Appendix C

Evaluation of Potential Measures for Reducing Water Temperature in the North Fork Feather River

EVALUATION OF POTENTIAL MEASURES FOR REDUCING WATER TEMPERATURE IN THE NORTH FORK FEATHER RIVER

The purpose of this report is to present and describe a comprehensive set of measures that may potentially reduce water temperature along all or a part of the NFFR. The geographic scope of the measures covers the entire UNFFR Project area as defined in the NOP. The measures mainly consist of physical and operational changes to existing UNFFR Project facilities, but changes to other PG&E-owned and non-PG&E-owned facilities in the NFFR basin are considered as well. Watershed management actions that may potentially reduce temperature are included too.

The potential temperature reduction measures described herein derive from those described in PG&E's 24 Alternatives Report (PG&E 2005b) as well as others developed by the State Water Board team. A brief description of each potential measure and a preliminary evaluation of its effectiveness in reducing temperature or its feasibility, in terms of constructability, cost, or logistics, are provided. Some of the initial evaluations conclude that certain measures are clearly ineffective or infeasible because they would not be effective or they are extremely costly, and those measures have been eliminated from further consideration. A final list is provided that contains the measures passing the preliminary evaluation: These measure are eligible for selection and inclusion in Level 1 alternatives.

MEASURES ABOVE OR AT LAKE ALMANOR

1. Increase release of cold water from Lake Almanor

a. to Butt Valley Reservoir through closely controlled, selective withdrawal from the Prattville Intake by installing a thermal curtain or other device

This measure consists of installing a thermal curtain in Lake Almanor at the existing Prattville Intake to cause colder water to enter the intake for release to the NFFR. PG&E evaluated six thermal curtains of different sizes and layouts and conducted physical model tests to compare and select the most effective and viable thermal curtain (IIHR, 2004). The most effective thermal curtain configuration is U-shaped, 900-feet x 770-feet x 900-feet. The most effective elevation of the curtain bottom is 4,455 ft (USGS datum). This configuration (without dredging of the Prattville Intake area) provides about 4.4°C and 3.6°C water temperature reduction at the Butt Valley PH during July and August respectively at its normal operating discharge of 1,600 cfs. (Note: The impacts of different discharges on outflow temperatures were tested by PG&E using the physical model, but the impacts of ON/OFF peaking operations on outflow temperatures were not tested).

PG&E also considered installing a submerged hooded pipeline at the existing Prattville Intake to cause colder water to enter the intake for release to the NFFR. PG&E evaluated two configurations (long and short) of a submerged hooded pipeline (three 12-foot diameter pipes) and conducted physical model tests to compare and select the most effective and viable measure between the submerged hooded pipeline and thermal curtain. The thermal curtain measure was determined to be more effective.

Conclusion: Consider this measure.

b. to the Seneca Reach through selective withdrawal from the existing Canyon Dam Outlet

This measure consists of re-operating the existing Canyon Dam Outlet to selectively withdraw warmer surface water through the high level outlet gates during the spring in a manner that would preserve more cold water in Lake Almanor and make it available for release to the NFFR through the Prattville Intake. During the summer, selectively release cold water to the Seneca Reach through the low level outlet at Canyon Dam. Evaluation of selective operation of the high/low outlet gates by PG&E indicated only a slight benefit was achievable; about 0.1°C cooler in water temperatures in Lake Almanor at the Prattville Intake. Such minor water temperature reduction at Prattville Intake would not produce measurable water temperature benefits in the Belden, Rock Creek, Cresta and Poe reaches.

Conclusion: Eliminate this measure.

c. to Butt Valley Reservoir through reduced withdrawal from the Prattville Intake

This measure consists of reducing Butt Valley Powerhouse flows so that cooler water is drawn from Lake Almanor and subsequently released to the NFFR system from the Butt Valley Powerhouse. It is expected that reducing Butt Valley Powerhouse flows to a point that allows selective cold water withdrawal would result in measurable water temperature reduction to the Belden, Rock Creek, Cresta and Poe reaches. Data collected by PG&E in August 1994 suggests that reduced intake velocities at the Prattville Intake and the resulting decrease of Butt Valley PH discharge to below 800 cfs will result in selective withdrawal of colder water from Lake Almanor.

Conclusion: Consider this measure.

d. to the Seneca Reach through increased cold water releases from the Canyon Dam low-level outlet

This measure consists of increasing the magnitude of cold water releases to the NFFR from the Canyon Dam Outlet low level gate. The amount of temperature reduction of this measure depends on the relative magnitude of the Canyon Dam releases and Caribou PH discharges. Increasing Canyon Dam releases would reduce warming in the Seneca Reach (Figure 1 shows that warming in the Seneca Reach above Caribou PH would reduce by about 1°C if dam release increases from 80 cfs to 400 cfs). Increasing Canyon Dam releases would enhance water temperature reduction in Belden Reservoir, which would benefit all downstream reaches. Increasing Canyon Dam release would require decreasing Prattville Intake release commensurately to avoid lake level fluctuation or changes from the operating rules agreed to in the Partial Settlement Agreement.

Conclusion: Consider this measure.

- ***Enhancement measure for both 1a and 1b would be to dredge the lake bottom levees in the Prattville Intake area***

  This measure consists of dredging of the Prattville Intake area and the nearby underwater channel at Lake Almanor exclusively or in combination with installing a thermal curtain or submerged pipeline to cause colder water to enter the intake for release to the NFFR. Physical model tests were conducted by PG&E to compare and select the most effective and viable combination of dredging, submerged pipeline and thermal curtain. Dredging alone provides about 1.4°C and 1.6°C water temperature reduction at the Butt Valley PH during July and August respectively at its normal operating discharge of 1,600 cfs (IIHR, 2004).

  Conclusion: Consider this measure.

- ***Enhancement measure for 1a to 1d would be to increase the inflow supply of cooler water into Lake Almanor (to prevent depletion of the hypolimnion).***

  - *by constructing an expansive, high-capacity wellfield that would pump directly from the basalt aquifer discharging to Big Springs/northeastern Lake Almanor. The pumped cold water could be discharged either (a) to the lake hypolimnion from where it would flow submerged to the Prattville Intake, or (b) conveyed by pipeline laid along the lakebed and connected for direct discharge into the Intake.*

    This enhancement measure consists of constructing a high-capacity wellfield near Big Springs and pumping the cold groundwater (about 8°C) and conveying it by pipeline either to the lake hypolimnion from where it would flow submerged to the Prattville Intake or by pipeline laid along the lakebed and connected, for direct discharge, to the Intake for release to the NFFR. Constructing a high-capacity wellfield near Big Springs and pumping the cold groundwater directly into the Prattville Intake would reduce outflow temperature at Butt Valley PH by about 1°C for every 100 cfs of the pumped groundwater at the powerhouse's normal operating discharge of 1,600 cfs (Figure 2). Little information is available on the hydrogeology and development potential of the basalt aquifer at Lake Almanor. Extensive field investigation would be required to evaluate the feasibility of this measure.

    Conclusion: Consider this measure.

  - *by connecting a conduit to the Hamilton Branch tailrace that extends out into the depths of Lake Almanor to replenish the hypolimnion with cool water.*

This enhancement measure consists of connecting a conduit to the Hamilton Branch tailrace that extends out into the depths of Lake Almanor to replenish the hypolimnion with cool water. The Hamilton Branch PH discharge temperatures are variable (range from 12°C to 19°C) and depend on the regulated discharge. When the powerhouse flows are greater than about 50 cfs, the powerhouse discharge temperatures are considerably warmer (by up to 5°C). Therefore replenishing Lake Almanor hypolimion using Hamilton Branch PH discharges would not be a reliably effective water temperature reduction measure.

Conclusion: Eliminate this measure.

- *by purchasing water rights along the UNFFR and Hamilton Branch above Lake Almanor and transferring the water rights to instream use or changing the point of diversion to below Oroville thereby causing cooler inflows into Lake Almanor by preventing the warming effect of diversions and return flows above the lake.*

  The UNFFR above Chester is close to natural and Hamilton Branch above Lake Almanor is natural except the use by PG&E. Therefore, this enhancement measure would not be an effective water temperature reduction measure.

  Conclusion: Eliminate this measure.

- *by reducing warming along the UNFFR and Hamilton Branch above Lake Almanor by increasing shading through planting of vegetation thereby causing cooler inflows.*

  Observed average water temperatures in July 2002 at the upper NFFR and Hamilton Branch above Lake Almanor were 15.7°C and 12.0°C respectively. These cool water temperatures suggest that warming in these streams is not important. It is expected that the benefit of increasing shading along these two streams would be minimal. Therefore, this enhancement measure would not be an effective water temperature reduction measure.

  Conclusion: Eliminate this measure.

\- ***Enhancement measure for 1a to 1d would be to raise the elevation of the dam/spillway and/or seasonal operating levels of the lake to raise the level of the top of the hypolimnion and increase its overall volume.***

This measure consists of raising the elevation of the dam/spillway and/or seasonal operating levels of the lake to increase the hypolimnion depth. The purpose would be to increase the storage volume of the hypolimnion and to enhance the hydraulic conveyance of cold water to the Prattville Intake. Lake Almanor subsurface hydraulics limits the amount of cold water that can be conveyed through the hypolimnion to the Prattville Intake. Increasing the depth of the hypolimnion may enhance cold water withdrawal by improving hydraulics. This benefit would need to be analyzed and tested through physical modeling or numerical modeling.

The maximum operating water level allowed by the DWR/DSOD is elevation 4,504 ft (USGS datum). PG&E right-of-way for flooding on waterfront lands is 4,510 ft (USGS datum). Raising the dam would require significant and costly modifications to the dam, as well as costly modifications to affected waterfront structures and the purchase of right-of-way to flood waterfront lands.

Conclusion: Eliminate this measure.

MEASURES AT BUTT VALLEY RESERVOIR

2. Increase release of cold water from Butt Valley Reservoir

a. to Belden Reservoir through preferential use of Caribou PH #1

This measure consists of preferentially operating the Caribou No. 1 Powerhouse over the Caribou No. 2 Powerhouse, thereby drawing cooler water from Butt Valley Reservoir for release to the NFFR. Because the Caribou No. 1 Powerhouse water intake is located in a deeper portion of Butt Valley Reservoir than the Caribou No. 2 Powerhouse water intake, it has better access to the deeper cooler water. A special operational test conducted with the exclusive use of Caribou No. 1 Powerhouse during the 8-day period of 7/18/2003 – 7/25/2003 resulted in downstream water temperature reductions of 3.0°C at Belden Reservoir, 2.5°C below Belden Dam, 1.1°C below Rock Creek Dam, 0.3°C below Cresta Dam, and 0.3°C below Poe Dam. The discharge water temperature from Caribou No. 1 Powerhouse during the test period increased steadily from 16.4°C to 18.4°C (see Table 1 and Figure 3). This special test provided very important information: Decreasing water temperature in Belden Forebay from approximately 20°C to 17.5°C would have minimal benefit in water temperature reduction below Cresta Dam and Poe Dam.

Conclusion: Consider this measure.

b. to Lower Butt Creek through releases from a new low level Butt Valley Dam Outlet

This measure consists of constructing a low level outlet at Butt Valley Dam and releasing water from the outlet and reducing Caribou Powerhouse flows so that cooler water is drawn from the new outlet and subsequently released to the NFFR. The Caribou No.1 Intake is located at an invert elevation of 4,077 ft (USGS datum), which is a low level intake. Constructing a new low level outlet at the dam, which would be close to the Caribou No.1 Intake, is not necessary because Caribou No.1 already provides a means for delivering cool Butt Valley Reservoir water to Belden Reservoir. This measure is not a necessary water temperature reduction measure.

Conclusion: Eliminate this measure.

c. ***to Belden Reservoir by directly conveying Butt Valley PH discharge to Butt Valley Reservoir near the Caribou Intakes.***

This measure consists of constructing a 5 mile pipeline laid along the bed of Butt Valley Reservoir for conveying Butt Valley PH discharge to Butt Valley Reservoir near the Caribou Intakes for the purpose of reducing warming that occurs as the water flows through Butt Valley Reservoir. Under this measure, outflow temperature from the Caribou PH would be the same as the discharge temperature at Butt Valley PH. This measure would reduce outflow temperature from Caribou PH by 1°C to 2°C in July and August under existing intake configurations.

Conclusion: Consider this measure.

- ***Enhancement measure for 3a would be to construct a "crossover" conduit connecting Caribou No. 1 to Caribou No. 2.***

This enhancement measure consists of constructing a conduit connecting Caribou No.1 to Caribou No.2. This would enable drawing cooler water from Butt Valley Reservoir while using the higher efficiency turbine of Caribou No.2. This is primarily a power generation enhancement measure with some additional temperature reduction benefit attributable to preferential use of Caribou No.1.

Conclusion: Consider this measure.

- ***Enhancement measure for both 3a and 3b would be to install thermal curtain across Butt Valley Reservoir at the Butt Valley PH and Caribou Intake.***

This enhancement measure consists of installing a combination of one thermal curtain at the Prattville Intake in Lake Almanor and two thermal curtains in Butt Valley Reservoir, with dredging of the Prattville Intake. PG&E conducted physical model tests to compare and select the most effective and viable combination of dredging, submerged pipeline and thermal curtain. The most effective thermal curtain with dredging provides 5.8°C and 5.2°C water temperature reduction at the Butt Valley PH during July and August respectively at its normal operating discharge of 1,600 cfs. (Note: The impacts of ON/OFF peaking operations on outflow temperatures were not tested).

Warming in Butt Valley Reservoir is about 1°C - 2°C in July and August under existing conditions. Warming in Butt Valley Reservoir would be more pronounced if the Prattville thermal curtain was installed and cooler water entered the reservoir. PG&E investigated measures to minimize Butt Valley Reservoir warming under the Prattville thermal curtain condition. PG&E considered two potential thermal curtain options in Butt Valley Reservoir: (1) two thermal curtains, one installed up-reservoir near the Butt Valley Powerhouse discharge and another installed down-reservoir near the Caribou No. 1 and No. 2 intakes, (2) one thermal curtain installed up-reservoir only. On average, the two curtain option (with the Prattville thermal curtain installed) resulted in reduced warming in Butt Valley Reservoir of about 0.9 to 2.5ºC for July and August based on the preliminary results from the numerical model MITEMP. But the 2006 special test demonstrated that cold water plunges at the entrance of Butt Valley Reservoir making the up-reservoir curtain unnecessary.

Conclusion: Consider this measure (one down-reservoir curtain only).

- ***Enhancement measure for both 3a and 3b would be to raise the elevation of the dam/spillway and/or seasonal operating levels of the reservoir to raise the top of the hypolimnion and its overall volume.***

  This enhancement measure consists of raising the elevation of the dam/spillway and/or seasonal operating levels of the reservoir to increase the hypolimnion depth. The purpose would be to increase the storage volume of the hypolimnion and to improve hydraulics and enhance its ability to convey cold water to the Caribou Intake. Butt Valley Reservoir subsurface hydraulics limit the amount of cold water that can be conveyed through the hypolimnion to the Caribou Intake. Increasing the depth of the hypolimnion may enhance cold water withdrawal by improving hydraulics. This benefit would need to be analyzed and tested through physical modeling or numerical modeling.

  Raising the dam would require significant and costly modifications to the existing dam structure, Butt Valley PH tailrace, and the purchase of additional right-of-way to flood waterfront lands.

  Conclusion: Eliminate this measure.

MEASURES ALONG SENECA REACH

3. Reduce warming along the Seneca Reach by increasing shading through planting of vegetation.

This measure consists of performing streamside vegetation management and planting on the Seneca Reach to promote shading and reduce warming, and thus decrease water temperature at Belden Forebay. Existing shading of the Seneca Reach is approximately 53%. Existing warming in the Seneca Reach is about 4°C at Canyon Dam release rate of 35 cfs. Water temperature modeling tests indicate that, if Canyon Dam release is increased to 80 cfs, by increasing shading by 20 percent (i.e., total shading increases to 64%) warming is only reduced by about 0.4°C. The warming reduction benefit for higher releases at Canyon Dam by increasing streamside shading of the Seneca Reach would be less. In addition, this marginal warming reduction benefit would be muted by relatively high discharges from Caribou PHs. Therefore, this measure would not be an effective water temperature reduction measure.

Conclusion: Eliminate this measure.

Measures along Belden Reach

4. Increase release of cold water to the Belden Reach

a. by increasing release of cold water from Belden Dam Outlet/Oak Flat PH

This measure consists of re-operating Belden Dam to provide increased magnitude water releases from Belden Dam to cool the Belden Reach of the NFFR. Note that increasing releases from Belden Dam could only reduce warming along the reach, not reduce water temperature at the starting point of the reach. Water temperature modeling indicates that increased magnitude of water releases from Belden Dam would reduce warming very slightly if the dam release temperature is higher than 19°C. Increasing the magnitude of water releases from Belden Dam from 80 cfs to 200 cfs would reduce warming by about 0.4°C and 0.6°C if dam release temperatures are 18°C and 17°C, respectively (Figure 4).

Conclusion: Consider this measure.

b. by constructing a bypass pipeline to convey cold Seneca Reach flows around Belden Reservoir to the Belden Reach.

This measure consists of constructing and operating a new diversion dam (e.g., inflatable/deflatable rubber dam) and about one mile water pipeline to deliver cooler water at the end of the Seneca Reach to the NFFR immediately below Belden Dam. Based on observed average mean daily flow and water temperature data in July and August 2002 (dry year), this measure would cool water below Belden Dam by approximately 1.9°C and 3.0°C in July and August, respectively.

Conclusion: Consider this measure.

c. by operating Caribou PH in strict peaking mode with several hours shut down time to prevent mixing at the Caribou PH/Seneca confluence and thereby allow cold Seneca Reach flows (enhanced by increasing Canyon Dam releases to the Seneca Reach) to submerge in Belden Reservoir for release to downstream reaches.

The July 2003 Caribou special test indicated that Belden Reservoir exhibits stratification (Figure 5). This is beneficial to the Belden Reach since the Belden Dam instream flow outlet is located at a depth of 90 - 100 ft. This benefit has already been used under existing operating conditions. The purpose of this measure would be to strengthen the stratification and enhance the benefit.

The stratification in Belden Reservoir may result from submerged cold water inflows from the Seneca Reach during Caribou off-peak hours. The degree of Belden Reservoir stratification would be affected by release rate at Canyon Dam, the duration of off-peak hours of the Caribou PH, and on-peak discharge rates at the Caribou PH. It is expected that increasing Canyon Dam releases, extending Caribou off-peak hours, or conveying cold Seneca Reach flows directly to an appropriate plunging location in Belden Reservoir would strengthen the stratification and enhance the benefit. Cold water plunging during Caribou off-peak hours and resulting strengthening of the stratification in Belden Reservoir were verified in the 2006 special test (2006 North Fork Feather River Special Testing Data Report, Stetson and PG&E, March 2007).

Conclusion: Consider this measure.

d. by constructing a pipeline to convey cold Seneca Reach flows (enhanced by increasing Canyon Dam releases to the Seneca Reach) to an appropriate plunging location in Belden Reservoir

This measure consists of constructing a new diversion dam (e.g., inflatable/deflatable rubber dam) and about 1,500 ft of pipeline to convey cold Seneca Reach flows to an appropriate location in Belden Reservoir for the cold water to submerge. For example, location A on Figure 6 could be a potential plunging point. It is expected this measure would strengthen Belden Reservoir stratification and reduce the temperature of Belden Dam water releases to the Belden Reach.

Conclusion: Consider this measure.

e. by constructing a mechanical water cooling tower or chiller at a site

- ***below Belden Dam***

  This measure consists of constructing and operating a mechanical water cooling tower or chiller at Belden Dam to cool incoming river water and delivering it back to the NFFR immediately downstream of the dam. The amount of water temperature reduction below Belden Dam would depend on the amount of flow delivered to the cooling tower or chiller and the degree of cooling by the cooling tower or chiller (Figure 7).

  Conclusion: Consider this measure.

- ***at the Belden Adit***

  This measure consists of constructing and operating a mechanical water cooling tower or chiller at the Belden Adit to cool a portion of the tunnel water and delivering it back to the NFFR immediately downstream of the dam. The amount of water temperature reduction below Belden Dam would depend on the amount of flow delivered to the cooling tower or chiller and the degree of cooling by the cooling tower or chiller.

  Conclusion: Consider this measure.

5. **Reduce warming along the lower Belden Reach by constructing a bypass pipeline to convey warm East Branch flows directly into Rock Creek Reservoir, bypassing the lower Belden Reach.**

   This measure consists of constructing a new diversion structure at the mouth of the East Branch (e.g., inflatable/deflatable rubber dam) and about 1.7 mile water pipeline to deliver warm water directly into the epilimnion of Rock Creek Reservoir. The relatively high discharges from Belden PH would mute this diverted warm water in the reservoir. This measure would significantly reduce water temperature of the lower Belden Reach below the East Branch.

   Conclusion: Consider this measure.

6. **Reduce warming of Belden Reach by increasing shading through planting of vegetation.**

   This measure consists of performing streamside vegetation management and planting along the Belden Reach to promote shading and thereby reduce warming. Existing shading of the upper Belden Reach before the East Branch and the lower Belden Reach after the East Branch is approximately 40% and 3% respectively. Warming in July 2002 in the upper Belden Reach was not significant (about 0.5°C) primarily because of relatively high existing shading. Warming in the lower Belden Reach was also not significant because of short length and relatively high flow rate in this segment. Water temperature modeling indicates that the benefit of increasing shading along the entire Belden Reach would be minimal. This measure would not be an effective water temperature reduction measure.

   Conclusion: Eliminate this measure.

7. ***Reduce warming along the East Branch by increasing shading through planting of vegetation.***

   This measure consists of performing streamside vegetation management and planting along the East Branch Feather River and its tributaries to promote shading and reduce water temperatures. The East Branch flows into the NFFR about 1.7 miles upstream of Rock Creek Reservoir. The flow at the mouth of East Branch in July 2002 was about one third of the lower Belden Reach flow below the East Branch confluence. Reducing water temperature by 1°C at the mouth of East Branch would reduce water temperature at the lower Belden Reach immediately below the East Branch confluence by about 0.3°C. Any water temperature benefits of streamside vegetation management along the East Branch or its tributaries would be beneficial mostly to the lower Belden Reach, because the much higher discharges from the Belden Powerhouse would mute this temperature benefit once these two discharges mix in Rock Creek Reservoir.

   Conclusion: Consider this measure.

8. **Replace discharge of warm water into the UNFFR from the East Branch with cooler water by collecting and discharging thermally stratified cold water to the NFFR**

   a. ***by constructing a new reservoir on the upper East Branch***

      This measure consists of constructing and operating a new large dam and reservoir on the East Branch Feather River or its tributaries to store cool water for later release to the East Branch. The East Branch flows into the NFFR upstream of the Rock Creek, Cresta, and Poe reaches. A new dam would need to have sufficient water depth and volume to produce a large quantity of stratified cold water. PG&E evaluated three potential sites for a new dam and reservoir. However, given the very long travel distance (30 to 40 river miles) and significant warming effect of the East Branch Feather River, cold water released from a new dam would not be expected to result in measurable water temperature changes at the Rock Creek, Cresta and Poe reaches. This measure would not be an effective water temperature reduction measure.

      Conclusion: Eliminate this measure.

   b. ***by enlarging the existing reservoir on the upper East Branch***

      This measure consists of enlarging and operating an existing dam and reservoir on the East Branch Feather River or its tributaries to provide a large amount of thermally stratified cold water for later release to the East Branch. The East Branch flows into the NFFR upstream of the Rock Creek, Cresta, and Poe reaches. An enlarged dam would need to have sufficient depth and volume to produce a large quantity of stratified cold water. PG&E evaluated potential enlargement of the existing Round Valley Dam and Reservoir as the most promising dam for this measure. However, the evaluation concluded that the annual runoff for the Round Valley basin is not large enough to produce the water volume needed to sustain an enlarged reservoir. This finding combined with the finding in 9a leads to the conclusion that enlargement of an existing dam is not an effective water temperature reduction measure.

      Conclusion: Eliminate this measure.

9. **Replace discharge of warm water into the UNFFR from the East Branch with cooler water by purchasing water rights and transferring the water rights to instream use or changing the point of diversion to below Oroville thereby causing cooler inflows into the UNFFR by preventing the warming effect of diversions and return flows along the East Branch above the confluence.**

   This measure consists of purchasing water rights in the East Branch watershed and transferring the water rights to instream use for the purpose of preventing the warming effect of diversions and return flows along the East Branch. Existing flow at the mouth of East Branch in July 2002 was about one third of the lower Belden Reach below the East Branch confluence. Reducing 1°C of water temperature at the mouth of East Branch from this measure would reduce water temperature at the lower Belden Reach by 0.3°C. Little information is available on the effects of diversions and return flows on warming along the East Branch. Extensive study would be required to evaluate the effectiveness of this measure.

Conclusion: Eliminate this measure.

10. Reduce temperature of East Branch inflows to the NFFR by stream channel restoration efforts in the upper East Branch drainage

This measure consists of stream channel restoration and improvement efforts on first and second order streams in the headwaters of the East Branch, as described in the Plumas County proposal (Appendix D). Data comparing thermal conditions in the tributaries before and after completion of stream channel restoration and meadow re-watering projects demonstrate significant reductions in water temperature within each local drainage area. These focused channel improvement projects are effective in reaching the goals of temperature reduction, wetland habitat enhancement, and increased seasonal release of cool groundwater to the localized stream system. However, benefits are limited by scale and there is no evidence that incremental improvements in the headwater streams can be sustained through the third and fourth order stream for benefit in the NFFR. Application of a simple mass balance equation to assess the preservation capability for flow and temperature contributions from treated headwater streams shows that benefits are overwhelmed by East Branch conditions with no measurable improvement at the confluence of the NFFR. This measure should be appreciated for its off-site potential, but removed from further evaluation in the NFFR alternatives screening.

Conclusion: Eliminate this measure.

MEASURES ALONG ROCK CREEK REACH

11. Increase release of cold water to the Rock Creek Reach

a. by increasing release of cold water from Rock Creek Dam

This measure consists of re-operating Rock Creek Dam to provide increased magnitude water releases at Rock Creek Dam to cool the Rock Creek Reach of the NFFR. Note that increasing release from Rock Creek Dam can only reduce warming, not reduce the temperature of water at the starting point of the Rock Creek Reach. Water temperature modeling tests indicate that the warming reduction benefit by increasing the magnitude of water releases at Rock Creek Dam is more measurable if the dam release temperature is lower than 20°C (Figure 8).

Conclusion: Consider this measure.

b. by constructing a new reservoir on the upper Yellow Creek to collect and discharge thermally stratified cold water to the UNFFR/Rock Creek Reservoir.

This measure consists of constructing and operating a new large dam and reservoir on Yellow Creek or its tributaries to store cool water for later release to Yellow Creek. Yellow Creek flows into the NFFR upstream of the Rock Creek, Cresta, and Poe reaches. A new dam would need to have sufficient water depth and volume to produce a large quantity of stratified cold water. Existing summer water temperatures at the mouth of Yellow Creek are cold. Constructing a reservoir on the upper Yellow Creek or its tributaries to produce stratified cold water is not expected to improve temperature conditions beyond existing. This measure is not an effective water temperature reduction measure.

Conclusion: Eliminate this measure.

c. by constructing a bypass pipeline to convey cold Yellow Creek/Chips Creek flows around Rock Creek Reservoir to the Rock Creek Reach

This measure consists of constructing a new diversion dam (e.g., inflatable/deflatable rubber dam) and about three miles of water pipeline to deliver cooler water to the NFFR immediately below Rock Creek Dam. Based on observed average mean daily flow and water temperature data in July and August 2002 (dry year), this measure would cool water below Rock Creek Dam by about 1.6°C and 1.8°C in July and August, respectively.

Conclusion: Consider this measure.

d. by constructing a mechanical water cooling tower or chiller at the site of PG&E's Rogers Flat Station for discharge to the Rock Creek Reach

This measure consists of constructing and operating a mechanical water cooling tower or chiller at the site of PG&E's Rogers Flat Station to cool Rock Creek Reservoir water and deliver it back to the NFFR immediately downstream of Rock Creek Dam. The amount of water temperature reduction below Rock Creek Dam depends on the amount of flow delivered to the cooling tower or chiller and the degree of cooling by the cooling tower or chiller (Figure 9).

Conclusion: Consider this measure.

e. by constructing a bifurcation berm/wall/partition within Yellow Creek channel and upstream of Rock Creek Reservoir to separate Yellow Creek flows from Belden PH discharges and Belden Reach flows, thereby preventing mixing and thus allowing cooler Yellow Creek flows to submerge in Rock Creek Reservoir for release to downstream reaches.

Rock Creek Reservoir exhibits weak stratification (Figure 10). This is beneficial to the Rock Creek Reach. This benefit has already been used under existing conditions. The purpose of this measure, combined with the following enhancement measures, would be to strengthen the stratification and enhance the benefit.

The weak stratification in Rock Creek Reservoir may result from submerged cold water inflows from Yellow Creek during Belden PH off-peak hours and submerged cold water inflows from Chips Creek. Under existing conditions, cold water inflows from Yellow Creek mix with warm discharges from Belden PH during on-peak hours and partially mix with warm inflows from Belden Reach during Belden PH off-peak hours. It would be expected that the stratification in Rock Creek Reservoir could be strengthened by constructing a bifurcation berm/wall/partition within Yellow Creek channel and upstream of Rock Creek Reservoir to separate Yellow Creek flows from Belden PH discharges and Belden Reach flows (Figure 11) to prevent mixing and thereby allow cooler Yellow Creek flows to submerge in Rock Creek Reservoir.

Conclusion: Consider this measure.

f. ***by constructing a diversion and bypass pipeline to capture and convey cold Yellow Creek flows directly to an appropriate plunging location of Rock Creek Reservoir***

This measure consists is very similar to the measure 11e above, except that this measure calls for a diversion dam and pipeline to capture and convey the water for discharge at an appropriate location at the reservoir bottom.

Conclusion: Consider this measure.

- ***Enhancement measure for 11e or 11f would be to dredge a submerged channel in Rock Creek Reservoir***

This enhancement measure consists of dredging a submerged channel in Rock Creek Reservoir for providing additional depth for cold water plunging and transport. This enhancement measure, in combination with measure 11e or 11f, would reduce cold water mixing with warm surface water during cold water transport through the reservoir and thereby provide temperature reduction benefit to Rock Creek Reach. Cold water movement along a submerged channel with little mixing with warm surface water was demonstrated in the 2006 special test in Butt Valley Reservoir (2006 North Fork Feather River Special Testing Data Report, Stetson and PG&E, March 2007).

Conclusion: Consider this measure.

- ***Enhancement measure for 11e or 11f and the enhancement measure above would be to construct a low level outlet at Rock Creek Dam***

This enhancement measure in combination with measure 11e or 11f and the enhancement measure above would enhance the stratification benefit to Rock Creek Reach. Currently there are two gates at Rock Creek Dam for making instream flow releases; one is at a depth of about 15 ft and the other is at a depth of about 40 ft. The lower gate (30″ diameter) has a capacity of approximately 150 cfs. At higher releases the upper gate is opened. The existing lower gate is not low enough and has insufficient capacity for higher instream flow releases. Constructing a low level outlet at Rock Creek Dam would provide access to the bottom colder water in the reservoir.

Conclusion: Consider this measure.

12. Increase release of cold water to the lower Rock Creek Reach by increasing release of cold water to the Rock Creek Reach from Lower Bucks Lake/Bucks Creek.

This measure consists of re-operating and/or reconfiguring the Bucks Creek Project to increase releases and thereby reduce water temperatures along the lowest portion of the Rock Creek Reach. The Bucks Creek PH discharges into the NFFR about 1.2 miles upstream of Cresta Reservoir. Increasing release of cold water from either the Bucks Creek PH or Lower Bucks Lake/Bucks Creek would be beneficial primarily to the lower Rock Creek Reach, because much higher discharges from the Rock Creek Powerhouse would mute this temperature benefit once these two discharges mix in Cresta Reservoir.

Conclusion: Consider this measure.

13. Reduce warming of Rock Creek reach by increasing shading through planting of vegetation.

This measure consists of performing streamside vegetation management and planting on the Rock Creek Reach to promote shading and reduce warming. Existing shading of the Rock Creek Reach is approximately 25%. Warming in July 2002 in the Rock Creek Reach was not significant (about 0.4°C) because the release temperatures from Rock Creek Dam were high (21.3°C) and close to air temperature. Water temperature modeling indicates that, if total shading of the Rock Creek Reach was increased to 50%, warming would be reduced by about 0.5°C for the existing dam release temperature condition. Warming reduction would be more significant for lower release temperatures from Rock Creek Dam.

Conclusion: Consider this measure.

MEASURES ALONG CRESTA REACH

14. Increase release of cold water to the Cresta Reach

a. by increasing release of cold water from Cresta Dam

This measure consists of increasing releases at Cresta Dam to cool the Cresta Reach of the NFFR. Note that increasing release from Cresta Dam can only reduce warming, not reduce the water temperature at the starting point of the Cresta Reach. Water temperature modeling tests indicate that the warming reduction benefit by increasing the magnitude of water releases at Cresta Dam is more measurable if the dam release temperature is lower than 20°C (Figure 12).

Conclusion: Consider this measure.

b. ***by increasing release of cold water to the Cresta Reach from Grizzly Forebay/Grizzly Creek***

This measure consists of increasing the cool water releases at Grizzly Forebay Dam to reduce warming in Grizzly Creek, thereby discharging more cooler water to the Cresta Reach. The water temperature of releases below Grizzly Dam in July 2002 was 14.4°C and warming from Grizzly Dam to the mouth of Grizzly Creek was about 5°C at release rate of about 6 cfs at Grizzly Dam (Note: The measured average flow near the mouth of Grizzly Creek in July 2002 was 24 cfs, indicating a flow accretion of about 18 cfs). Preliminary water temperature modeling indicates that this warming could be reduced by about 3.0°C if water releases at Grizzly Dam were increased to 100 cfs.

Conclusion: Consider this measure.

c. ***by constructing a bypass pipeline to convey cold Buck Creek PH flows around Cresta Reservoir to the Cresta Reach***

This measure consists of constructing a new diversion structure at the Bucks Powerhouse tailrace and about four miles of water pipeline to deliver cooler water to the NFFR immediately below Cresta Dam. Based on observed average mean daily flow and water temperature data in July and August 2002 (dry year), this measure would cool water below Cresta Dam by about 1.6°C and 3.0°C in July and August, respectively.

Conclusion: Consider this measure.

d. ***by constructing a pipeline to convey all or a portion of the cold Buck Creek PH flows directly into Cresta Reservoir thereby avoiding mixing with Rock Creek flows thus allowing the cold Buck Creek PH flows to submerge in Cresta Reservoir for release to downstream reaches.***

Unlike Belden and Rock Creek Reservoirs, Cresta Reservoir exhibits no stratification (Figure 13) because there is no cold water source to the reservoir under existing conditions. The purpose of this measure would be to develop some degree of stratification in Cresta Reservoir by conveying all or a portion of the cold Buck Creek flows directly to an appropriate plunging location at Cresta Reservoir.

Conclusion: Consider this measure.

\- ***Enhancement measure for 14d would be to dredge a submerged channel in Cresta Reservoir***

This enhancement measure consists of dredging a submerged channel in Cresta Reservoir to provide additional depth for cold water plunging and transport. This enhancement measure, in combination with measure 14d, would reduce cold water mixing with warm surface water during cold water transport through the reservoir and thereby provide temperature reduction benefit to Rock Creek Reach. Cold water movement along a submerged channel with little mixing with warm surface water was demonstrated in the 2006 special test in Butt Valley Reservoir (2006 North Fork Feather River Special Testing Data Report, Stetson and PG&E, March 2007).

Conclusion: Consider this measure.

- ***Enhancement measure for 14d and the enhancement measure above would be to construct a low level outlet at Cresta Dam***

This enhancement measure, in combination with measure 14d and the enhancement measure above, would provide cooler water releases to the Cresta Reach. There are two level gates at Cresta Dam, one is at a depth of about 15 ft and another is at a depth of about 40 ft. The lower gate (30″ diameter) has a capacity of approximately 150 cfs. At higher releases the upper gate is opened. The existing lower gate is not low enough and has insufficient capacity for higher instream flow releases. If measure 14d and the enhancement measure above were implemented, constructing a low level outlet at Cresta Dam would provide access to the cooler water in the reservoir bottom.

Conclusion: Consider this measure.

e. by constructing a mechanical water cooling tower or chiller below Cresta Dam

This measure consists of constructing and operating a mechanical water cooling tower or chiller below Cresta Dam to cool incoming river water and delivering it back to the NFFR immediately downstream of the dam. The amount of water temperature reduction below Cresta Dam would depend on the amount of flow delivered to the cooling tower or chiller and the degree of cooling by the cooling tower or chiller.

Conclusion: Consider this measure.

15. Reduce warming of Cresta reach by increasing shading through planting of vegetation.

This measure consists of performing streamside vegetation management and planting on the Cresta Reach to promote shading and reduce warming. Existing shading of the Cresta Reach is approximately 30%. Warming in July 2002 in the Cresta Reach was not significant (about 0.5°C) because existing release temperatures from Rock Creek Dam were high (21.2°C) and close to air temperature. Water temperature modeling indicates that the benefit of increasing Cresta Reach shading from existing 30% to 60% would be a reduction in warming by about 0.5°C.

Conclusion: Consider this measure.

MEASURES ALONG POE REACH

16. Increase release of cold water to the Poe Reach

a. by increasing release of cold water from Poe Dam

This measure consists of re-operating Poe Dam to provide increased magnitude water releases at Poe Dam to reduce warming in the Poe Reach. The amount of reduction in warming is related to Poe Dam release water temperature and the rate of release (Figure 14).

Conclusion: Consider this measure.

b. by releasing water to the Poe Reach directly from the Poe Adit

This measure consists of constructing and operating a water pipeline to transport cool Poe Tunnel water from Poe Tunnel Adit #1 to the NFFR near Bardees Bar, located approximately 4.5 river miles below Poe Dam. This measure would provide water temperature benefits to the lower Poe Reach below Bardees Bar.

Conclusion: Consider this measure.

c. by constructing a mechanical water cooling tower or chiller below Poe Dam

This measure consists of constructing and operating a mechanical water cooling tower or chiller below Poe Dam to cool incoming river water and delivering it back to the NFFR immediately downstream of the dam. The amount of water temperature reduction below Poe Dam would depend on the amount of flow delivered to the cooling tower or chiller and the degree of cooling by the cooling tower or chiller (Figure 15).

Conclusion: Consider this measure.

17. Reduce warming of Poe reach by increasing shading through planting of vegetation.

This measure consists of performing streamside vegetation management and planting on the Poe Reach to promote shading and reduce warming. Existing shading of the Poe Reach is approximately 22%. Warming in July 2002 in the Poe Reach was about 2.1°C. Water temperature modeling indicates that increasing total shading of the Poe Reach to 50% would reduce warming by about 0.8°C. Warming reduction would be more significant for lower release temperatures from Poe Dam.

Conclusion: Consider this measure.

MEASURES ALONG ALL REACHES

18. Increase release of cold water to all reaches by discharging cold water to the reaches from water wells that are drilled into adjacent rock and intercept and produce from fractures containing large volumes of cold water.

This measure consists of drilling, constructing and operating large water wells that would tap fracture zones along the NFFR to deliver cooler well water to the river below each dam. The cooling requirement would require numerous very productive cold water wells at each dam. According to PG&E, existing geologic information and well driller's data demonstrate that it is not likely that an adequate aquifer exists near the dams. Extensive field investigation would be required to evaluate the feasibility of this measure.

Conclusion: Eliminate this measure.

19. Increase release of cold water to all reaches by discharging cold water to the reaches from a pipeline that conveys cold water pumped from Lake Oroville.

This measure consists of constructing and operating up to about 40 miles of very large diameter water pipeline and pumping stations along the NFFR to deliver cooler water from the depths of Lake Oroville to the NFFR at each dam. This measure would cool water by approximately 3°C below each dam. The cooling requirement would require a large diameter pipeline, several large pumping stations, and a substantial amount of electrical power to operate the pumping stations.

Conclusion: Consider this measure.

Results of Evaluation of Potential Measures for Reducing Water Temperature in the North Fork Feather River

Alternative # in the 24 Alternatives Report		Measures	Evaluation Result
		Above or At Lake Almanor	
	1.	Increase release of cold water from Lake Almanor	
1, 2	a.	to Butt Valley Reservoir through closely controlled, selective withdrawal from the Prattville Intake by installing a thermal curtain or other device	Consider
8	b.	to the Seneca Reach through selective withdrawal from the existing Canyon Dam Outlet	Eliminate
5	c.	to Butt Valley Reservoir through reduced withdrawal from the Prattville Intake	Consider
6	d.	to the Seneca Reach through increased cold water releases from Canyon Dam low-level outlet	Consider
3	-	Enhancement measure for both 1a and 1b would be to dredge the lake bottom levees in the Prattville Intake area	Consider
N/A	-	Enhancement measure for 1a to 1d would be to increase the inflow supply of cooler water into Lake Almanor (to prevent depletion of the hypolimnion).	Consider
		• by constructing an expansive, high-capacity wellfield that would pump directly from the basalt aquifer discharging to Big Springs/northeastern Lake Almanor. The pumped cold water could be conveyed by pipeline laid along the lakebed and connected for direct discharge into the Prattville Intake or Canyon Dam Outlet.	Consider
		• by connecting a conduit to the Hamilton Branch tailrace that extends out into the depths of Lake Almanor to replenish the hypolimnion with cool water.	Eliminate
		• by purchasing water rights along the UNFFR and Hamilton Branch above Lake Almanor and transferring the water rights to instream use or changing the point of diversion to below Oroville thereby causing cooler inflows into Lake Almanor by preventing the warming effect of diversions and return flows above the lake.	Eliminate
		• by reducing warming along the UNFFR and Hamilton Branch above Lake Almanor by increasing shading through planting of vegetation thereby causing cooler inflows.	Eliminate
N/A	-	Enhancement measure for 1a to 1d would be to raise the elevation of the dam/spillway and/or seasonal operating levels of the lake to raise the level of the top of the hypolimnion and increase its overall volume.	Eliminate
		At Butt Valley	
	2.	Increase release of cold water from Butt Valley Reservoir	
7	a.	to Belden Reservoir through preferential use of Caribou PH #1	Consider
N/A	b.	to Lower Butt Creek through releases from a new low level Butt Valley Dam Outlet	Eliminate

N/A	c.	to Belden Reservoir by directly conveying Butt Valley PH discharge to Caribou No.2 and/or Caribou No.1.	Consider
N/A	-	Enhancement measure for 3a would be to construct a "crossover" conduit connecting Caribou No. 1 to Caribou No. 2.	Consider
4	-	Enhancement measure for both 3a and 3b would be to install a thermal curtain across Butt Valley Reservoir near the Caribou Intakes.	Consider
N/A	-	Enhancement measure for both 3a and 3b would be to raise the elevation of the dam/spillway and/or seasonal operating levels of the reservoir to raise the top of the hypolimnion and its overall volume.	Eliminate

Along Seneca Reach

N/A	3.	Reduce warming along the Seneca Reach by increasing shading through planting of vegetation.	Eliminate

Along Belden Reach

	4.	Increase release of cold water to the Belden Reach	
9	a.	by increasing release of cold water from Belden Dam Outlet/Oak Flat PH	Consider
18	b.	by constructing a bypass pipeline to convey cold Seneca Reach flows around Belden Reservoir to the Belden Reach.	Consider
N/A	c.	by operating Caribou PH in strict peaking mode with several hours shut down time to prevent mixing at the Caribou PH/Seneca confluence and thereby allow cold Seneca Reach flows (enhanced by increasing Canyon Dam releases to the Seneca Reach) to submerge in Belden Reservoir for release to downstream reaches.	Consider
N/A	d.	by constructing a pipeline to convey cold Seneca Reach flows (enhanced by increasing Canyon Dam releases to the Seneca Reach) to an appropriate plunging location in Belden Reservoir.	Consider
N/A	e.	by constructing a mechanical water cooling tower or chiller at a site	
14, 15		- below Belden Dam	Consider
14, 15		- at the Belden Adit	Consider
N/A	5.	Reduce warming along the lower Belden Reach by constructing a bypass pipeline to convey warm East Branch flows directly into Rock Creek Reservoir, bypassing the lower Belden Reach.	Consider
N/A	6.	Reduce warming of Belden reach by increasing shading through planting of vegetation.	Eliminate
23	7.	Reduce warming along the East Branch by increasing shading through planting of vegetation.	Consider
	8.	Replace discharge of warm water into the UNFFR from the East Branch with cooler water by collecting and discharging thermally stratified cold water to the NFFR	
21	a.	by constructing a new reservoir on the upper East Branch	Eliminate
22	b.	by enlarging the existing reservoir on the upper East Branch	Eliminate
N/A	9.	Replace discharge of warm water into the UNFFR from the East Branch with cooler water by purchasing water rights and transferring the water rights to instream use or changing the point of diversion to below Oroville thereby causing cooler inflows into the UNFFR by preventing the warming	Eliminate

		effect of diversions and return flows along the East Branch above the confluence.	
N/A	10.	Reduce temperature of East Branch inflows to the NFFR by stream channel restoration efforts in the upper East Branch watershed.	Eliminate

Along Rock Creek Reach

	11.	Increase release of cold water to the Rock Creek Reach	
10	a.	by increasing release of cold water from Rock Creek Dam	Consider
21	b.	by constructing a new reservoir on the upper Yellow Creek to collect and discharge thermally stratified cold water to the UNFFR/Rock Creek Reservoir.	Eliminate
19	c.	by constructing a bypass pipeline to convey cold Yellow Creek/Chips Creek flows around Rock Creek Reservoir to the Rock Creek Reach	Consider
14,15	d.	by constructing a mechanical water cooling tower or chiller at the site of PG&E's Rogers Flat Station for discharge to the Rock Creek Reach	Consider
N/A	e.	by constructing a bifurcation berm/wall/partition within Yellow Creek channel and upstream of Rock Creek Reservoir to separate Yellow Creek flows from Belden PH discharges and Belden Reach flows, thereby preventing mixing and thus allowing cooler Yellow Creek flows to submerge in Rock Creek Reservoir for release to downstream reaches.	Consider
N/A	f.	by constructing a bypass pipeline to convey cold Yellow Creek flows directly to an appropriate plunging location in Rock Creek Reservoir	Consider
N/A	-	Enhancement measure for 11e would be to dredge a submerged channel in Rock Creek Reservoir.	Consider
N/A	-	Enhancement measure for 11e or 11f and the enhancement measure above would be to construct a low level outlet at Rock Creek Dam.	Consider
13	12.	Increase release of cold water to the lower Rock Creek Reach by increasing release of cold water to the Rock Creek Reach from Lower Bucks Lake/Bucks Creek.	Consider
N/A	13.	Reduce warming of Rock Creek reach by increasing shading through planting of vegetation.	Consider

Along Cresta Reach

	14.	Increase release of cold water to the Cresta Reach	
11	a.	by increasing release of cold water from Cresta Dam	Consider
N/A	b.	by increasing release of cold water to the Cresta Reach from Grizzly Forebay/Grizzly Creek	Consider
20	c.	by constructing a bypass pipeline to convey cold Buck Creek PH flows around Cresta Reservoir to the Cresta Reach	Consider
N/A	d.	by constructing a pipeline to convey all or a portion of the cold Buck Creek PH flows directly into Cresta Reservoir thereby avoiding mixing with Rock Creek flows thus allowing the cold Buck Creek PH flows to submerge in Cresta Reservoir for release to downstream reaches.	Consider
N/A	-	Enhancement measure for 14d would be to construct a submerged channel in Cresta Reservoir	Consider
N/A	-	Enhancement measure for 14d and the enhancement measure above would be to construct a low level outlet at Cresta Dam	Consider
14, 15	e.	by constructing a mechanical water cooling tower or chiller below Cresta	Consider

		Dam	
N/A	15.	Reduce warming of Cresta reach by increasing shading by planting veg..	Consider
		Along Poe Reach	
	16.	Increase release of cold water to the Poe Reach	Consider
12	a.	by increasing release of cold water from Poe Dam	Consider
24	b.	by releasing water to the Poe Reach directly from the Poe Adit	Consider
14, 15	c.	by constructing a mechanical water cooling tower or chiller below Poe Dam	Consider
N/A	17.	Reduce warming of Poe reach by increasing shading through planting of vegetation.	Consider
		Along All Reaches	
16	18.	Increase release of cold water to all reaches by discharging cold water to the reaches from water wells that are drilled into adjacent rock and intercept and produce from fractures containing large volumes of cold water.	Eliminate
17	19.	Increase release of cold water to all reaches by discharging cold water to the reaches from a pipeline that conveys cold water pumped from Lake Oroville.	Consider

Table 1 Summary of Observed Mean Daily Water Temperatures during July 2003 Caribou Special Test

Date	Caribou No. 1 Temperature (°C)	Caribou No. 1 Flow (cfs)	Caribou No. 2 Temperature (°C)	Caribou No. 2 Flow (cfs)	Resultant Caribou Blend * (°C)	Belden Forebay (BD1) (°C)	NFFR below Belden Dam (NF5) (°C)	NFFR above EBNFFR (NF7) (°C)	EBNFFR above NFFR (EB1) (°C)	NFFR above Belden PH (NF8) (°C)	Remarks
07/12/03	---	9	20.1	1076	20.1	19.7	18.8	18.9	22.5	20.8	Part 1
07/13/03	---	7	20.0	1172	20.0	19.8	19.0	18.9	22.4	20.7	Part 1
07/14/03	---	0	20.2	1214	20.2	19.8	19.2	19.1	22.3	20.7	Part 1
07/15/03	---	14	20.5	1270	20.5	20.1	19.4	19.3	22.5	20.9	Part 1
07/16/03	---	57	20.6	1191	20.6	20.2	19.4	19.4	22.7	21.1	Part 1
07/17/03	---	66	21.0	1250	21.0	20.3	19.6	19.5	22.8	21.1	Part 1
07/18/03	16.4	893	---	67	16.4	19.1	18.3	19.1	23.2	21.3	Part 2
07/19/03	16.8	940	---	21	16.8	17.5	17.2	18.6	23.8	21.2	Part 2
07/20/03	17.0	994	---	12	17.0	17.3	17.1	18.5	24.4	21.4	Part 2
07/21/03	17.5	996	---	0	17.5	17.6	17.2	18.8	25.4	22.0	Part 2
07/22/03	17.8	996	---	0	17.8	17.8	17.4	19.0	25.8	22.1	Part 2
07/23/03	18.0	997	---	9	18.0	18.1	17.6	19.0	26.4	22.3	Part 2
07/24/03	18.4	992	---	3	18.4	18.4	17.8	19.0	25.8	22.0	Part 2
07/25/03	18.4	564	---	3	18.4	19.8	18.1	19.0	25.1	21.8	Part 2
07/26/03	18.4	628	23.0	897	21.1	20.9	18.5	19.1	24.7	21.6	Part 3
07/27/03	18.8	495	23.0	1001	21.6	21.3	19.4	19.6	24.5	21.7	Part 3
07/28/03	19.1	495	23.0	842	21.5	21.4	20.0	20.4	24.9	22.4	Part 3
07/29/03	19.0	552	23.4	904	21.7	21.5	20.1	20.6	25.4	22.9	Part 3
07/30/03	19.1	460	23.2	874	21.8	21.7	20.5	20.7	25.6	23.0	Part 3

** Based on mass balance calculations.*

Table 1 Summary of Observed Water Temperatures during July 2003 Caribou Special Test (Continued)

Date	Belden PH Temperature (°C)	Belden PH Flow (cfs)	NFFR below Rock Creek Dam (NF9) (°C)	NFFR above Bucks Creek (NF12) (°C)	NFFR above Rock Creek PH (NF13) (°C)	NFFR below Cresta Dam (NF14) (°C)	NFFR above Cresta PH (NF16) (°C)	NFFR below Poe Dam (°C)	Remarks
07/12/03	19.6	984	19.8	20.1	18.2	19.4	19.8	19.6	Part 1
07/13/03	19.8	1086	19.9	20.2	18.2	19.5	20.0	19.9	Part 1
07/14/03	19.8	1172	19.8	20.0	18.1	19.6	19.9	19.9	Part 1
07/15/03	20.1	1140	20.1	20.3	18.3	19.7	20.1	19.9	Part 1
07/16/03	20.2	1221	20.2	20.5	18.4	19.9	20.2	20.2	Part 1
07/17/03	20.3	1199	20.2	20.5	18.4	19.9	20.3	20.3	Part 1
07/18/03	19.5	900	20.4	20.7	18.5	20.0	20.4	20.3	Part 2
07/19/03	17.8	913	19.7	21.1	18.8	20.2	20.8	20.5	Part 2
07/20/03	17.4	903	19.1	21.0	18.7	19.6	20.6	20.2	Part 2
07/21/03	17.6	957	19.3	21.3	19.0	19.6	20.9	20.0	Part 2
07/22/03	17.9	962	19.6	21.5	19.2	19.8	21.0	20.1	Part 2
07/23/03	18.2	944	19.9	21.7	19.3	20.1	21.2	20.4	Part 2
07/24/03	18.4	932	19.8	21.4	19.1	20.1	21.2	20.5	Part 2
07/25/03	19.5	1352	19.9	21.1	18.8	19.9	21.0	20.3	Part 2
07/26/03	20.8	1441	20.7	21.1	18.8	20.1	20.5	20.4	Part 3
07/27/03	21.3	1323	21.2	21.2	19.8	20.6	21.0	20.8	Part 3
07/28/03	21.4	1318	21.5	21.8	20.5	21.4	21.7	21.4	Part 3
07/29/03	21.5	1413	21.7	22.4	22.3	21.7	22.2	22.0	Part 3
07/30/03	21.7	1361	22.0	22.7	23.0	22.1	22.7	22.4	Part 3

Figure 1 Estimated Water Temperatures of Seneca Reach above Caribou PH with Different Canyon Dam Releases (Release Temperature = 13°C)
(Data Used: July 2002 Meteorology Data at Prattville Intake and Observed Average Flow and Temperature at Lower Butt Creek Mouth)

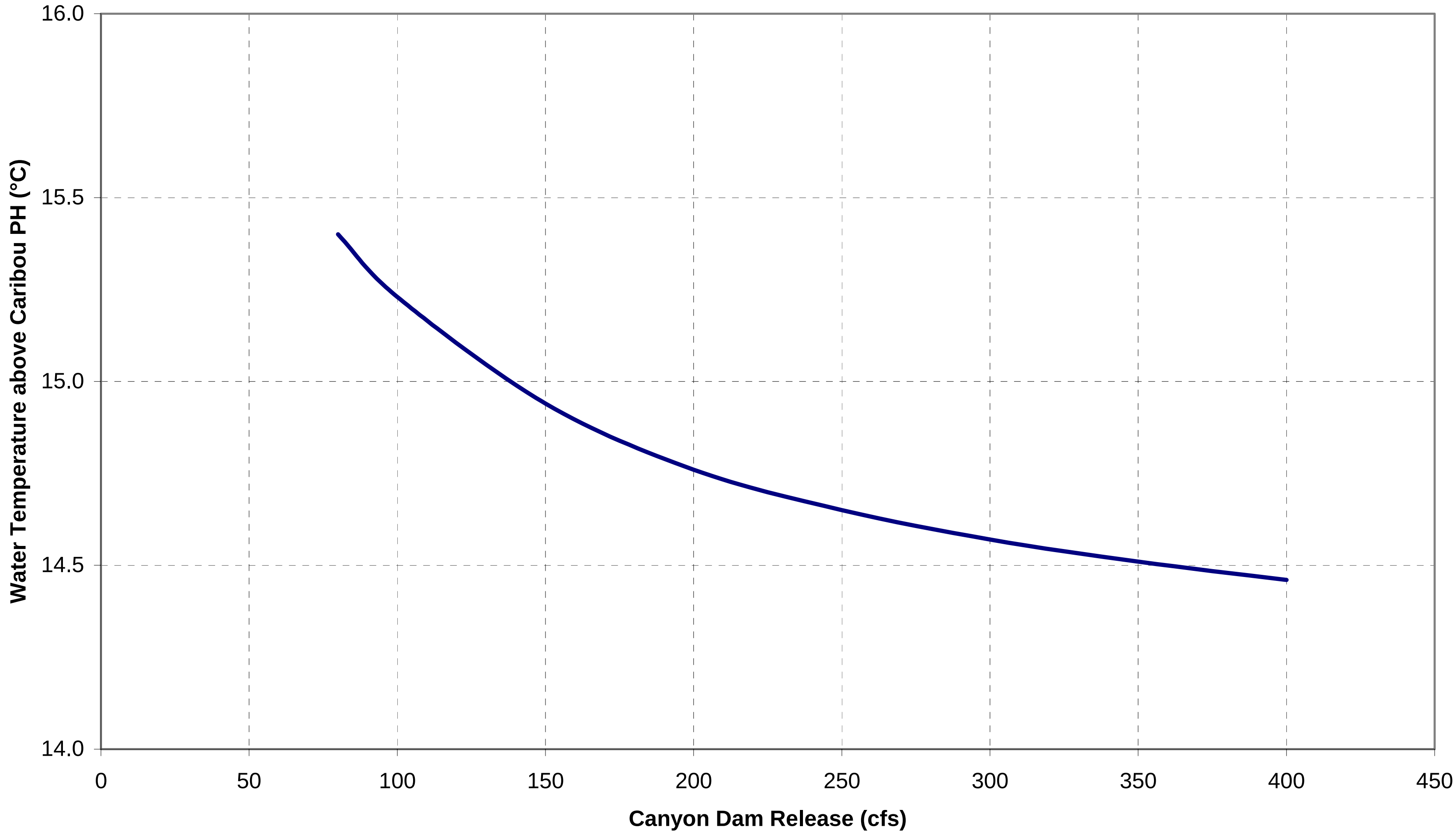


Figure 2 Estimated Water Temperature at Butt Valley PH for a Range of Groundwater Diversions at Prattville Intake (Groundwater Temperature = 8°C)

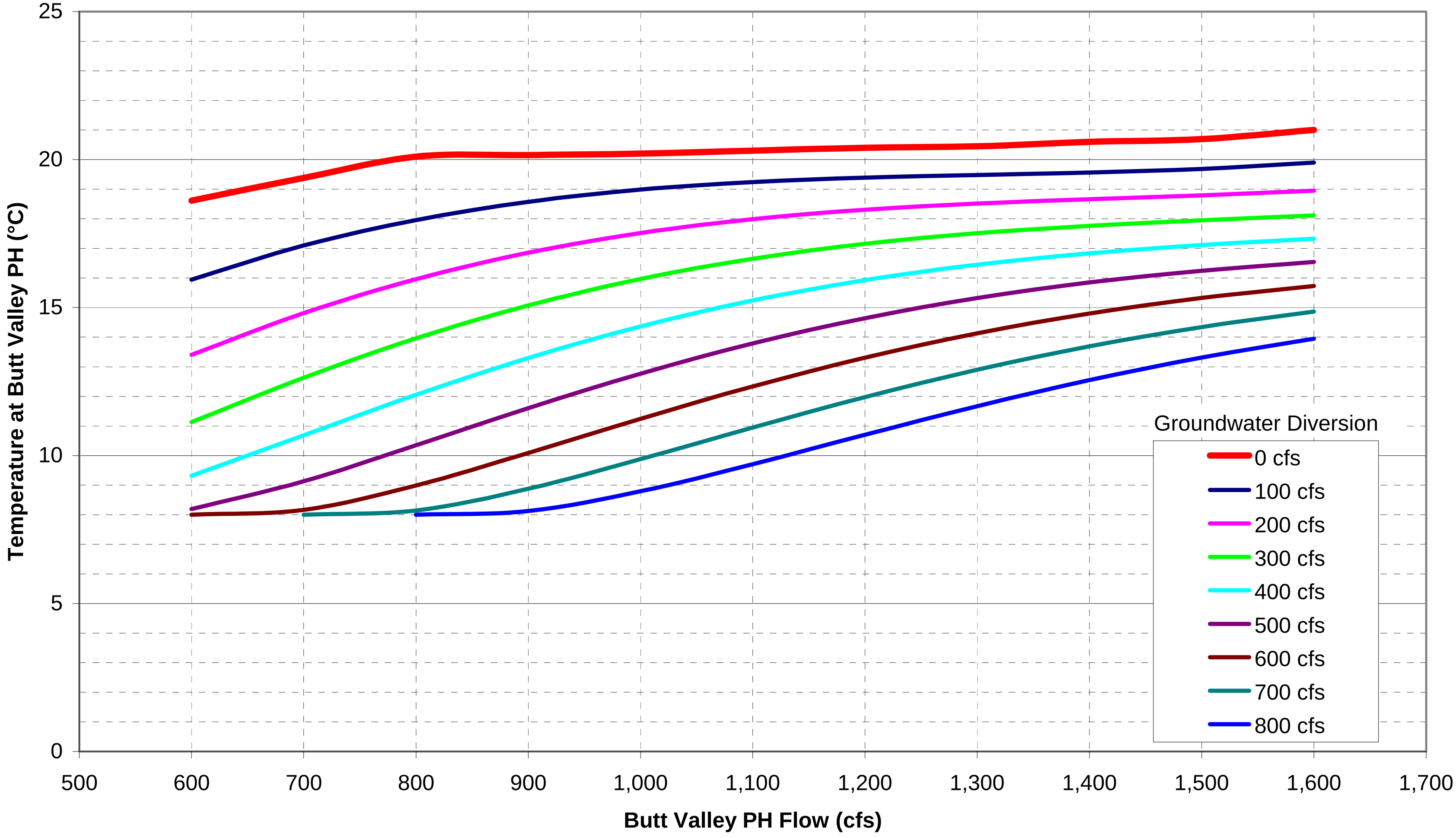


Figure 3 Observed Mean Daily Temperatures along NFFR during July 2003 Caribou Special Test

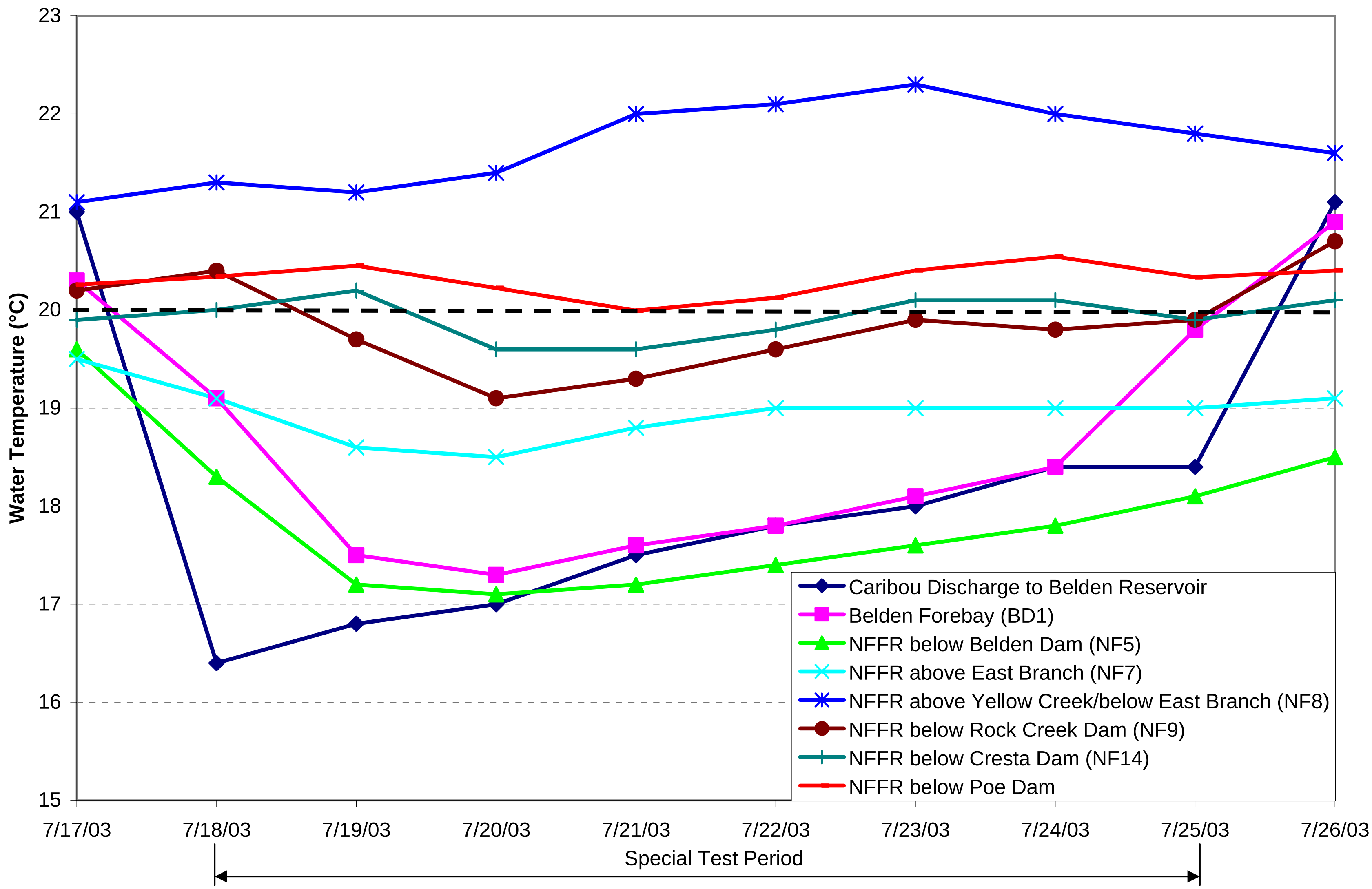


Figure 4 Simulated July 2002 Mean Daily Water Temperatures of Belden Reach above EBNFFR Confluence for a Range of Dam Releases and Release Temperatures

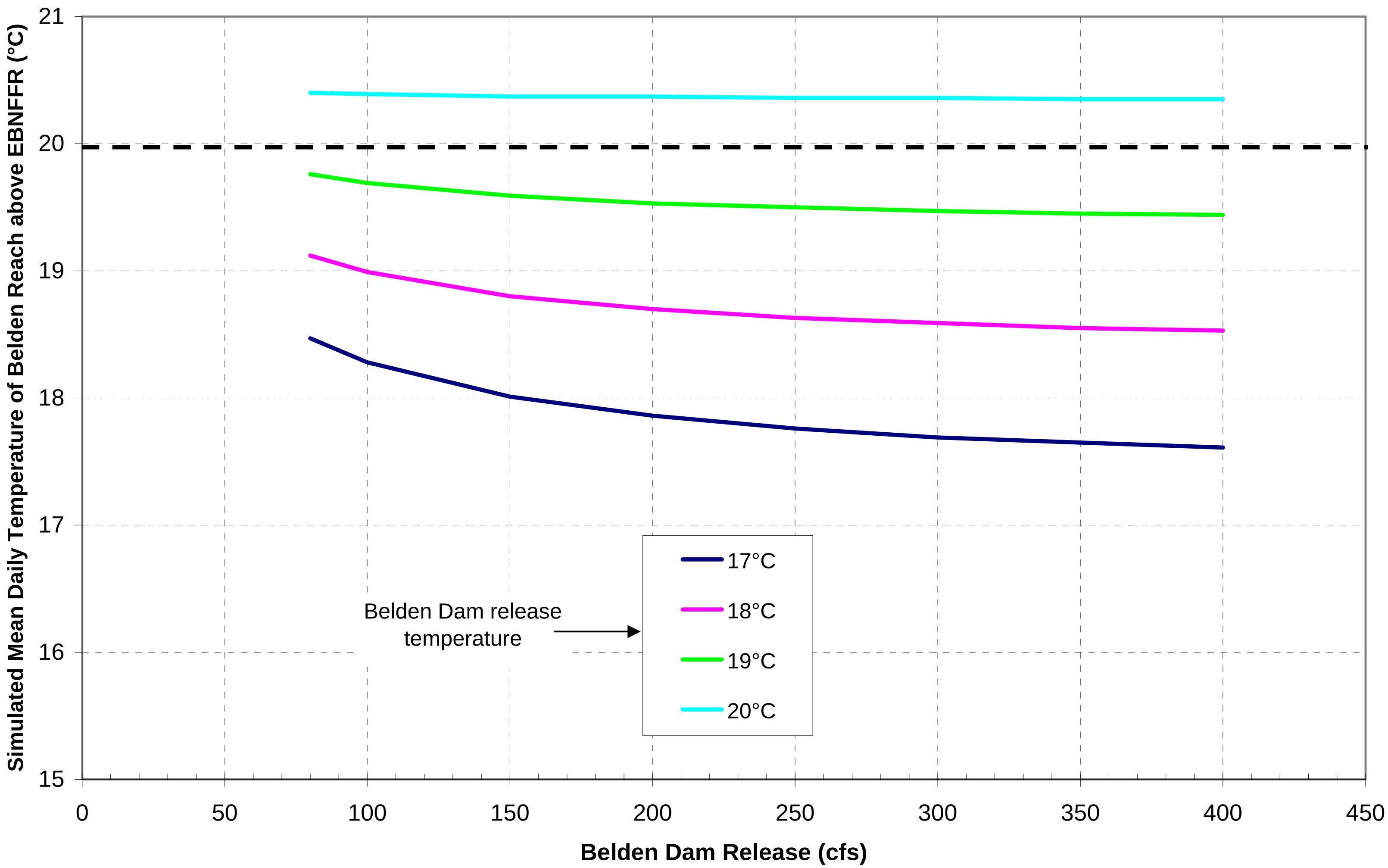
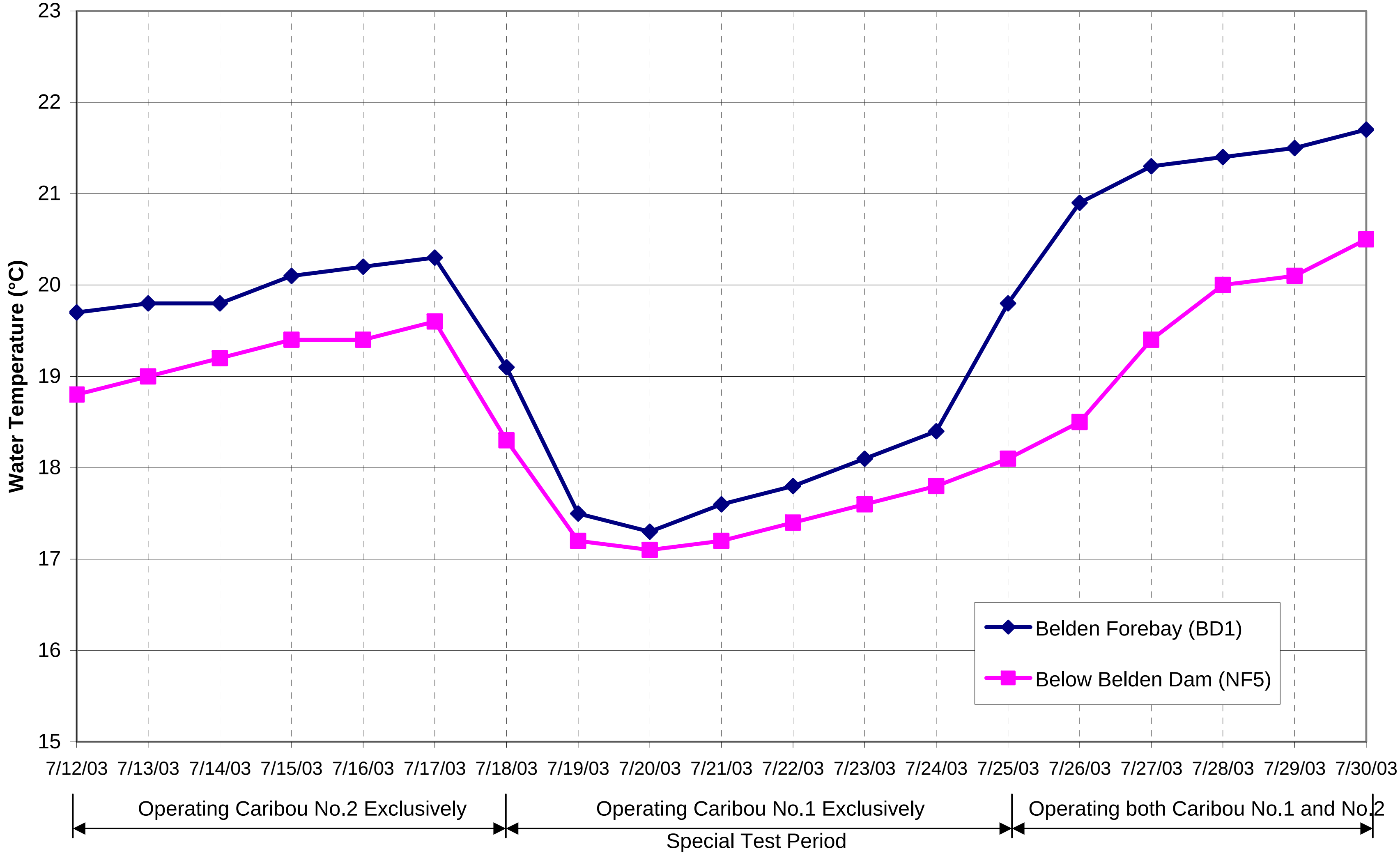


Figure 5 Observed Mean Daily Temperatures Indicating Possible Belden Reservoir Stratification during July 2003 Caribou Special Test



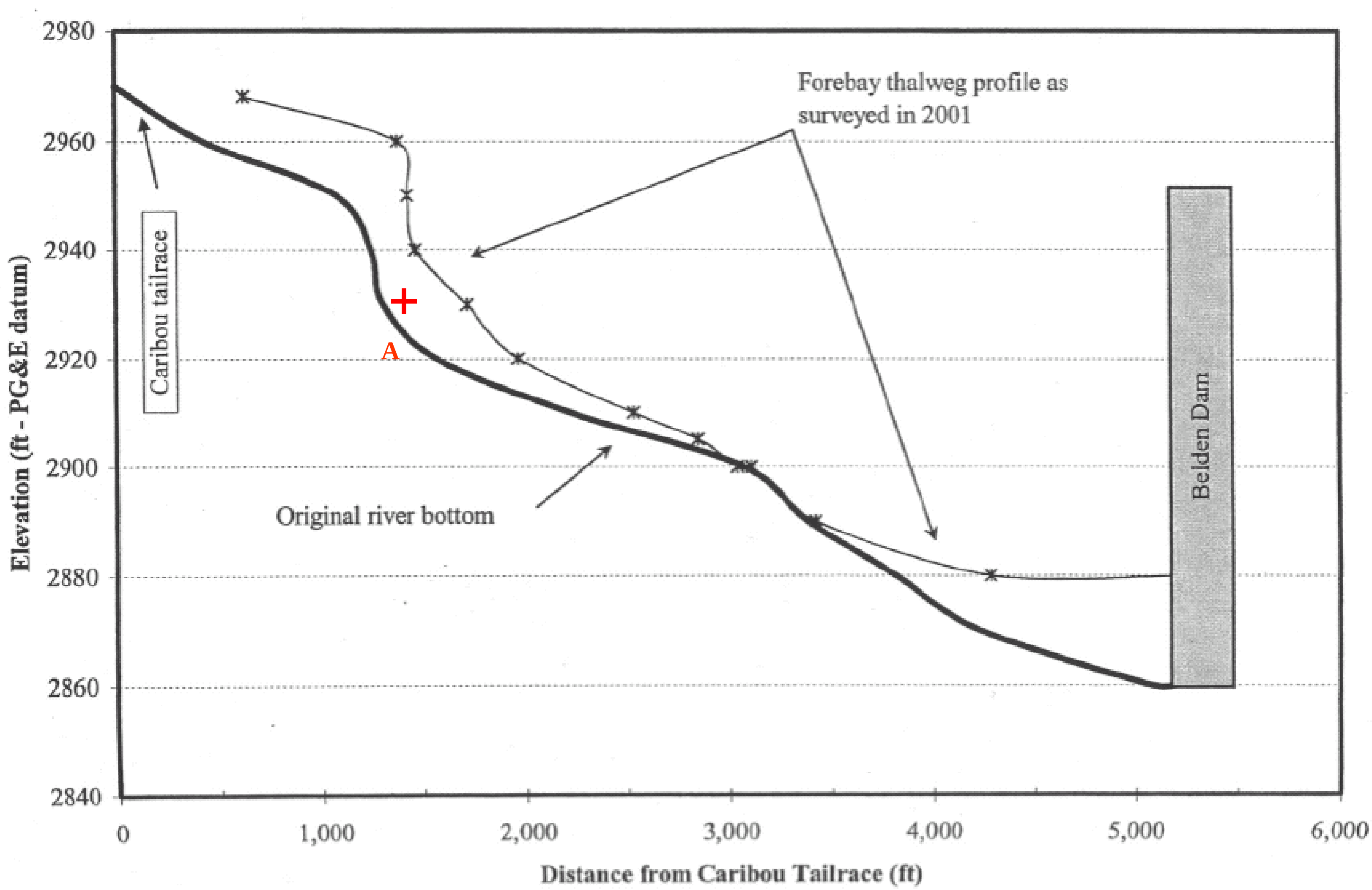


Figure 6 Possible Plunging Location (Location A) at Belden Reservoir for Cold Seneca Reach Flows

Figure 7 Water Temperature Reduction below Belden Dam for Different Flows through Mechanical Cooling Tower or Chiller and Different Degrees of Cooling
(Assumption: July Required Release in Dry Year = 130 cfs; Inflow Temperature = 19.4°C)

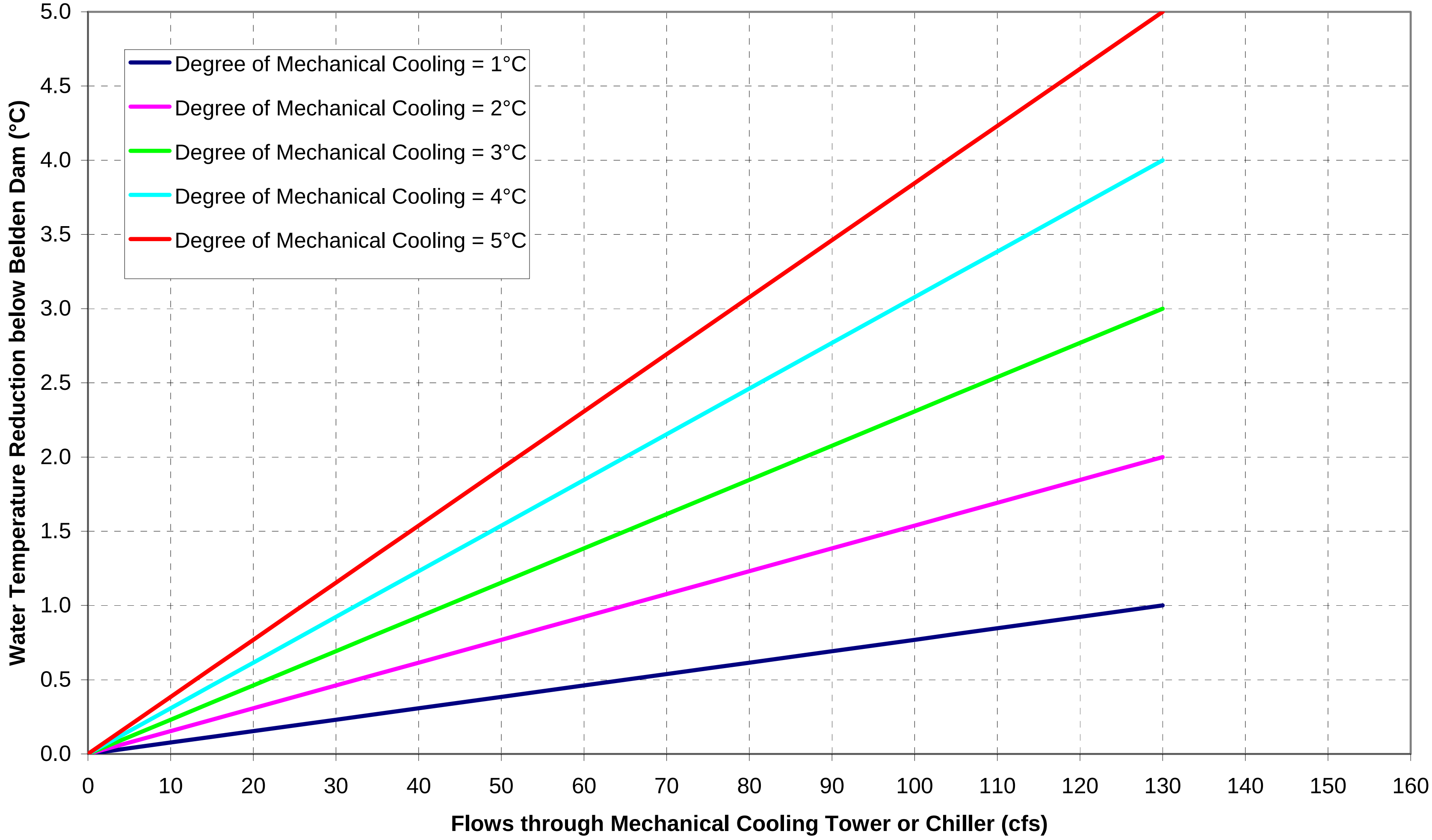


Figure 8 Simulated July 2002 Mean Daily Water Temperatures of Rock Creek Reach above Bucks Creek Confluence for a Range of Dam Releases and Release Temperatures

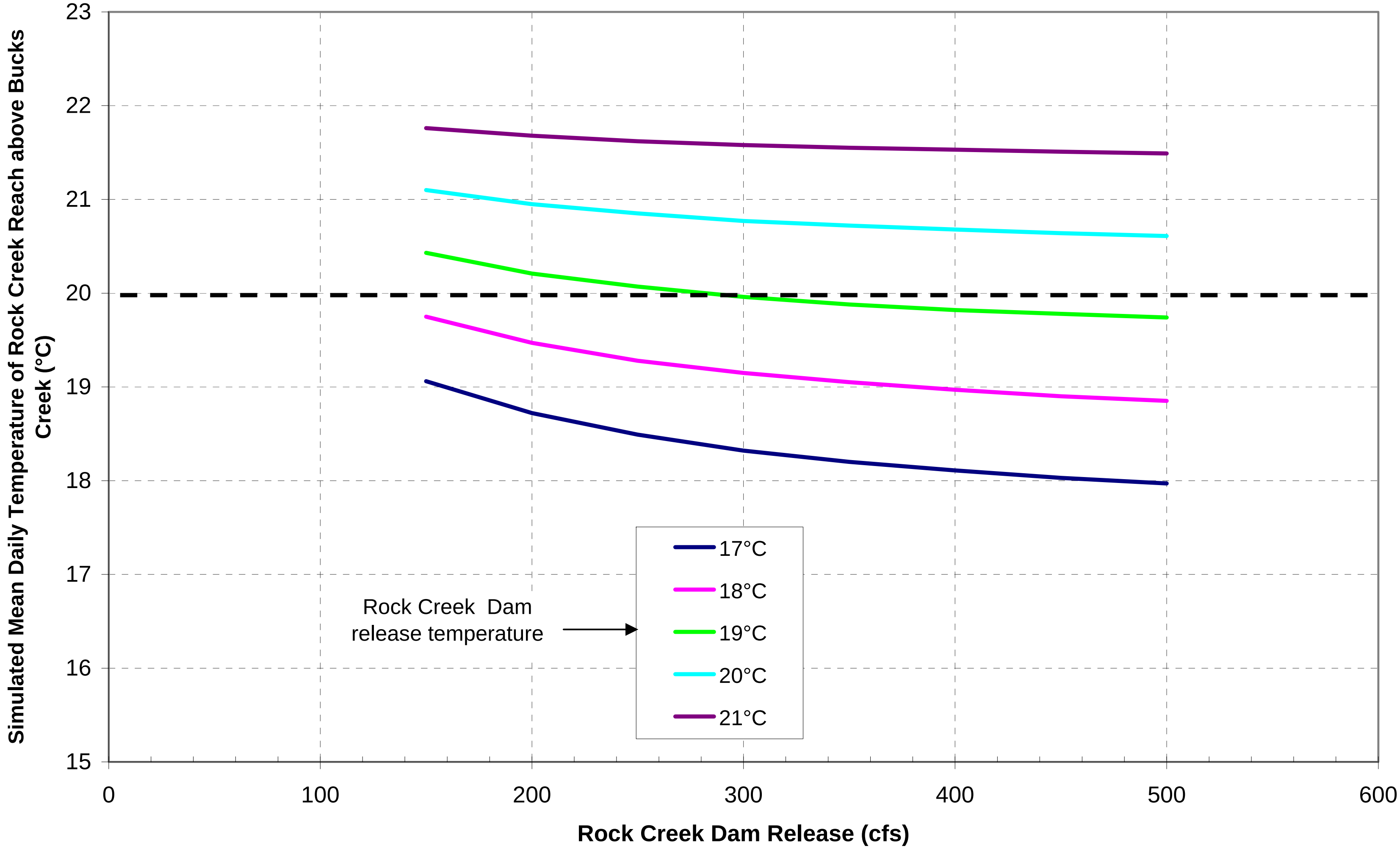


Figure 9 Water Temperature Reduction below Rock Creek Dam for Different Flows through Mechanical Cooling Tower or Chiller and Different Degrees of Cooling
(Assumption: July Required Release in Dry Year = 150 cfs; Inflow Temperature = 21.3°C)

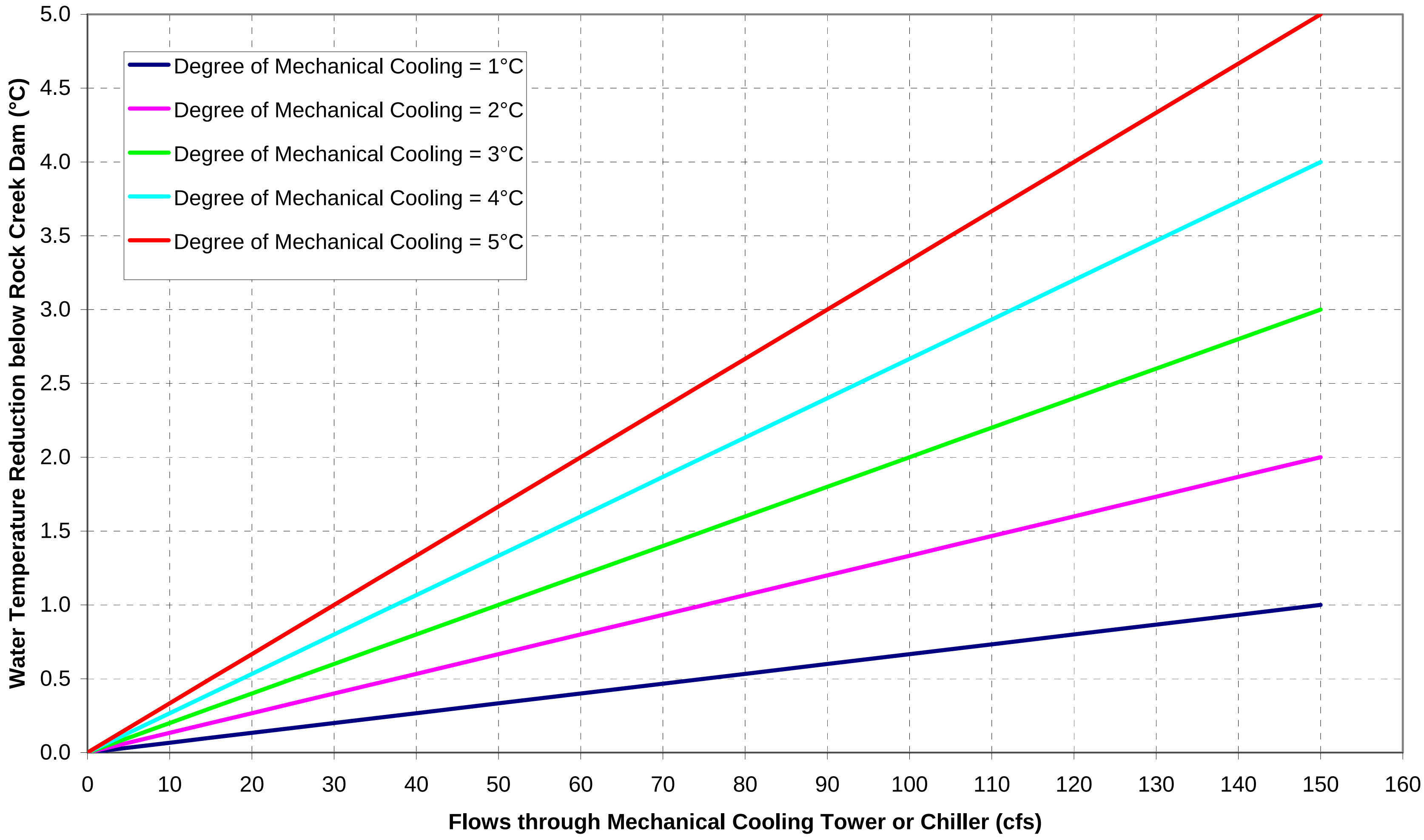
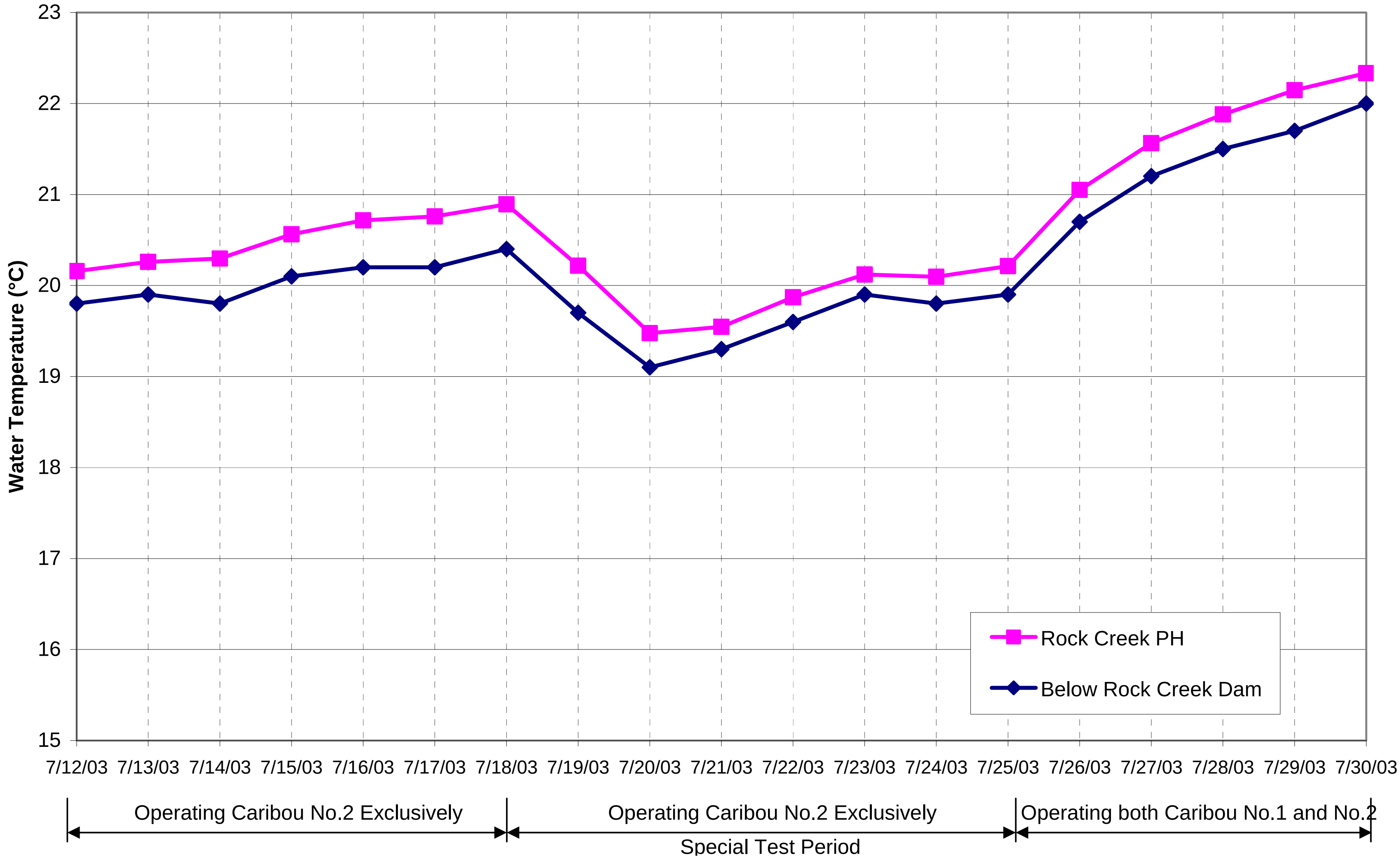


Figure 10 Observed Mean Daily Temperatures Indicating Possible Rock Creek Reservoir Stratification during July 2003 Caribou Special Test



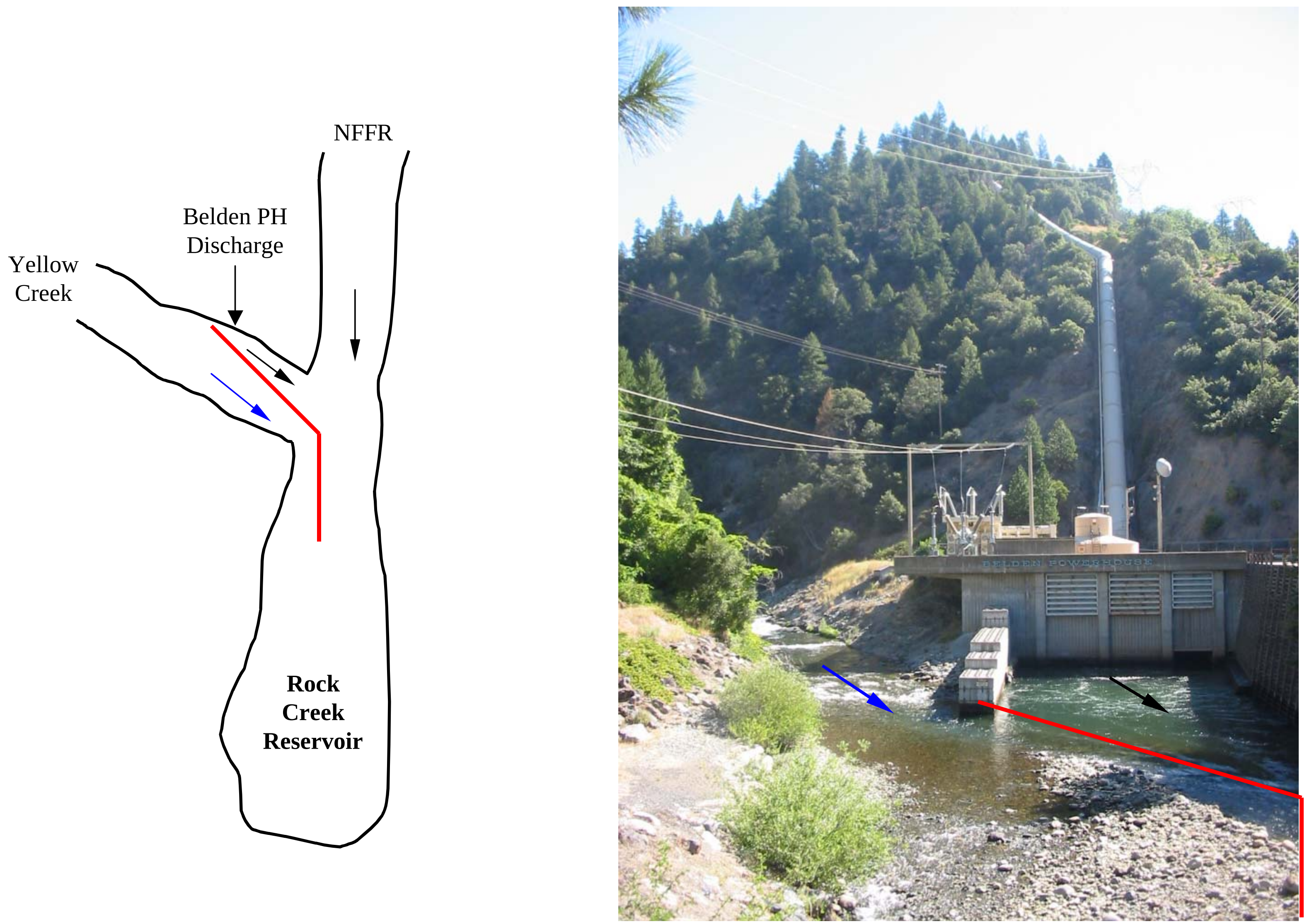


Figure 11 Schematic of Yellow Creek/Belden Powerhouse Bifurcation Berm/Wall/Partition

Figure 12 Simulated July 2002 Mean Daily Water Temperatures of Cresta Reach above Cresta PH for a Range of Dam Releases and Release Temperatures

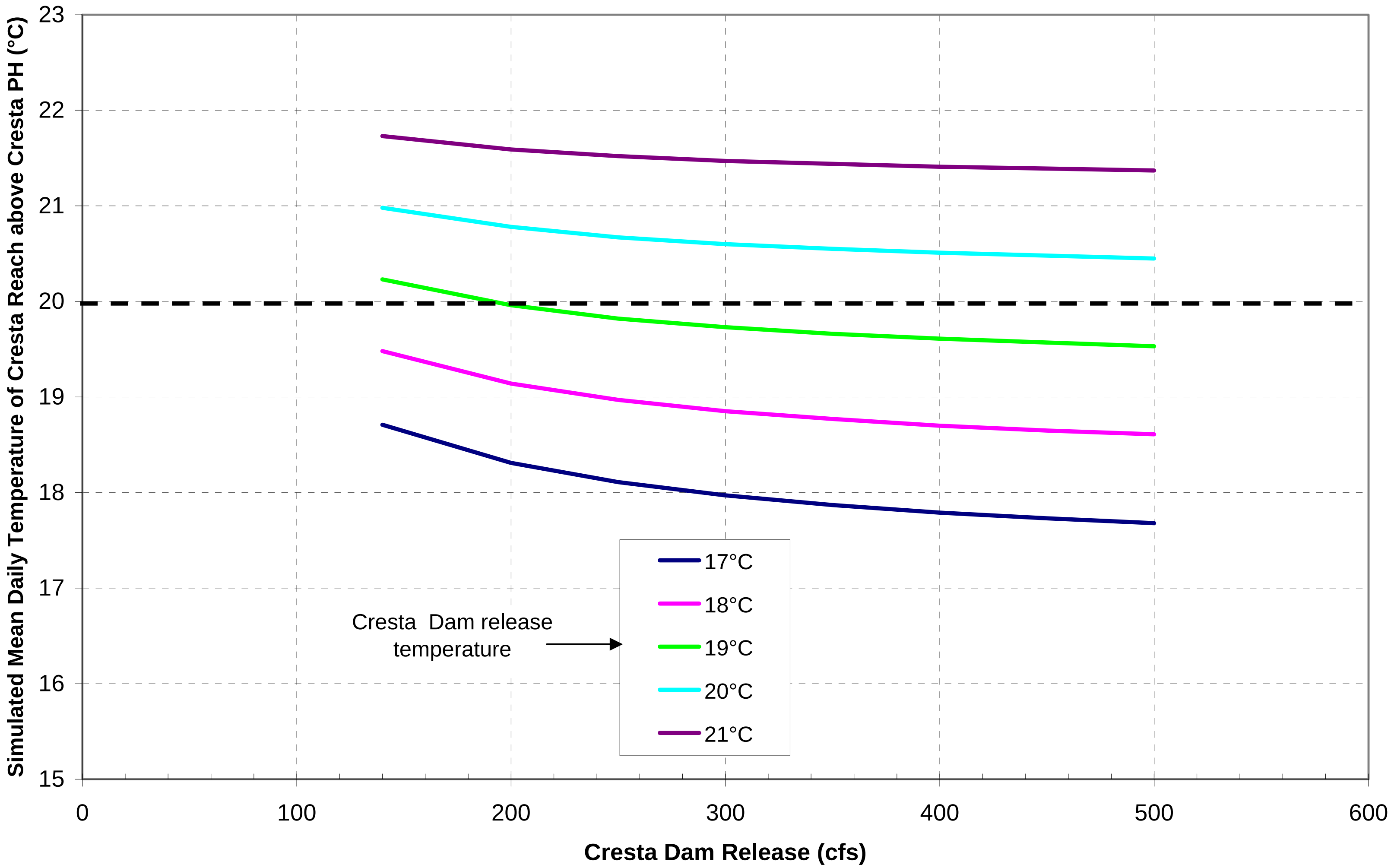


Figure 13 Observed Mean Daily Temperatures Indicating No Possible Cresta Reservoir Stratification during July 2003 Caribou Special Test

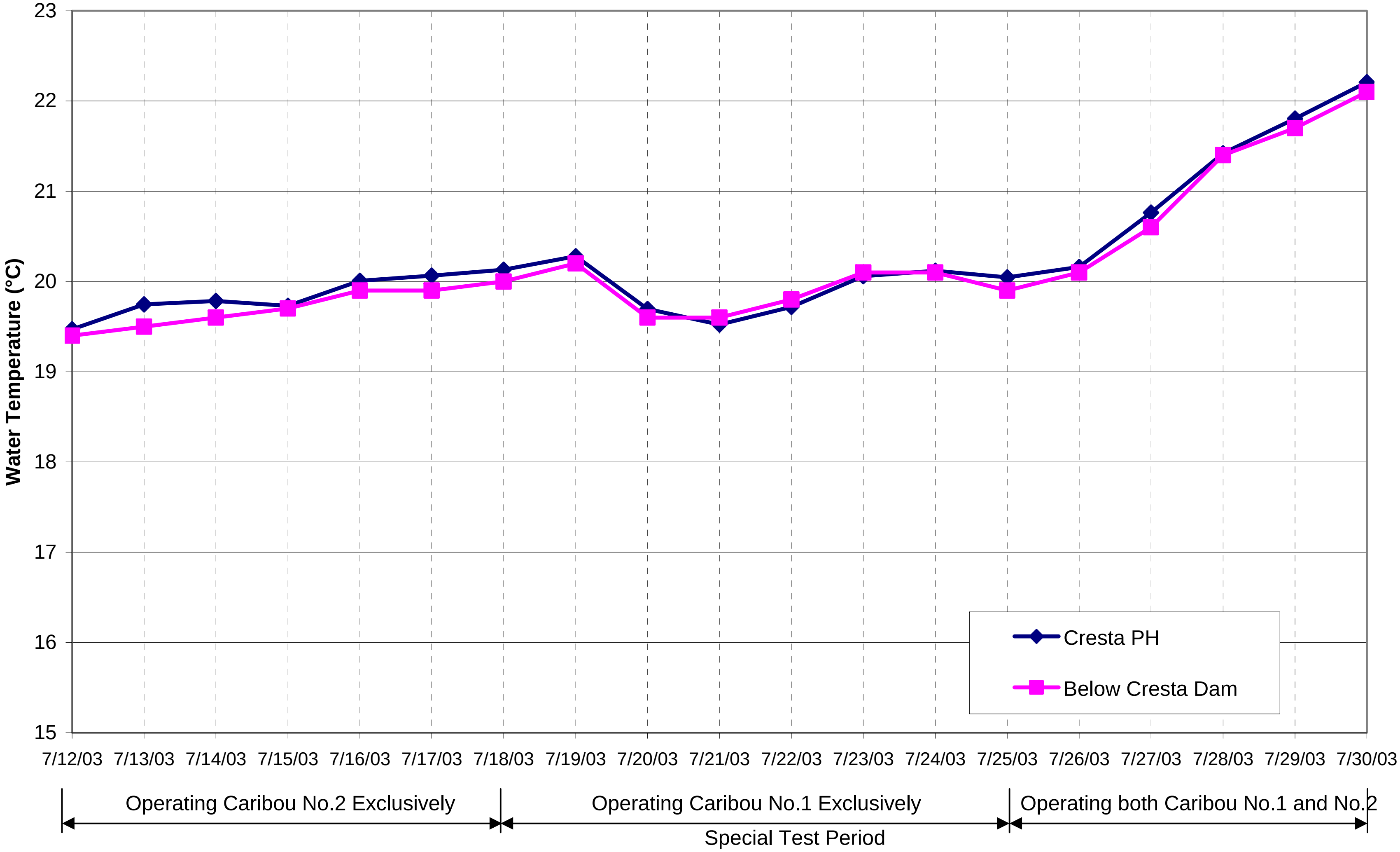


Figure 14 Simulated July 2002 Mean Daily Water Temperatures of Poe Reach above Poe PH for a Range of Dam Releases and Release Temperatures

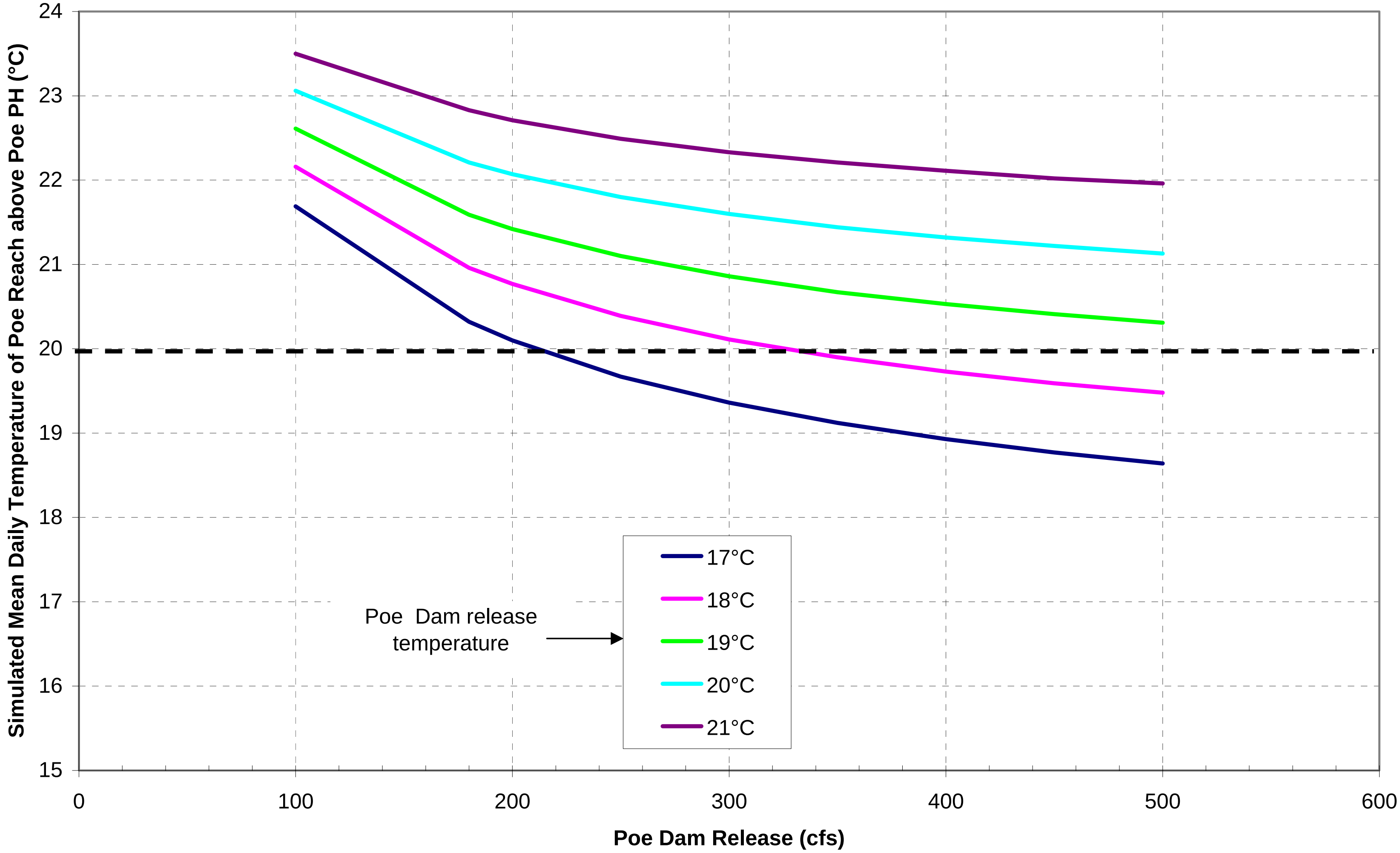


Figure 15 Water Temperature Reduction below Poe Dam for Different Flows through Mechanical Cooling Tower or Chiller and Different Degrees of Cooling
(Assumption: July Required Release in Dry Year = 200 cfs; Inflow Temperature = 21.6°C)