) / Flow (cfs) $^{0.5}$

The actual warming response may be smaller as the initial water temperature approaches the equilibrium temperature] , but this linear relationship is assumed adequate for the monthly temperature model needed for evaluating the restoration alternatives.

Measured Warming Relationships

The summary of the monthly average temperatures and average warming measured in each reach of Battle Creek during the 5 years for which data are available (Tables R-1 to R-5) have been used to estimate warming equations. For example, in 1989, the measured warming between North Battle Creek Feeder Dam and Eagle Canyon Diversion Dam was about 4˚F in July and August with a flow of 5 cfs. The assumed warming equation is:

$$\text{Feeder Warming (˚F)} = 0.3 * (\text{Equil T} - \text{Upstream T}) / \text{Flow (cfs)}^{0.5}$$

For July and August, with an equilibrium temperature of 80ºF and the Feeder Dam temperature of 57.5ºF, the warming at a flow of 5 cfs is 4˚F, and the warming with a flow of 20 cfs would be 2˚F. Unfortunately, the higher flows at Feeder Dam are not estimated from the water level (i.e., stage) records] (i.e., limited stage-discharge rating curve), so the validity of the warming relationship cannot be confirmed.

The 1989 warming in the Eagle reach was about 8˚F at a flow of 4 cfs. The assumed Eagle warming equation is:

$$\text{Eagle Warming (˚F)} = 0.5 * (\text{Equil T} - \text{Upstream T}) / \text{Flow (cfs)}^{0.5}$$

For July and August, with the Eagle temperature of about 60ºF, the warming at a flow of 5 cfs would be 4.5˚F, and the warming at a flow of 20 cfs would be 2.2˚F. Warming at a flow of 40 cfs would be 1.5˚F. The actual warming measured in 1999, 2000, and 2001, when the interim Eagle Canyon Diversion Dam flow was between about 33 cfs and 40 cfs, suggests that warming was between 1.5 and 2.5˚F. This is about the warming that would be expected using the assumed relationship, but more than would be expected if the alternative warming equation that is proportional to 1/flow was used.

The measured warming in the Wildcat reach was very small in 1989. The warming observed in the 1999–2001 period with interim flows of about 35–40 cfs was about 3–4˚F. The assumed warming equation for the Wildcat reach is:

$$\text{Wildcat Warming (˚F)} = 1.0 * (\text{Equil T} - \text{Upstream T}) / \text{Flow (cfs)}^{0.5}$$

This equation gives an estimated July and August warming of about 6.5ºF with a flow of 5 cfs, of 4ºF with a flow of 20 cfs, and of 3ºF with a flow of 40 cfs.

For the three South Fork Battle Creek reaches, similar warming equations were developed. The assumed South Diversion Dam temperatures are 5ºF warmer than the Feeder Dam temperatures. For the South reach in 1989, with a flow of 6 cfs, the warming in July and August was about 6ºF. The warming was about 4–5˚F with flows of 6–7 cfs in the 1999–2001 measurements. The assumed warming in the South reach is:

$$\text{South Warming (˚F)} = 0.75 * (\text{Equil T} - \text{Upstream T}) / \text{Flow (cfs)}^{0.5}$$

For July and August, the warming with a flow of 5 cfs would be 5.5ºF, the warming with a flow of 20 cfs would be 2.7ºF, and the warming with a flow of 40 cfs would be 2ºF.

For the Inskip reach, the measured warming in June and July 2000 and 2001 was about 10–14˚F with flows of about 8–10 cfs. During August 1999, warming was 10ºF with a flow of 7 cfs. The assumed warming in the Inskip reach is:

$$\text{Inskip Warming (˚F)} = 2.00 * (\text{Equil T} - \text{Upstream T}) / \text{Flow (cfs)}^{0.5}$$

The calculated warming would be 15.5ºF with a flow of 5 cfs, 11˚F with a flow of 10 cfs, 8˚F with a flow of 20 cfs, and 5ºF with a flow of 40 cfs.

The measured warming in the Coleman reach was about 3˚F when the interim flows were 33–36 cfs in 1998–2000. The warming was about 9–10˚F in July and August 2001, when the Coleman flows were reduced to 6 cfs to discourage fish from using South Fork Battle Creek. The assumed Coleman reach warming is:

$$\text{Coleman Warming (˚F)} = 1.5 * (\text{Equil T} - \text{Upstream T}) / \text{Flow (cfs)}^{0.5}$$

For July and August, with a Coleman Diversion Dam temperature of 62.5ºF, the warming would be 12ºF with a flow of 5 cfs, 8ºF with a flow of 10 cfs, 6ºF with a flow of 20 cfs, and 4ºF with a flow of 40 cfs.

The mainstem warming in 2001 with a flow of 42 cfs was 5–7˚F in July and August. During July and August 1999 and 2000, when the confluence flow was about 75 cfs, the measured warming was still 4–5˚F. The assumed mainstem warming between the confluence and upstream of the Coleman powerhouse is:

$$\text{Mainstem Warming (˚F)} = 2.5 * (\text{Equil T} - \text{Upstream T}) / \text{Flow (cfs)}^{0.5}$$

The estimated warming in July and August with a confluence temperature of 68ºF with a flow of 10 cfs would be 9.5˚F. The estimated warming with a flow of 40 cfs would be 4.5˚F, and the estimated warming with a flow of 80 cfs would be 3.5˚F. These estimates are slightly lower than the measured warming in 1999 and 2000, when the confluence flow was about 75 cfs.

The temperature-warming model used in the fish habitat assessment will generally calculate temperatures that are warmer than observed at higher flows. This discrepancy will lead to a conservative assessment of the temperature benefits of alternative restoration actions because the actual temperatures may be slightly lower than calculated.

Temperatures have not been measured at Keswick Dam, so the temperatures in the Keswick reach are assumed to be the same as measured at North Battle Creek Feeder Diversion-Dam. However, the temperatures at the North Battle Creek Feeder Diversion-Dam may be largely influenced by the Rock Creek and Bailey Creek flows that enter North Fork Battle Creek just upstream of the dam. Therefore, there may be substantial warming below Keswick Dam at the minimum required FERC flows of only 3 cfs. A temperature measurement location should be established upstream of the Rock Creek confluence to identify this possible warming condition in the Keswick reach with relatively low flows.

A similar situation may exist at the Eagle Canyon Diversion Dam, where temperature measurements may be influenced by the Digger Creek flows that enter North Fork Battle Creek just upstream of the dam. Temperature measurements at the mouth of Digger Creek in 2001 and 2002 were identical to the Eagle Canyon Diversion Dam measurements, with June and July temperatures of almost 60ºF. A temperature measurement location should be established upstream of Digger Creek to identify potential warming in the Feeder reach with relatively low flows.

Finally, an adaptive management experiment to measure temperatures while flows are varied from 5 to 10 to 20 to 40 cfs for about a week each during the July and August period would increase the accuracy of the South and Inskip warming estimates. These warming estimates should be replaced with a daily stream hydraulic and hourly water temperature model that can be used during the restoration period as part of the AMP to evaluate the temperature benefits and habitat conditions in each reach of Battle Creek.

Calculated Temperatures for 2000 and 2001

Measured water temperatures are shown for comparison with the temperature results from these warming equations for 2000 and 2001. Figure R-33 shows the North Fork Battle Creek temperatures calculated from these warming equations and historical water temperatures for 2000. Measured warming in the Feeder reach was about 2–3˚F. The calculated temperatures at Eagle Canyon Diversion Dam matched this warming. Measured warming in the Eagle reach was about 1–2˚F. The calculated temperatures at Wildcat Diversion Dam were about 1˚F lower than the historical record. Measured warming in the Wildcat reach was about 1–3˚F. The calculated temperatures at the mouth were about 1˚F higher than the historical record. Measured warming in the mainstem reach was about 3–5˚F during the summer months. The calculated warming in the mainstem reach was similar, although calculated temperatures at the Coleman powerhouse were higher than historical temperatures. Overall, the calculated temperatures provide a reasonable approximation of the measured data during the year.

Figure R-34 shows the South Fork Battle Creek temperatures calculated from these warming equations and historical water temperatures for 2000. Warming in the South reach was about 4˚F. The calculated temperatures at the South powerhouse matched this warming. Warming in the Inskip reach was about 8–12˚F. The calculated temperatures at the Inskip powerhouse matched this warming. The calculated temperatures in July, August, and September were higher than the historically recorded temperatures. Warming in the Coleman reach was about 1–3˚F because of the interim flow of 30 cfs. The calculated temperatures at the mouth were about 3˚F higher than the historical record. In general, however, the calculated South Fork Battle Creek temperatures matched the 2000 data.

Figure R-35 shows the North Fork Battle Creek calculated and historical water temperatures for 2001. Warming in the Feeder reach was about 2˚F. The calculated temperatures at Eagle Canyon Diversion Dam matched this warming in June and September, but showed about 1˚F more warming than the historical record in July and August. Warming in the Eagle reach was about 2˚F. The calculated temperatures at Wildcat Diversion Dam matched this warming in June, but were about 1˚F higher than the historical temperatures from July through September. Warming in the Wildcat reach was about 2–3˚F. The calculated temperatures at the mouth matched this warming in June and July, but were about 1˚F higher than the historical temperatures in August and September. The warming in the mainstem reach was about 3–6˚F. The calculated temperatures at the Coleman powerhouse were about 3–4˚F higher than the historical temperatures for June and July, and about 1˚F higher than the historical temperatures for August and September. Overall, the match between the calculated temperatures and the 2001 data was good.

Figure R-36 shows the South Fork Battle Creek calculated and historical water temperatures for 2001. Warming in the South reach was about 5˚F. The calculated temperatures at the South powerhouse matched the data for July and August, but were about 1˚F cooler than the historical temperatures in June and September. Warming in the Inskip reach was about 9–13˚F. The calculated temperatures at the Inskip powerhouse were about 1˚F lower than the historical temperatures in June and July, but matched the data in August and September. Warming in the Coleman reach was about 7–10˚F. The calculated temperatures at the mouth matched this warming, but were about 1˚F higher than the historical temperatures from July through September.

The releases below Coleman Diversion Dam were greater than 30 cfs in 2000 (interim flows) but were reduced to about 8 cfs in 2001. The warming estimates in 2000 were a little higher than the measured warming. The warming estimates in 2001, when the flows were reduced, were very close to measurements. The assumed warming relationship, with $1/\text{flow}^{0.5}$, may overestimate the actual warming at higher flows. These 2 years of monthly comparisons of the warming equations with temperature data suggest that the monthly temperature estimates are adequate for accurately assessing the temperature effects of flow changes in Battle Creek.

Calculating Monthly Temperature Survival

Many of the Battle Creek reaches have a wide range of temperatures: a relatively cool temperature at the upstream end and a warmer temperature at the downstream end. The monthly fish production model assumed a linear effect of temperature and calculated the survival at the cooler upstream end and the survival at the warmer downstream end. An average survival was used for fish in the reach.

Rather than comparing water temperature estimates for the different restoration alternatives directly, temperatures were factored into the fish production model, allowing a comparison of the likely effects on fish of the alternatives. Temperature change is not considered a significant impact itself unless potential fish production is reduced by warmer temperatures.

To estimate fish production without any temperature limits, the fish production model was run with all temperatures assumed to be ideal (below 53˚F). Comparing the change in fish production once temperatures are included in the calculations provides a direct indication of the magnitude of potential temperature effects under each alternative. The calculated reduction in fish production compared with ideal temperature conditions was quite large for several of the alternatives. Winter-run and spring-run Chinook salmon would be the most severely limited by temperatures.

Battle Creek Temperature Results

The monthly temperatures calculated for each restoration alternative for the full range of possible Battle Creek monthly flows in each reach are given in Tables R-8 through R-18. The percentage values refer to the monthly flow percentile at the Coleman gage. For a given alternative, the flows (and therefore temperatures) in a reach may not change as the percentile of monthly flow at Coleman increases, because the required flow is satisfied and the additional flow is diverted. The consequences of water temperatures for minimum instream flow requirements on fish populations are described in Section 4.1, “Fish,” of the EIS/EIR. A relatively large reduction (compared to existing, No Action conditions) in summer temperatures is simulated for each of the restoration alternatives. The actual releases of about 5 cfs on North Fork Battle Creek and 7 cfs on South Fork Battle Creek were used in these temperature calculations to represent existing conditions. The difference in temperatures with higher flows (i.e., Memorandum of Understanding [MOU] flows rather than AFRP flows) is not as great as the reduction achieved when comparing No Action flows to AFRP flows. The increase in South Fork Battle Creek temperatures assuming use of the South and Inskip connectors is properly included in these calculations.

References

CALFED. 2000. *Ecosystem restoration program plan.* Volumes 1–3 and maps. Technical appendix, final programmatic EIS/EIR for the CALFED Bay-Delta Program. July.

Kier Associates. 1999. *Battle Creek salmon and steelhead restoration plan.* Prepared for the Battle Creek Working Group. January.

McCullough, D. A. 1999. *A review and synthesis of effects of alterations to the water temperature regime on freshwater life stages of salmonids, with special reference to Chinook salmon.* July. (EPA 910-R-99-010.)

Pacific Gas and Electric Company. 2001. *Stream temperature model for the Battle Creek salmon and steelhead restoration project.* January 12.

Thomas R. Payne and Associates. 1996a. *Lower Battle Creek temperature model: Eagle Canyon and Coleman Diversions to Coleman powerhouse.* Sacramento, CA: U.S. Fish and Wildlife Service.

———. 1996b. *Upper Battle Creek stream temperature model: Al Smith Diversion to Eagle Canyon on North Fork Battle Creek, South Diversion to Inskip powerhouse on South Fork Battle Creek.* Redding, CA: California Department of Fish and Game.

———. 1998a. *A 1989 study of fish species abundance and distribution in Battle Creek: 1 of 8 components.* Draft. Prepared for California Department of Fish and Game.

———. 1998b. *A 1989 survey of barriers to the upstream migration of anadromous salmonids: 1 of 8 components.* Prepared for California Department of Fish and Game.

Table R-1a. North Fork Battle Creek Warming Estimates, 1989

	June	July	August	September
Flows (cfs)				
North Battle Creek Feeder	10+	5	5	4
Eagle Canyon	4	4	4	4
Wildcat	6	6	6	6
Temperatures (˚F)				
North Battle Creek-Feeder	56.1	56.6	55.3	53.5
Eagle Canyon	59.5	60.3	59.6	57.9
Wildcat	64.4	69.2	67.1	61.9
Mouth	64.2	68.7	67.1	62.6
ΔT				
North Battle Creek-Feeder–Eagle	3.4	3.7	4.3	4.4
Eagle–Wildcat	4.9	8.9	7.5	4.0
Wildcat–Mouth	-0.2	-0.5	0.0	0.7

Table R-1b. South Fork Battle Creek Warming Estimates, 1989

	June	July	August	September
Flows (cfs)				
South	6	6	6	6
Inskip	7	6	6	7
Coleman	8	7	7	7
Temperatures (˚F)				
South	58.5	58.9	57.2	54.4
Above South powerhouse	64.4	65.1	63.4	59.8
Inskip	--	--	--	--
Above Inskip powerhouse	63.4	72.1	69.4	63.4
Coleman	--	--	--	--
Mouth	64.2	65.1	59.9	60.0
ΔT				
South–above South powerhouse	5.9	6.2	6.2	5.4
Inskip–above Inskip powerhouse	--	--	--	--
Coleman–Mouth	--	--	--	--

Table R-2a. North Fork Battle Creek Warming Estimates, 1998

	June	July	August	September
Flows (cfs)				
North Battle Creek-Feeder	10+	10+	10+	10+
Eagle	10+	10+	10+	10+
Wildcat	30+	30+	30+	30+
Temperatures (˚F)				
North Battle Creek-Feeder	51.8	56.1	57.9	52.7
Eagle	52.8	57.2	58.0	56.3
Wildcat	--	58.5	59.3	57.7
Mouth	54.2	59.4	60.8	56.1
ΔT				
North Battle Creek Feeder–Eagle	1.0	1.1	0.1	3.6
Eagle–Wildcat	--	1.3	1.3	1.4
Wildcat–Mouth	--	0.9	1.5	-1.6

Table R-2b. South Fork Battle Creek Warming Estimates, 1998

	June	July	August	September
Flows (cfs)				
South	10+	10+	7	7
Inskip	30+	30+	35	25
Coleman	30+	30+	33	33
Temperatures (˚F)				
South	50.9	58.9	--	54.1
Above South powerhouse	--	--	--	--
Inskip	54.3	60.0	--	53.8
Above Inskip powerhouse	--	--	--	--
Coleman	55.4	60.3	60.8	55.0
Mouth	54.7	63.4	63.9	59.0
ΔT				
South–above South powerhouse	--	--	--	--
Inskip–above Inskip powerhouse	--	--	--	--
Coleman–Mouth	-0.7	3.1	3.1	4.0

Table R-3a. North Fork Battle Creek Warming Estimates, 1999

	June	July	August	September
Flows (cfs)				
North Battle Creek-Feeder	10+	10+	6	5
Eagle	35+	35	33	33
Wildcat	30+	40	36	36
Temperatures (˚F)				
North Battle Creek Feeder	54.1	56.8	56.0	54.6
Eagle	55.7	58.5	57.7	56.2
Wildcat	56.9	60.2	59.8	57.8
Mouth				
ΔT				
North Battle Creek-Feeder–Eagle	1.6	1.7	1.7	1.6
Eagle–Wildcat	1.2	1.7	2.1	1.6
Wildcat–Mouth	-2.2	3.2	4.1	1.2

Table R-3b. South Fork Battle Creek Warming Estimates, 1999

	June	July	August	September
Flows (cfs)				
South	30+	7	6	7
Inskip	49	22	14	11
Coleman	38	36	36	35
Temperatures (˚F)				
South	57.5	61.9	60.5	57.7
Above South powerhouse	60.6	66.3	64.7	61.5
Inskip	57.1	59.2	58.0	55.8
Above Inskip powerhouse	61.8	68.9	68.1	64.0
Coleman	58.6	60.7	59.5	57.2
Mouth	60.6	63.9	62.0	58.7
ΔT				
South–above South powerhouse	3.1	4.4	4.2	3.8
Inskip–above Inskip powerhouse	4.7	9.7	10.1	8.2
Coleman–Mouth	2.0	3.2	2.5	1.5

Table R-4a. North Fork Battle Creek Warming Estimates, 2000

	June	July	August	September
Flows (cfs)				
North Battle Creek Feeder	10+	5	5	5
Eagle	10	34	37	38
Wildcat	47	37	40	41
Temperatures (˚F)				
North Battle Creek Feeder	55.9	56.6	55.9	53.2
Eagle	--	59.6	58.6	55.6
Wildcat	59.2	61.5	60.0	56.4
Mouth	--	64.2	62.2	57.5
ΔT				
North Battle Creek Feeder–Eagle	--	3.0	2.7	2.4
Eagle–Wildcat	--	1.9	1.4	0.8
Wildcat–Mouth	--	2.7	2.2	1.1

Table R-4b. South Fork Battle Creek Warming Estimates, 2000

	June	July	August	September
Flows (cfs)				
South	7	6	7	6
Inskip	32	10	8	8
Coleman	40+	39	33	33
Temperatures (˚F)				
South	61.2	62.1	61.2	55.7
Above South powerhouse	65.3	66.6	65.5	59.6
Inskip	59.1	59.1	58.4	53.6
Above Inskip powerhouse	66.9	70.9	70.1	61.8
Coleman	60.9	61.1	60.5	55.5
Mouth	62.1	63.3	63.3	57.5
ΔT				
South–above South powerhouse	4.1	4.5	4.3	3.9
Inskip–above Inskip powerhouse	7.8	11.8	11.7	8.2
Coleman–Mouth	1.2	2.2	2.8	2.0

Table R-5a. North Fork Battle Creek Warming Estimates, 2001

	June	July	August	September
Flows (cfs)				
North Battle Creek-Feeder	5	5	5	5
Eagle	34	33	33	33
Wildcat	37	36	36	36
Temperatures (˚F)				
North Battle Creek-Feeder	55.6	56.7	56.1	54.6
Eagle	58.1	59.2	58.6	56.9
Wildcat	60.1	61.8	60.9	58.6
Mouth	62.7	64.8	63.6	60.4
ΔT				
North Battle Creek Feeder–Eagle	2.5	2.5	2.5	2.3
Eagle–Wildcat	2.0	2.6	2.3	1.7
Wildcat–Mouth	2.6	3.0	2.7	1.8

Table R-5b. South Fork Battle Creek Warming Estimates, 2001

	June	July	August	September
Flows (cfs)				
South	6	6	6	6
Inskip	8	8	9	9
Coleman	6	6	6	6
Temperatures (˚F)				
South	59.6	61.7	60.2	56.8
Above South powerhouse	64.9	67.0	65.4	61.7
Inskip	58.0	60.0	59.0	56.5
Above Inskip powerhouse	69.7	73.6	71.2	65.3
Coleman	59.6	62.0	61.3	57.6
Mouth	68.8	72.0	69.9	64.9
ΔT				
South–above South powerhouse	5.3	5.3	5.2	4.9
Inskip–above Inskip powerhouse	11.7	13.6	12.2	8.8
Coleman–Mouth	9.2	10.0	8.6	7.3

Table R-6. Selected Feeder Dam and South Diversion Dam Temperatures for PG&E SNTEMP Modeling

Dam and Meteorology	June	July	August	September
Feeder-cool	54	55	54	52
South-cool	50	57	57	53
Feeder-normal	56	57	55	53
South-normal	56	60	58	55
Feeder-warm	56	58	57	54
South-warm	60	62	60	58

Table R-7. SNTEMP Simulated Average Temperatures and Warming in South Fork Battle Creek for a Range of Hypothetical Flows under July 1989 South Diversion Dam Temperatures and Meteorology

	Temp (ºC)	Temp (ºF)	Warming (ºF)
South Diversion Dam data	15.0	58.9	
South powerhouse data (7 cfs)	18.4	65.1	6.2
SNTEMP 5 cfs	18.6	65.5	6.6
SNTEMP 10 cfs	18.5	65.3	6.4
SNTEMP 20 cfs	18.1	64.6	5.7
SNTEMP 40 cfs	17.5	63.5	4.6
Inskip Diversion Dam data	14.5	58.0	
Inskip powerhouse data (7 cfs)	22.3	72.1	14.1
SNTEMP 5 cfs	22.1	71.7	13.7
SNTEMP 10 cfs	22.0	71.5	13.3
SNTEMP 20 cfs	20.7	69.2	11.2
SNTEMP 40 cfs	18.9	66.1	8.1
SNTEMP 80 cfs	17.4	63.3	5.3

Table R-8. Calculated Battle Creek Temperatures (^{o}F) for All of the Alternatives at Eagle Canyon Diversion Dam

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Assumed Temperatures at North Fork Feeder												
	45.0	45.0	47.5	52.5	55.0	56.0	57.5	57.5	55.0	52.5	50.0	45.0
No Action Alternative												
10%	45.9	45.9	48.8	54.7	57.6	59.3	61.4	61.4	58.5	54.7	50.9	45.9
30%	45.9	45.9	48.8	54.7	57.6	59.3	61.4	61.4	58.5	54.7	50.9	45.9
50%	45.9	45.9	48.8	54.0	57.6	59.3	61.4	61.4	58.5	54.7	50.9	45.9
70%	45.9	45.4	47.9	53.1	55.6	59.3	61.4	61.4	58.5	54.7	50.9	45.9
90%	45.3	45.2	47.7	52.9	55.5	57.0	61.4	61.4	58.5	54.7	50.9	45.9
Five Dam Removal Alternative												
10%	45.3	45.3	47.9	53.1	55.8	57.2	59.1	59.2	56.5	53.4	50.3	45.3
30%	45.3	45.3	47.9	53.1	55.7	57.0	59.0	59.0	56.4	53.3	50.3	45.3
50%	45.2	45.2	47.8	53.0	55.7	56.9	58.8	58.9	56.3	53.3	50.3	45.3
70%	45.2	45.2	47.8	53.0	55.6	56.8	58.7	58.8	56.2	53.2	50.3	45.2
90%	45.2	45.2	47.7	52.9	55.5	56.8	58.6	58.7	56.1	53.1	50.2	45.2
No Dam Removal Alternative												
10%	45.3	45.3	47.9	53.1	55.8	57.2	59.1	59.2	56.5	53.4	50.3	45.3
30%	45.3	45.3	47.9	53.1	55.8	57.0	59.0	59.0	56.4	53.3	50.3	45.3
50%	45.2	45.2	47.9	53.1	55.8	57.0	58.8	58.9	56.3	53.3	50.3	45.3
70%	45.2	45.2	47.9	53.1	55.6	57.0	58.7	58.8	56.2	53.2	50.3	45.2
90%	45.2	45.2	47.7	52.9	55.5	57.0	58.7	58.7	56.1	53.1	50.2	45.2
Three Dam Removal Alternative												
10%	45.3	45.3	47.9	53.1	55.8	57.2	59.1	59.2	56.5	53.4	50.3	45.3
30%	45.3	45.3	47.9	53.1	55.8	57.0	59.0	59.0	56.4	53.3	50.3	45.3
50%	45.2	45.2	47.9	53.1	55.8	57.0	58.8	58.9	56.3	53.3	50.3	45.3
70%	45.2	45.2	47.9	53.1	55.6	57.0	58.7	58.8	56.2	53.2	50.3	45.2
90%	45.2	45.2	47.7	52.9	55.5	57.0	58.7	58.7	56.1	53.1	50.2	45.2
Six Dam Removal Alternative												
10%	45.3	45.3	47.9	53.1	55.8	57.2	59.1	59.2	56.5	53.4	50.3	45.3
30%	45.3	45.3	47.9	53.1	55.7	57.0	59.0	59.0	56.4	53.3	50.3	45.3
50%	45.2	45.2	47.8	53.0	55.7	56.9	58.8	58.9	56.3	53.3	50.3	45.3
70%	45.2	45.2	47.8	53.0	55.6	56.8	58.7	58.8	56.2	53.2	50.3	45.2
90%	45.2	45.2	47.7	52.9	55.5	56.8	58.6	58.7	56.1	53.1	50.2	45.2

Table R-9. Calculated Battle Creek Temperatures (^oF) for All of the Alternatives at Wildcat Diversion Dam

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No Action Alternative												
10%	47.1	47.1	50.6	57.6	61.2	63.8	66.8	66.8	63.2	57.6	52.1	47.1
30%	47.1	47.1	50.6	57.6	61.2	63.8	66.8	66.8	63.2	57.6	52.1	47.1
50%	47.1	47.1	50.6	57.2	61.2	63.8	66.8	66.8	63.2	57.6	52.1	47.1
70%	47.1	46.0	48.7	54.0	56.4	63.8	66.8	66.8	63.2	57.6	52.1	47.1
90%	45.8	45.5	48.1	53.4	56.1	58.7	66.8	66.8	63.2	57.6	52.1	47.1
Five Dam Removal Alternative												
10%	45.6	45.6	48.4	54.0	57.0	58.7	60.9	61.0	58.2	54.4	50.7	45.7
30%	45.6	45.6	48.4	53.9	56.9	58.6	60.7	60.8	58.0	54.3	50.7	45.6
50%	45.6	45.6	48.4	53.9	56.8	58.5	60.6	60.7	57.8	54.2	50.7	45.6
70%	45.6	45.5	48.3	53.7	56.4	58.3	60.5	60.6	57.8	54.2	50.7	45.6
90%	45.5	45.4	48.1	53.4	56.1	58.1	60.4	60.5	57.7	54.1	50.6	45.6
No Dam Removal Alternative												
10%	45.6	45.6	48.4	54.0	57.1	58.8	61.0	61.1	58.2	54.4	50.8	45.6
30%	45.6	45.6	48.4	53.9	57.1	58.7	60.9	60.9	58.1	54.4	50.7	45.6
50%	45.6	45.6	48.4	53.9	57.1	58.7	60.8	60.8	58.0	54.3	50.7	45.6
70%	45.6	45.6	48.4	53.9	56.4	58.7	60.7	60.7	57.9	54.3	50.7	45.6
90%	45.6	45.5	48.1	53.4	56.1	58.7	60.7	60.7	57.8	54.2	50.7	45.6
Three Dam Removal Alternative												
10%	45.6	45.6	48.4	53.9	56.7	58.5	60.9	61.0	58.2	54.3	50.7	45.6
30%	45.6	45.5	48.3	53.7	56.7	58.2	60.5	60.7	57.9	54.2	50.6	45.6
50%	45.5	45.5	48.2	53.7	56.6	58.1	60.3	60.4	57.6	54.1	50.6	45.6
70%	45.5	45.5	48.2	53.7	56.2	58.0	60.0	60.2	57.4	54.0	50.6	45.5
90%	45.5	45.4	48.0	53.3	56.0	58.0	60.0	60.0	57.2	53.8	50.5	45.5
Six Dam Removal Alternative												
10%	45.6	45.6	48.4	53.9	56.7	58.5	60.9	61.0	58.2	54.3	50.7	45.6
30%	45.6	45.5	48.3	53.7	56.5	58.2	60.5	60.7	57.9	54.2	50.6	45.6
50%	45.5	45.5	48.2	53.6	56.4	58.0	60.3	60.4	57.6	54.1	50.6	45.6
70%	45.5	45.4	48.1	53.5	56.2	57.7	60.0	60.2	57.4	54.0	50.6	45.5
90%	45.4	45.4	48.0	53.3	56.0	57.7	59.7	60.0	57.2	53.8	50.5	45.5

Table R-10. Calculated Battle Creek Temperatures (°F) for All of the Alternatives in North Fork Battle Creek at the Confluence

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No Action Alternative												
10%	48.8	48.8	53.1	61.6	66.3	70.3	74.4	74.4	70.0	61.9	53.8	48.8
30%	48.8	48.7	52.6	60.6	65.0	70.3	74.4	74.4	70.0	61.9	53.8	48.8
50%	48.5	48.3	52.2	59.8	64.3	69.3	74.4	74.4	70.0	61.9	53.8	48.8
70%	48.2	46.8	49.8	55.5	57.8	67.7	74.1	74.4	70.0	61.9	53.8	48.5
90%	46.5	46.0	48.8	54.4	57.3	61.3	72.6	74.1	70.0	61.5	53.4	48.2
Five Dam Removal Alternative												
10%	46.2	46.2	49.3	55.4	58.8	61.0	63.6	63.8	60.7	55.9	51.3	46.2
30%	46.2	46.2	49.2	55.3	58.7	60.8	63.5	63.5	60.4	55.8	51.3	46.2
50%	46.1	46.1	49.2	55.2	58.6	60.7	63.3	63.4	60.3	55.8	51.3	46.2
70%	46.1	46.0	49.0	54.8	57.7	60.5	63.1	63.3	60.2	55.7	51.3	46.1
90%	46.0	45.8	48.7	54.3	57.2	60.1	63.0	63.1	60.0	55.6	51.2	46.1
No Dam Removal Alternative												
10%	46.3	46.2	49.3	55.5	59.5	61.8	64.5	64.6	61.3	56.4	51.5	46.3
30%	46.2	46.2	49.3	55.5	59.4	61.7	64.4	64.4	61.2	56.3	51.5	46.2
50%	46.2	46.2	49.3	55.4	59.3	61.6	64.3	64.3	61.1	56.3	51.5	46.2
70%	46.2	46.2	49.2	55.4	57.8	61.4	64.2	64.2	61.0	56.2	51.5	46.2
90%	46.2	46.0	48.8	54.4	57.3	61.3	64.1	64.2	60.9	56.2	51.4	46.2
Three Dam Removal Alternative												
10%	46.2	46.1	49.1	55.0	58.2	60.6	63.5	63.8	60.7	55.8	51.2	46.2
30%	46.1	46.0	48.9	54.8	58.0	60.1	63.0	63.3	60.2	55.5	51.2	46.1
50%	46.0	45.9	48.9	54.7	57.9	59.9	62.6	62.8	59.8	55.4	51.1	46.0
70%	45.9	45.9	48.8	54.6	57.2	59.7	62.2	62.5	59.5	55.3	51.0	46.0
90%	45.9	45.8	48.5	54.1	56.9	59.5	62.1	62.2	59.2	55.0	51.0	45.9
Six Dam Removal Alternative												
10%	46.2	46.1	49.1	55.0	58.1	60.6	63.5	63.8	60.7	55.8	51.2	46.2
30%	46.1	46.0	48.9	54.8	57.8	60.1	63.0	63.3	60.2	55.5	51.2	46.1
50%	46.0	45.9	48.8	54.6	57.6	59.7	62.6	62.8	59.8	55.4	51.1	46.0
70%	45.9	45.8	48.7	54.4	57.2	59.3	62.1	62.5	59.5	55.3	51.0	46.0
90%	45.8	45.7	48.5	54.1	56.9	59.2	61.7	62.1	59.2	55.0	51.0	45.9

Table R-11. Calculated Battle Creek Temperatures (°F) for All of the Alternatives above South Powerhouse

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Assumed Temperatures at South Diversion Dam												
	45.0	45.0	47.5	50.0	55.0	60.0	62.5	62.5	60.0	55.0	50.0	45.0
No Action Alternative												
10%	46.7	46.7	50.0	55.0	60.0	65.0	68.4	68.4	65.0	58.4	51.7	46.7
30%	46.7	46.7	50.0	55.0	60.0	65.0	68.4	68.4	65.0	58.4	51.7	46.7
50%	46.7	46.7	50.0	52.8	60.0	65.0	68.4	68.4	65.0	58.4	51.7	46.7
70%	46.7	45.8	48.6	51.9	56.6	63.8	68.4	68.4	65.0	58.4	51.7	46.7
90%	45.7	45.6	48.3	51.4	56.4	62.1	68.4	68.4	65.0	58.4	51.7	46.7
Five Dam Removal Alternative												
10%	45.6	45.6	48.4	51.6	56.7	62.1	65.3	65.5	62.6	56.6	50.7	45.7
30%	45.6	45.6	48.3	51.4	56.5	61.8	65.0	65.1	62.3	56.4	50.7	45.6
50%	45.5	45.5	48.2	51.3	56.3	61.6	64.7	64.8	62.0	56.3	50.6	45.6
70%	45.5	45.4	48.1	51.1	56.1	61.3	64.4	64.6	61.9	56.2	50.6	45.5
90%	45.4	45.4	48.0	51.0	56.0	61.2	64.2	64.4	61.7	56.1	50.5	45.5
No Dam Removal Alternative												
10%	45.7	45.7	48.5	52.1	57.5	62.5	65.4	65.5	62.6	56.7	50.8	45.7
30%	45.7	45.7	48.5	52.1	57.5	62.5	65.4	65.4	62.5	56.7	50.8	45.7
50%	45.7	45.7	48.5	52.1	57.5	62.5	65.4	65.4	62.5	56.7	50.8	45.7
70%	45.7	45.7	48.5	52.1	56.7	62.5	65.4	65.4	62.5	56.7	50.8	45.7
90%	45.7	45.6	48.3	51.5	56.5	62.3	65.4	65.4	62.5	56.7	50.8	45.7
Three Dam Removal Alternative												
10%	45.7	45.7	48.5	52.1	57.5	62.5	65.4	65.5	62.6	56.7	50.8	45.7
30%	45.7	45.7	48.5	52.1	57.5	62.5	65.4	65.4	62.5	56.7	50.8	45.7
50%	45.7	45.7	48.5	52.1	57.5	62.5	65.4	65.4	62.5	56.7	50.8	45.7
70%	45.7	45.7	48.5	52.1	56.7	62.5	65.4	65.4	62.5	56.7	50.8	45.7
90%	45.7	45.6	48.3	51.5	56.5	62.3	65.4	65.4	62.5	56.7	50.8	45.7
Six Dam Removal Alternative												
10%	45.6	45.6	48.4	51.6	56.7	62.1	65.3	65.5	62.6	56.6	50.7	45.7
30%	45.6	45.6	48.3	51.4	56.5	61.8	65.0	65.1	62.3	56.4	50.7	45.6
50%	45.5	45.5	48.2	51.3	56.3	61.6	64.7	64.8	62.0	56.3	50.6	45.6
70%	45.5	45.4	48.1	51.1	56.1	61.3	64.4	64.6	61.9	56.2	50.6	45.5
90%	45.4	45.4	48.0	51.0	56.0	61.2	64.2	64.4	61.7	56.1	50.5	45.5

Table R-12. Calculated Battle Creek Temperatures (°F) for All of the Alternatives at Inskip Diversion Dam

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No Action Alternative												
10%	46.0	46.0	48.3	52.7	56.3	59.0	60.9	60.8	58.2	54.6	50.9	46.0
30%	45.9	45.9	48.3	52.7	56.4	59.1	61.1	61.0	58.4	54.7	50.9	45.9
50%	45.8	45.8	48.2	52.5	56.4	59.2	61.3	61.2	58.5	54.7	50.9	45.9
70%	45.8	45.7	48.1	52.4	56.2	59.2	61.4	61.3	58.5	54.7	50.9	45.8
90%	45.6	45.6	48.1	52.1	56.1	59.2	61.5	61.4	58.6	54.8	50.9	45.8
Five Dam Removal Alternative												
10%	45.6	45.6	48.4	51.6	56.7	62.1	65.3	65.5	62.6	56.6	50.7	45.7
30%	45.6	45.6	48.3	51.4	56.5	61.8	65.0	65.1	62.3	56.4	50.7	45.6
50%	45.5	45.5	48.2	51.3	56.3	61.6	64.7	64.8	62.0	56.3	50.6	45.6
70%	45.5	45.4	48.1	51.1	56.1	61.3	64.4	64.6	61.9	56.2	50.6	45.5
90%	45.4	45.4	48.0	51.0	56.0	61.2	64.2	64.4	61.7	56.1	50.5	45.5
No Dam Removal Alternative												
10%	45.8	45.8	48.3	52.4	56.4	59.7	62.0	62.0	59.3	55.0	50.8	45.8
30%	45.7	45.7	48.2	52.4	56.4	59.7	62.0	62.0	59.3	55.0	50.8	45.8
50%	45.7	45.6	48.1	52.4	56.4	59.6	62.0	62.0	59.2	55.0	50.8	45.7
70%	45.6	45.6	48.1	52.4	56.3	59.5	62.0	62.0	59.2	55.0	50.8	45.7
90%	45.6	45.5	48.1	52.2	56.2	59.4	61.9	62.0	59.2	55.0	50.8	45.6
Three Dam Removal Alternative												
10%	45.7	45.7	48.5	52.1	57.5	62.5	65.4	65.5	62.6	56.7	50.8	45.7
30%	45.7	45.7	48.5	52.1	57.5	62.5	65.4	65.4	62.5	56.7	50.8	45.7
50%	45.7	45.7	48.5	52.1	57.5	62.5	65.4	65.4	62.5	56.7	50.8	45.7
70%	45.7	45.7	48.5	52.1	56.7	62.5	65.4	65.4	62.5	56.7	50.8	45.7
90%	45.7	45.6	48.3	51.5	56.5	62.2	65.4	65.4	62.5	56.7	50.8	45.7
Six Dam Removal Alternative												
10%	45.6	45.6	48.4	51.6	56.7	62.1	65.3	65.5	62.6	56.6	50.7	45.7
30%	45.6	45.6	48.3	51.4	56.5	61.8	65.0	65.1	62.3	56.4	50.7	45.6
50%	45.5	45.5	48.2	51.3	56.3	61.6	64.7	64.8	62.0	56.3	50.6	45.6
70%	45.5	45.4	48.1	51.1	56.1	61.3	64.4	64.6	61.9	56.2	50.6	45.5
90%	45.4	45.4	48.0	51.0	56.0	61.2	64.2	64.4	61.7	56.1	50.5	45.5

Table R-13. Calculated Battle Creek Temperatures (^oF) for All of the Alternatives above Inskip Powerhouse

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No Action Alternative												
10%	49.6	49.6	54.3	63.7	68.6	73.3	78.0	78.0	73.2	63.9	54.6	49.6
30%	49.6	49.6	54.3	63.7	68.6	73.3	78.0	78.0	73.2	63.9	54.6	49.6
50%	49.6	49.6	51.7	56.2	61.5	73.3	78.0	78.0	73.3	63.9	54.6	49.6
70%	49.6	46.8	49.9	55.3	59.1	64.6	78.0	78.0	73.3	63.9	54.6	49.6
90%	46.8	46.6	49.5	54.6	58.8	63.1	78.0	78.0	73.3	63.9	54.6	48.8
Five Dam Removal Alternative												
10%	46.8	46.8	50.0	55.1	60.9	66.2	70.0	70.4	66.9	59.2	52.1	46.9
30%	46.7	46.6	49.7	54.9	60.8	66.0	69.7	69.8	66.3	59.1	52.0	46.8
50%	46.5	46.5	49.6	54.8	60.6	65.8	69.6	69.6	66.1	59.1	52.0	46.7
70%	46.5	46.4	49.6	54.7	59.1	65.6	69.4	69.5	66.0	59.0	52.0	46.5
90%	46.4	46.4	49.5	53.7	58.7	65.4	69.2	69.4	65.9	58.9	51.9	46.4
No Dam Removal Alternative												
10%	47.1	47.1	50.4	56.4	61.4	65.3	68.6	68.6	65.0	58.7	52.3	47.1
30%	47.1	47.1	50.3	56.4	61.4	65.3	68.6	68.6	65.0	58.7	52.3	47.1
50%	47.0	47.0	50.3	56.4	61.3	65.2	68.6	68.6	65.0	58.7	52.3	47.1
70%	47.0	47.0	50.2	55.4	59.1	65.1	68.6	68.6	65.0	58.7	52.3	47.0
90%	47.0	46.5	49.4	54.5	58.8	63.1	68.5	68.6	65.0	58.7	52.3	47.0
Three Dam Removal Alternative												
10%	47.0	47.0	50.6	56.1	62.1	67.1	70.8	70.8	67.2	59.7	52.4	47.0
30%	47.0	47.0	50.6	56.1	62.1	67.1	70.8	70.8	67.1	59.7	52.4	47.0
50%	47.0	47.0	50.6	56.1	62.1	67.1	70.8	70.8	67.1	59.7	52.4	47.0
70%	47.0	47.0	50.5	55.2	59.6	67.1	70.8	70.8	67.1	59.7	52.4	47.0
90%	47.0	46.6	49.7	54.1	59.1	65.5	70.8	70.8	67.1	59.7	52.4	47.0
Six Dam Removal Alternative												
10%	46.8	46.8	50.0	55.1	60.9	66.2	70.0	70.4	66.9	59.2	52.1	46.9
30%	46.7	46.6	49.7	54.9	60.8	66.0	69.7	69.8	66.3	59.1	52.0	46.8
50%	46.5	46.5	49.6	54.8	60.6	65.8	69.6	69.6	66.1	59.1	52.0	46.7
70%	46.5	46.4	49.6	54.7	59.1	65.6	69.4	69.5	66.0	59.0	52.0	46.5
90%	46.4	46.4	49.5	53.7	58.7	65.4	69.2	69.4	65.9	58.9	51.9	46.4

Table R-14. Calculated Battle Creek Temperatures (^{o}F) for All of the Alternatives at Coleman Diversion Dam

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No Action Alternative												
10%	45.5	45.7	48.6	54.4	58.5	61.0	63.1	62.7	59.2	55.1	50.6	45.5
30%	45.7	45.9	48.8	54.7	58.8	61.7	63.9	63.5	60.0	55.6	50.9	45.7
50%	45.8	46.1	48.7	53.9	58.3	62.0	64.4	64.2	60.6	55.8	51.0	45.8
70%	45.9	45.8	48.4	53.6	57.6	61.4	64.9	64.5	60.9	56.1	51.3	46.0
90%	45.7	45.7	48.4	53.4	57.6	61.0	65.2	64.9	61.3	56.4	51.5	46.0
Five Dam Removal Alternative												
10%	46.8	46.8	50.0	55.1	60.9	66.2	70.0	70.4	66.9	59.2	52.1	46.9
30%	46.7	46.6	49.7	54.9	60.8	66.0	69.7	69.8	66.3	59.1	52.0	46.8
50%	46.5	46.5	49.6	54.8	60.6	65.8	69.6	69.6	66.1	59.1	52.0	46.7
70%	46.5	46.4	49.6	54.7	59.1	65.6	69.4	69.5	66.0	59.0	52.0	46.5
90%	46.4	46.4	49.5	53.7	58.7	65.4	69.2	69.4	65.9	58.9	51.9	46.4
No Dam Removal Alternative												
10%	42.7	43.0	46.2	51.6	55.8	57.6	59.4	59.0	55.8	51.6	47.3	42.3
30%	43.5	43.9	47.0	52.3	56.5	58.8	60.1	59.8	56.6	52.3	48.2	43.2
50%	44.1	44.5	47.4	52.7	57.0	59.5	61.1	60.6	57.3	52.9	48.6	43.7
70%	44.5	45.0	47.7	52.9	57.0	60.3	62.0	61.3	57.9	53.5	49.3	44.2
90%	45.0	45.1	47.8	52.8	57.0	60.3	62.6	62.0	58.6	54.2	49.8	44.7
Three Dam Removal Alternative												
10%	47.0	47.0	50.6	56.1	62.1	67.1	70.8	70.8	67.2	59.7	52.4	47.0
30%	47.0	47.0	50.6	56.1	62.1	67.1	70.8	70.8	67.1	59.7	52.4	47.0
50%	47.0	47.0	50.6	56.1	62.1	67.1	70.8	70.8	67.1	59.7	52.4	47.0
70%	47.0	47.0	50.5	55.2	59.6	67.1	70.8	70.8	67.1	59.7	52.4	47.0
90%	47.0	46.6	49.7	54.1	59.1	65.5	70.8	70.8	67.1	59.7	52.4	47.0
Six Dam Removal Alternative												
10%	46.8	46.8	50.0	55.1	60.9	66.2	70.0	70.4	66.9	59.2	52.1	46.9
30%	46.7	46.6	49.7	54.9	60.8	66.0	69.7	69.8	66.3	59.1	52.0	46.8
50%	46.5	46.5	49.6	54.8	60.6	65.8	69.6	69.6	66.1	59.1	52.0	46.7
70%	46.5	46.4	49.6	54.7	59.1	65.6	69.4	69.5	66.0	59.0	52.0	46.5
90%	46.4	46.4	49.5	53.7	58.7	65.4	69.2	69.4	65.9	58.9	51.9	46.4

Table R-15. Calculated Battle Creek Temperatures (^{o}F) for All of the Alternatives in South Fork Battle Creek at Confluence

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No Action Alternative												
10%	49.0	49.1	53.6	62.7	67.5	72.0	76.3	76.2	71.6	62.8	54.0	49.0
30%	49.1	49.1	53.7	62.8	67.6	72.1	76.5	76.4	71.7	63.0	54.1	49.1
50%	49.1	49.1	52.3	56.5	62.0	72.2	76.6	76.6	71.9	63.0	54.1	49.1
70%	49.1	46.6	49.7	55.6	59.6	65.3	76.7	76.6	71.9	63.1	54.2	49.1
90%	46.7	46.4	49.4	55.0	59.3	63.6	76.8	76.7	72.0	63.1	54.2	49.1
Five Dam Removal Alternative												
10%	47.5	47.4	50.9	56.8	62.7	68.1	72.3	72.7	68.9	60.5	52.7	47.5
30%	47.3	47.2	50.5	56.6	62.5	67.8	72.0	72.1	68.3	60.4	52.7	47.4
50%	47.1	47.0	50.4	56.4	62.3	67.6	71.8	71.9	68.1	60.3	52.6	47.2
70%	47.0	46.9	50.4	56.3	60.6	67.3	71.5	71.7	67.9	60.2	52.6	47.1
90%	47.0	46.9	50.2	55.1	60.1	67.0	71.3	71.5	67.7	60.1	52.5	47.0
No Dam Removal Alternative												
10%	44.5	44.7	48.4	54.9	60.4	63.1	66.0	65.7	60.5	54.9	49.2	44.2
30%	45.1	45.4	49.0	55.4	60.8	64.0	66.5	66.2	61.1	55.5	49.9	44.9
50%	45.6	45.9	49.3	55.8	61.1	64.5	67.1	66.8	61.7	55.9	50.2	45.2
70%	45.8	46.2	49.5	55.2	59.1	65.0	67.8	67.3	62.2	56.3	50.7	45.6
90%	46.2	45.9	48.9	54.5	58.8	63.2	68.2	67.8	62.7	56.8	51.1	46.0
Three Dam Removal Alternative												
10%	47.8	47.8	51.6	58.2	64.1	69.4	73.6	73.7	69.7	61.3	53.2	47.8
30%	47.8	47.7	51.6	58.0	64.0	69.2	73.5	73.6	69.5	61.3	53.1	47.8
50%	47.7	47.7	51.5	57.9	63.8	69.1	73.4	73.4	69.4	61.2	53.1	47.8
70%	47.7	47.6	51.4	56.8	61.2	68.8	73.1	73.3	69.3	61.2	53.0	47.7
90%	47.7	47.1	50.4	55.6	60.6	67.1	73.0	73.1	69.2	61.1	53.0	47.7
Six Dam Removal Alternative												
10%	47.5	47.4	50.9	56.8	62.7	68.1	72.3	72.7	68.9	60.5	52.7	47.5
30%	47.3	47.2	50.5	56.6	62.5	67.8	72.0	72.1	68.3	60.4	52.7	47.4
50%	47.1	47.0	50.4	56.4	62.3	67.6	71.8	71.9	68.1	60.3	52.6	47.2
70%	47.0	46.9	50.4	56.3	60.6	67.3	71.5	71.7	67.9	60.2	52.6	47.1
90%	47.0	46.9	50.2	55.1	60.2	67.0	71.3	71.5	67.7	60.1	52.5	47.0

Table R-16. Calculated Battle Creek Temperatures (^{o}F) for All of the Alternatives below Confluence

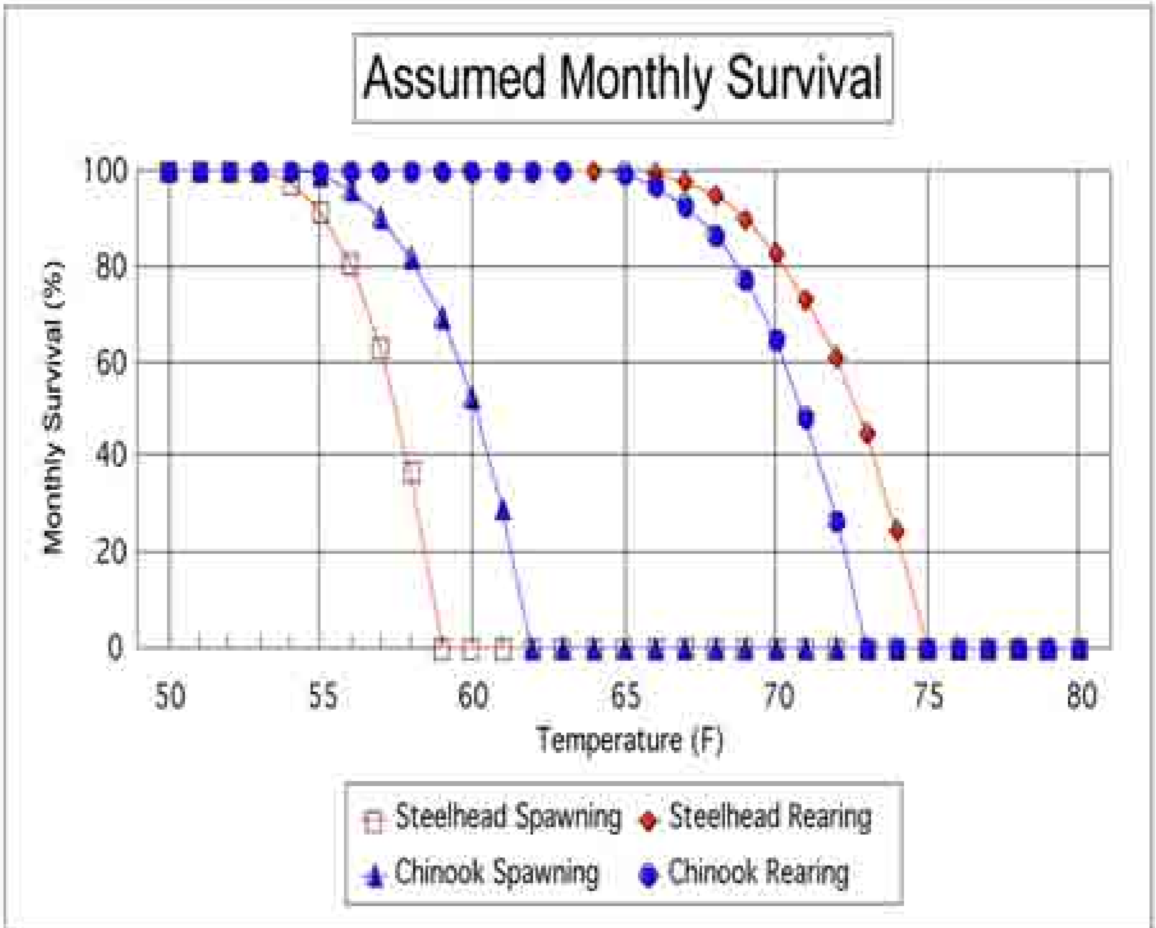
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No Action Alternative												
10%	48.9	48.9	53.4	62.3	67.0	71.3	75.6	75.6	71.0	62.5	53.9	48.9
30%	48.9	48.9	53.1	61.6	66.2	71.4	75.7	75.7	71.1	62.6	54.0	49.0
50%	48.8	48.7	52.3	57.0	62.5	70.9	75.8	75.7	71.2	62.6	54.0	49.0
70%	48.6	46.7	49.7	55.6	58.8	65.8	75.7	75.8	71.2	62.6	54.0	48.8
90%	46.6	46.3	49.1	54.7	58.4	62.9	74.6	75.7	71.3	62.5	53.8	48.6
Five Dam Removal Alternative												
10%	46.9	46.9	50.2	56.3	61.1	65.0	68.4	68.5	65.0	58.4	52.1	46.9
30%	46.8	46.8	50.1	56.1	61.0	64.9	68.2	68.3	64.7	58.4	52.1	46.9
50%	46.7	46.7	50.0	56.0	60.9	64.8	68.1	68.2	64.7	58.4	52.1	46.8
70%	46.7	46.6	49.9	55.7	59.5	64.6	68.1	68.1	64.6	58.3	52.0	46.8
90%	46.6	46.4	49.5	54.8	58.9	64.2	68.0	68.1	64.6	58.3	52.0	46.7
No Dam Removal Alternative												
10%	45.4	45.5	48.9	55.2	59.9	62.5	65.2	65.1	60.8	55.5	50.1	45.2
30%	45.7	45.8	49.1	55.5	60.1	62.8	65.4	65.3	61.1	55.8	50.5	45.6
50%	45.9	46.0	49.3	55.6	60.1	63.0	65.7	65.6	61.4	56.0	50.7	45.7
70%	46.0	46.2	49.4	55.3	58.6	63.1	66.0	65.8	61.7	56.3	51.0	45.9
90%	46.2	46.0	48.8	54.5	58.1	62.6	66.0	66.0	62.0	56.6	51.2	46.1
Three Dam Removal Alternative												
10%	46.8	46.8	50.1	56.3	60.3	63.8	67.4	67.7	64.3	57.9	51.9	46.9
30%	46.7	46.7	49.9	56.1	60.2	63.3	66.8	67.1	63.7	57.6	51.9	46.8
50%	46.6	46.6	49.9	56.0	60.1	63.2	66.4	66.6	63.2	57.5	51.8	46.7
70%	46.6	46.6	49.8	55.6	59.0	63.1	66.1	66.3	63.0	57.3	51.7	46.7
90%	46.5	46.4	49.4	54.8	58.5	63.1	66.0	66.1	62.6	57.1	51.7	46.6
Six Dam Removal Alternative												
10%	46.8	46.8	50.1	56.0	60.3	64.4	68.3	68.5	65.0	58.3	52.0	46.9
30%	46.7	46.7	49.8	55.7	59.9	63.8	67.6	67.9	64.5	58.0	51.9	46.8
50%	46.6	46.5	49.7	55.4	59.6	63.3	67.1	67.4	64.0	57.9	51.9	46.7
70%	46.5	46.4	49.5	55.2	58.9	62.8	66.5	67.0	63.6	57.7	51.8	46.6
90%	46.3	46.2	49.3	54.6	58.5	62.6	66.0	66.5	63.2	57.4	51.7	46.5

Table R-17. Calculated Battle Creek Temperatures (°F) for All of the Alternatives above Coleman Powerhouse

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No Action Alternative												
10%	49.5	49.6	54.4	64.0	68.9	73.7	78.5	78.5	73.7	64.1	54.6	49.6
30%	49.5	49.6	54.2	63.5	68.4	73.7	78.5	78.5	73.7	64.1	54.6	49.6
50%	49.4	49.4	53.6	59.3	65.2	73.4	78.5	78.5	73.7	64.1	54.6	49.6
70%	49.2	47.5	50.9	57.4	60.7	68.9	78.4	78.5	73.7	64.1	54.6	49.5
90%	47.4	46.9	50.0	56.2	60.0	65.5	77.7	78.4	73.6	64.0	54.5	49.4
Five Dam Removal Alternative												
10%	47.5	47.5	51.2	57.9	63.0	67.3	71.1	71.3	67.5	60.0	52.8	47.6
30%	47.4	47.4	51.0	57.7	62.8	67.1	70.9	71.0	67.1	59.9	52.7	47.5
50%	47.3	47.3	50.9	57.6	62.7	67.0	70.8	70.8	67.0	59.8	52.7	47.4
70%	47.3	47.2	50.7	57.2	61.0	66.7	70.6	70.7	66.9	59.8	52.7	47.3
90%	47.1	47.0	50.3	56.1	60.3	66.2	70.5	70.6	66.8	59.7	52.6	47.3
No Dam Removal Alternative												
10%	46.5	46.6	50.3	57.5	62.9	66.2	69.6	69.6	64.6	58.0	51.4	46.4
30%	46.7	46.8	50.5	57.7	62.9	66.4	69.7	69.7	64.8	58.2	51.7	46.6
50%	46.8	47.0	50.6	57.7	62.9	66.5	69.9	69.8	65.0	58.4	51.8	46.7
70%	46.9	47.1	50.6	57.2	60.5	66.4	70.1	70.0	65.2	58.6	52.0	46.9
90%	47.0	46.7	49.8	56.0	59.8	65.2	70.1	70.1	65.4	58.8	52.2	47.0
Three Dam Removal Alternative												
10%	47.5	47.5	51.1	58.0	62.3	66.3	70.5	70.9	67.0	59.6	52.7	47.6
30%	47.4	47.3	50.9	57.7	62.1	65.7	69.9	70.2	66.4	59.3	52.6	47.5
50%	47.3	47.2	50.8	57.5	61.9	65.5	69.4	69.6	65.9	59.2	52.5	47.4
70%	47.2	47.1	50.7	57.1	60.5	65.2	68.9	69.2	65.6	59.0	52.4	47.3
90%	47.1	46.9	50.1	56.0	59.9	64.9	68.7	68.9	65.1	58.7	52.3	47.2
Six Dam Removal Alternative												
10%	47.5	47.4	51.0	57.6	62.2	66.7	71.0	71.3	67.5	59.9	52.7	47.5
30%	47.3	47.3	50.7	57.2	61.7	66.0	70.3	70.7	66.9	59.5	52.6	47.4
50%	47.1	47.1	50.5	56.9	61.4	65.5	69.8	70.1	66.4	59.4	52.5	47.3
70%	47.0	46.9	50.3	56.6	60.4	64.8	69.1	69.6	66.0	59.2	52.4	47.2
90%	46.8	46.7	50.0	55.9	59.9	64.6	68.5	69.1	65.5	58.8	52.3	47.0

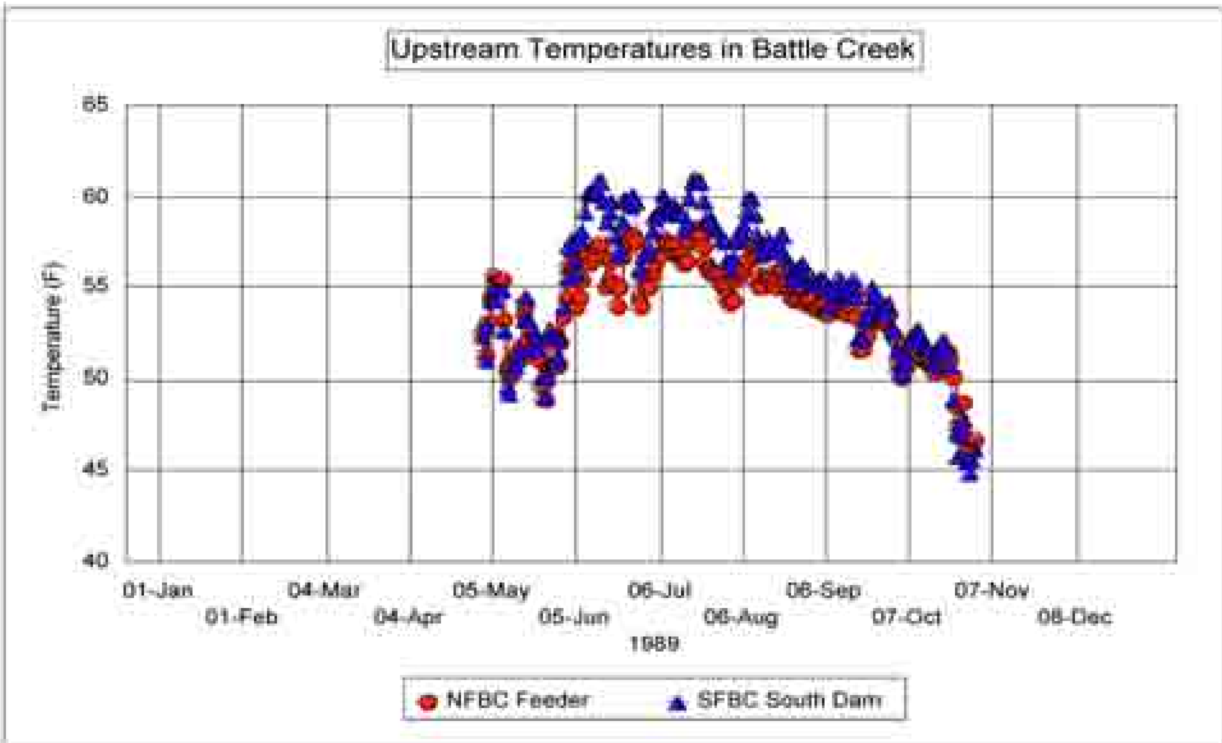
Table R-18. Calculated Battle Creek Temperatures (°F) for All of the Alternatives at Coleman National Fish Hatchery (Coleman Powerhouse Tailwater)

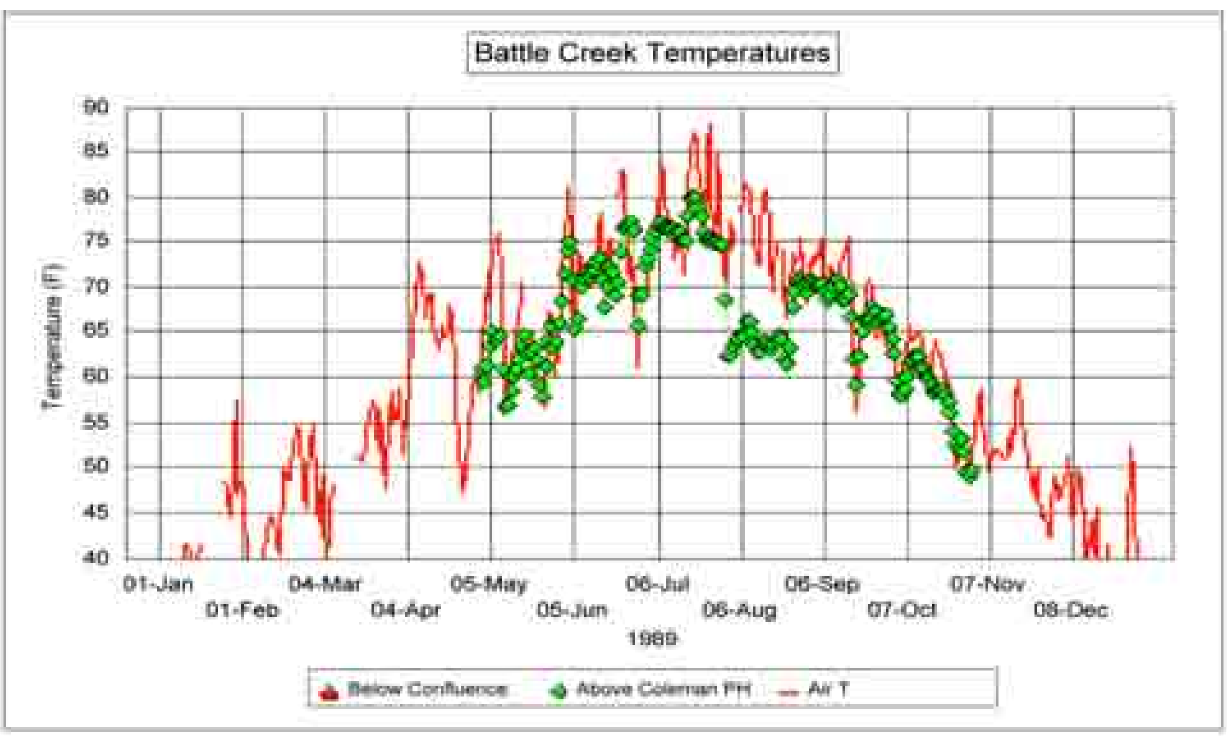
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No Action Alternative												
10%	46.6	46.7	49.2	54.7	58.5	60.7	62.4	61.9	58.8	55.3	51.3	46.7
30%	46.7	46.8	49.4	55.0	59.0	61.5	63.4	62.9	59.7	55.8	51.5	46.7
50%	46.7	46.9	49.2	54.3	58.6	62.0	64.0	63.7	60.3	56.0	51.7	46.8
70%	46.8	46.6	49.0	54.0	57.8	61.7	64.8	64.2	60.7	56.3	51.9	46.8
90%	46.6	46.6	49.0	53.7	57.7	61.1	65.3	64.8	61.2	56.7	52.1	46.8
Five Dam Removal Alternative												
10%	47.9	47.7	49.3	54.0	57.6	58.9	58.6	58.0	55.9	54.2	52.0	48.0
30%	47.6	47.4	49.2	54.1	57.9	60.0	60.8	59.7	57.0	55.1	52.1	47.7
50%	47.3	47.2	49.2	54.2	58.0	60.5	61.9	61.4	58.4	55.5	52.2	47.5
70%	47.2	47.0	49.1	54.1	58.0	61.0	62.9	62.2	59.1	55.7	52.2	47.3
90%	46.9	46.9	49.1	54.1	57.9	61.2	63.3	62.9	59.6	56.0	52.3	47.1
No Dam Removal Alternative												
10%	45.5	45.5	47.6	52.3	56.1	57.4	58.4	57.9	54.7	52.5	49.4	45.6
30%	45.6	45.6	48.0	52.8	56.8	58.7	59.5	59.0	55.9	53.0	49.7	45.5
50%	45.7	45.8	48.2	53.2	57.3	59.5	60.6	60.1	56.8	53.4	49.9	45.6
70%	45.8	46.0	48.4	53.4	57.3	60.6	61.8	60.9	57.6	53.9	50.3	45.7
90%	46.0	46.1	48.5	53.2	57.2	60.6	62.6	61.8	58.4	54.6	50.6	45.9
Three Dam Removal Alternative												
10%	42.5	42.8	45.1	49.6	53.3	52.8	51.9	50.4	48.2	47.7	45.9	42.1
30%	43.3	43.8	46.1	50.8	54.8	55.4	54.5	53.3	50.7	49.2	47.0	43.0
50%	44.1	44.6	46.8	51.7	55.7	57.1	56.6	55.6	52.6	50.2	47.6	43.5
70%	44.6	45.2	47.4	52.0	55.9	59.1	59.0	57.2	54.1	51.2	48.5	44.1
90%	45.3	45.3	47.4	52.0	55.8	59.0	60.4	59.0	55.6	52.5	49.2	44.8
Six Dam Removal Alternative												
10%	48.0	47.9	49.4	53.8	57.3	58.5	58.4	58.0	55.9	54.1	52.0	48.0
30%	47.8	47.7	49.4	53.9	57.6	59.8	60.3	59.3	56.7	54.9	52.1	47.9
50%	47.7	47.5	49.3	53.9	57.8	60.4	61.5	61.0	58.1	55.3	52.2	47.8
70%	47.5	47.2	49.2	53.9	57.9	61.1	62.7	61.8	58.8	55.6	52.2	47.7
90%	47.2	47.1	49.2	53.9	57.8	61.3	63.2	62.7	59.5	56.0	52.3	47.4



03035.03 FEIS/EIR

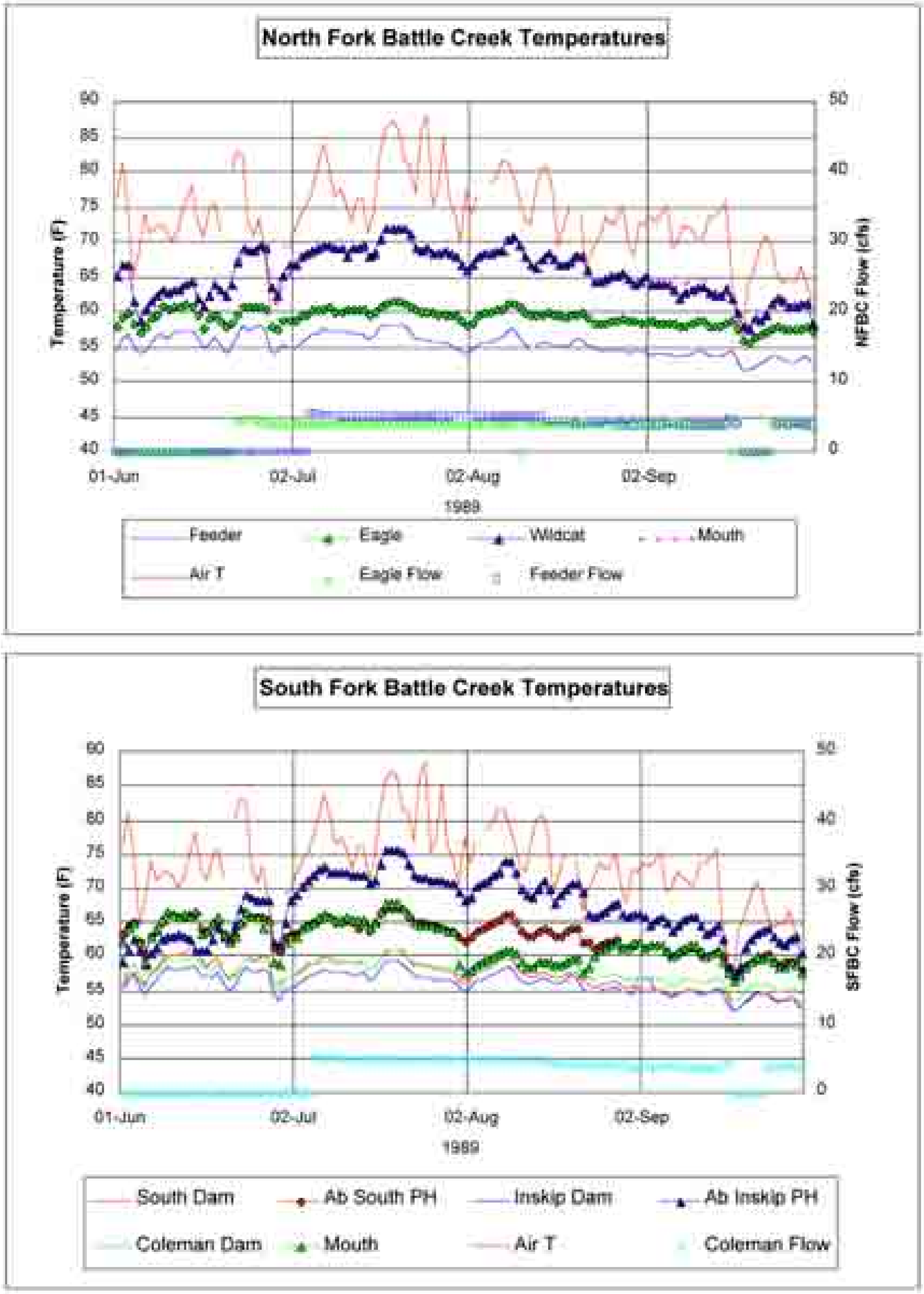
Figure R-1
Effects of Temperature on Assumed Monthly Survival of Steelhead and Chinook Salmon in Battle Creek





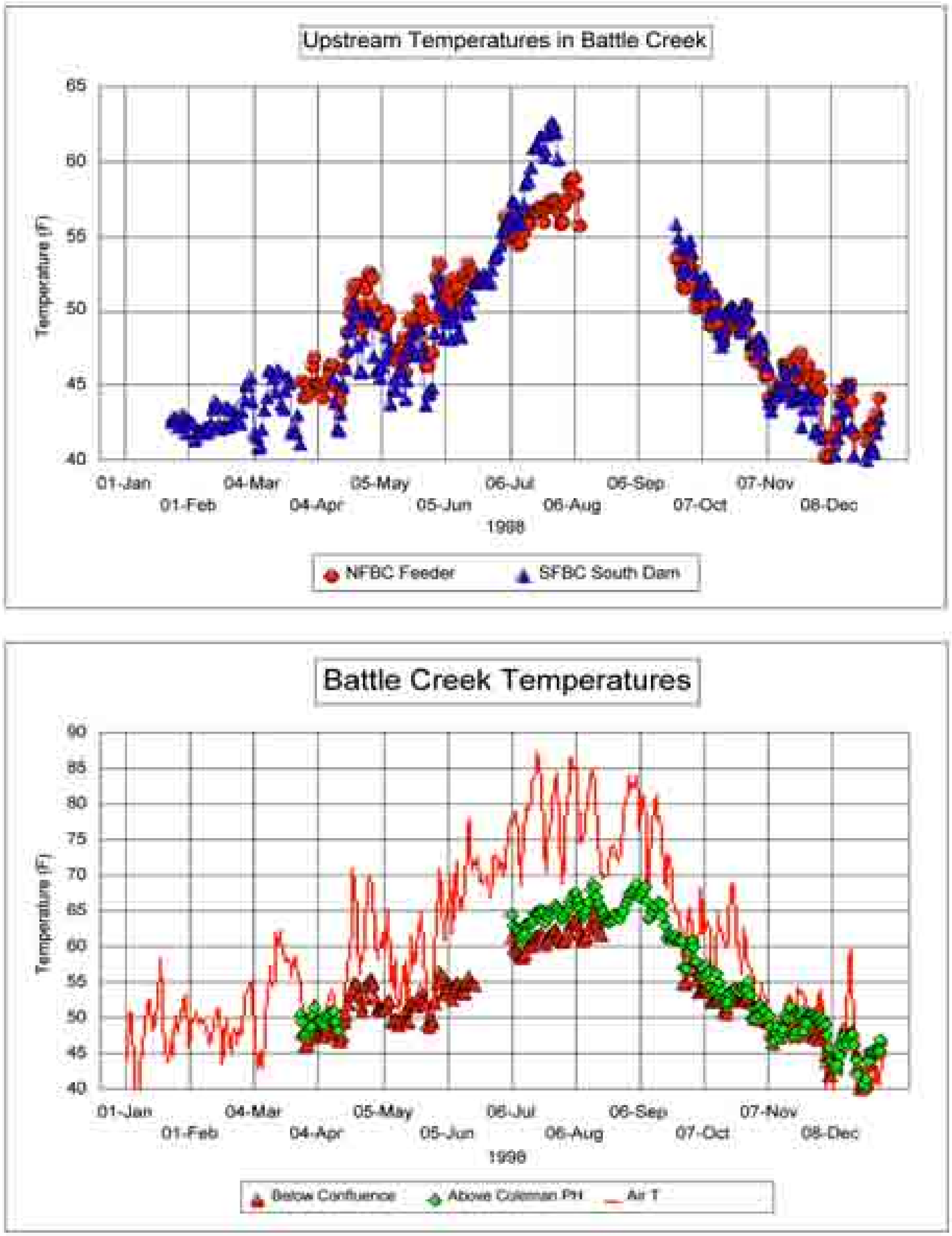
03035.03 FEIS/EIR

Figure R-2
Battle Creek Water Temperatures at Upstream Dams and below Confluence of North Fork Battle Creek and South Fork Battle Creek for 1989



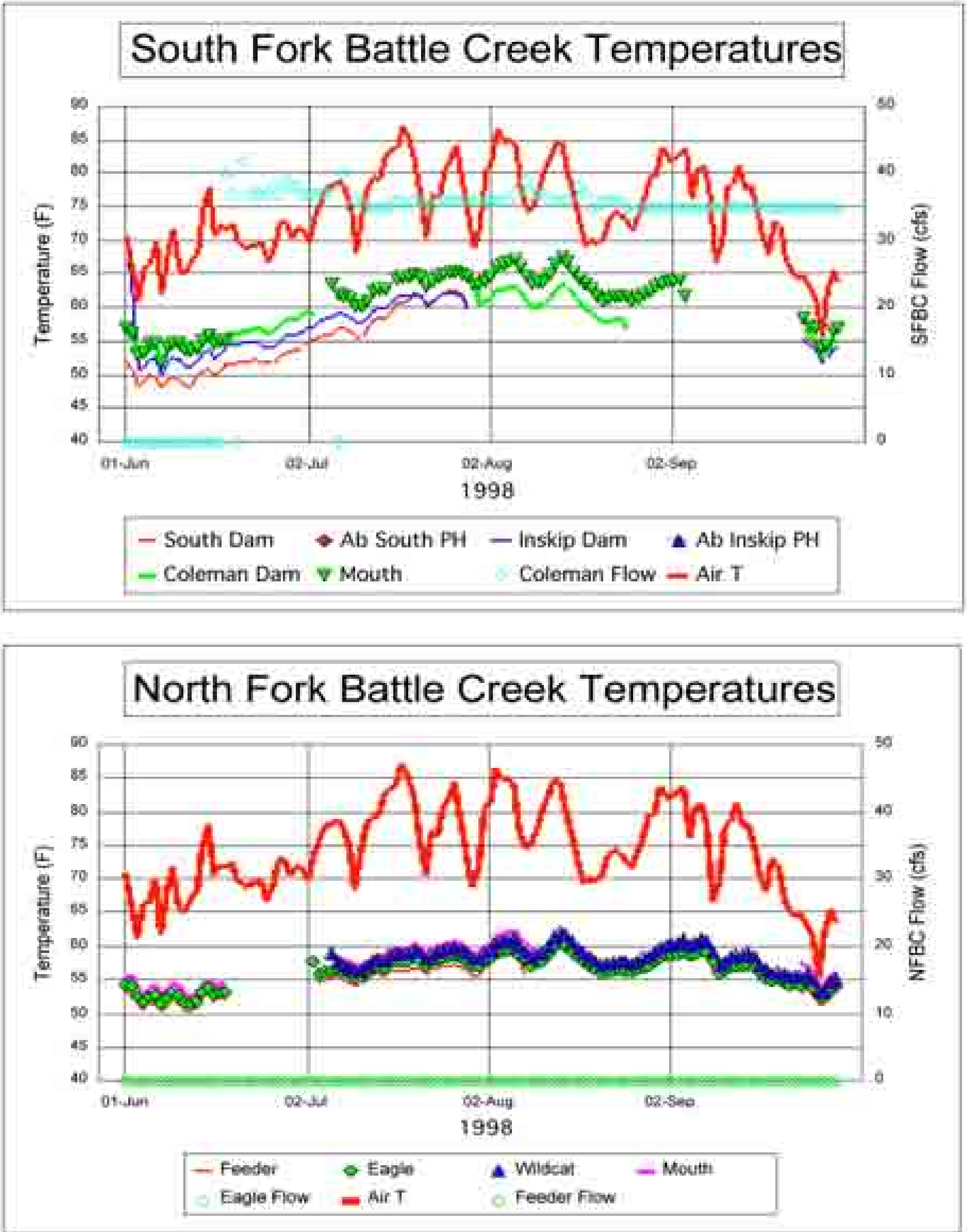
03035.03 FEIS/EIR

Figure R-3
Measured Temperatures and Flows in North Fork Battle Creek and South Fork Battle Creek during the Summer (June–September) of 1989



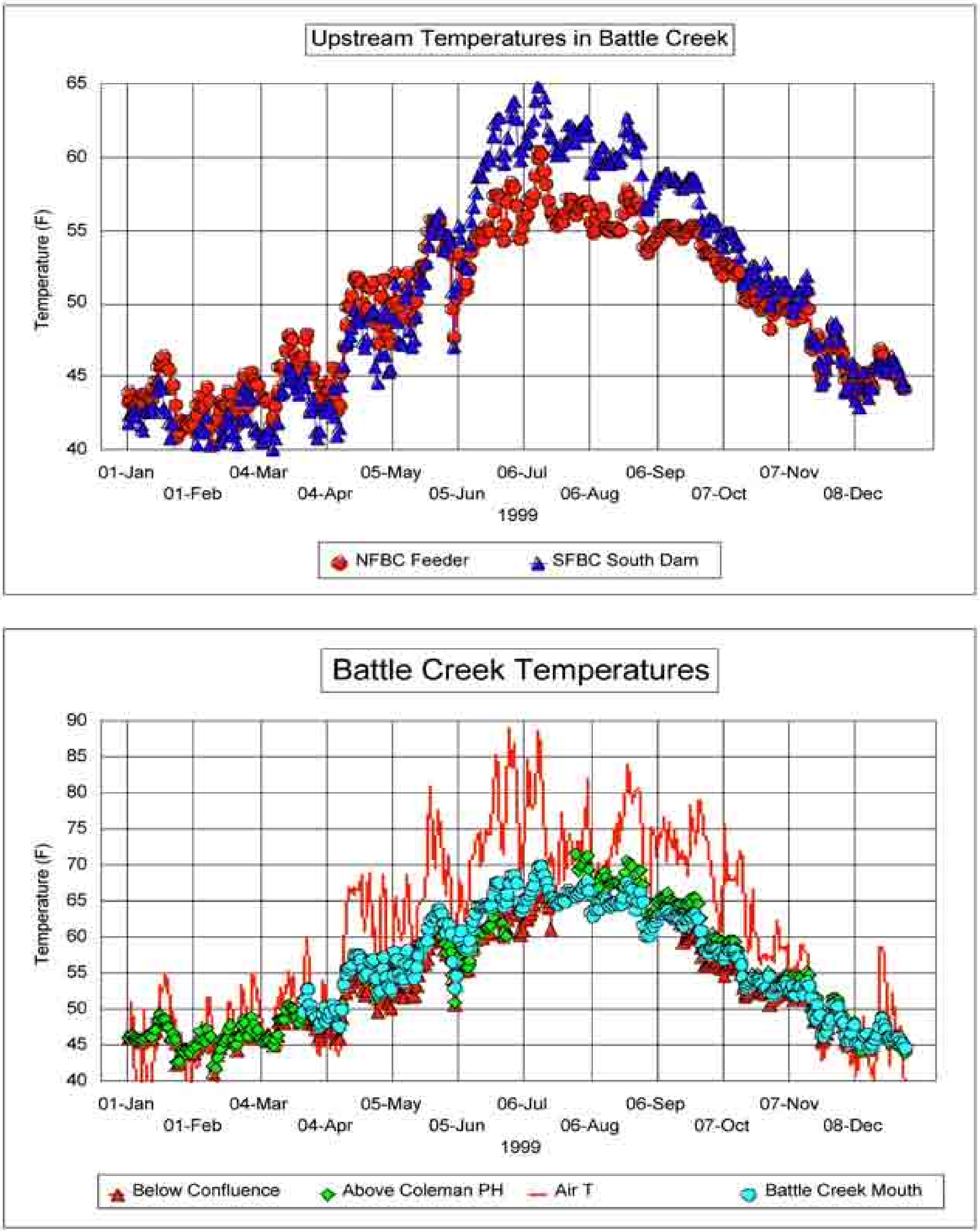
03035.03 FEIS/EIR

Figure R-4
Battle Creek Water Temperatures at Upstream Dams and below Confluence of North Fork Battle Creek and South Fork Battle Creek for 1998



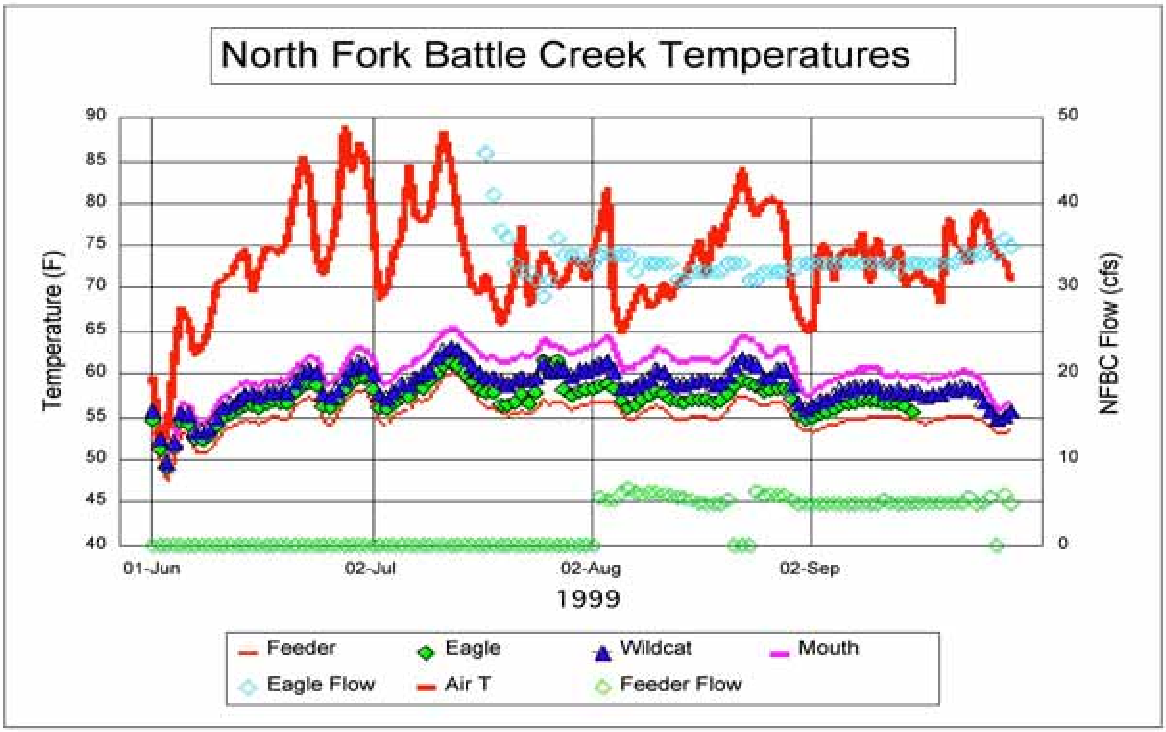
03035.03 FEIS/EIR

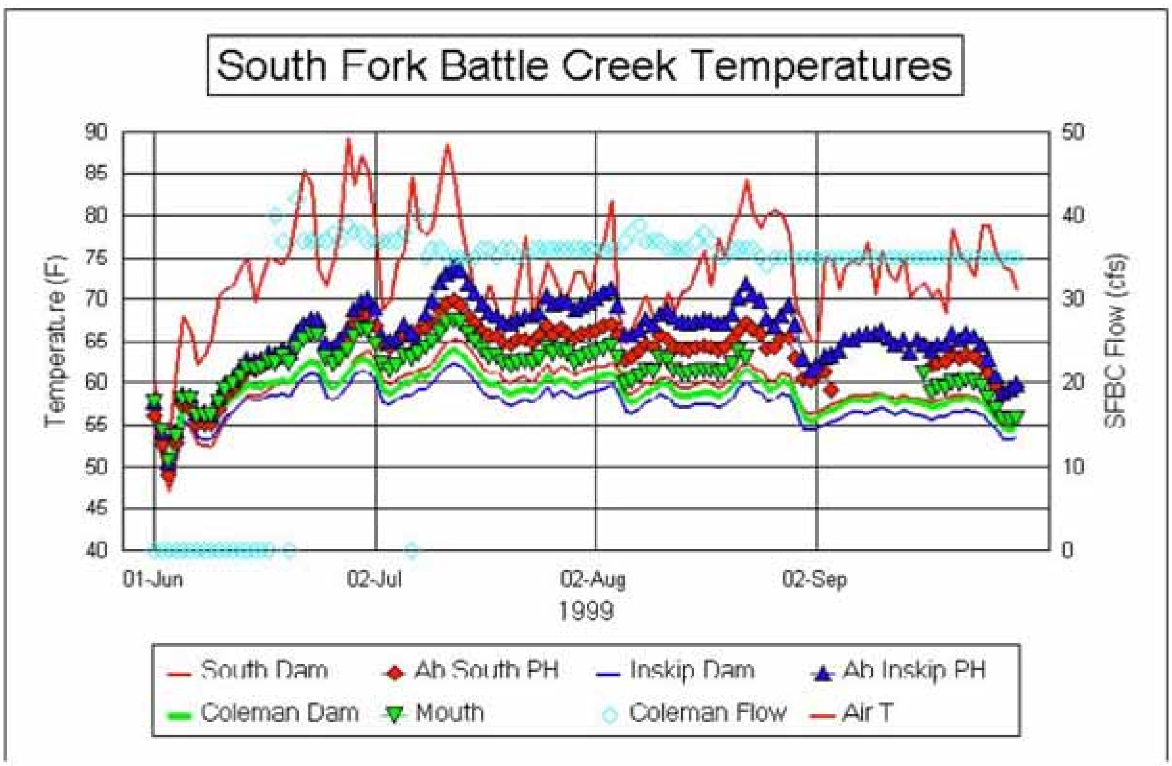
Figure R-5
Measured Temperatures and Flows in North Fork Battle Creek and South Fork Battle Creek during the Summer (June–September) of 1998



03035.03 FEIS/EIR

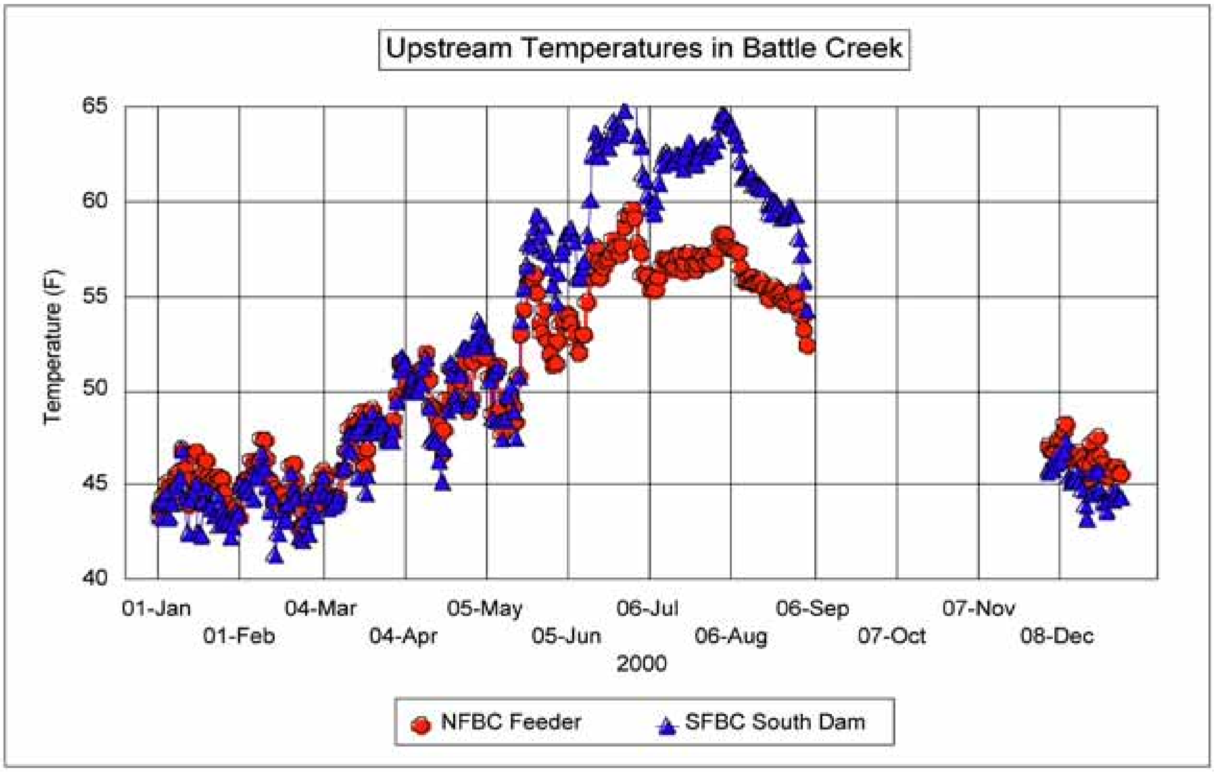
Figure R-6
Battle Creek Water Temperatures at Upstream Dams and below Confluence of North Fork Battle Creek and South Fork Battle Creek for 1999

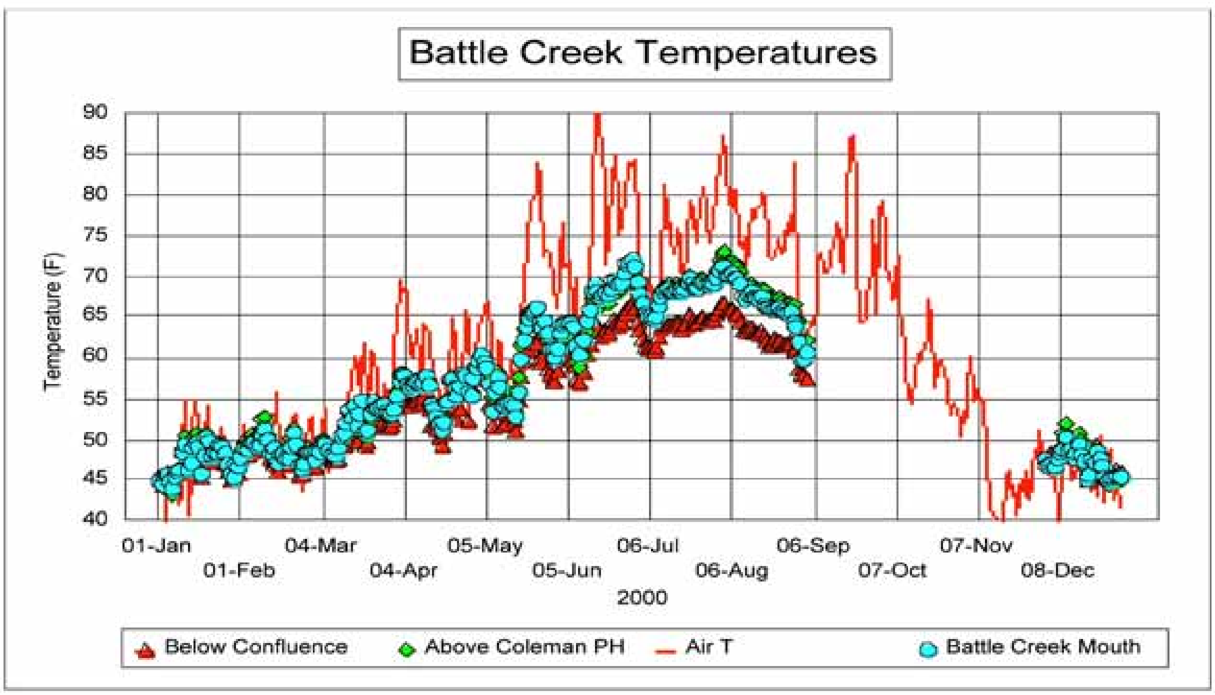




03035.03 FEIS/EIR

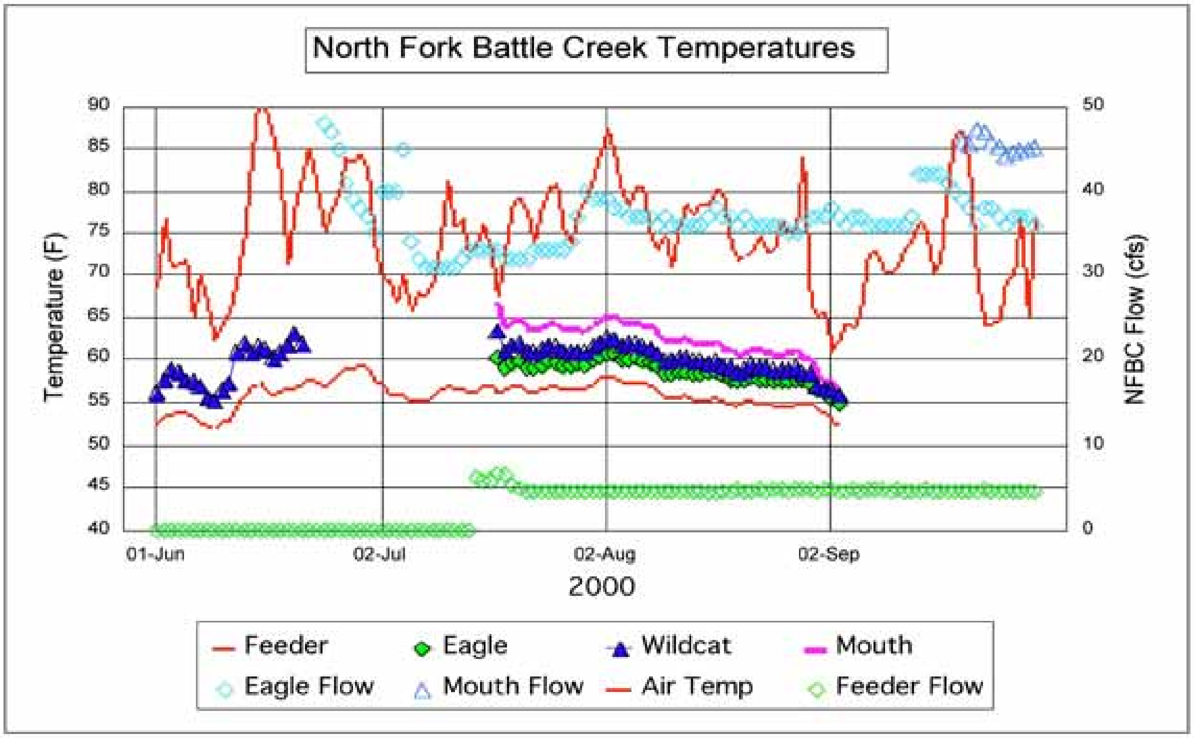
Figure R-7
Measured Temperatures and Flows in North Fork Battle Creek and South Fork Battle Creek during the Summer (June–September) of 1999

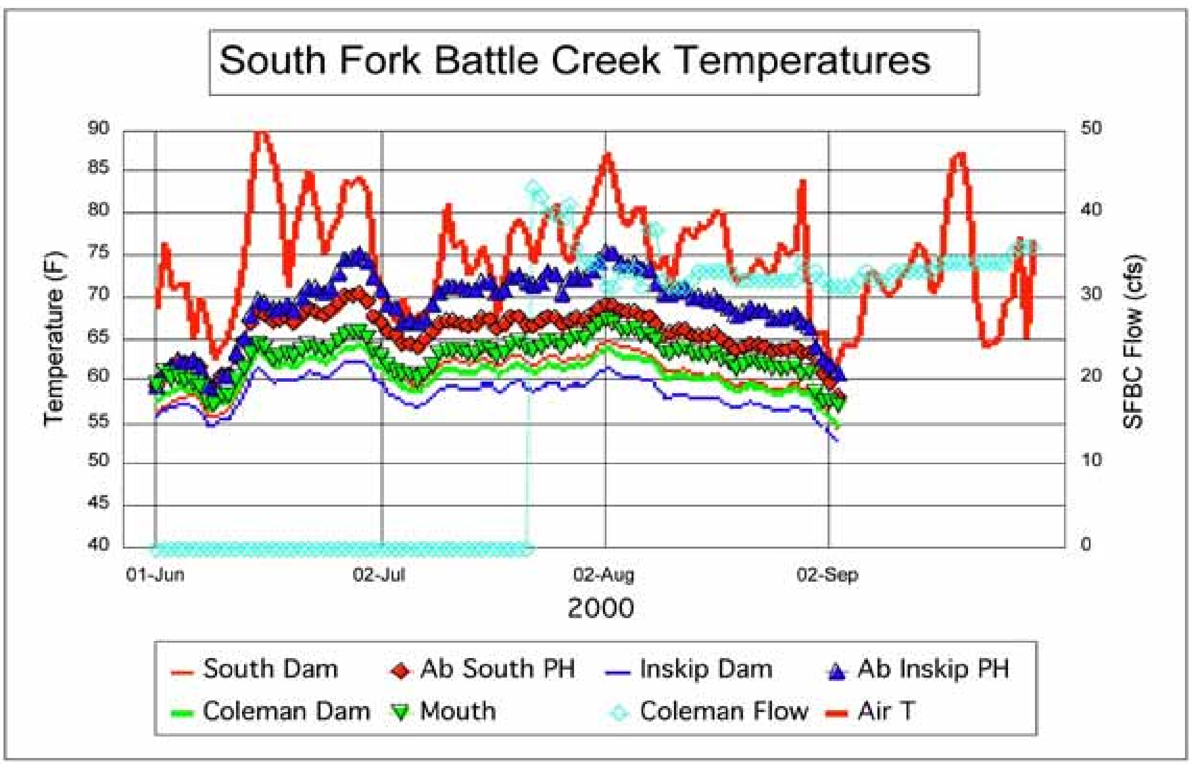




03035.03 FEIS/EIR

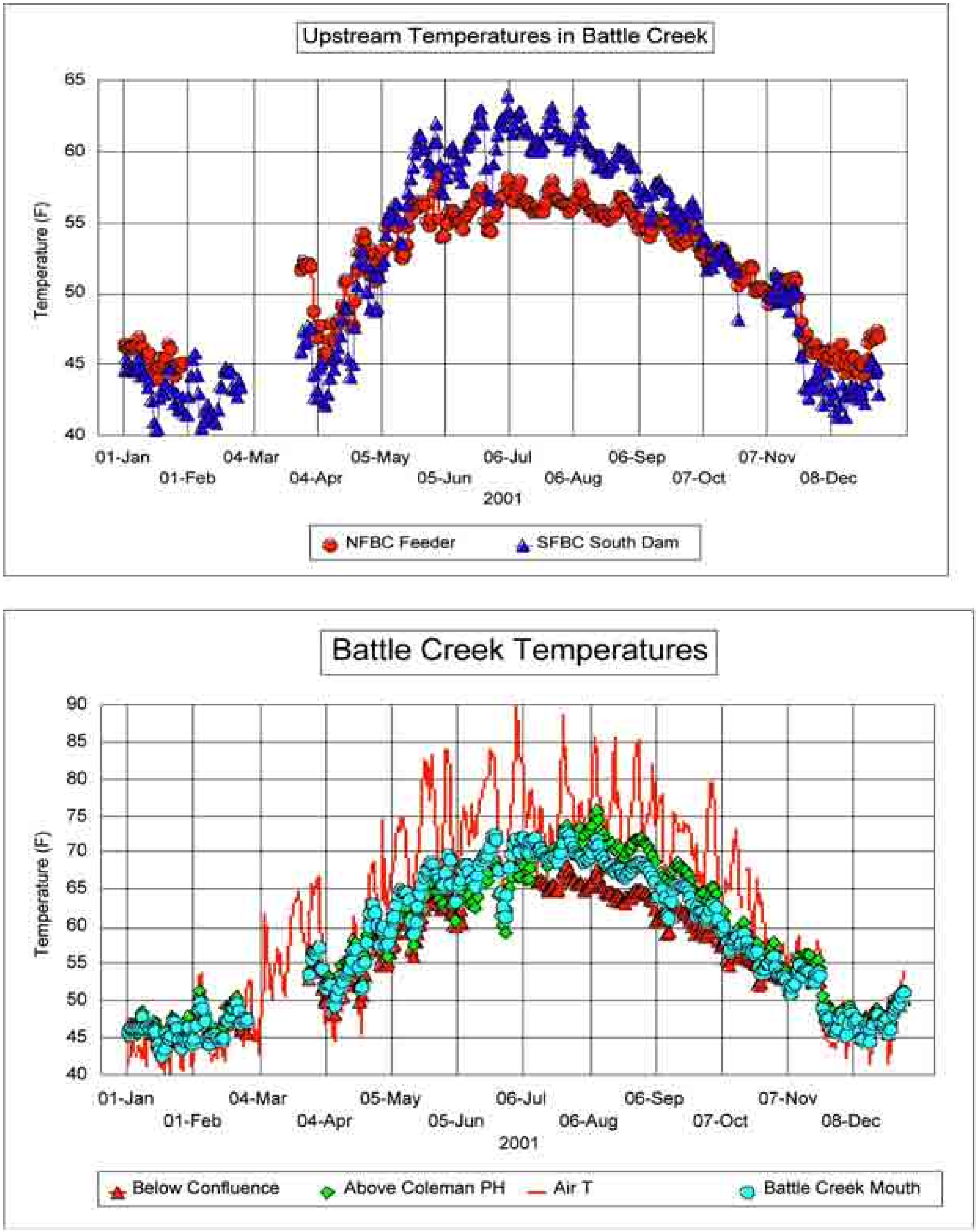
Figure R-8
Battle Creek Water Temperatures at Upstream Dams and below Confluence of North Fork Battle Creek and South Fork Battle Creek for 2000





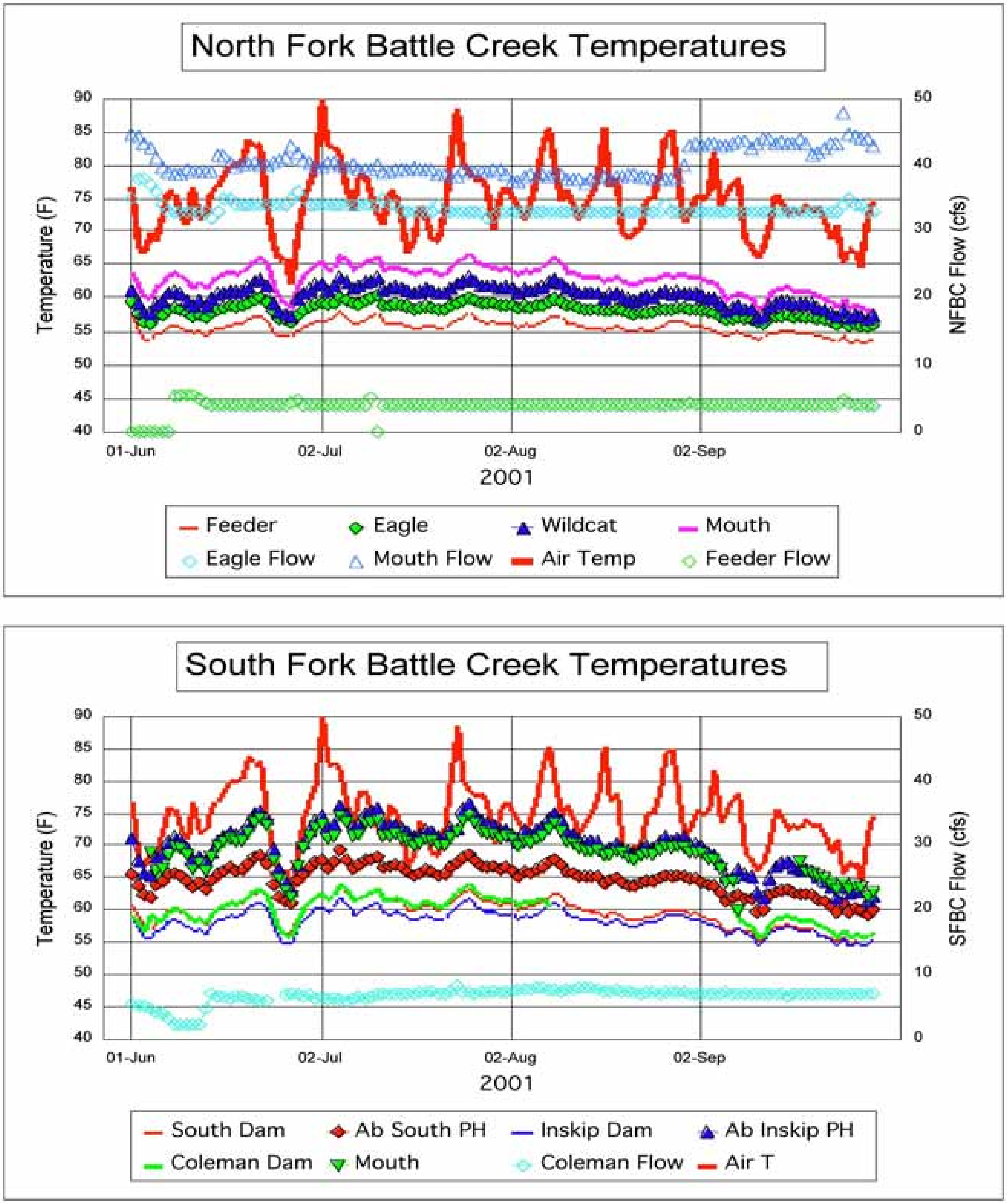
03035.03 FEIS/EIR

Figure R-9
Measured Temperatures and Flows in North Fork Battle Creek and South Fork Battle Creek during the Summer (June–September) of 2000



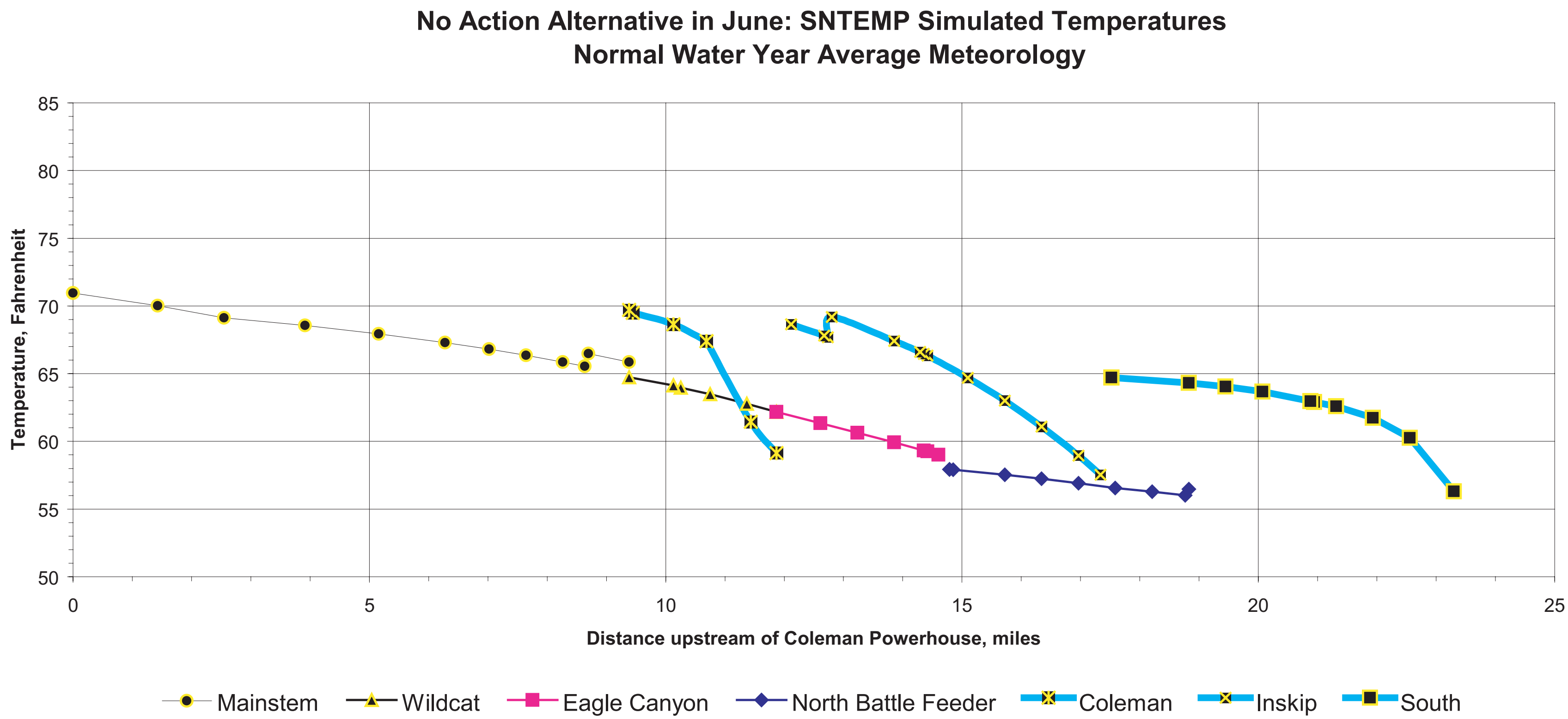
03035.03 FEIS/EIR

Figure R-10
Battle Creek Water Temperatures at Upstream Dams and below Confluence of North Fork Battle Creek and South Fork Battle Creek for 2001



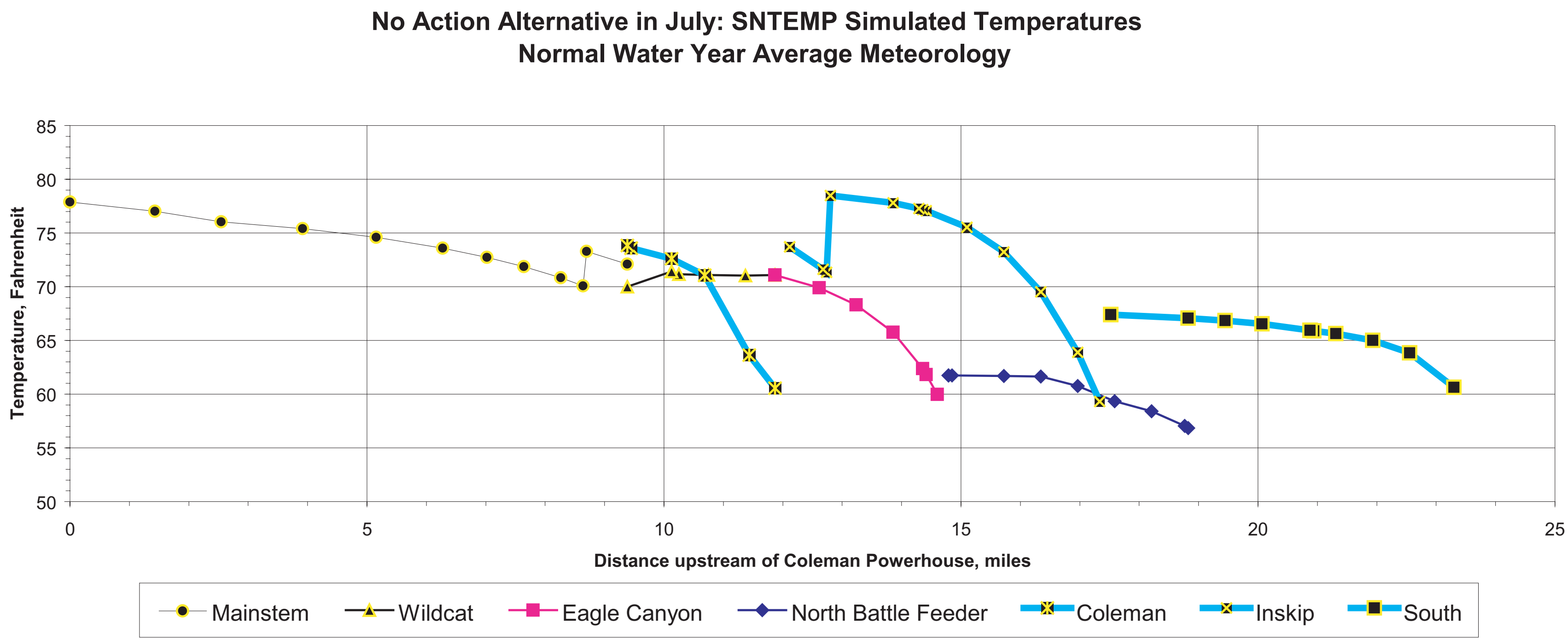
03035.03 FEIS/EIR

Figure R-11
Measured Temperatures and Flows in North Fork Battle Creek and South Fork Battle Creek during the Summer (June–September) of 2001



03035.03 FEIS/EIR

Figure R-12
SNTEMP Simulated Temperatures in Battle Creek for the No Action Alternative in June



03035.03 FEIS/EIR

Figure R-13
SNTEMP Simulated Temperatures in Battle Creek for the No Action Alternative in July

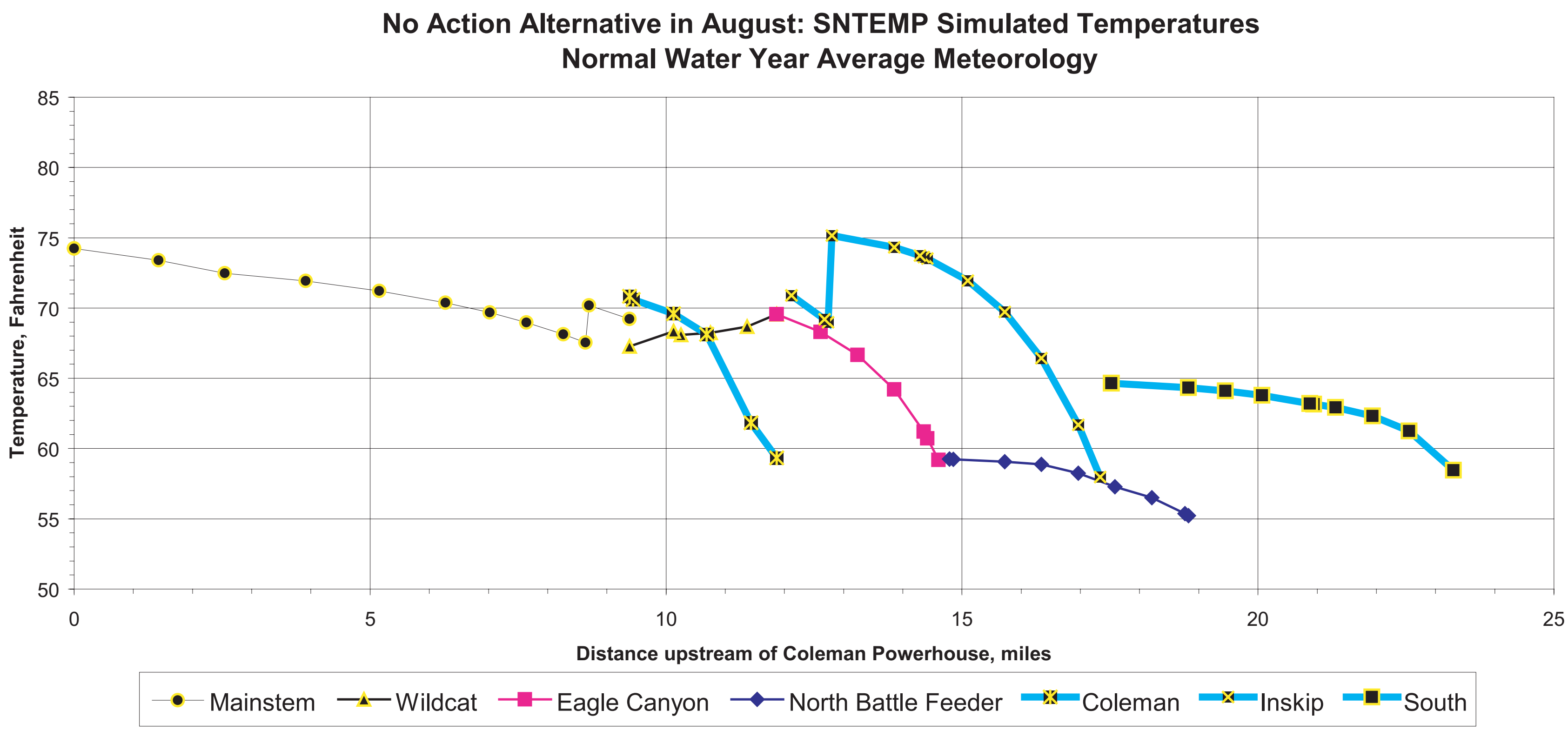
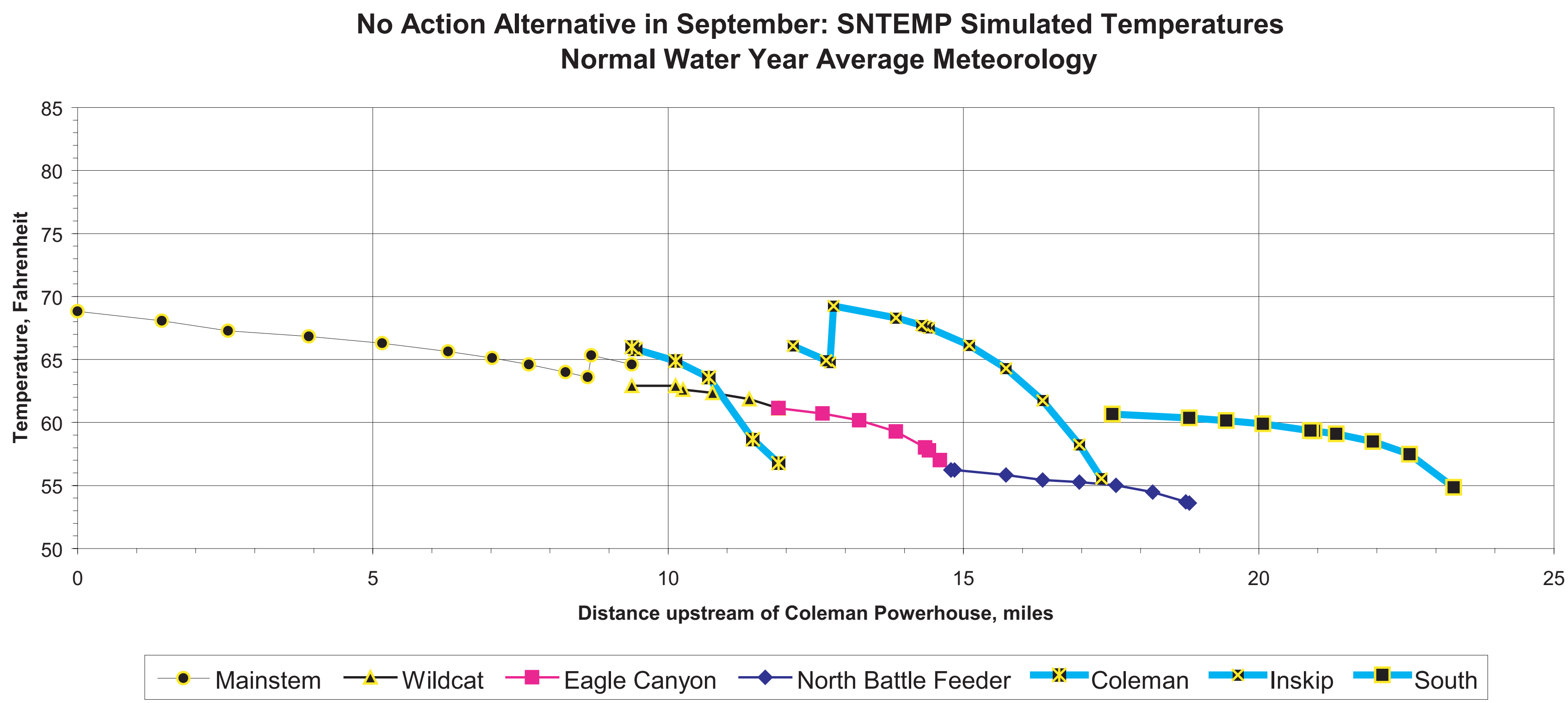
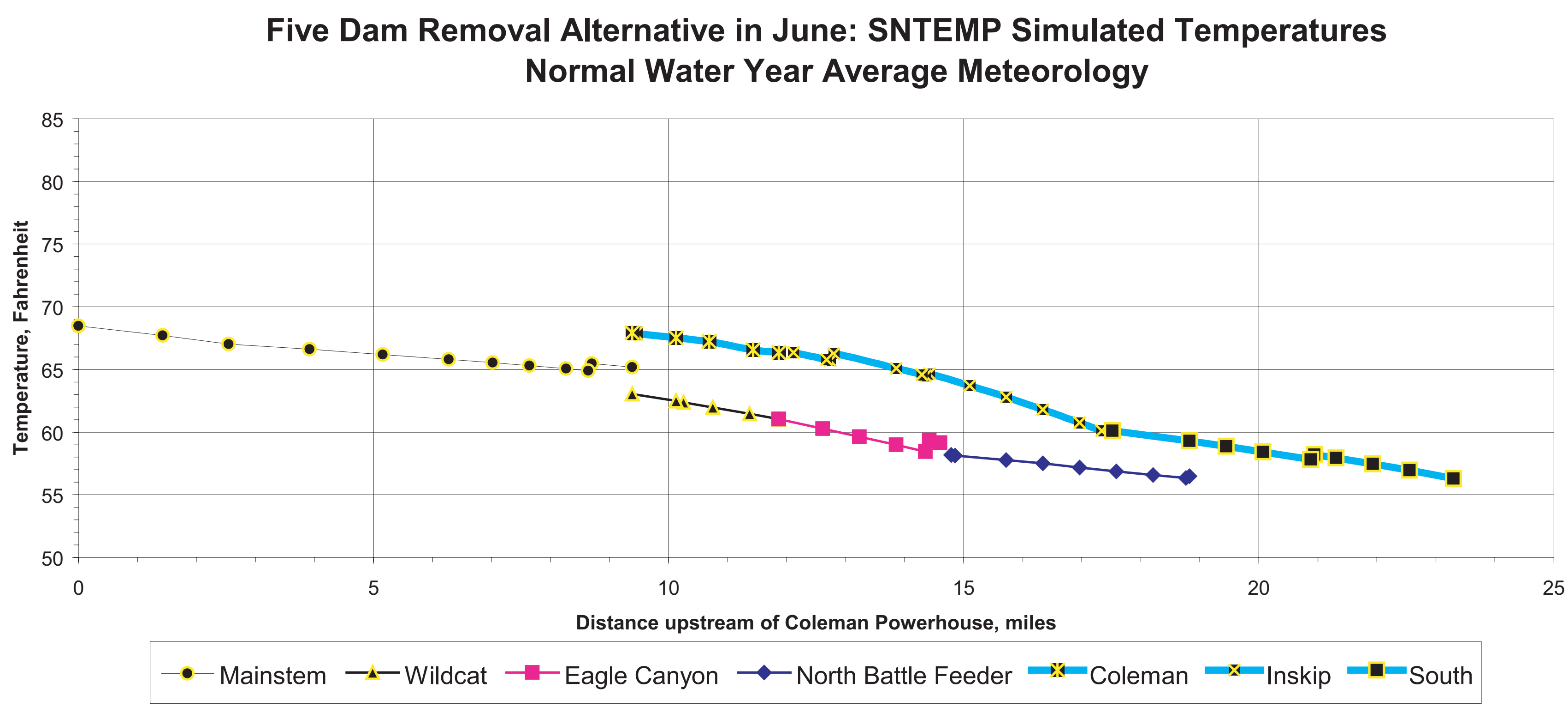


Figure R-14
SNTEMP Simulated Temperatures in Battle Creek for the No Action Alternative in August



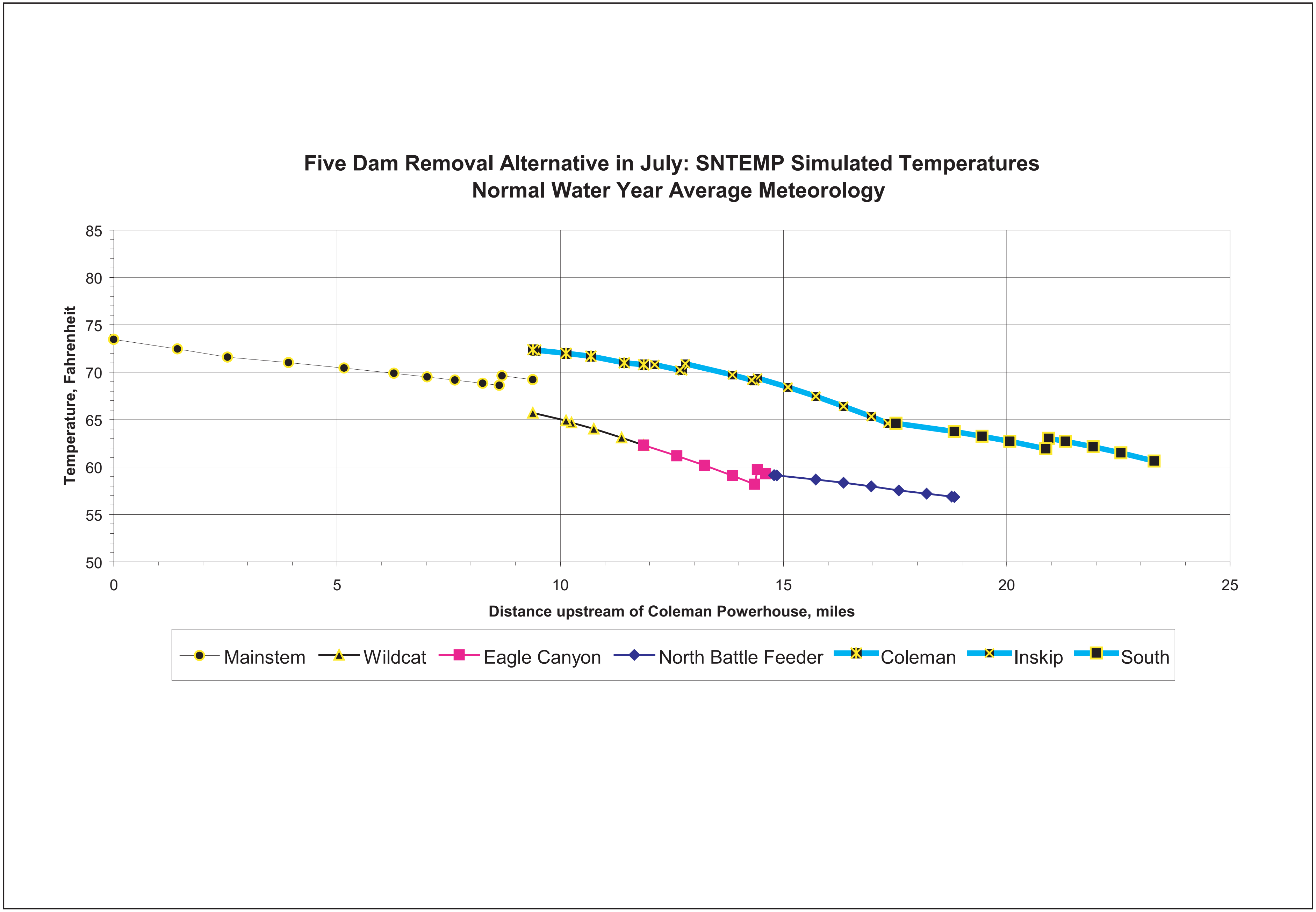
03035.03 FEIS/EIR

Figure R-15
SNTEMP Simulated Temperatures in Battle Creek for the No Action Alternative in September



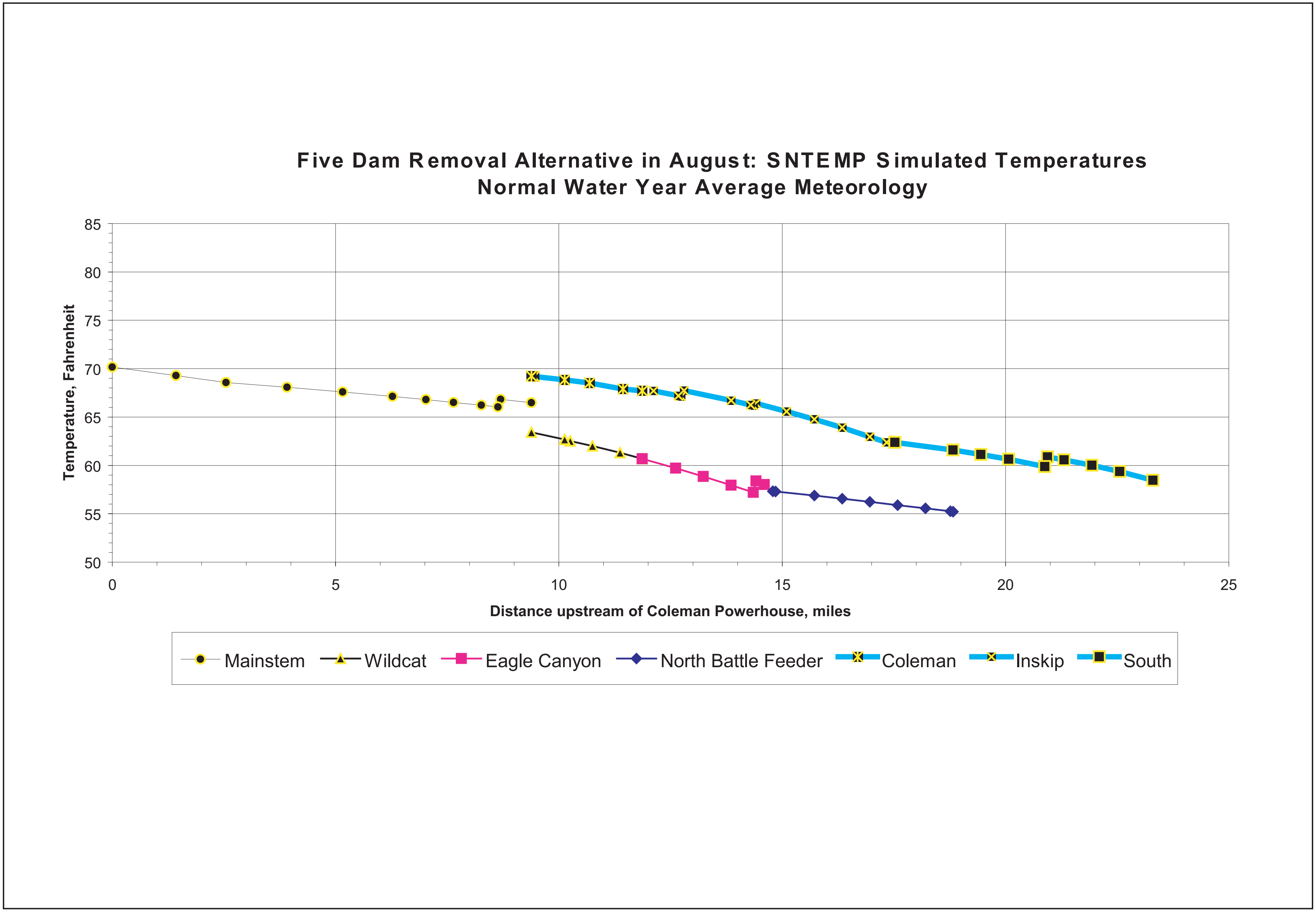
03035.03 FEIS/EIR

Figure R-16
SNTEMP Simulated Temperatures in Battle Creek
for the Five Dam Removal Alternative in June



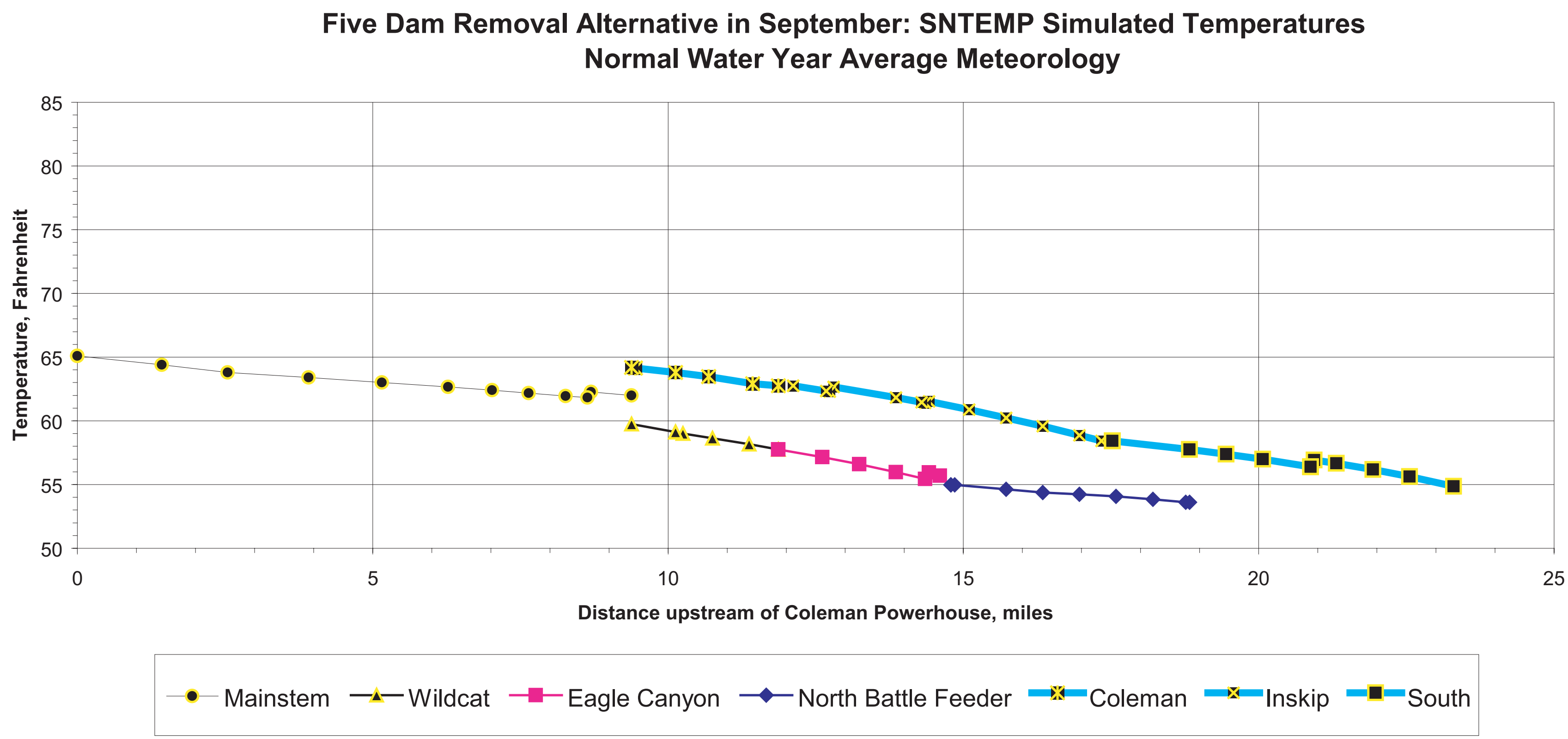
03035.03 FEIS/EIR

Figure R-17
SNTEMP Simulated Temperatures in Battle Creek for the Five Dam Removal Alternative in July



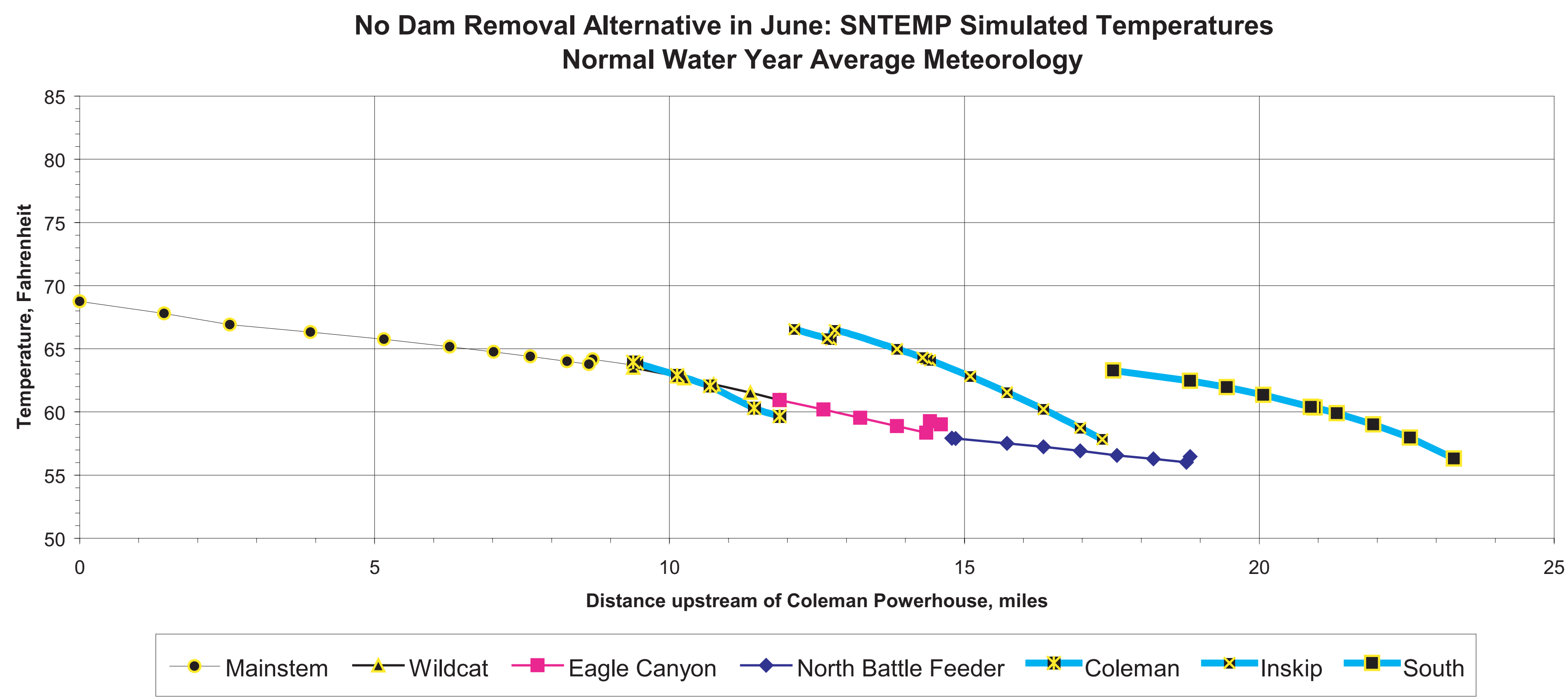
03035.03

Figure R-18
SNTEMP Simulated Temperatures in Battle Creek for the Five Dam Removal Alternative in August



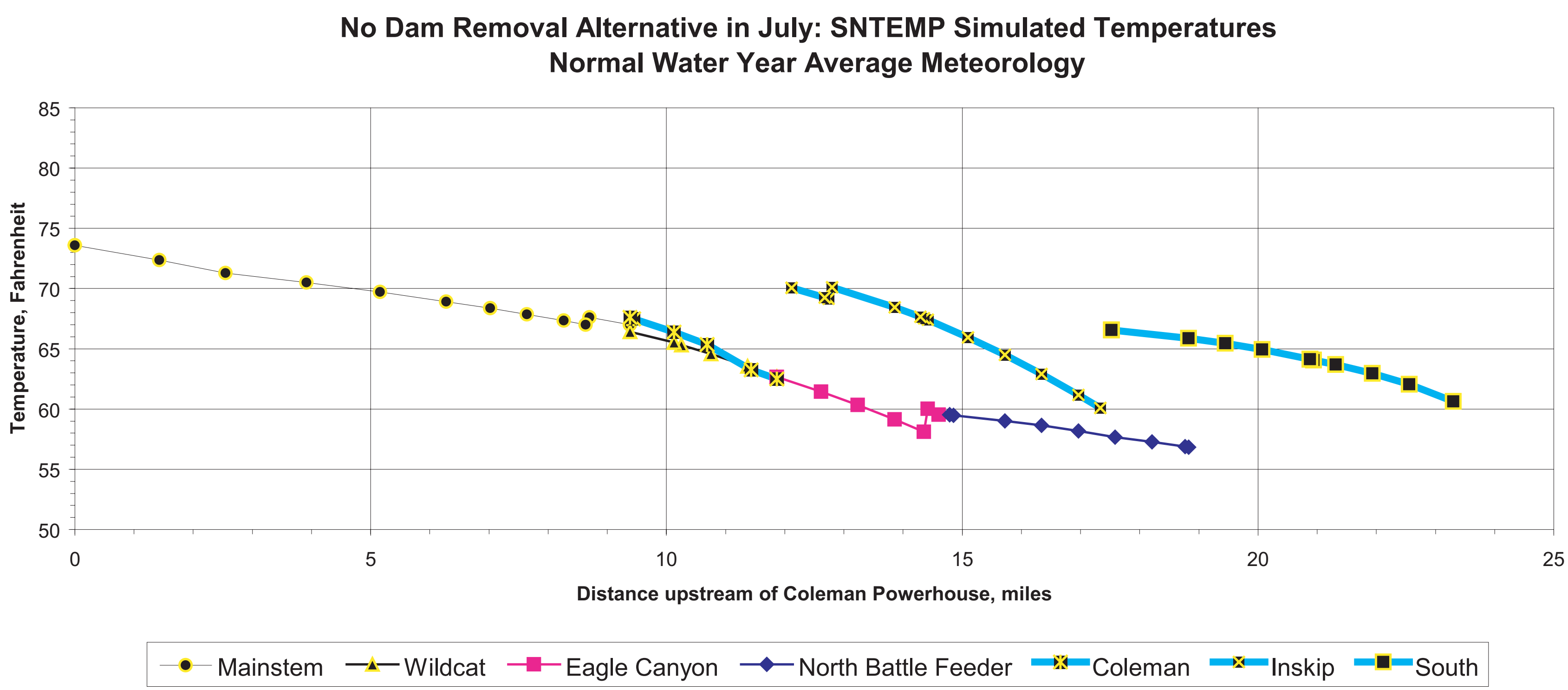
03035.03 FEIS/EIR

Figure R-19
SNTEMP Simulated Temperatures in Battle Creek for the Five Dam Removal Alternative in September



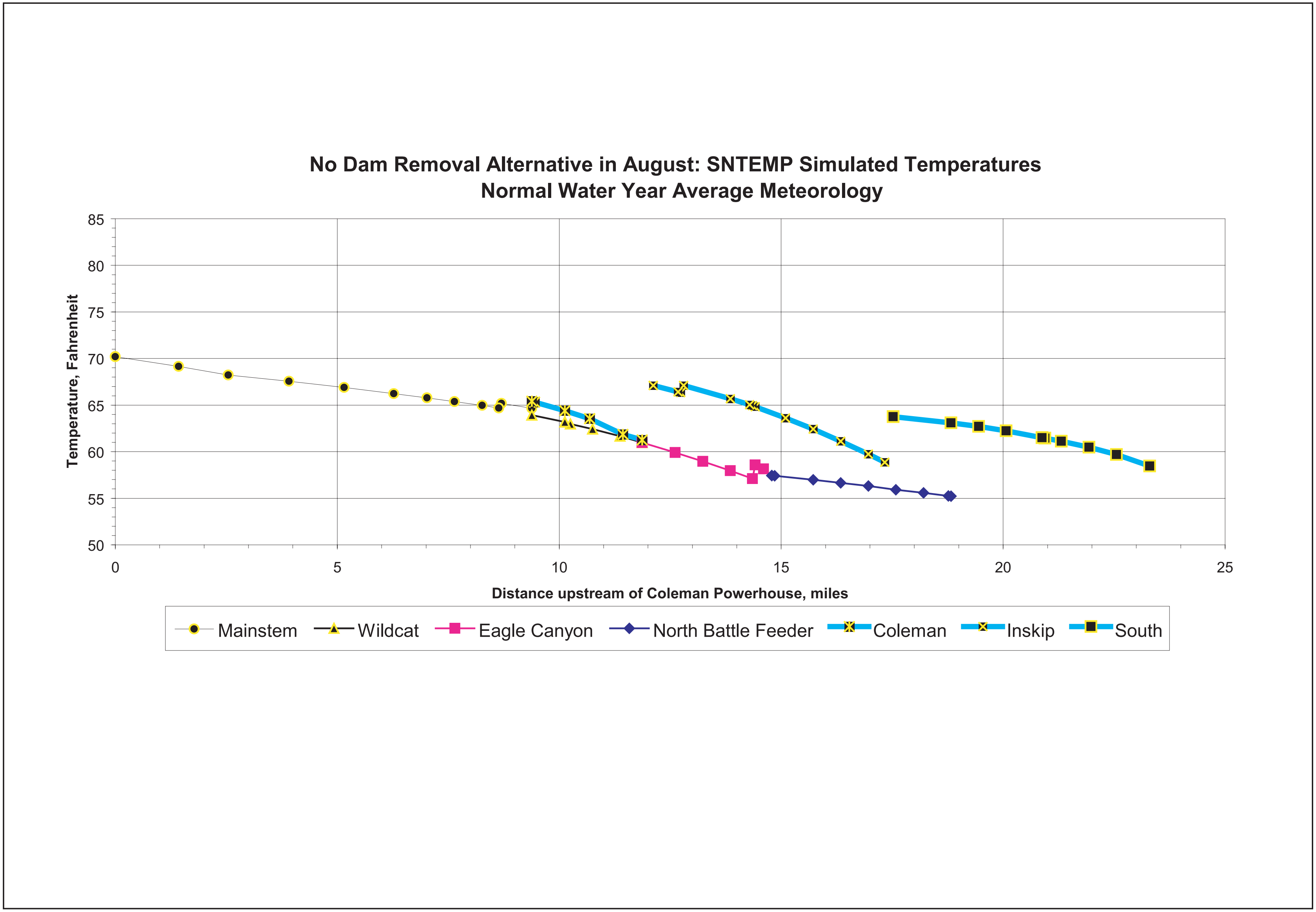
03035.03 FEIS/EIR

Figure R-20
SNTEMP Simulated Temperatures in Battle Creek for the No Dam Removal Alternative in June



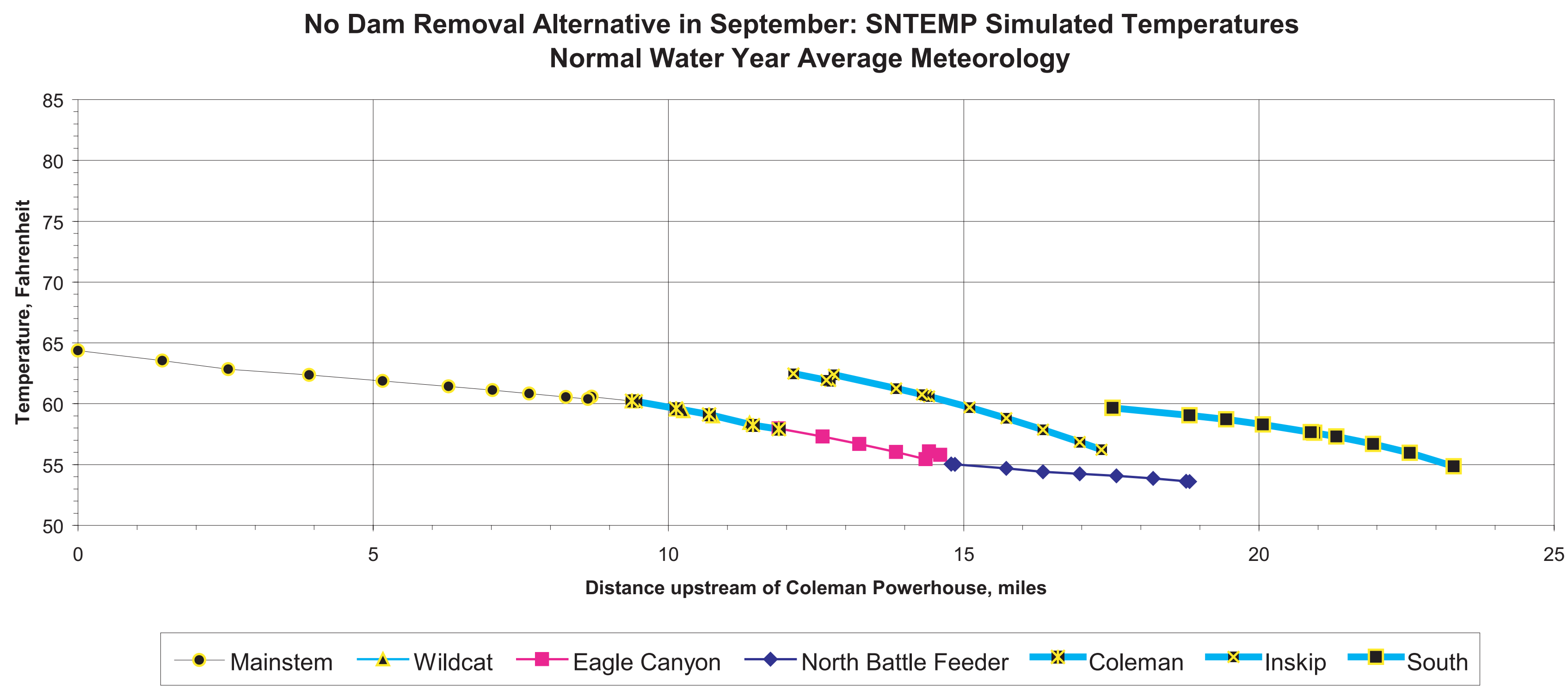
03035.03 FEIS/EIR

Figure R-21
SNTEMP Simulated Temperatures in Battle Creek for the No Dam Removal Alternative in July



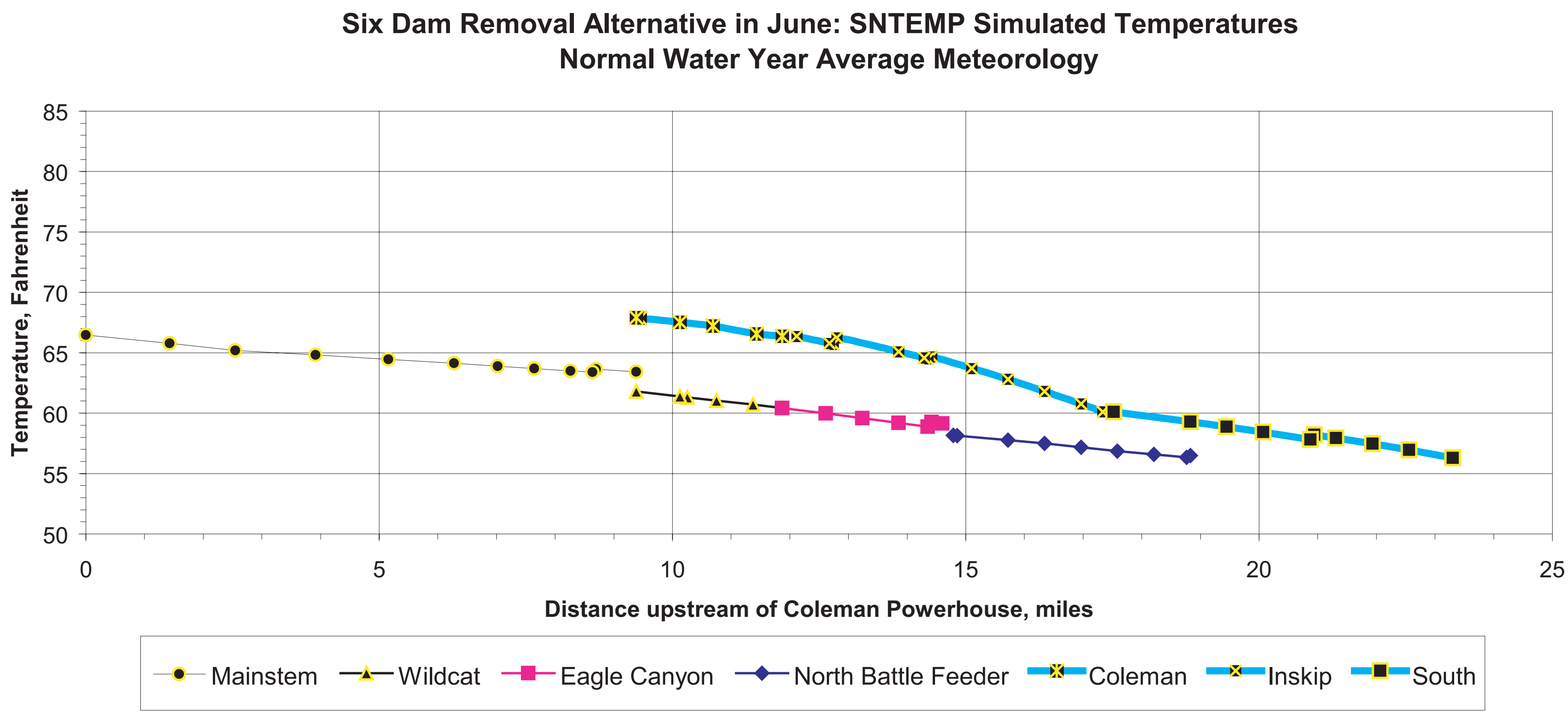
03035.03 FEIS/EIR

Figure R-22
SNTEMP Simulated Temperatures in Battle Creek for the No Dam Removal Alternative in August



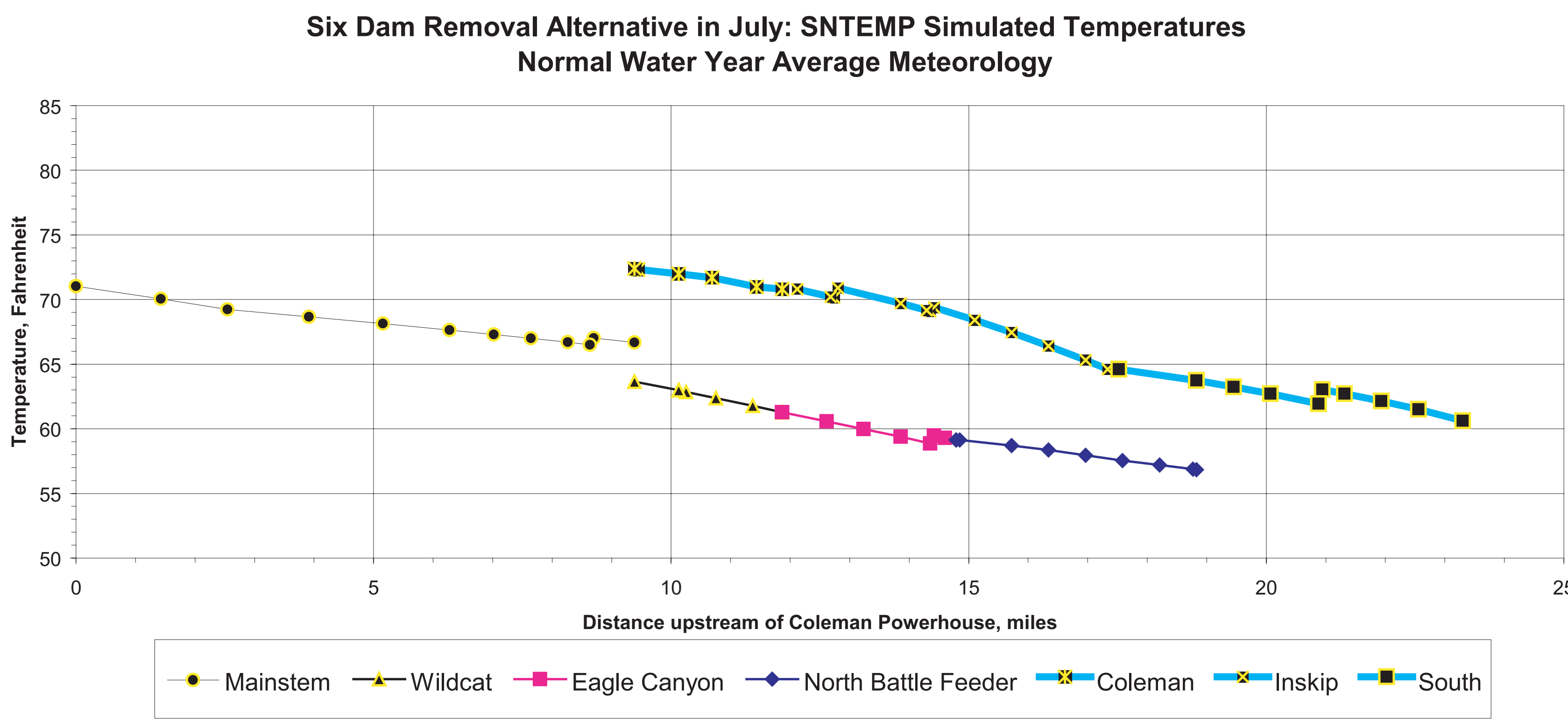
03035.03 FEIS/EIR

Figure R-23
SNTEMP Simulated Temperatures in Battle Creek for the No Dam Removal Alternative in September



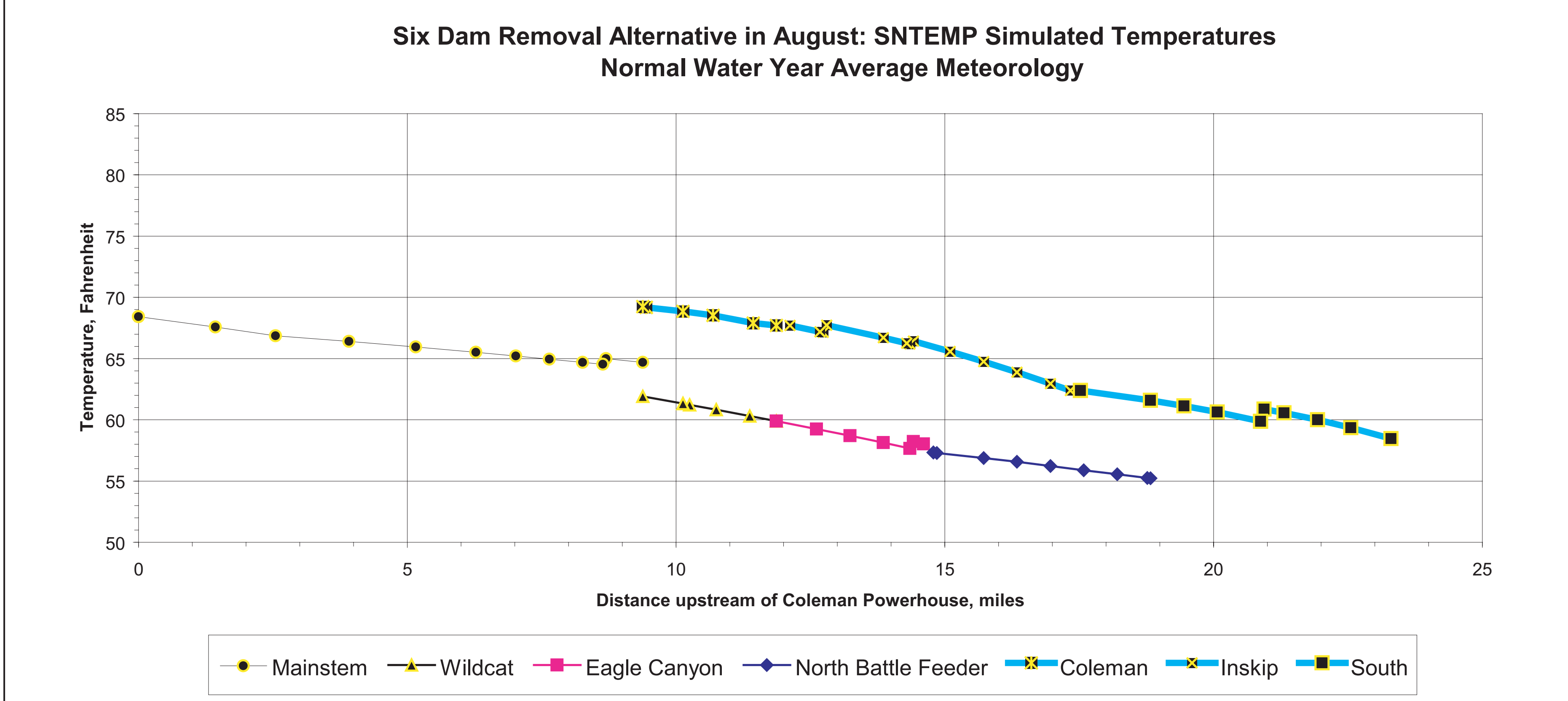
03035.03 FEIS/EIR

Figure R-24
SNTEMP Simulated Temperatures in Battle Creek for the Six Dam Removal Alternative in June



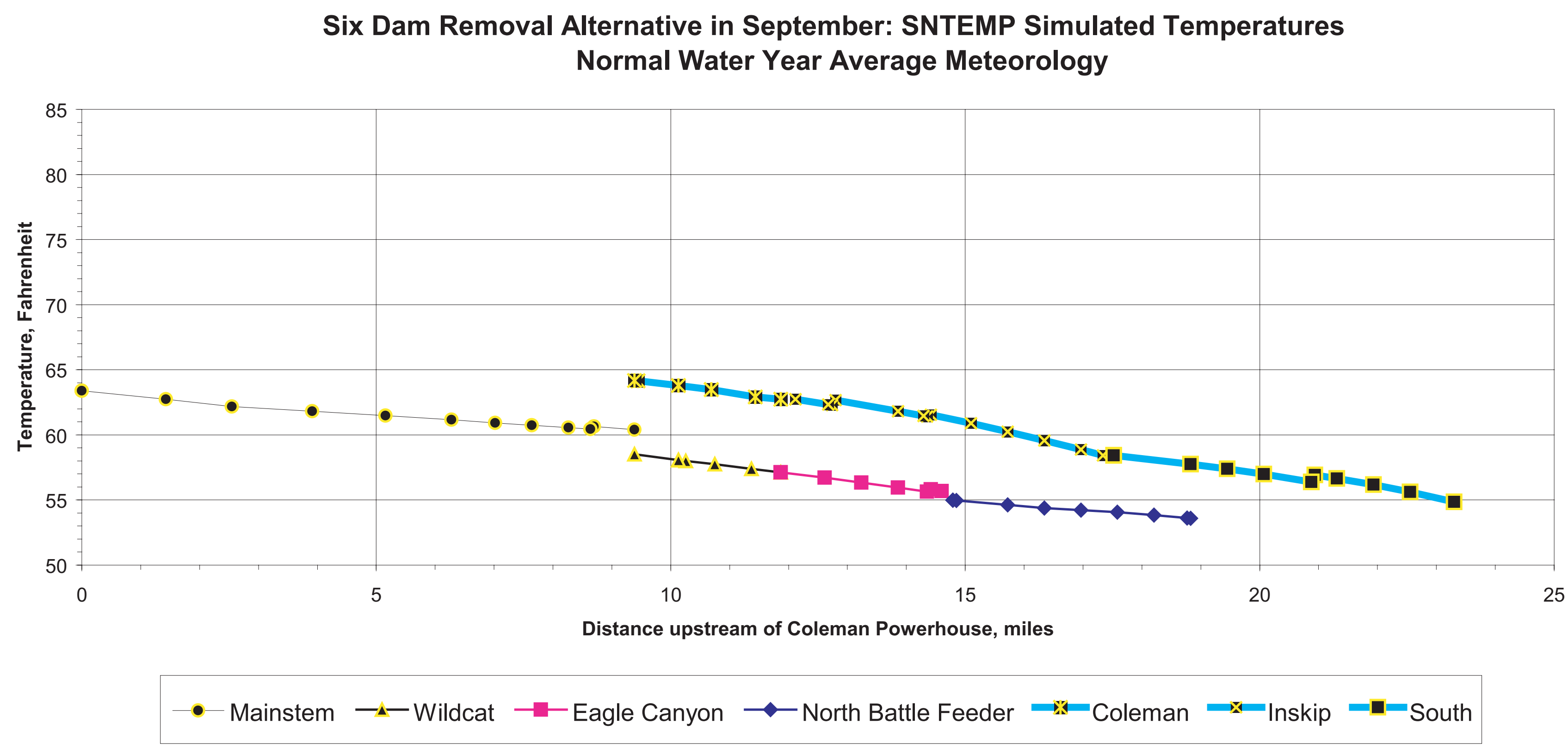
03035.03 FEIS/EIR

Figure R-25
SNTEMP Simulated Temperatures in Battle Creek for the Six Dam Removal Alternative in July



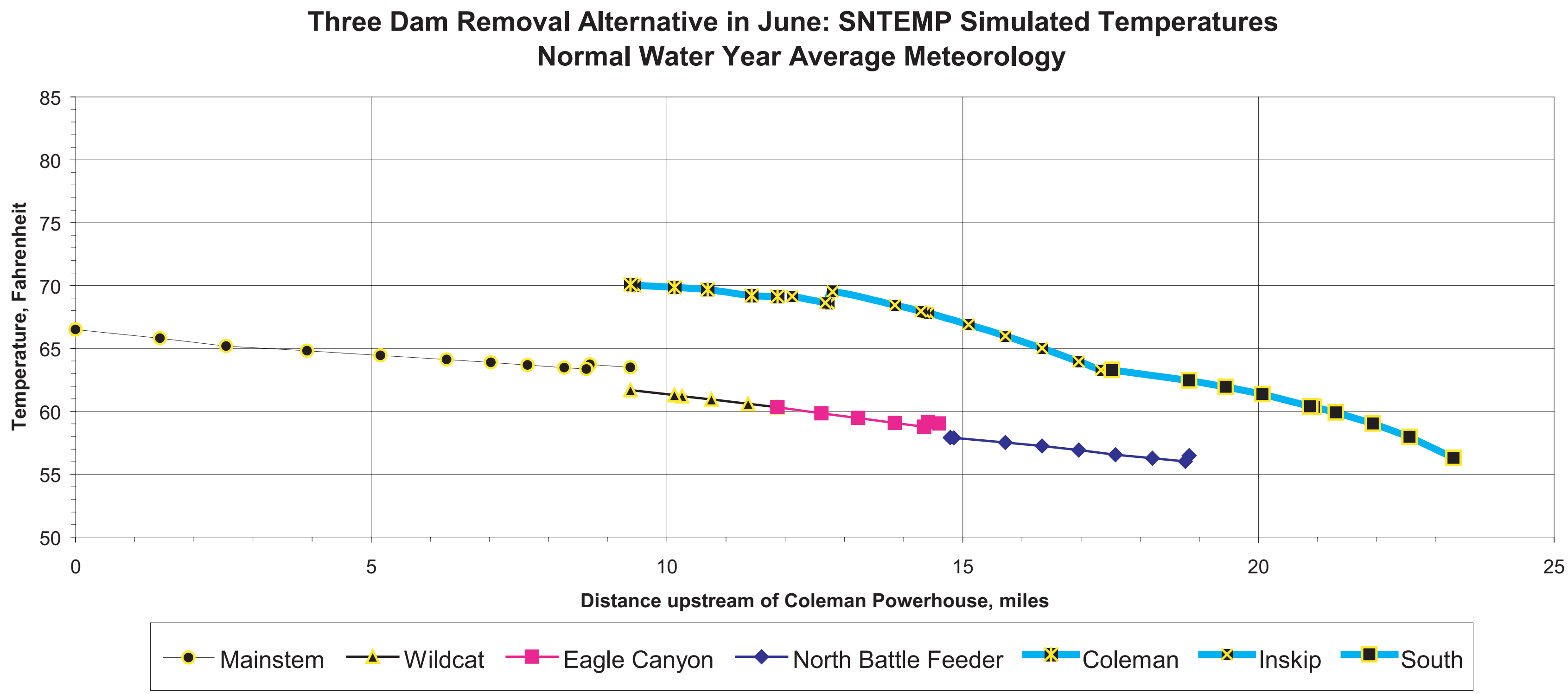
03035.03 FEIS/EIR

Figure R-26
SNTEMP Simulated Temperatures in Battle Creek for the Six Dam Removal Alternative in August



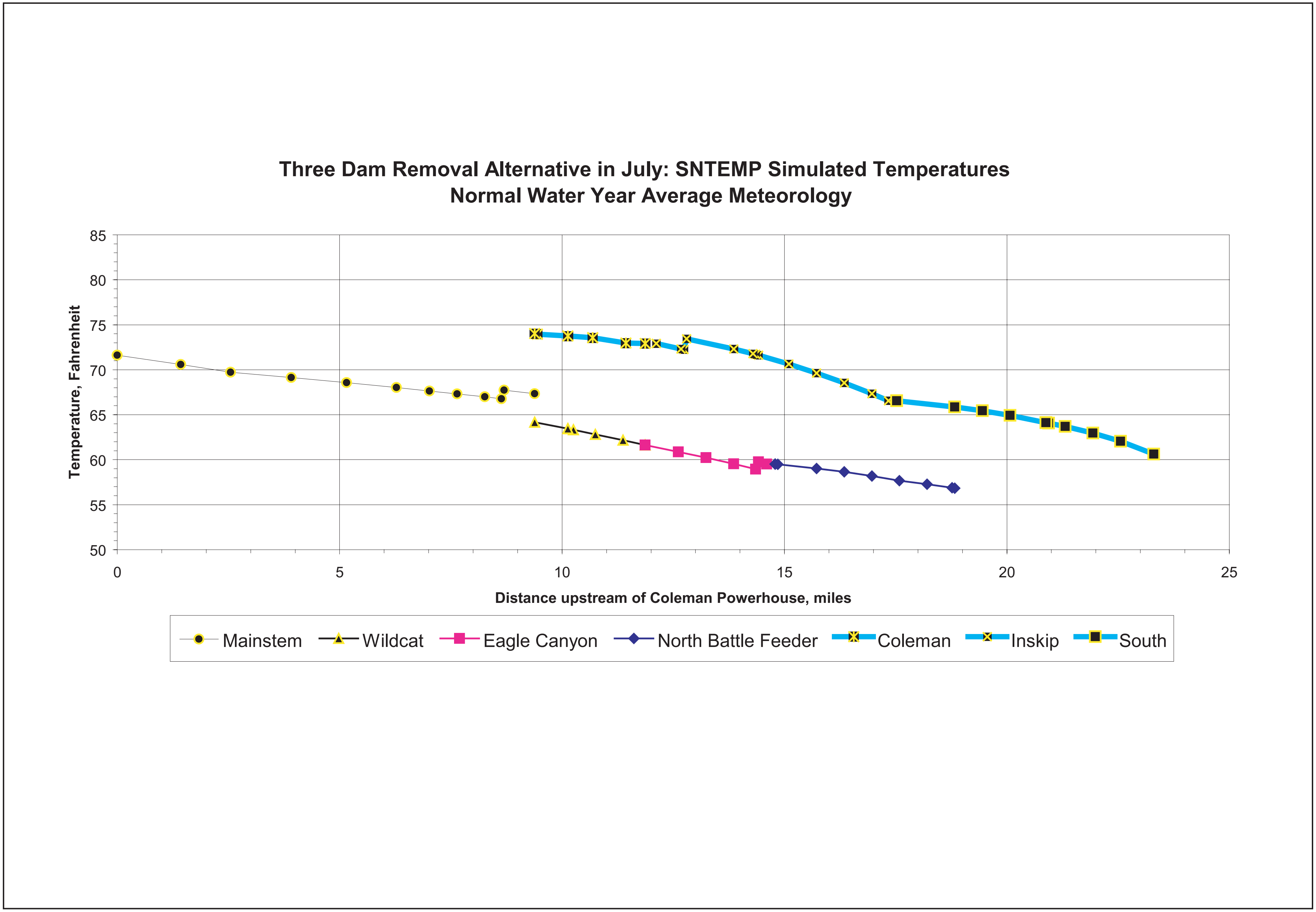
03035.03 FEIS/EIR

Figure R-27
SNTEMP Simulated Temperatures in Battle Creek for the Six Dam Removal Alternative in September



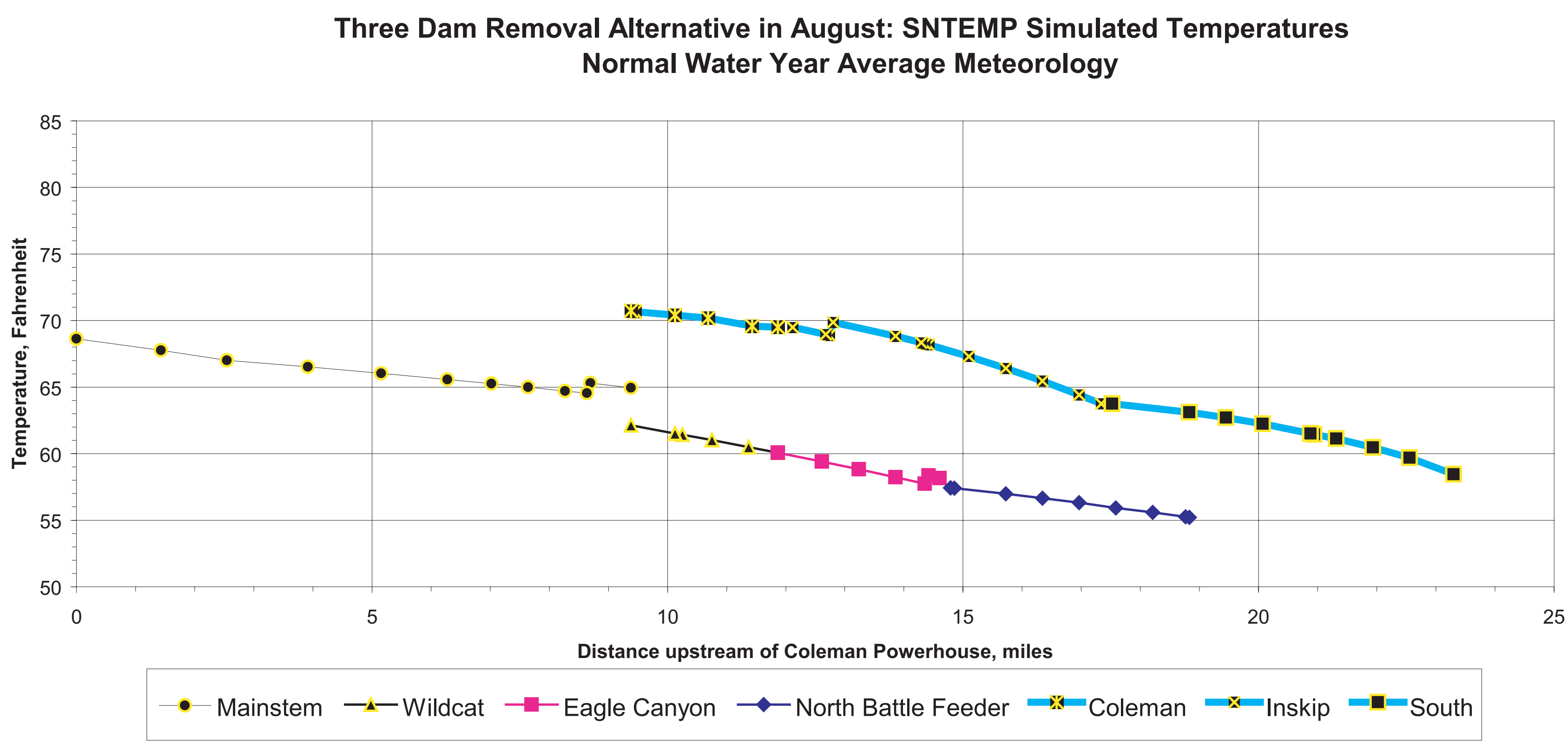
03035.03 FEIS/EIR

Figure R-28
SNTEMP Simulated Temperatures in Battle Creek for the Three Dam Removal Alternative in June



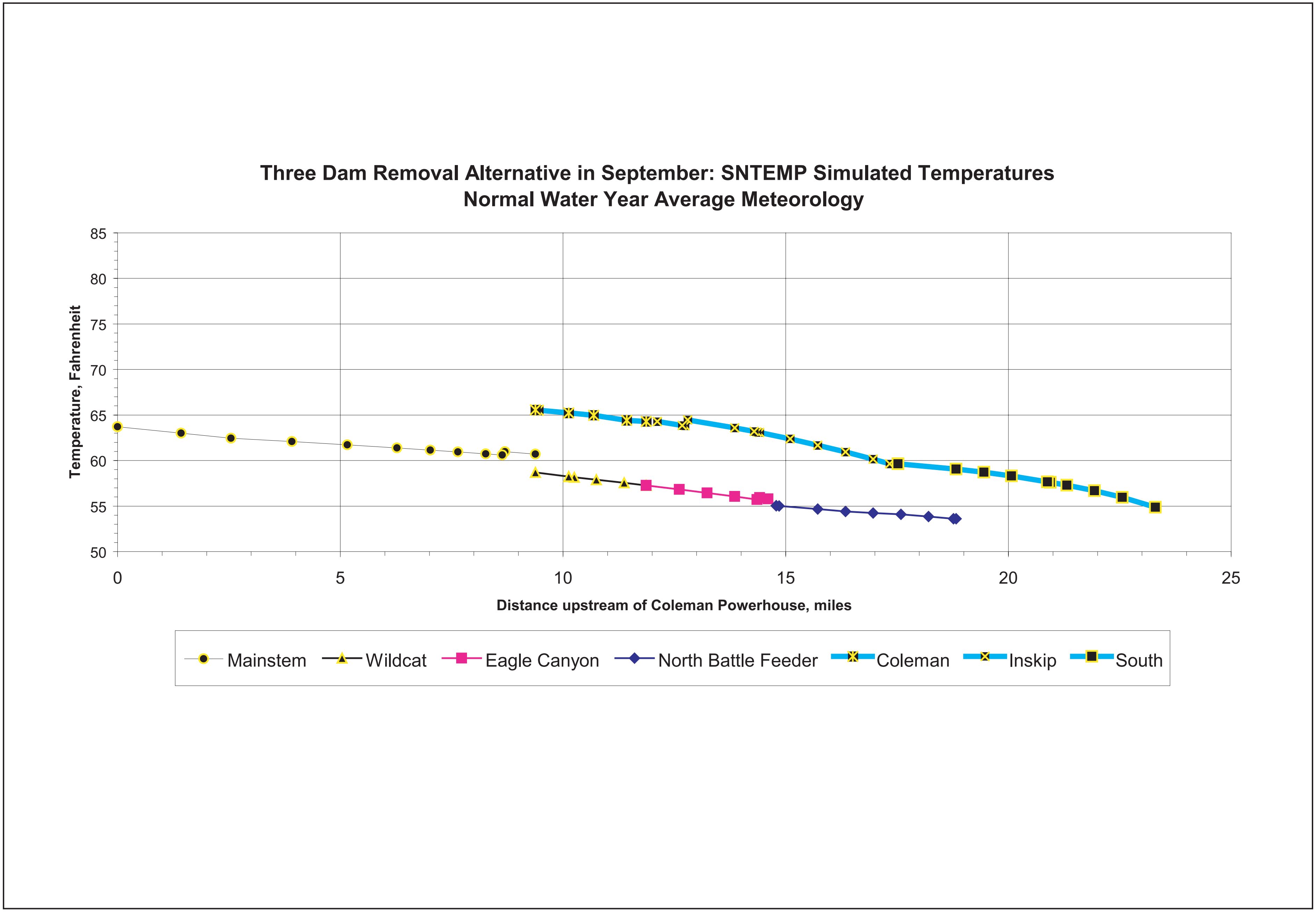
03035.03 FEIS/EIR

Figure R-29
SNTEMP Simulated Temperatures in Battle Creek for the Three Dam Removal Alternative in July



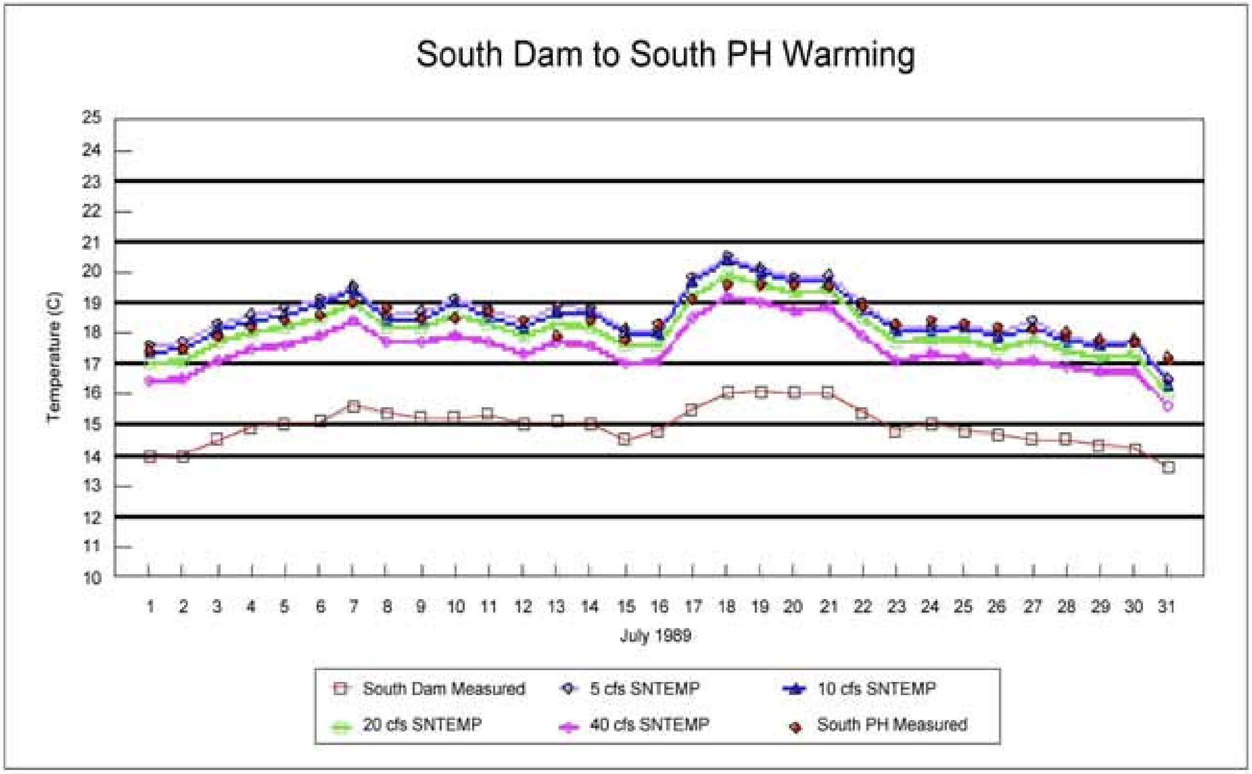
03035.03 FEIS/EIR

Figure R-30
SNTEMP Simulated Temperatures in Battle Creek for the Three Dam Removal Alternative in August



03035.03 FEIS/EIR

Figure R-31
SNTEMP Simulated Temperatures in Battle Creek for the Three Dam Removal Alternative in September



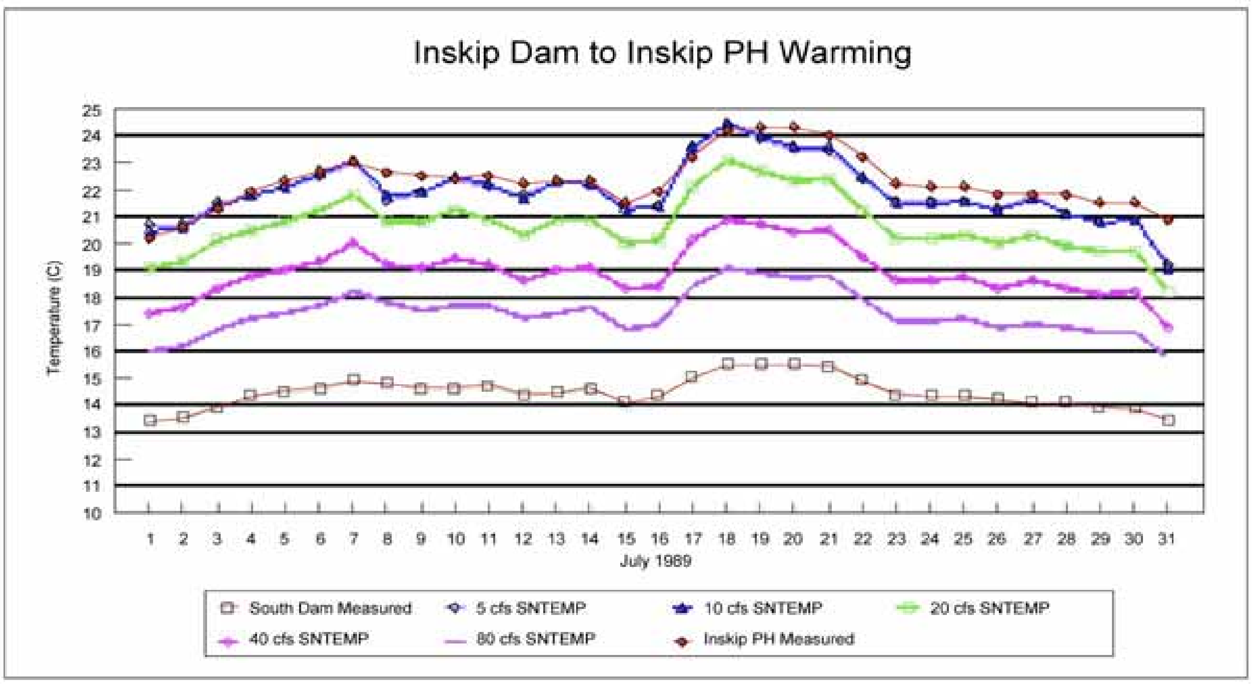
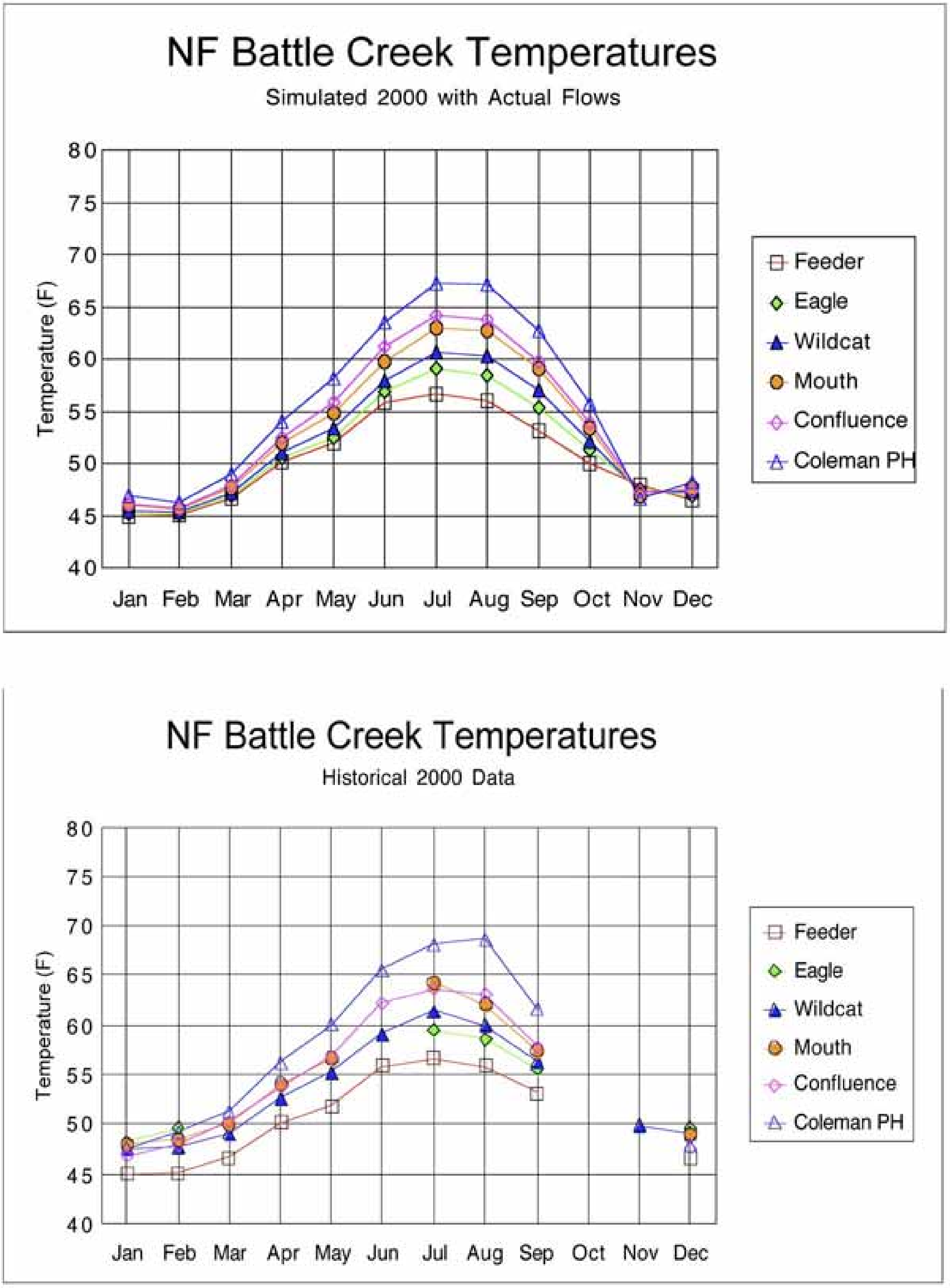
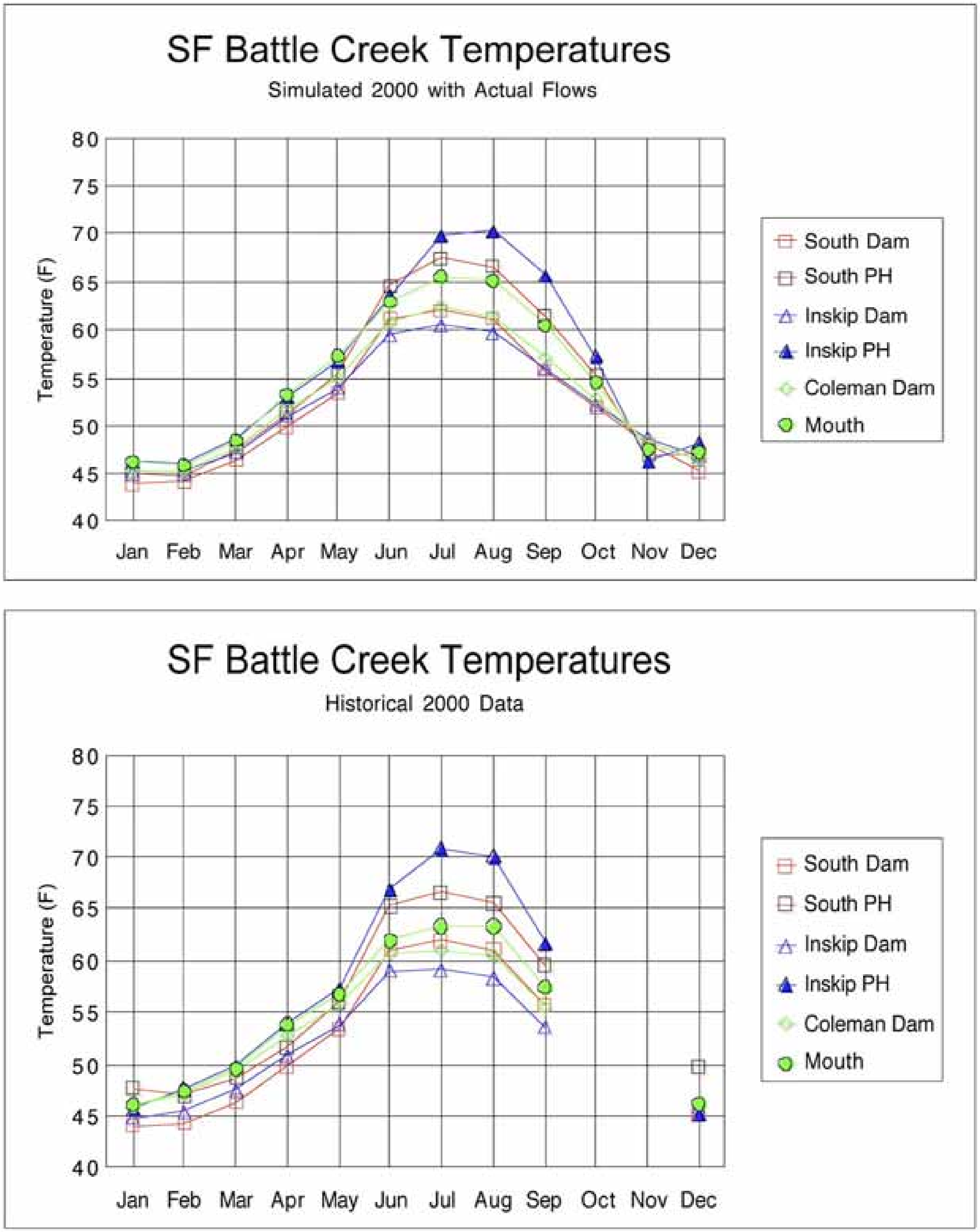


Figure R-32
SNTEMP Simulated Warming below South Dam and below InskipDam for a Range of Flows with 1989 Upstream Temperatures and Meteorology



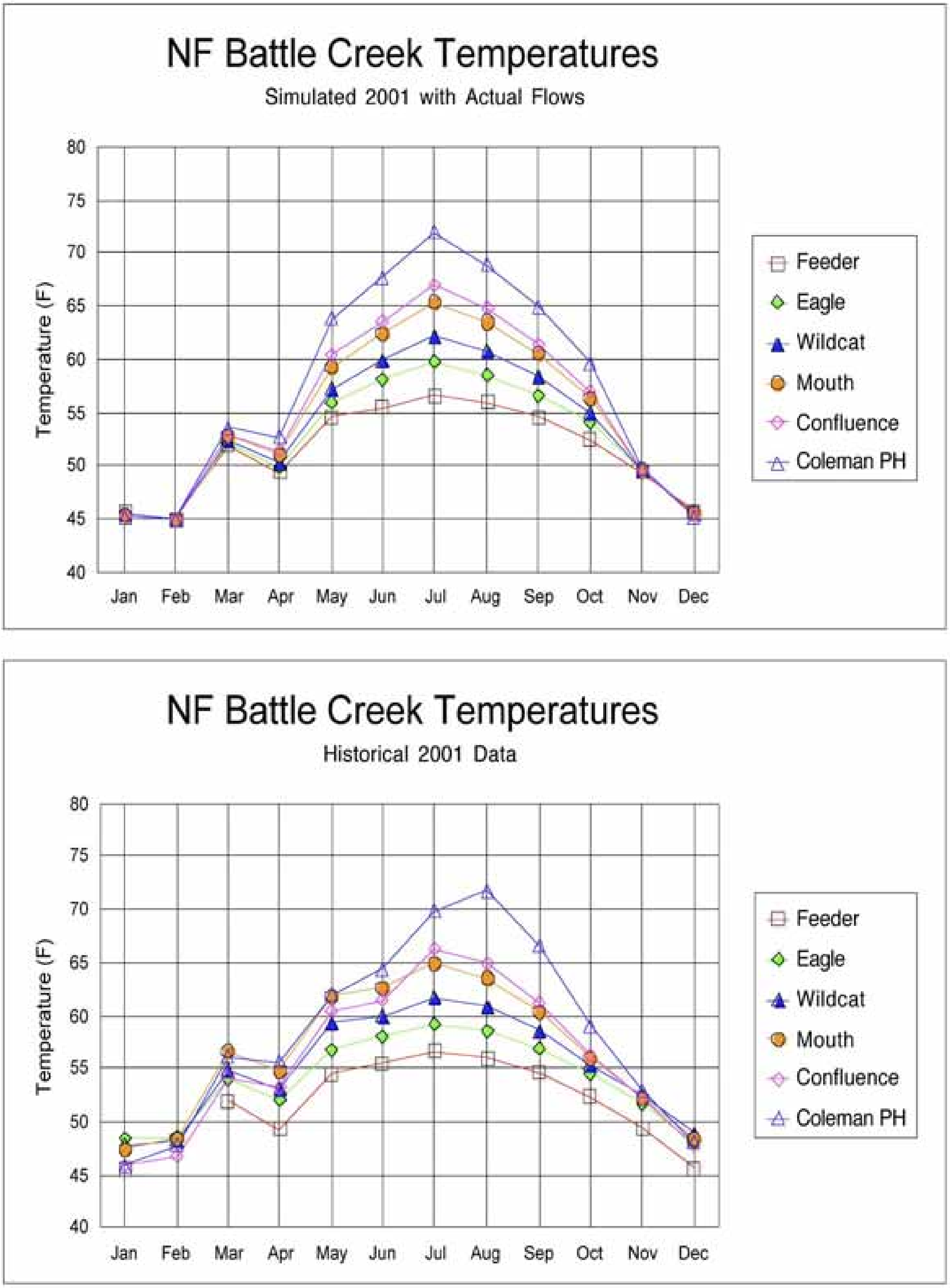
03035.03 FEIS/EIR

Figure R-33
Calibrated North Fork Battle Creek Temperatures for 2000 using Measured Feeder Dam Temperatures and Air Temperature Estimates of Equilibrium Temperatures



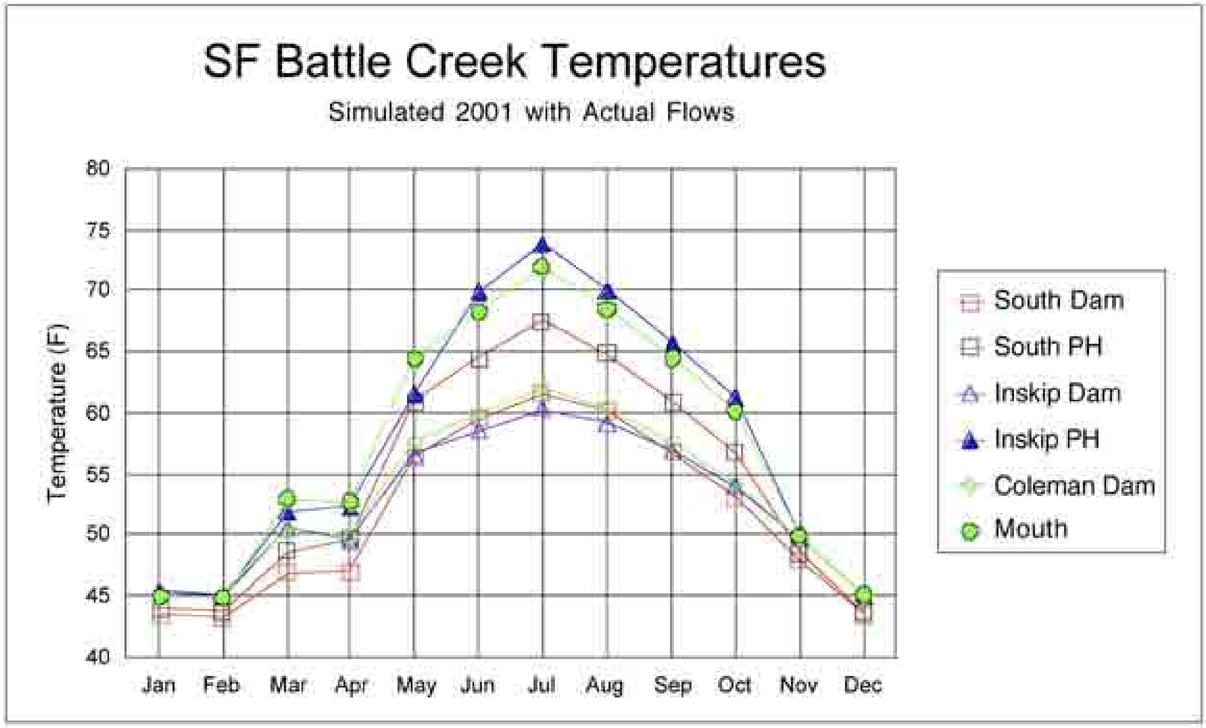
03035.03 FEIS/EIR

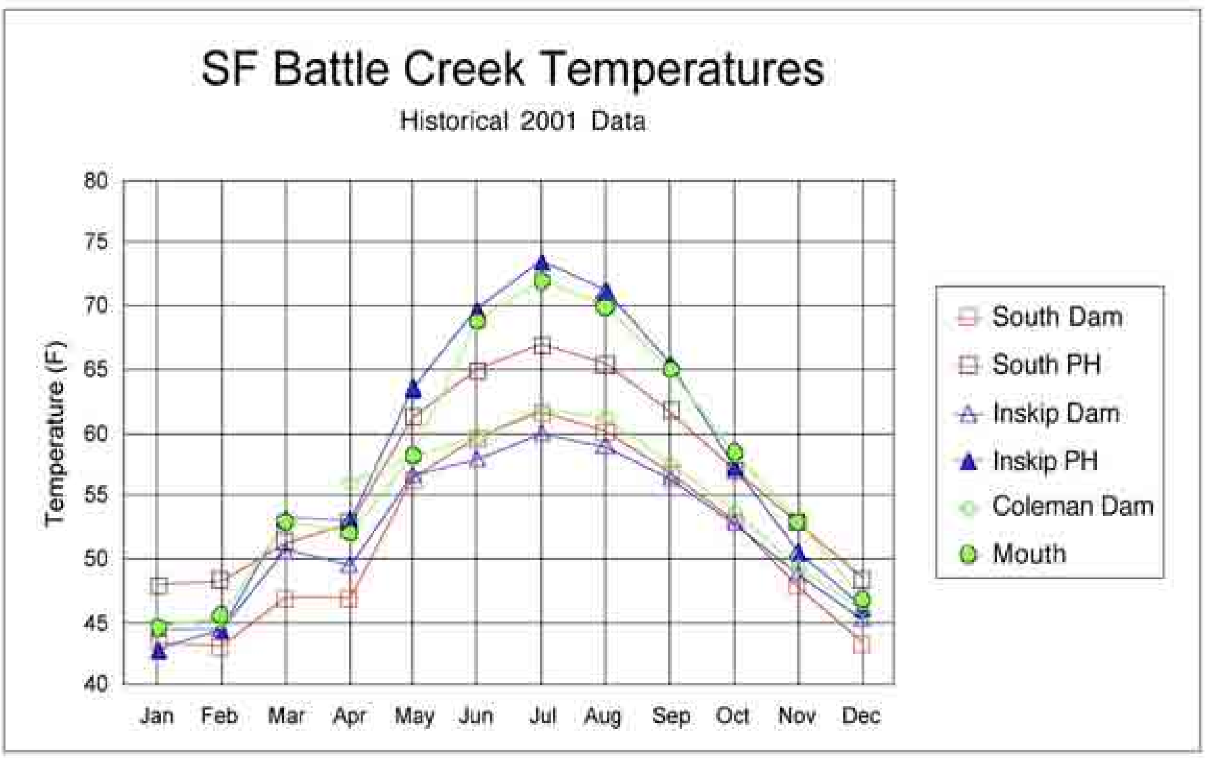
Figure R-34
Calibrated South Fork Battle Creek Temperatures for 2000 using Measured Feeder Dam Temperatures and Air Temperature Estimates of Equilibrium Temperatures



03035.03 FEIS/EIR

Figure R-35
Calibrated North Fork Battle Creek Temperatures for 2001 using Measured Feeder Dam Temperatures and Air Temperature Estimates ofEquilibrium Temperatures





03035.03 FEIS/EIR

Figure R-36
Calibrated South Fork Battle Creek Temperatures for 2001 using Measured Feeder Dam Temperatures and Air Temperature Estimates of Equilibrium Temperatures

Appendix S

Historical Battle Creek Water Quality Data

Appendix S
Historical Battle Creek Water Quality Data

This appendix contains water quality measurements made in Battle Creek by a variety of agencies that indicate the general mineral water composition. Water temperature measurements collected by TRPA in 1989 and by the California Department of Water Resources from 1998 to 2001 are also summarized as daily average values.

Table S-1. U.S. Geological Survey Water Quality Data for Battle Creek below Coleman National Fish Hatchery (40°23’54” N 122°08’43” W; 5.7 miles upstream from mouth), 1961–1970

Date	Temp (°F)	Flow (cfs)	TSS (mg/L)	TDS (mg/L)	Specific Conductance (:mhos/cm)	pH	Alkalinity (mg/L)	Total Hardness (mg/L)	Ca (mg/L)	Mg (mg/L)
10/5/61		213			148	8.4	71	59		
11/2/61	52	241	3							
11/9/61		241			153	8.1	74	58		
11/21/61	43	245	3							
11/29/61	48	461	12							
12/7/61		304			142	7.9	68	57		
12/20/61	47	709	17							
12/27/61	47	219	9							
1/4/62	45	286	16							
1/11/62		273			147	7.8	67	59		
1/19/62	47	866	121							
2/6/62	47	309	12							
2/9/62	50	1080	69		80	7.4	34	31		
2/15/62	46	2650	149							
2/16/62	46	930	27							
3/9/62	47	530	7							
3/13/62	48	426	7							
3/14/62		417			126	7.6	59	49		
4/6/62	58	484	16							

Date	Temp (°F)	Flow (cfs)	TSS (mg/L)	TDS (mg/L)	Specific Conductance (: mhos/cm)	pH	Alkalinity (mg/L)	Total Hardness (mg/L)	Ca (mg/L)	Mg (mg/L)
4/11/62	458				107	7.9	52	43		
5/3/62	61	512	12							
6/3/62		498		93	106	7.8	48	40	8.0	4.9
6/5/62	59	408	35							
6/8/62		399			114	7.8	54	44		
6/15/62	58	422	12							
7/2/62		268			130	8.1	61	51		
8/1/62		206			146	8.1	69	56		
8/2/62	67	201	4							
9/11/62		170		125	156	8.1	75	60	12.0	7.3
9/26/62	58	188	3							
10/1/62		210			152	8.0	75	57		
10/16/62	51	579	40							
11/1/62		322			135	8.0	66	50		
11/23/62	50	309	5							
12/7/62		417			118	8.1	59	45		
12/19/62	49	704	16							
1/4/63		368			128	7.8	62	49		
1/24/63	45	309	4							
2/4/63		1120			77	7.6	35	29		
2/12/63	51	602	11							
2/28/62		385	9							
3/4/63		365			124	7.9	62	48		
3/21/63	52	355	11							
4/5/63		461			118	8.1	58	45		
4/25/63	51	704	10							
5/3/63		856		86	94	7.9	46	37	7.2	4.6
5/21/63	59	814	25							
6/5/63		520			104	8.0	56	42		
6/27/63	63	372	42							
7/12/63		314			130	8.2	65	51		
8/1/63	64	304	7							
8/2/63		250			137	8.2	68	52		

Date	Temp (°F)	Flow (cfs)	TSS (mg/L)	TDS (mg/L)	Specific Conductance (: mhos/cm)	pH	Alkalinity (mg/L)	Total Hardness (mg/L)	Ca (mg/L)	Mg (mg/L)
9/4/63	64	237	8							
9/12/63		242		119	146	8.2	71	56	10.0	7.5
10/3/63	61	246	5							
10/1063		278			138	8.0		56		
11/7/63		404			125	8.0		44		
11/8/63	50	555	40							
11/14/63	54	358	12							
12/5/63	40	318	4		137	8.0		52		
12/13/63	45	309	7							
12/31/63	49	309	6							
1/2/64		309			137	8.2		52		
1/16/64	45	296	4							
2/4/64	45	370	5							
2/6/64		352			130	8.2		50		
2/20/64	50	334	4							
3/4/64	50	334	8							
3/12/64		343			139	8.3		49		
3/26/64	52	320	9							
3/31/64		384	11							
4/9/64		384			124	8.2		48		
5/2/64	49	428	6							
5/5/64	50	388	7							
5/7/64		366		110	122	8.0		49	11.0	5.2
6/11/64	59	338	23		114	7.9		45		
7/9/64		235			142	8.3		54		
7/15/64	67	732	8							
8/3/64		182			154	8.5		60		
8/19/64	64	660	17							
9/4/64		190		124	150	8.3		59	11.0	7.7
9/26/64	59	235	7							
10/8/64		222			153	8.1		58		
11/9/64		1300			80	7.3		28		
11/13/64	47	440	6							

Date	Temp (°F)	Flow (cfs)	TSS (mg/L)	TDS (mg/L)	Specific Conductance (:mhos/cm)	pH	Alkalinity (mg/L)	Total Hardness (mg/L)	Ca (mg/L)	Mg (mg/L)
12/10/64		395			132	8.0		48		
12/17/64	42	375	4							
12/2264	52	9340	722							
12/29/64	42	1250	72							
1/14/65		827			98	8.2		38		
1/19/65	47	748	19							
2/1/65		685			106	8.2		40		
2/28/65	45	585	7							
3/1/65		540			113	8.5		43		
4/1/65	49	530	15							
4/5/65		515			115	7.9		45		
5/6/65	52	645	12	88	99	8.0		39	9.6	3.6
6/14/65		498			107	8.6		41		
6/16/65	61	455	10							
7/12/65		371			123	8.2		46		
8/3/65	69	264	5							
8/13/65		328			130	8.3		51		
9/1/65	61	291	5							
9/13/65		277		124	142	8.1		54	8.8	7.8
10/7/65		272			142	8.3		58		
10/9/65	58	273	3							
11/4/65		272			143	8.2		55		
11/18/65	51	827	102							
12/13/65		380			138	7.8		52		
12/16/65	41	282	7							
1/5/66	46	906	21		85	7.7		34		
2/4/66		844			93	8.1		36		
3/1/66	48	380	20							
3/8/66		377			131	8.1		52		
3/10/66	52	425	12							
3/31/66	53	535	39							
4/11/66	49	620	21							
4/12/66		583			100	8.0		38		

Date	Temp (°F)	Flow (cfs)	TSS (mg/L)	TDS (mg/L)	Specific Conductance (: mhos/cm)	pH	Alkalinity (mg/L)	Total Hardness (mg/L)	Ca (mg/L)	Mg (mg/L)
5/2/66	57	450	10	101	110	7.9		44	8.8	5.4
6/2/66		331			125	8.2		48		
7/6/66		266			142	8.2		55		
9/1/66		190		125	152	8.2		58	10.0	8.0
103/66	58	217	5							
11/1/66	54	233	5							
12/2/66	51	632	9							
1/3/67	43	290	5							
2/1/67	48	1260	37							
3/1/67	50	410	6							
4/3/67	49	590	9							
11/2/67	55	244	6							
12/4/67	48	440	8							
1/9/68	45	280	4							
2/12/68	52	464	11							
2/20/68	50	2440	147							
3/19/68	48	608	4							
5/3/68	57	410	8							
6/4/68	61	350	7							
7/31/68	63	220	8							
9/5/68	61	234	14							
10/3/68	54	244	10							
11/21/68	50	324	11							
12/20/68	41	440	7							
1/22/69	41	2630	341							
2/11/69	46	1620	204							
2/17/69	46	1070	19							
3/5/69	45	795	26							
4/7/69	46	970	35							
5/6/69	54	942	31							
6/5/69	61	893	25							
8/11/69	63	324	10							
9/19/69	59	297	12							

Date	Temp (°F)	Flow (cfs)	TSS (mg/L)	TDS (mg/L)	Specific Conductance (:mhos/cm)	pH	Alkalinity (mg/L)	Total Hardness (mg/L)	Ca (mg/L)	Mg (mg/L)
10/6/69	52	306	6							
11/3/69	58	316	4							
12/15/69	49	618	10							
12/20/69	53	2820	112							
1/7/70	45	466	7							
1/14/70	48	4380	383							
1/19/70	50	1690	79							
1/30/70	45	1590	109							
2/18/70	46	905	30							
3/9/70	47	1060	65							
3/20/70	50	710	10							
4/9/70	54	710	7							
5/8/70	55	604	13							
6/11/70	58	541	24							
7/6/70	66	473	7							
8/27/70	60	281	4							

Table S-1 Continued. U.S. Geological Survey Water Quality Data for Battle Creek below Coleman National Fish Hatchery (40°23’54” N 122°08’43” W; 5.7 miles upstream from mouth), 1961–1970

Date	Na (mg/L)	K (mg/L)	Cl (mg/L)	F (mg/L)	SO_4 (mg/L)	B (: g/L)	SiO_2 (mg/L)	NO_3–N (mg/L)
10/5/61	8.4							
11/2/61								
11/9/61	8.7		2.4			100		
11/21/61								
11/29/61								
12/7/61	7.7		1.5			100		
12/20/61								
12/27/61								
1/4/62								
1/11/62	7.9		4.2			0		
1/19/62								
2/6/62								
2/9/62	4.3		1.1			0		
2/15/62								
2/16/62								
3/9/62								
3/13/62								
3/14/62	6.6		2.0			100		
4/6/62								
4/11/62	6.5		1.2			300		
5/3/62								
6/3/62	5.9	1.7	1.5	0.00	3.4	0	39	0.00
6/5/62								
6/8/62	6.3		1.3			100		
6/15/62								
7/2/62	7.9		1.8			0		
8/1/62	9.2		4.3			0		
8/2/62								
9/11/62	9.1	2.1	2.5	0.01	1.0	0	45	0.07
9/26/62								
10/1/62	9.6		2.8			200		

Date	Na (mg/L)	K (mg/L)	Cl (mg/L)	F (mg/L)	SO_4 (mg/L)	B (: g/L)	SiO_2 (mg/L)	NO_3–N (mg/L)
10/16/62								
11/1/62	7.8		1.2			0		
11/23/62								
12/7/62	6.6		0.1			0		
12/19/62								
1/4/63	7.3		3.5			0		
1/24/63								
2/4/63	3.9		1.0			0		
2/12/63								
2/28/62								
3/4/63	6.6		3.6			0		
3/21/63								
4/5/63	6.3		2.1			0		
4/25/63								
5/3/63	5.0	1.5	1.5	0.10	0.0	0	37	1.00
5/21/63								
6/5/63	5.6		1.2			100		
6/27/63								
7/12/63	7.2		1.8			0		
8/1/63								
8/2/63	7.4		1.5			200		
9/4/63								
9/12/63	7.8	1.8	2.0	0.01	1.0	0	45	0.05
10/3/63								
10/1063	7.6		3.9			0		
11/7/63	7.0		2.0			100		
11/8/63								
11/14/63								
12/5/63	8.0		3.4			0		
12/13/63								
12/31/63								
1/2/64	8.0		3.6			0		
1/16/64								
2/4/64								

Date	Na (mg/L)	K (mg/L)	Cl (mg/L)	F (mg/L)	SO_4 (mg/L)	B (: g/L)	SiO_2 (mg/L)	NO_3–N (mg/L)
2/6/64	8.5		3.0			0		
2/20/64								
3/4/64								
3/12/64	8.6		3.2			100		
3/26/64								
3/31/64								
4/9/64	7.5		3.0			0		
5/2/64								
5/5/64								
5/7/64	6.9	1.8	3.2	0.0	3.0	100	43	1.0
6/11/64	7.0		1.0			0		
7/9/64	8.2		1.0			100		
7/15/64								
8/3/64	9.0		3.0			0		
8/19/64								
9/4/64	8.3	3.1	2.1		2.0	100	46	0.8
9/26/64								
10/8/64	8.1		1.9			0		
11/9/64	4.4		2.1			100		
11/13/64								
12/10/64	7.1		1.4			0		
12/17/64								
12/2264								
12/29/64								
1/14/65	5.3		1.1			0		
1/19/65								
2/1/65	5.8		1.0			0		
2/28/65								
3/1/65	5.7		1.0			0		
4/1/65								
4/5/65	6.2		1.3			0		
5/6/65	5.3	2.1	1.1		1.0	0	37	1.4
6/14/65	5.8		1.2			0		
6/16/65								

Date	Na (mg/L)	K (mg/L)	Cl (mg/L)	F (mg/L)	SO_4 (mg/L)	B (: g/L)	SiO_2 (mg/L)	NO_3–N (mg/L)
7/12/65	7.1		1.3			0		
8/3/65								
8/13/65	7.4		1.7			0		
9/1/65								
9/13/65	8.3	2.0	2.0		3.0	0	48	0.2
10/7/65	8.2		1.3			0		
10/9/65								
11/4/65	8.1		1.3			0		
11/18/65								
12/13/65	7.6		2.1			0		
12/16/65								
1/5/66	5.0		1.6			0		
2/4/66	4.9		1.4			100		
3/1/66								
3/8/66	7.1		0.9			0		
3/10/66								
3/31/66								
4/11/66								
4/12/66	5.4		0.6			0		
5/2/66	6.1	1.6	1.3		3.0	0	35	0.5
6/2/66	7.0		1.2			0		
7/6/66	7.9		1.4			0		
9/1/66	9.2	2.3	1.8		3.0	0	46	0.1
103/66								
11/1/66								
12/2/66								
1/3/67								
2/1/67								
3/1/67								
4/3/67								
11/2/67								
12/4/67								
1/9/68								
2/12/68								

Date	Na (mg/L)	K (mg/L)	Cl (mg/L)	F (mg/L)	SO_4 (mg/L)	B (: g/L)	SiO_2 (mg/L)	NO_3–N (mg/L)
2/20/68								
3/19/68								
5/3/68								
6/4/68								
7/31/68								
9/5/68								
10/3/68								
11/21/68								
12/20/68								
1/22/69								
2/11/69								
2/17/69								
3/5/69								
4/7/69								
5/6/69								
6/5/69								
8/11/69								
9/19/69								
10/6/69								
11/3/69								
12/15/69								
12/20/69								
1/7/70								
1/14/70								
1/19/70								
1/30/70								
2/18/70								
3/9/70								
3/20/70								
4/9/70								
5/8/70								
6/11/70								
7/6/70								
8/27/70								

Date	Na (mg/L)	K (mg/L)	Cl (mg/L)	F (mg/L)	SO_4 (mg/L)	B (: g/L)	SiO_2 (mg/L)	NO_3–N (mg/L)

Source: U.S. Geological Survey; U.S. Environmental Protection Agency STORET database.

Table S-2. U.S. Environmental Protection Agency Water Quality Data for Battle Creek below Coleman Powerhouse (40°23’54” N 122°08’10” W), 1971–1972

Date	BOD_5 (mg/L)	Alkalinity (mg/L)	Total Hardness (mg/L)	Total Residue (mg/L)	TSS (mg/L)	NH_3+NH_4 (mg/L)	NO_2–N (mg/L)
7/14/71	3.5	75	102	66	15.0	0.02	0.20
8/10/71	2.3	88	116	97	8.0	0.05	0.03
9/13/71	1.8	73	100	68	10.0	0.01	0.02
10/21/71	1.2	70	110	69	11.0	0.04	0.06
11/8/71	2.1	72	85	72	16.0	0.10	0.05
12/20/71	3.1	74	73	146	12.0	0.30	0.02
1/10/72	2.0	75	52	115	3.7	0.33	0.09
2/14/72	2.3	70	52	112	2.5	0.35	0.10
3/15/72	2.5	56	45	110	2.1	0.30	0.10
4/10/72	3.0	54	50	110	3.7	0.30	0.14
5/8/72	4.0	66	72	120	3.0	0.26	0.14
6/15/72	2.8	68	60	124	2.0	0.20	0.09

Table S-2 Continued. U.S. Environmental Protection Agency Water Quality Data for Battle Creek below Coleman Powerhouse (40°23’54” N 122°08’10” W), 1971–1972

Date	NO_3–N (mg/L)	Total Kjeldahl N (mg/L)	Total PO_4 (mg/L)	OrthoPO_4 (mg/L)	Total Coliforms (100/mL)	Fecal Coliforms (100/mL)
7/14/71	0.10	0.14	0.36	0.03	10	0
8/10/71	0.11	0.20	0.40	0.03	32	0
9/13/71	0.15	0.20	0.30	0.03	75	0
10/21/71	0.14	0.30	0.23	0.05		
11/8/71	0.17	0.42	0.43	0.04		
12/20/71	0.14	0.75	0.73	0.03		
1/10/72	0.20	0.65	0.35	0.15	32	3
2/14/72	0.38	0.88	0.33	0.30		
3/15/72	0.16	0.58	0.45	0.28		
4/10/72	0.14	0.59	0.46	0.30		
5/8/72	0.12	0.58	0.70	0.29		
6/15/72	0.10	0.45	0.88	0.30		

Source: U.S. Environmental Protection Agency (USEPA) Region 1, USEPA STORET database.

Table S-3. California Department of Water Resources Water Quality Data for Battle Creek Below Coleman National Fish Hatchery (40°23"54" N 122°08'43" W; 5.7 miles upstream from mouth), 1988–1989

Date	Time	Temp (°F)	Specific Conductance (:mhos/cm)	Turbidity (NTU)	DO (mg/L)	pH	Alkalinity (mg/L)	Total Hardness (mg/L)	Ca mg/L	Mg mg/L	Na mg/L	SO_4 mg/L	B mg/L
1988													
3/16	0930	49	142		12.0	7.5		54	10	7	7	3	<0.1
6/13	0508	60	160	1.0	6.5	7.3	78						
6/13	1000	66	126	0.8	11.7	7.8	68						
6/13	1400	68	135	0.7	10.4	8.2	65						
6/13	1940	66	140	0.9	7.7	8.1	62						
6/13	2110	66	143	0.9	8.3	7.9	64						
6/14	0215	63	142	0.8	8.3	7.3	63						
6/14	0505	61	160	1.1	7.2	7.2	65						
6/14	1010	67	145	1.9	10.2	8.1							
6/14	1400	69	140	1.1	9.6	7.8	65						
6/14	1910	67	141	1.1	8.3	7.9							
6/14	2100	67	158	1.1	8.2	7.9	66						
6/15	0150	64	155	1.0	8.3	7.9							
9/12	0505	59	87	0.4	8.2	7.3	76						
9/12	0910	60	165	0.9	10.7	7.5							
9/12	1330	65	258	0.5	11.0	8.3							
9/12	1715	64	176	0.4	10.1	8.6	75						
9/12	2135	64	120	0.5	8.6	7.9							
9/13	0125	59	160	0.5	9.0	7.6							
9/13	0515	66	156	0.6	9.3	7.7							
9/13	0930	59	160	0.5	10.6	8.0	75	64	11	9	9	3	<0.1
9/13	1320	63	165	0.5	11.2	8.1							
9/13	1820	62	170	0.5	8.5	8.2							
9/13	2115	61	137	0.5	8.7	8.0							
9/14	0050	60	162	0.5	9.6	7.6	75						
1989													
3/20	0615	48	67	5.0	11.0	7.2							
3/20	1005	50	88	3.5	11.8	7.3	42						
3/20	1435	52	112		10.8	7.5							

Date	Time	Temp (°F)	Specific Conductance (:mhos/cm)	Turbidity (NTU)	DO (mg/L)	pH	Alkalinity (mg/L)	Total Hardness (mg/L)	Ca mg/L	Mg mg/L	Na mg/L	SO_4 mg/L	B mg/L
3/20	1915	54	95	2.6	10.3	7.5							
3/20	2220	52	105	2.8	10.6	7.3							
3/21	0235	52	30	2.5	3.2	7.2	45						
3/21	0615	51	117	2.4	10.6	7.1							
3/21	1105	53	96	2.1	10.6	7.2		38	7	5	5	2	<0.1
3/21	1505	55	122	3.0	11.2	7.3	46						
3/21	1815	55	100	3.1	10.8	7.4							
3/21	2220	53	108	3.2	10.6	7.3							
3/22	0240	52	97	3.1	10.5	7.3	46						
8/14	0600	69	120	0.7	8.1	7.8	85						
8/14	0910	66	153	0.6	10.2	8.1							
8/14	1325	70	173	0.7	9.8	8.1	82						
8/14	1710	73	156	0.6	8.6	8.3	75						
8/14	2140	68	158	0.9	8.8	8.5							
8/15	0115	64	156	0.7	8.6	8.2	75						
8/15	0530	63	148	0.9	8.5	7.9							
8/15	0916	67	157	0.7	9.8	8.1		58	10	8	9	2	<0.1
8/15	1435	74	154	0.8	9.1	8.1	83						
8/15	1725	70	153	0.9	8.6	8.4							
8/15	2125	66	150	0.9	8.3	8.6							
8/16	0120	68	147	0.6	8.6	8.3	80						

Table S-3 Continued. California Department of Water Resources Water Quality Data for Battle Creek Below Coleman Fish Hatchery (40°23”54” N 122°08’43” W; 5.7 miles upstream from mouth), 1988–1989

Date	Time	Cl mg/L	Br mg/L	Cd μg/L	Cu μg/L	Fe mg/L	Pb μg/L	Mn μg/L	Hg μg/L	Zn μg/L	NH_3+ Org N mg/L	NO_2+ NO_3 mg/L	NO_3 mg/L	Ortho PO_4 mg/L	Total P mg/L
1988															
3/16	0930	2	0.02	<5	<5	0.1	<5	7	<1	<5	0.2		0.07	0.04	0.08
6/13	0508														
6/13	1000														
6/13	1400														
6/13	1940														
6/13	2110														
6/14	0215														
6/14	0505														
6/14	1010														
6/14	1400														
6/14	1910														
6/14	2100														
6/15	0150														
9/12	0505														
9/12	0910														
9/12	1330														
9/12	1715														
9/12	2135														
9/13	0125														
9/13	0515														
9/13	0930	2	<1.00	<5	<5	<0.1	<5	7	<1	33	0.5		0.03	0.03	0.05
9/13	1320														
9/13	1820														
9/13	2115														
9/14	0050														
1989															
3/20	0615														
3/20	1005														
3/20	1435														
3/20	1915														

Date	Time	Cl mg/L	Br mg/L	Cd µg/L	Cu µg/L	Fe mg/L	Pb µg/L	Mn µg/L	Hg µg/L	Zn µg/L	NH_3+ Org N mg/L	NO_2+ NO_3 mg/L	NO_3 mg/L	Ortho PO_4 mg/L	Total P mg/L
3/20	2220														
3/21	0235														
3/21	0615														
3/21	1105	1		<5	<5	0.2	<5	47	<1	13	0.4		0.13	0.02	0.04
3/21	1505														
3/21	1815														
3/21	2220														
3/22	0240														
8/14	0600														
8/14	0910														
8/14	1325														
8/14	1710														
8/14	2140														
8/15	0115														
8/15	0530														
8/15	0916	22		<5	<5	<0.1	<5	37	<1	11	0.4	0.01		0.02	0.05
8/15	1435														
8/15	1725														
8/15	2125														
8/16	0120														

Source: California Department of Water Resources (DWR), Red Bluff.

Table S-4. U.S. Environmental Protection Agency Water Quality Data for Battle Creek below Coleman Powerhouse (40°23’54” N 122°08’10” W), 1971-1972

Date	BOD_5 (mg/L)	Alkalinity (mg/L)	Total Hardness (mg/L)	Total Residue (mg/L)	TSS (mg/L)	NH_3+NH_4 (mg/L)	NO_2–N (mg/L)
7/14/71	3.5	75	102	66	15.0	0.02	0.20
8/10/71	2.3	88	116	97	8.0	0.05	0.03
9/13/71	1.8	73	100	68	10.0	0.01	0.02
10/21/71	1.2	70	110	69	11.0	0.04	0.06
11/8/71	2.1	72	85	72	16.0	0.10	0.05
12/20/71	3.1	74	73	146	12.0	0.30	0.02
1/10/72	2.0	75	52	115	3.7	0.33	0.09
2/14/72	2.3	70	52	112	2.5	0.35	0.10
3/15/72	2.5	56	45	110	2.1	0.30	0.10
4/10/72	3.0	54	50	110	3.7	0.30	0.14
5/8/72	4.0	66	72	120	3.0	0.26	0.14
6/15/72	2.8	68	60	124	2.0	0.20	0.09

Table S-4 Continued. U.S. Environmental Protection Agency Water Quality Data for Battle Creek below Coleman Powerhouse (40°23'54" N 122°08'10" W), 1971–1972

Date	NO_3–N (mg/L)	Total Kjeldahl N (mg/L)	Total PO_4 (mg/L)	$OrthoPO_4$ (mg/L)	Total Coliforms (100/mL)	Fecal Coliforms (100/mL)
7/14/71	0.10	0.14	0.36	0.03	10	0
8/10/71	0.11	0.20	0.40	0.03	32	0
9/13/71	0.15	0.20	0.30	0.03	75	0
10/21/71	0.14	0.30	0.23	0.05		
11/8/71	0.17	0.42	0.43	0.04		
12/20/71	0.14	0.75	0.73	0.03		
1/10/72	0.20	0.65	0.35	0.15	32	3
2/14/72	0.38	0.88	0.33	0.30		
3/15/72	0.16	0.58	0.45	0.28		
4/10/72	0.14	0.59	0.46	0.30		
5/8/72	0.12	0.58	0.70	0.29		
6/15/72	0.10	0.45	0.88	0.30		

Source: U.S. Environmental Protection Agency (USEPA) Region 1, USEPA STORET database.

Table S-5. State Water Resources Control Board Water Quality Data for Battle Creek below Coleman Powerhouse (40º23’54” N 122º08’06” W), 1955–1989

Date	Temp (°F)	Flow (cfs)	DO (mg/L)	Turbidity (NTU)	Specific Conductance (:mhos/cm)	TDS (mg/L)	pH	Alkalinity (mg/L)	Total Hardness (mg/L)	Ca mg/L	Mg mg/L	Na mg/L	K mg/L
1/28/55	46	300	10.7	1	133		7.4		52	11.0	5.8	7.6	2.0
4/28/58	59	700	9.2		102		7.4	51	38	7.8	4.5	6.2	2.0
5/21/58	58	750	8.8	2	76		7.8		30	6.0	3.6	4.1	1.3
6/26/58	66		8.0		100		7.9	48	40	7.8	5.0	5.0	1.5
7/25/58	72	500	8.5		121		7.2	57	44	8.6	5.5	6.4	2.0
8/27/58	62	400	8.2		142		7.5	67	53	12.0	5.6	7.6	2.3
9/19/58	63		10.0		149		7.8	69	54	9.5	7.4	9.0	2.4
10/24/58	55	280	6.3		148		7.4	66	53	9.4	7.2	8.0	2.4
11/14/58	58	300			146		7.6		52	8.4	7.5	7.6	2.4
12/23/58	47		10.3		139		7.6	69	54	9.6	7.3	8.2	2.3
1/5/59		350			111		7.5	47	44	7.6	6.1	6.6	1.9
2/9/59	42	290			134		7.8	65	54	10.0	7.1	7.7	2.1
3/11/59	51		12.0		122		7.4	58	46	9.6	5.5	6.5	1.9
4/15/59	57		10.6		117		7.7	58	48	8.8	6.3	6.5	1.4
5/15/59	54		10.9	3	118		7.8		45	8.0	6.1	6.5	1.9
6/16/59	63		10.0		135		8.1	65	52	9.2	7.1	7.5	1.8
7/9/59	64	700	8.7		154		8.1	69	54	12.0	5.8	8.7	2.6
8/11/59	63		9.4	20	152		7.9	72	60			9.1	1.5
9/1/59	59		10.2	10	148		8.0		58	11.0	7.4	8.8	2.2
10/13/59	56		10.0	2	149		7.8	75	58			10.0	3.5
11/11/59	49		11.4	4	149		7.8	74	58			9.7	
12/10/59	44		12.6	4	147		7.8	74	58			9.0	
1/14/60	42		11.5	2	147		7.9	72	57			8.8	
2/24/60	48		11.0	35	123		7.6	63	57			7.2	
3/7/60	53		10.0	125	68		7.2	30	26			2.7	
4/11/60	57		10.0	15	117		7.8	54	48			5.6	
5/11/60	59	600	9.9	25	108		7.7		46	7.6	6.6	5.7	2.1
6/13/60	68		9.2	4	116		7.8	24	48			5.6	
7/12/60	64	350	10.0	1	142		8.0	72	54			16.0	
8/8/60	63	90	9.5	1	149		8.0	77	58			8.8	
9/5/60	65	200	10.1	3	149		7.6		58	11.0	7.4	11.0	2.4

Date	Temp (°F)	Flow (cfs)	DO (mg/L)	Turbidity (NTU)	Specific Conductance (:mhos/cm)	TDS (mg/L)	pH	Alkalinity (mg/L)	Total Hardness (mg/L)	Ca mg/L	Mg mg/L	Na mg/L	K mg/L
10/10/60	54	179	10.5	2	149		8.0	71	59			8.5	
11/7/60	56	171	10.9	4	154		7.9	73	58			9.2	
12/12/60	47	255	11.6	3	140		8.0	71	57			8.5	
1/3/61	43	233	11.6	5	144		7.9	71	58			8.5	
2/15/61	52	1320	10.8	20	95		7.9	42	38			4.2	
3/14/61	55	271	11.4	3	127		8.1	63	51			7.5	
4/11/61	53	409	10.4	1	118		7.9	53	47			6.6	
5/2/61	52	379	10.2	5	113		8.0		43	9.2	4.9	7.9	1.8
6/6/61	58	367	8.4	1	109		8.1	51	43			6.0	
7/6/61	65	233	10.1	4	135		8.1	64	52			7.9	
8/8/61	65	180	9.5	3	145		8.1	71	56			8.5	
9/7/61	63	200	10.3	3	153		8.3		56	10.0	7.5	8.4	2.2
10/5/61	65	217	10.4	10	148		8.4	72	59			8.4	
11/9/61	51	225	11.2	5	153		8.1	74	58			8.7	
12/7/61	46	305	11.2	5	142		7.9	68	57			7.7	
1/11/62	47	280	10.2	2	147		7.8	67	59			7.9	
2/9/62	51	1530	10.5	20	80		7.4	34	31			4.3	
3/14/62	48	432	11.4	5	126		7.6	59	49			6.6	2.0
4/11/62	55	460	10.9	4	107		7.9	52	43			6.5	
5/3/62	60	470	10.0	2	106		7.8	48	40	8.0	4.7	5.9	1.7
6/8/62	64	400	9.6	10	114		7.8	54	44			6.3	
7/2/62	66	230	9.5	2	130		8.1	61	51			7.9	
8/1/62	70	222	9.5	5	146		8.1	69	56			9.2	4.3
9/11/62	65	138	10.4	3	156	133	8.1	75	60	12.0	7.3	9.1	2.1
10/1/62	62	217	11.5	10	152		8.0	75	57			9.6	
11/1/62	57	277	10.4	5	135		8.0	66	50			7.8	
12/7/62	50	380	11.6	3	118		8.1	59	45			6.6	
1/4/63	46	355	11.7	2	128		7.8	62	49			7.3	
2/4/63	51	1060	11.0	9	77		7.6	35	29			3.9	
3/4/63	47	398	12.7	1	124		7.9	62	48			6.6	
4/5/63	53	470	10.7	3	118		8.1	58	45			6.3	
5/3/63	55	990	10.1	6	94	82	7.9	46	37	7.2	4.6	5.0	1.5
6/5/63	63	510	10.1	1	104		8.0	56	42			5.6	

Date	Temp (°F)	Flow (cfs)	DO (mg/L)	Turbidity (NTU)	Specific Conductance (: mhos/cm)	TDS (mg/L)	pH	Alkalinity (mg/L)	Total Hardness (mg/L)	Ca mg/L	Mg mg/L	Na mg/L	K mg/L
7/12/63	65	322	9.8	1	130		8.2	65	51			7.2	
8/2/63	63	235	10.1	6	137		8.2	68	52			7.4	
9/12/63	60	300	9.8	3	146	115	8.2	71	56	10.0	7.5	7.8	1.8
10/10/63	57	278	10.1	1	138		8.0	71	56			7.6	
11/7/63	50	420	11.0	15	125		8.0	59	44			7.0	
12/5/63	48	322	12.1	1	137		8.0	66	52			8.0	
1/2/64	46	318	11.9	2	137		8.2	67	52			8.0	
2/6/64	45	370	12.7	2	130		8.2	62	50			8.5	
3/12/64	47	345	12.5	1	139		8.3	67	49			8.6	
4/9/64	54	426	11.1	2	124		8.2	57	48			7.5	
5/7/64	55	365	11.0	2	122	102	8.0	58	49	11.0	5.2	6.9	1.8
6/11/64	57	390	10.5	3	114		7.9	54	45			7.0	
7/9/64	65		9.9	2	142		8.3	68	54			8.2	
8/3/64	63	190	9.9	1	154		8.5	75	60			9.0	
9/4/64	63	204	10.1	3	150	112	8.3	72	59	11.0	7.7	8.3	3.1
10/8/64	58	271	10.0	1	153		8.1	72	58			8.1	
11/9/64	52	2100	10.7	40	80		7.2	23	28			4.4	
12/10/64	50	356	9.6	3	132		8.0	61	48			7.1	
1/14/65	47	806	10.3	5	98		8.2	44	38			5.3	
2/1/65	48	664	10.4	4	106		8.2	49	40			5.8	
3/1/65	50	532	10.2	1	113		8.5	53	43			5.7	
4/3/65	53	537	9.3	5	115		7.9	54	45			6.2	
5/6/65	52	658	9.5	3	99	82	8.0	44	39	9.6	3.6	5.3	2.1
6/14/65	57	505	8.2	6	107		8.6	49	41			5.8	
7/12/65	67	380	8.6	1	123		8.2	59	46			7.1	
8/13/65	61	307	9.6	5	130		8.3	61	51			7.4	
9/13/65	59	284	10.3	1	142	124	8.1	69	54	8.8	7.8	8.3	2.0
10/7/65	58	296	10.0	1	142		8.3	70	58			8.2	
11/4/65	55	325	10.8	1	143		8.2	69	55			8.1	
12/13/65	46	330	12.0	3	138		7.8	64	52			7.6	
1/5/66	46	906	11.3	10	85		7.7	38	34			5.0	
2/4/66	47	815	11.5	5	93		8.1	41	36			4.9	
3/8/66	52	376	12.2	2	131		8.1	63	52			7.1	

Date	Temp (°F)	Flow (cfs)	DO (mg/L)	Turbidity (NTU)	Specific Conductance (: mhos/cm)	TDS (mg/L)	pH	Alkalinity (mg/L)	Total Hardness (mg/L)	Ca mg/L	Mg mg/L	Na mg/L	K mg/L
4/12/66	54	589	11.3	5	100		8.0	47	38			5.4	
5/2/66	57	450	10.6	1	110	101	7.9	54	44	8.8	5.4	6.1	1.6
6/2/66	56	312	10.7	1	125		8.2	60	48			7.0	
7/6/66	62	275	10.5	1	142		8.2	69	55			7.9	
9/1/66	60	250	9.5	2	152	119	8.2	75	58	10.0	8.0	9.2	2.3
11/2/66	53	250	11.7	1	152		8.2	74	60	11.0	7.8	9.1	2.4
1/10/67	48	304	12.1	1	140		8.2	67	54	9.8	7.0	8.2	2.0
3/6/67	49	390	12.3	1	128		8.0	62	50	9.5	6.6	7.4	1.9
5/4/67	54	686	11.3	1	110	101	7.8	52	42	8.0	5.4	5.8	1.7
7/5/67	65	579	9.5	2	106		7.9	46	40			5.6	
9/6/67	64	254	9.5		144	123	8.2	69	54	9.8	7.1	8.5	2.2
11/2/67	55	258	10.6	2	147		8.0	69	55			8.3	
1/16/68	44	1240	11.6	25	81		7.7	34	33			3.6	
3/7/68	49	632	11.3	5	112		7.9	51	48			5.0	
5/1/68	57	425	10.6	2	117	102	7.9	55	44	8.3	5.7	6.8	1.2
7/5/68	68	258	9.4	5	146		8.3	68	62			8.0	
9/3/68	64	240	10.6	2	152	130	7.8	71	57	10.0	7.8	9.2	2.4
11/4/68	52	372	11.4		131		8.1	59	54			7.4	
1/6/69	46	423	12.2		129		8.0	61	56			6.9	
5/1/69	55	907	11.7		89	66	7.6	41	34	5.5	5.0	4.2	1.5
9/3/69	62	320	10.4		139	115	7.9	69	58	9.7	8.3	7.2	1.6
1/7/70	43	472	13.0	2	124		7.6	60	48			6.6	
5/7/70	54	449	11.7	2	119	91	7.9	58	45	8.1	6.1	7.2	1.7
10/7/70	54	305	11.6	7	146	116	8.3	68	58	9.8	8.1	8.2	2.2
2/8/71	48	546	12.3	3	120	86	8.1	58	47	11.0	4.7	6.0	1.5
2/9/72	46	407	11.8	2	127		8.4	63	56			7.2	
10/16/72	54	502	10.0	5	123		7.7	53	44			7.3	
2/2/73	46	546	11.6	2	118		7.4						
10/11/73	52	281	12.9	1	148		7.7	74	56			10.0	
1/18/74		1000		35	63								
2/14/74	45	604	12.7	3	115		7.4						
10/11/74	54	390	12.2	1	143		7.8						
2/6/75	45	676	12.2	4	101		7.6	51	42			7.0	

Date	Temp (°F)	Flow (cfs)	DO (mg/L)	Turbidity (NTU)	Specific Conductance (: mhos/cm)	TDS (mg/L)	pH	Alkalinity (mg/L)	Total Hardness (mg/L)	Ca mg/L	Mg mg/L	Na mg/L	K mg/L
10/17/75	54	325	10.4	1	142		7.6						
2/11/76	46	325	12.4	1	150		7.6	68	54			7.6	
10/18/76	54	237	11.0	1	155		8.2	74	61			9.1	
1/3/77		750		9	141								
6/15/77	63		10.3	1	155		7.8	68					
10/14/77	57	197	10.7	0	166		7.6	75	61			8.8	
2/14/78	47	800	12.1	4	97		7.4						
10/18/78	56		10.5	1	153		7.6						
2/21/79	47	2320	11.4		64	63	7.4	28	22	4.0	3.0	3.0	1.1
10/22/79	52	228	11.9	2	147		7.5						
1/14/80	49	5000		60	56		7.5	25	25	5.0	3.0	3.0	1.3
2/19/80	49	1000		31	57		8.4						
2/26/80	51	882	11.2	4	115		7.7						
10/24/80	56	250	12.0	1	153		7.9	69	54	10.0	7.0	9.0	2.5
2/26/81	47	465	12.1	2	126		8.1	57	47	9.0	6.0	7.0	1.9
10/27/81	59	158	10.7	3	164		7.9						
2/10/82	46	481	12.3		122		7.8						
10/28/82	51	415	11.3	1	125		7.5	59	47	9.0	6.0	7.0	2.1
12/22/82	45	1000		15	84		7.3						
2/9/83	48		11.5	3	97		7.6	40	38	7.0	5.0	5.0	1.5
10/19/83	52		10.6	2	135		7.3						
2/23/84	45	675	12.7	2	118		7.6						
2/14/85	50	384	11.3	2	142		8.1	65	54	10.0	7.0	8.0	
10/24/85	55	376	11.1	5	141		7.6						
3/3/86	56	937	10.8	33	99		7.8						
10/21/86	58	353	11.7	3	276		8.3	69	68	9.0	11.0	30.0	
2/19/87	48		11.9	3	135		7.6	54	45	8.0	6.0	7.0	
2/16/88	45	371	12.5	1	138	112	7.9	64	52	9.0	7.0	7.0	2.0
9/19/88	59	280	10.2	2	190	132	7.9	79	64	11.0	9.0	10.0	3.0
10/20/88	59	181	10.0		157		7.7						
2/15/89	48		12.7		153		7.7						

Table S-6. U.S. Environmental Protection Agency Water Quality Data for Battle Creek near Coleman Power House (40°24'04" N 122°07'43" W), 1971–1972

Date	BOD_5 (mg/L)	Alkalinity (mg/L)	Total Hardness (mg/L)	Total Residue (mg/L)	TSS (mg/L)	NH_3+NH_4 (mg/L)	NO_2–N (mg/L)
7/14/71	3.3	76	112	72	1.5	0.03	0.01
8/10/71	3.1	94	115	103	1.4	0.06	0.03
9/13/71	2.3	74	115	85	1.2	0.02	0.03
10/21/71	1.2	70	85	60	0.8	0.08	0.02
11/8/71	1.0	78	78	67	0.9	0.09	0.01
12/20/71	1.5	84	61	94	0.8	0.08	0.02
1/10/72	1.7	80	55	103	0.2	0.32	0.05
2/14/72	1.5	80	54	110	0.6	0.22	0.06
3/15/72	1.4	56	50	106	2.0	0.23	0.05
4/10/72	1.2	54	48	115	1.0	0.21	0.06
5/8/72	1.5	56	50	110	1.3	0.25	0.05
6/15/72	0.8	58	48	118	1.0	0.22	0.04

Table S-6 Continued. U.S. Environmental Protection Agency Water Quality Data for Battle Creek near Coleman Power House (40°24’04” N 122°07’43” W), 1971–1972

Date	NO_3–N (mg/L)	Total Kjeldahl N (mg/L)	Total PO_4 (mg/L)	OrthoPO_4 (mg/L)	Total Coliforms (100/mL)	Fecal Coliforms (100/mL)
7/14/71	0.18	0.23	0.20	0.05	0	0
8/10/71	0.20	0.31	0.30	0.06	0	0
9/13/71	0.20	0.25	0.25	0.05	15	0
10/21/71	0.22	0.36	0.20	0.01		
11/8/71	0.20	0.38	0.20	0.03		
12/20/71	0.16	0.30	0.22	0.05		
1/10/72	0.12	0.52	0.25	0.08	10	
2/14/72	0.10	0.40	0.20	0.05		
3/15/72	0.10	0.42	0.25	0.02		
4/10/72	0.15	0.45	0.20	0.05		
5/8/72	0.13	0.44	0.26	0.03		
6/15/72	0.13	0.42	0.25	0.05		

Source: U.S. Environmental Protection Agency (USEPA) Region 1, USEPA STORET database.

Appendix T

Memorandum of Agreement among the Bureau of Reclamation, the Federal Energy Regulatory Commission, and the California State Historic Preservation Officer Regarding the Battle Creek Salmon and Steelhead Restoration Project, Shasta and Tehama Counties, California

MEMORANDUM OF AGREEMENT AMONG THE BUREAU OF RECLAMATION, THE FEDERAL ENERGY REGULATORY COMMISSION AND THE CALIFORNIA STATE HISTORIC PRESERVATION OFFICER REGARDING THE BATTLE CREEK SALMON AND STEELHEAD RESTORATION PROJECT, SHASTA AND TEHAMA COUNTIES, CALIFORNIA

Whereas, the Bureau of Reclamation (Reclamation) and the Federal Energy Regulatory Commission (Commission) have determined that implementation of the Battle Creek Salmon and Steelhead Restoration Project (Undertaking) in Shasta and Tehama Counties, California, will have an adverse effect on Inskip, Coleman, Eagle Canyon, and Wildcat Canyon Dams, properties determined eligible for inclusion in the National Register of Historic Places (historic properties), have consulted with the California State Historic Preservation Officer (SHPO) pursuant to 36 CFR Part 800, regulations effective January 11, 2001, implementing Section 106 of the National Historic Preservation Act of 1966, as amended (16 U.S.C. 470f), and have notified the Advisory Council on Historic Preservation (Council) of the adverse effect pursuant to 36 CFR § 800.6(a)(1); and

Whereas, Pacific Gas and Electric Company (PG&E Company) which owns, operates and manages these historic properties and other structures and facilities associated with hydroelectric power generation within the Battle Creek Drainage in accordance with a license issued by the Federal Energy Regulatory Commission, FERC No. 1121, participated in the consultation and has been invited to concur in this Memorandum of Agreement (MOA);

Now, Therefore, Reclamation, the Commission and the SHPO agree that if the Undertaking proceeds, the Undertaking shall be implemented in accordance with the following stipulations in order to take into account the effects of the Undertaking on historic properties, and further agree that these stipulations shall govern the Undertaking and all of its parts until this MOA expires or is terminated.

Stipulations

Reclamation will ensure that the following measures are carried out:

1. Recordation

Reclamation will ensure that each historic property is documented as follows:

a. The National Park Service (NPS) prepared Historic American Engineering Record (HAER) documentation for the former South, Inskip, and Coleman hydroelectric power generating stations. This documentation provides a historic context for the four historic properties covered by this MOA. Reclamation will ensure that a combined historic context report (Report) for these four historic properties is prepared, utilizing the HAER documentation prepared by NPS.

b. Both color and black and white 35mm photographs of each dam that show elevations, profiles, and the context of each dam will be prepared. The black and white photographs will be archivally processed and catalogued consistent with HAER standards. Color photographs will be incorporated into the body of the Report.

c. An "Index to Photographs" will be prepared and such index will include a "photo key" showing the location and direction of each photographic view.

d. Research will be conducted to seek historic photographs that depict the operation of each dam, and if such photographs exist, they will be included in the Report.

e. Original drawings and contemporary drawings, as available and free from copyright restrictions, for each dam will be included in the Report.

f. Interviews and the summary report of the Battle Creek Conservancy Historical Study will be included as an appendix in CD form. This study includes oral histories from individuals associated with the Battle Creek Hydroelectric System.

2. Report Dissemination

Reclamation will ensure that within 2 years following execution of this MOA, a copy of the Report cited in Stipulation 1. above, is sent to the SHPO, the Northeast Information Center, Battle Creek Conservancy, Shasta County Historical Society, FERC, California State Department of Water Resources, and to other archives that may be designated by Reclamation or the SHPO.

3. Notice to Proceed

When Reclamation, in consultation with the SHPO and the Commission, determines that all field work needed to fulfill the terms of Stipulation 1., above, has been satisfactorily completed, Reclamation may thereafter authorize construction-related activities to proceed.

4. Resolving Objections

a. Should any party to this MOA object to the manner in which the terms of this MOA are implemented, to any action carried out or proposed with respect to implementation of the MOA, or to any documentation prepared in accordance with and subject to the terms of this MOA, Reclamation shall immediately notify the other parties to this MOA of the objection and consult with the objecting party and with the other parties to this MOA for no more than 14 days to resolve the objection. Reclamation shall reasonably determine when this consultation will commence. If the objection is resolved through such consultation, the action subject to dispute may proceed in accordance with the terms of that resolution. If, after initiating such consultation, Reclamation determines that the objection cannot be resolved through consultation, Reclamation shall forward all documentation relevant to the objection to the Council, including Reclamation's proposed response to the objection, with the expectation that the Council will within thirty (30) days after receipt of such documentation:

(1) Advise Reclamation that the Council concurs in Reclamation's proposed response to the objection, whereupon Reclamation will respond to the objection accordingly; or

(2) Provide Reclamation with recommendations, which Reclamation will take into account in reaching a final decision regarding its response to the objection; or

(3) Notify Reclamation that the objection will be referred for comment pursuant to 36 CFR § 800.7(c), and proceed to refer the objection and comment. Reclamation shall take the resulting comment into account in accordance with 36 CFR 800.7(c)(4) and Section 110(l) of the NHPA.

b. Should the Council not exercise one of the above options within 30 days after receipt of all pertinent documentation, Reclamation may assume the Council's concurrence in its proposed response to the objection.

c. Reclamation shall take into account any Council recommendation or comment provided in accordance with this stipulation with reference only to the subject of the objection. Reclamation's responsibility to carry out all actions under this MOA that are not the subjects of the objection will remain unchanged.

d. At any time during implementation of the measures stipulated in this MOA should an objection pertaining to such implementation be raised by a member of the public, Reclamation shall notify the parties to the MOA and take the objection into account, consulting with the objector and, should the objector so request, with any of the parties to this MOA to address the objection.

e. Reclamation shall provide all parties to this MOA, the Council when Council comments have been issued hereunder, and any parties that have objected pursuant to paragraph D.4., with a copy of its final written decision regarding any objection addressed pursuant to this stipulation.

f. Reclamation may authorize any action subject to objection under this stipulation to proceed after the objection has been resolved in accordance with the terms of this stipulation.

5. Amendments

Any party to this MOA may propose that this MOA be amended, whereupon the parties to this MOA will consult for no more than 30 days to consider such amendment. The amendment process shall comply with 36 CFR §§ 800.6(c)(1) and 800.6(c)(7). This MOA may be amended only upon the written agreement of the signatory parties. If it is not amended, this MOA may be terminated by any signatory party in accordance with Stipulation 6., below.

6. Termination

a. If this MOA is not amended as provided for in Stipulation 5., above, or if any signatory party proposes termination of this MOA for other reasons, the signatory party proposing termination shall, in writing, notify the other parties to this MOA, explain the reasons for proposing termination, and consult with the other parties for at least 30 days to seek alternatives to termination. Should such consultation result in an agreement on an alternative to termination, then the parties shall proceed in accordance with the terms of that agreement.

b. Should such consultation fail, the signatory party proposing termination may terminate this MOA by promptly notifying the other parties to this MOA in writing. Termination hereunder shall render this MOA null and void.

c. If this MOA is terminated hereunder and if Reclamation determines that the Undertaking will nonetheless proceed, then Reclamation shall either consult in accordance with 36 CFR § 800.6 to develop a new MOA or request the comments of the Council pursuant to 36 CFR Part 800.

7. Duration of the MOA

a. Unless terminated pursuant to Stipulation 6. above, or unless it is superceded by an amended MOA, this MOA will be in effect until Reclamation, in consultation with the other parties to this MOA, determines that all of its stipulations have been satisfactorily fulfilled. Upon a determination by Reclamation that all of the terms of this MOA have been satisfactorily fulfilled, this MOA will terminate and have no further force or effect. Reclamation will promptly provide the other parties to this MOA with written notice of its determination and of the termination of this MOA. Following provision of such notice, this MOA will be considered null and void.

b. The terms of this MOA shall be satisfactorily fulfilled within 5 years following the date of execution. If Reclamation determines that this requirement cannot be met, the parties to this MOA will consult to reconsider its terms. Reconsideration may include the continuation of the MOA as originally executed, amendment of the MOA, or termination of the MOA.

8. Effective Date of this MOA

This MOA will take effect on the date that it has been executed by Reclamation, the Commission and the SHPO.

EXECUTION of this MOA by Reclamation, the Commission and the SHPO, its transmittal by Reclamation to the Council in accordance with 36 CFR § 800.6(b)(1)(iv), and subsequent implementation of its terms, shall evidence, pursuant to 36 CFR § 800.6(c), that this MOA is an agreement with the Council for purposes of Section 110(l) of the NHPA, and shall further evidence that Reclamation and the Commission have afforded the Council an opportunity to comment on the Undertaking and its effects on historic properties, and that Reclamation and the Commission have taken into account the effects of the Undertaking on historic properties.

SIGNATORY PARTIES:

BUREAU OF RECLAMATION

By: ______________________ Date: 12/11/02

FEDERAL ENERGY REGULATORY COMMISSION

By: Joseph D Morgan Date: 1/23-03

CALIFORNIA STATE HISTORIC PRESERVATION OFFICER

By: ______________________ DSHPO Date: 4/25/03

CONCURRING PARTY:

PACIFIC GAS AND ELECTRIC COMPANY

By: ______________________ Date: 12/18/02

RANDAL S. LIVINGSTON

Appendix U
Shasta and Tehama County Production Statistics and Field Notes from Site Visit to Mount Lassen Trout Farms, Inc.

Appendix U

Shasta and Tehama County Production Statistics and Field Notes from Site Visit to Mount Lassen Trout Farms, Inc.

This appendix presents agricultural production statistics for Tehama and Shasta Counties for 1997 and 1992 and field notes from a site visit to Mount Lassen Trout Farms, Inc. The source of the production statistics is the U.S. Department of Agriculture's 1997 Census of Agriculture Volume I Geographic Area Series. Some of the production statistics include quantities of crops produced, farm production expenses, the market value of agricultural products sold, and the farm sizes. Facilities of Mount Lassen Trout Farms, Inc., were visited December 14, 2000. Field notes shown in Table U-3 in this appendix describe the connectivity of the facilities with the surrounding environment, wildlife species observed near the facilities, and the general location of each facility.

Table U-1. Tehama County Production Statistics, 1997 and 1992

		All Farms	
Item	Unit	1997	1992
Farms	number	1,362	1,381
Land in farms	acres	885,426	1,016,851
Average size of farm	acres	650	736
Value of land and buildings*			
Average per farm	Dollars	772,234	651,023
Average per acre	Dollars	1,106	939
Estimated market value of all machinery and equipment*			
Average per farm	Dollars	39,255	34,737

		All Farms	
Item	Unit	1997	1992
Farms by size			
1 to 9 acres		251	240
10 to 49 acres		529	556
50 to 179 acres		259	249
180 to 499 acres		144	142
500 to 999 acres		67	70
1,000 acres or more		112	124
Total cropland	farms	1,063	1,116
	acres	127,019	20,902
Harvested cropland	farms	831	897
	acres	62,038	60,380
Irrigated land	farms	1,001	988
	acres	85,571	71,572
Market value of agricultural products sold			
Total for county	Dollars	$107,102	$95,041
Average per farm	Dollars	$78,636	$68,820
Crops, including nursery and greenhouse crops	Dollars	$66,798	$56,677
Livestock, poultry, and their products	Dollars	$40,304	$38,364
Farms by value of sales			
Less than $2,500		357	383
$2,500 to $4,999		176	182
$5,000 to $9,999		160	181
$10,000 to $24,999		241	213
$25,000 to $49,999		125	136
$50,000 to $99,999		109	94
$100,000 or more		194	192
Total farm production expenses			
Total for county	Dollars	80,743	79,887
Average per farm	Dollars	59,282	57,874
Operators by principal occupation			
Farming		694	719
Other		668	662

Item	Unit	All Farms 1997	All Farms 1992
Operators by days worked off farm			
Any		716	743
200 days or more		462	480
Livestock and poultry			
Cattle and calves inventory	Farms	559	570
	Number	85,270	80,440
Hogs and pigs inventory	Farms	40	52
	Number	458	2,053
Sheep and lambs inventory	Farms	74	110
	Number	6,522	7,782
Layers and pullets 13 weeks old and older inventory	Farms	62	83
	Number	1,226	1,582
Selected crops harvested			
Wheat for grain	Farms	35	28
	Acres	6,413	4,367
	Bushels	331,438	263,592
Barley for grain	Farms	4	7
	Acres	465	1,242
	Bushels	21,250	47,114
Rice	Farms	4	7
	Acres	723	1,277
	Hundred-weight	51,805	90,210
Hay, alfalfa, other wild silage	Farms	149	214
	Acres	12,069	14,123
	Tons, dry	36,301	48,232
Vegetables harvested	Farms	28	16
	Acres	186	61
Land in orchards	Farms	662	685
	Acres	36,956	35,422

		All Farms	
Item	Unit	1997	1992

* Data are based on a sample of farms.

Source: U.S. Department of Agriculture, National Agricultural Statistics Service. 1997 Census of Agriculture, Volume 1 Geographic Area Series, "Table 1. County Summary Highlights: 1997." This electronic series presents summary statistics for each county and state together with comparable data from the 1992 census. The items included are the same for all states and counties, except selected crops harvested, which vary by state. Data for 1997 and 1992 are directly comparable for acreage and inventories. Dollar values have not been adjusted for changes in price levels.

Table U-2. Shasta County Production Statistics, 1997 and 1992

		All Farms	
Item	Unit	1997	1992
Farms	number	850	844
Land in farms	acres	316,743	388,084
Average size of farm	acres	373	460
Value of land and buildings*			
Average per farm	Dollars	$419,564	$469,095
Average per acre	Dollars	$1,021	$1,066
Estimated market value of all machinery and equipment*			
Average per farm	Dollars		
Farms by size			
1 to 9 acres		261	224
10 to 49 acres		260	272
50 to 179 acres		135	137
180 to 499 acres		75	93
500 to 999 acres		47	37
1,000 acres or more		72	81
Total cropland	farms	612	621
	acres	59,487	62,649
Harvested cropland	farms	401	396
	acres	22,659	23,897
Irrigated land	farms	605	594
	acres	38,863	44,282
Market value of agricultural products sold			
Total for county	Dollars	$31,349	$33,198
Average per farm	Dollars	$36,881	$39,334
Crops, including nursery and greenhouse crops	Dollars	$18,375	$13,031
Livestock, poultry, and their products	Dollars	$12,975	$20,167

Item	Unit	All Farms 1997	All Farms 1992
Farms by value of sales			
Less than $2,500		356	346
$2,500 to $4,999		135	141
$5,000 to $9,999		112	102
$10,000 to $24,999		106	108
$25,000 to $49,999		5,741	6,024
$50,000 to $99,999		43	63
$100,000 or more			
Total farm production expenses			
Total for county	Dollars	$23,652	$28,965
Average per farm	Dollars	$27,794	$32,359
Operators by principal occupation			
Farming		354	385
Other		496	459
Operators by days worked off farm			
Any		477	457
200 days or more		319	282
Livestock and poultry			
Cattle and calves inventory	Farms	486	482
	Number	37,758	45,050
Hogs and pigs inventory	Farms	43	67
	Number	273	1,189
Sheep and lambs inventory	Farms	65	74
	Number	1,417	1,682
Layers and pullets 13 weeks old and older inventory	Farms	78	74
	Number	1,819	1,682

		All Farms	
Item	Unit	1997	1992
Selected crops harvested			
Wheat for grain	Farms	15	17
	Acres	945	958
	Bushels	46,518	43,663
Barley for grain	Farms	9	14
	Acres	493	706
	Bushels	29,064	44,873
Rice	Farms	1	14
Hay, alfalfa, other wild silage	Farms	189	213
	Acres	13,363	17,147
	Tons, dry	41,670	66,512
Vegetables harvested	Farms	37	28
	Acres	99	235
Land in orchards	Farms	163	174
	Acres	997	1,539

* Data are based on a sample of farms.

Source: U.S. Department of Agriculture, National Agricultural Statistics Service. 1997 Census of Agriculture, Volume 1 Geographic Area Series, "Table 1. County Summary Highlights: 1997." This electronic series presents summary statistics for each county and state together with comparable data from the 1992 census. The items included are the same for all states and counties, except selected crops harvested, which vary by state. Data for 1997 and 1992 are directly comparable for acreage and inventories. Dollar values have not been adjusted for changes in price levels.

Table U-3. Mount Lassen Trout Farms Facilities Visited on December 14, 2000, and Excerpted Notes About Each Facility

Facility and Location	Type of Visit	Potential Connection to Restoration Project*	Comments
Willow Springs Battle Creek Watershed; 1000' NW of Coleman Canal and South Fork Battle Creek near Coleman Diversion Dam	Drove by, did not tour but saw from a distance, saw water supply pipe	The source springs for this facility are hydrologically connected to the Inskip canal. Potential connectivity with the environment is high, entails direct use of Battle Creek water in facility.	Water supply here is reduced up to 50% (4-5 cfs) when PG&E's Inskip canal is offline. PG&E believes that Willow Springs are augmented by leakage from canal (per Mr. Mackey). <u>Even without a disease risk, construction of new facilities at Inskip could temporarily and/or permanently affect water supply at this facility.</u>
Macam Springs Battle Creek Watershed; 1400' SW South Fork Battle Creek about 0.5 miles u.s. Inskip Powerhouse	Toured raceways, exterior of R&D facilities, saw water supply from about 100 yards	Potential connectivity with environment from birds is moderate, lower potential connectivity due to terrestrial animals.	
Jeffcot West Battle Creek Watershed; water supply springs are about 30 feet west of Eagle Canyon Canal, approx. 1.3 miles due south of EC Diversion Dam and about 0.3 miles S. of North Fork Battle Creek; earthen ponds are about 1000 feet S. of North Fork Battle Creek directly under transmission lines.	Toured water supply springs, concrete raceways, earthen ponds	Extremely high potential connectivity with environment from avian, terrestrial, and/or amphibious animals due to extremely close proximity of source springs (in circa 1 acre wetland) to Eagle Canyon canal, and the isolated, open nature of earthen ponds.	Blue and green herons were present in the immediate vicinity of the earthen ponds. Source spring is a wetland that undoubtedly harbors individual animals that may contact Eagle Canyon canal waters. Facility likely could not be completely disinfected due to earthen nature and nature of source springs/wetland.
Jeffcot East Battle Creek Watershed; water supply springs are perhaps 100 to 200 feet east of Eagle Canyon Canal, approx. 1.3 miles due south of EC Diversion Dam and about 1500 feet S of North Fork Battle Creek; facility discharges directly into EC canal.	Toured water supply, spawning sheds, concrete raceways, some buildings, discharge site into Eagle Canyon canal	High potential connectivity with environment from birds, terrestrial animals and/or amphibians due to close proximity of source springs and discharge to Eagle Canyon canal.	This facility includes perhaps 33% of the MLTF brood stock. Most of the facility is indoors. 90% of source springs have been capped with plastic and gravel. Possible that the facility could be disinfected, though probably not the source springs.

Facility and Location	Type of Visit	Potential Connection to Restoration Project*	Comments
Volta Battle Creek Watershed; water supply is a diversion from Brush Creek, likely upstream of anadromous fish passage (not verified) but within perhaps 1500 feet of the anadromous section of North Fork of Battle Creek, discharges back into Brush Creek.	Toured earthen ponds, water supply from Brush Creek, discharge to Brush Creek	Unknown level of potential connectivity. Mr. Mackey felt that this facility was at relatively low risk (they have had no otter problems, though bears have raided the ponds), but it is directly connected to surface water and is also connected to Battle Creek by a riparian corridor; would be impossible to isolate from surface water.	
Battle Creek Battle Creek Watershed; water supply is springs that feed upper Ripley Creek (probably above anadromous reach – need to verify), earthen ponds are within 100 feet of X-C canal; facility discharges directly to X-C canal, facility is about 5000 feet from nearest segment of South Fork Battle Creek.	Toured water supply, circular tanks, earthen ponds, discharge to X-C canal, exterior of buildings	Extremely high potential connectivity with environment from birds, terrestrial animals, and/or amphibians due to extremely close proximity of facilities to X-C canal.	Currently, Ripley Creek water runs through this facility into X-C canal. Would this water be available for adaptive management? Who has rights to the water discharged into canal, what about the rest of upper Ripley Creek not used by MLTF?
Meadow Brook Paynes Creek Watershed; at confluence with Plum Creek; approximately 5.5 air miles S. of nearest segment of South Fork Battle Creek.	Toured water supply, exterior concrete raceways, exterior of buildings, office	Low potential connectivity with environment due to distance from Battle Creek. However, anecdotes suggest some overlap in bird populations between Battle Creek and Paynes Creek. Facility already is either indoors or under bird nets.	Mr. Mackey told of an increased number of bird vectors that showed up here when CDFG excluded birds from Darrah Springs Hatchery. Also gave anecdotal evidence of hatchery-habituated birds (some birds wouldn't leave, and instead nearly starved, when bird exclusion nets were installed here).
Dales Paynes Creek Watershed; approximately 7.0 air miles S. of nearest segment of Battle Creek in vicinity of CNFH.	Self-tour of exterior raceways, did not see water supply	Low risk due to distance from Battle Creek. However, anecdotes suggest some overlap in bird populations between Battle Creek and Paynes Creek.	

* Level of potential connection between the aquaculture facility and the natural environment/Battle Creek is through animal vectors and/or hydrologic connection