APPENDIX F
EVALUATION OF THE BIOLOGICAL PERFORMANCE OF POTENTIAL WATER QUALITY MEASURES TO IMPROVE COMPLIANCE WITH TEMPERATURE OBJECTIVES OF THE WATER QUALITY CONTROL PLAN FOR THE SACRAMENTO AND SAN JOAQUIN RIVER BASINS

July 2012

Upper North Fork Feather River Hydroelectric Project

Draft Environmental Impact Report

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Evaluation of the Biological Performance of Potential Water Quality Measures to Improve Compliance with Temperature Objectives of the Water Quality Control Plan for the Sacramento and San Joaquin River Basins

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Upper North Fork Feather River Hydroelectric Project (FERC Project No. 2105)

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Executive Summary

This technical memorandum describes the rationale for water temperature metrics, criteria, and the analytic approach used to evaluate potential water quality measures for Pacific Gas & Electric Company's (PG&E) Upper North Fork Feather River Hydroelectric Project (Federal Energy Regulatory Commission [FERC] Project No. 2105) (UNFFR Project). The measures would better protect the designated aquatic life uses and associated water quality objectives for the North Fork Feather River (NFFR) specified in the Water Quality Control Plan for the Sacramento and San Joaquin River Basins (Basin Plan)[1].

In 2006, a 49-mile segment of the NFFR below Lake Almanor, from Belden Dam downstream to Lake Oroville, was listed by the United States Environmental Protection Agency (EPA) under Section 303(d) of the Clean Water Act (CWA) for non-compliance with the Basin Plan's water temperature objectives, based on limitations for coldwater aquatic life caused by occurrences of high summertime water temperatures. The primary cause of this water temperature impairment in the NFFR is attributable to hydromodification through flow regulation and diversions.

Three PG&E hydroelectric projects are located on the mainstem of the NFFR: (1) UNFFR Project, (2) Rock Creek–Cresta Project (FERC Project No. 1962), and (3) Poe Project (FERC Project No. 2107). Although minimum flow levels to protect aquatic habitat in the bypass reaches below each of the hydropower diversion dams have been required and implemented as part of FERC licensing procedures for each of the PG&E hydroelectric projects, the current existing operational features and relationships among the projects have only a limited combined ability to control dam releases to manage water temperatures for the benefit of coldwater fisheries during the summer.

The Basin Plan requires analyses to assess water quality impairment, so that measures to reduce impairment can be identified, developed, and effectively implemented and so that performance of these measures can be objectively evaluated. As part of its responsibility in issuing a CWA Section 401 water quality certification for the UNFFR Project, the State Water Resources Control Board (State Water Board) staff independently reviewed, evaluated, and updated information that PG&E developed on alternative water temperature control measures for the NFFR, which is described in an accompanying engineering feasibility analysis (see Stetson Engineers 2009). The biological benefits and impacts of a range of alternative temperature control measures described herein will be included in an Environmental Impact Report for compliance with the California Environmental Quality Act that must accompany issuance of this CWA Section 401 water quality certification.

The State Water Board staff identified rainbow trout (*Oncorhynchus mykiss*) as an appropriate representative coldwater species for this analysis of water temperature requirements for the NFFR. Information on temperature requirements of rainbow trout was compiled from an extensive scientific literature review, which included recent and relevant data for locally important species of trout that are adapted to regional conditions (Eagle Lake rainbow trout and Feather River steelhead). Because temperature control measures for the UNFFR Project focus on the period of summer maximum water temperatures, this evaluation is limited to the thermal requirements of non-spawning adult and juvenile

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[1] This water quality performance analysis for the UNFFR Project was conducted in accordance with Section 401 of the CWA as implemented by the State Water Board's Water Quality Certification Program (33 U.S.C.§ 1341) and the Regional Water Board's Controllable Factors Policy.

rainbow trout, which are the predominate life stages in the NFFR during summer months. A variety of data on ecophysiological responses and several temperature metrics were used for this analysis because some debate exists within scientific and regulatory communities about the best temperature statistics and criteria for evaluating temperature regimes and defining protective standards. The influences of life stage, season, genetic traits, food availability, nutritional status, health condition, and other environmental factors, such as dissolved oxygen (DO) concentrations, on thermal requirements of trout were considered.

From the scientific literature, a normative annual temperature regime[2] for regionally adapted strains of rainbow trout was identified to seasonally range up to as high as 21ºC (69.8ºF) in the summer; however, the most optimal temperature range for feeding and growth occurs between 10–20°C (50–68°F). Within this range, most non-reproductive life functions, such as growth rate, feeding efficiency, swimming performance, and behavior, vary, but trout populations remain largely unimpaired. Commonly recommended maximum water temperature standards protective of coldwater habitat in other states range from 17.8–20°C (64–68°F), with differences depending on the species, habitat conditions, geographic-specific factors, and the temperature compliance statistic used (e.g., mean daily, daily maximum, or mean weekly values). In view of this information, two statistical thermal criteria based on the typical summer daily temperature fluctuations in the NFFR (which ranges from 1–3ºC) and thermal tolerances of trout were selected for this evaluation: (1) an average daily temperature of 20ºC (68ºF) and (2) a maximum weekly average temperature (MWAT) of 20ºC. Average daily temperatures exceeding 20ºC, up to the ultimate upper incipient lethal temperature for rainbow trout of 25ºC (77ºF), were considered to cause thermal stress, progressively worsening with increasing temperature in this range, and result in physiological impairment with a potential to impact survival of coldwater species.

Temperature Control Measures

As part of the companion engineering study (Stetson Engineers 2009), a range of feasible temperature control measures for use in various combinations during the summer months at the UNFFR Project were identified, including: (1) a thermal curtain at the Prattville intake in Lake Almanor, with and without removal of the submerged levees in the vicinity of the intake; (2) a thermal curtain in Butt Valley reservoir or preferential use of the Caribou #1 over Caribou #2 powerhouses; (3) increased Canyon Dam releases of 250 cubic feet per second (cfs); and (4) increased Canyon Dam releases of 600 cfs into the Seneca Reach of NFFR. The “feasibility” of the alternative temperature control measures that were evaluated was limited to (1) discretionary actions to affect water temperatures of the NFFR within PG&E’s control that are features or operations of the UNFFR Project and (2) actions that are subject to meeting instream flow requirements under the existing UNFFR Project FERC license for baseline conditions and under the UNFFR Project Settlement Agreement for the alternative temperature control measures. The relative improvement in thermal conditions for coldwater aquatic life in the NFFR was evaluated for six different combinations of these feasible temperature control measures using simulations of water temperatures along the NFFR under hydrological and meteorological conditions occurring during a representative 19-year historical period (1984–2002).

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[2] The term “normative temperature regime” is used here to refer to a temperature range spanning the annual thermal cycle to which a species is adapted. Exposures to seasonal temperature extremes within this normative range result in little physiological and behavioral impairment. Peak performances of most physiological functions occur within the normative range but may differ for different functions such as growth rate and reproduction, and may also vary depending on factors such as life stage, season, nutritional status, and health.

Improvement of Coldwater Riverine Conditions

A thermal curtain at the Prattville intake in Lake Almanor was common to all combinations of temperature control measures and together with a thermal curtain at the Caribou intakes or preferential use of the deeper Caribou #1 powerhouse intake (the latter performing about the same as a thermal curtain in Butt Valley reservoir) reduced mean monthly MWAT, on average, by 2.2–2.3ºC from 21.3°C in July and by 2.1ºC from 21.4°C in August at the lower end of the Belden Reach. Trout growth, disease resistance, and ecological interactions contributing to survival would be expected to significantly improve compared to the "baseline" conditions from the lower Belden Reach downstream to the middle of the Cresta Reach in most years because temperatures would remain within the normative range for trout. In dry and critical dry years, water temperatures would be warmer, but the thermal curtains would prevent daily temperature fluctuations from encroaching on lethal temperatures in the lower ends of the Rock Creek and Cresta reaches as they can now. Mean daily temperatures and MWAT in the Poe Reach would continue to regularly exceed 20ºC, even during normal and wetter water years, and encroach on lethal temperatures in dry and critical dry years, with thermal curtains installed in Lake Almanor and Butt Valley reservoir.

Canyon Dam releases of 250 cfs or 600 cfs, with concomitant reductions of the diversion through the Prattville intake, and in combination with the thermal curtains in both Lake Almanor and Butt Valley reservoir, were found to achieve further cooling of NFFR temperatures and some additional improvement of coldwater habitat conditions downstream of Belden Dam. Addition of a Canyon Dam release of 600 cfs resulted in a further 1.8–2ºC reduction in July and August at the lower end of the Belden Reach compared to use of thermal curtains alone and would prevent thermal conditions from exceeding rainbow trout normative temperatures downstream through the middle of the Poe Reach in most normal and wetter years. In dry and critical dry years, a reduction in frequency of mean daily and monthly MWAT exceeding 20ºC in longer segments of Rock Creek and Cresta reaches would be achieved; however, mean daily temperatures in the Poe Reach would still regularly exceed 20ºC, although the frequency of encroachment on lethal levels would be reduced. However, a significant drawback of a 600 cfs Canyon Dam release is that it would decrease the amount of suitable rearing habitat area for juvenile trout and further cool an already cold Seneca Reach sufficiently to result in reduced trout growth rates during the summer, which would reduce the quality of the fishery in this reach.

In contrast to the drawbacks associated with a 600 cfs release at Canyon Dam, the cooling effect of a 250 cfs release in the Seneca Reach would result in only a somewhat reduced trout growth rate and a smaller reduction in suitable juvenile trout habitat, while providing an incremental temperature reduction of about 0.5–1ºC in July and August at the lower end of the Belden Reach compared to use of thermal curtains alone. The use of a 250 cfs Canyon Dam release would generally prevent thermal conditions from exceeding rainbow trout normative temperatures throughout much of the NFFR downstream through the Cresta Reach in normal and wet years and reduce the frequency of exceeding an MWAT of 20ºC in dry and critical years compared to use of thermal curtains alone. And, although MWAT would regularly exceed 20ºC throughout the Poe Reach in most years, the addition of a 250 cfs Canyon Dam release would further reduce the frequency of daily fluctuations that encroach or exceed lethal temperatures compared to use of thermal curtains alone.

Effects on Lake Almanor and Butt Valley Reservoir

Coldwater habitat during the summer season, constrained by the availability of water with both suitable temperatures and DO concentrations, has been hypothesized as a limiting factor for trout and salmon fisheries in Lake Almanor. Therefore, the potential for hypolimnetic releases to impact the water quality and fisheries in Lake Almanor and Butt Valley reservoir was evaluated by examining the modeled effects of temperature control measures on the lakes' suitable coldwater habitat. Two attributes to characterize the availability of suitable coldwater habitat were used: (1) suitable coldwater habitat volume and (2) surface area of the thermocline, a thermal feature at depth around which coldwater fish tend to congregate in the summer. Coldwater refugia were defined to have both temperatures ≤ 20ºC and DO ≥ 5mg/L. A strong thermocline is not typical in Butt Valley reservoir so we only evaluated the effects on coldwater habitat volume and the effect of the Prattville intake thermal curtain on DO concentration at the Butt Valley powerhouse discharge.

Use of a thermal curtain at the Prattville intake, by itself, or in combination with increased Canyon Dam releases, has the effect of increasing the withdrawal of cold water from the hypolimnion. The consequence of this process is that the cold hypolimnetic volume of the lake decreases (however, much of this volume is not habitable by fish during the summer because of very low DO concentrations) and depth profiles of temperature and DO can change relative to current discharge operations of the reservoir. Because the same amount of water is discharged from Lake Almanor, regardless of release location, differences in the effects of alternative combinations of temperature control measures are minor, including whether or not the submerged levees are removed.

A thermal curtain operated in Lake Almanor, with or without increased Canyon Dam releases, would reduce coldwater habitat volume by about 21% in August during normal water years; however, this would be accompanied by only a 3% reduction in the thermocline-to-lake wide surface area ratio, which is not likely to adversely affect the fishery. In critical dry years, available coldwater habitat ≤ 20ºC nearly disappears even under existing operations. In this case, the remaining available lake habitat with temperatures ≤ 21ºC would be reduced by 37% compared to the baseline. This impact could be potentially significant and several practicable mitigation measures are feasible, such as increased fish stocking following such years and using trout strains with higher thermal tolerances.

Another potential effect of operation of thermal curtains during the summer in Lake Almanor is an interruption of the entrainment of the forage fish, wakasagi, at the Prattville intake to Butt Valley reservoir. This transfer of forage fish between the reservoirs has been associated with producing a trophy trout fishery at Butt Valley reservoir. However, because of the widespread distribution and abundance of this forage fish throughout the NFFR, including in Butt Valley reservoir, the potential that operation of a thermal curtain in Lake Almanor would eliminate this forage fish from Butt Valley reservoir is not likely. This impact is considered to be less than significant.

Operation of a thermal curtain at the Prattville intake would result in a Butt Valley powerhouse discharge with colder water temperatures and lower DO concentrations during the months of July and August. DO levels would be as low as 2–3mg/L. This could have a localize effect on limiting fish distributions in Butt Valley powerhouse tailrace. This impact could be potentially significant and several aeration and reoxygenation technologies are available to mitigate this effect (e.g., passive venturi tube reaeration, Speece cone reoxygenation).

The changes in temperature and DO levels at the Butt Valley powerhouse discharge, with a Prattville intake thermal curtain in operation, would generally increase available coldwater habitat in Butt Valley reservoir in July and August in most water years.

In-water construction for installation of thermal curtains at the Prattville and Caribou intakes in Lake Almanor and Butt Valley reservoir and for installation of the bulkhead-mounted slide gates on the Canyon Dam outlet tower could result in temporary and localized impacts on water quality but would not have significant long-term impacts to fish habitat in the vicinity of these sites. These impacts would be reduced to less than significant with implementation of construction site stormwater BMPs, hazardous materials management and containment BMPs, and appropriate fish screens/filters fitted to pumps and siphons used for construction water or to provide in-stream flows downstream of the Canyon Dam outlet during construction.

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1. Introduction and Background

This technical memorandum describes the biological rationale for water temperature metrics, criteria, and analyses used to evaluate potential water quality measures for Pacific Gas & Electric Company's (PG&E) Upper North Fork Feather River Hydroelectric Project (Federal Energy Regulatory Commission [FERC] Project No. 2105) (UNFFR Project) to better protect the designated aquatic life uses and associated water quality objectives for the North Fork Feather River (NFFR) specified in the Water Quality Control Plan for the Sacramento and San Joaquin River Basins (Basin Plan) (Central Valley RWQCB 2009). This water quality performance analysis for the UNFFR Project was conducted in accordance with Section 401 of the Clean Water Act (CWA) as implemented by the California State Water Resources Control Board's (State Water Board) Water Quality Certification Program (33 U.S.C.§ 1341) and the Central Valley Regional Water Quality Control Board's (Regional Water Board) Controllable Factors Policy, as adopted in the 1975 Basin Plan.

The Basin Plan lists the beneficial uses for the NFFR as shown in Table 1.

The Regional Water Board's Policy for Application of Water Quality Objectives (Central Valley Regional Water Quality Control Board 2009) requires that water quality objectives be implemented in a manner that fully protects the designated beneficial uses of a water body (California Water Code Section 13000). The Basin Plan currently designates three aquatic life uses of the NFFR: 1) cold freshwater habitat; 2) spawning, reproduction, and early development for coldwater fisheries; and 3) water-dependent wildlife habitat. For water quality management purposes, these aquatic life uses represent important and valued resources supported by the NFFR, the characteristics and qualities of which are sensitive to water quality degradation and must be protected under state law. Coldwater fisheries habitats, particularly for salmonids, represent the beneficial uses most sensitive to water temperature. The Basin Plan's water temperature objectives for the NFFR include the following narrative provisions:

1. "At no time or place shall the temperature of intrastate waters be increased more than 5ºF [2.8ºC] above natural receiving water temperature;" and,

2. "The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such alteration does not adversely affect beneficial uses."[3]

In 2006, a 49-mile segment of the NFFR below Lake Almanor, primarily from Belden Dam downstream to Lake Oroville, was listed by the United States Environmental Protection Agency (EPA) under CWA Section 303(d) for non-compliance with the Basin Plan's water quality objectives, based on limitations caused by occurrences of high summertime water temperatures and elevated mercury concentrations.

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[3] Protection and attainment of beneficial uses designated in the Basin Plan requires the State Water Board and Regional Water Boards in issuing CWA Section 401 water quality certifications to apply the water quality objectives to reasonably controllable water quality factors. "Controllable water quality factors" are those actions, conditions, or circumstances resulting from human activities that may influence the quality of the waters of the State that are subject to the authority of the State Water Board and Regional Water Boards and may be reasonably controlled.

Elevated mercury concentrations in the NFFR are attributable to historic residual mining wastes, not the UNFFR Project (State Water Board 2006). The primary causes of water temperature impairment in the NFFR are attributable to hydromodification and flow regulation/modification as specified in the 2006 Staff Revisions to the CWA Section 303(d) List of Water Quality Limited Segments (State Water Board 2006). A long history of hydroelectric development on the NFFR has greatly altered the river's physical character and flow regime. Three hydroelectric projects on the mainstem of the NFFR, consisting of five diversion dams, include PG&E's UNFFR Project, Rock Creek–Cresta Project (FERC Project No. 1962), and Poe Project (FERC Project No. 2107). Associated features of these projects, as well as several additional hydroelectric projects, occur on tributaries to the NFFR. As a result, much of the flow of the river from Lake Almanor to Lake Oroville is diverted through tunnels and penstocks. Although minimum flow levels to protect aquatic habitat in bypass reaches below each of the hydro-diversion dams have been required and implemented as part of FERC licensing procedures for each of the PG&E hydroelectric projects, the current existing operational features and relationships among the projects have a limited combined ability to control dam releases to manage water temperatures for the benefit of coldwater fisheries during the summer (PG&E 1979, 2000, 2005; Woodward-Clyde Consultants 1987; CDFG 1988; FERC 2005).

The physical habitat alterations of the NFFR caused by construction and operation of the hydropower diversion dams, inundation of the river channel behind the dams, and alteration of streamflows, including effects on the river's water temperature regime, have long been identified as important factors limiting the NFFR coldwater fishery (Wales and Hansen 1952; PG&E 1979; Wixom 1989; Moyle et al. 1983). The State Water Board and the EPA examined multiple lines of available evidence, including water temperature records and data on the historic and current conditions of cold freshwater habitat and fishery resources, when listing the NFFR as a water quality limited segment for water temperature in 2006 (State Water Board 2006, 2010). Changes in the relative diversity, abundance, and distribution of native coldwater species within the NFFR are attributable, in part, to a combination of hydroelectric project-related factors and other watershed factors, including habitat alteration, changes in flow and temperature regimes, sedimentation, hydromodification, and introduction of non-native species. The adverse impacts of water temperature impairment to the cold freshwater fishery were noted to become progressively more significant downstream of the UNFFR Project through the Rock Creek–Cresta and Poe hydroelectric project reaches, where summer maximum water temperatures are highest (State Water Board 2006).

Available temperature data for the UNFFR Project reach and downstream reaches of the NFFR show that high water temperatures in excess of 20ºC (68ºF) occur frequently during the period of summer maximum temperatures in July and August (PG&E 2000, 2005; Figures 2-58 to 2-69 in Stetson Engineers 2009)[4]. Commonly recommended water temperature standards protective of coldwater habitat in other states range from maximum temperatures of 17.8ºC (64ºF) to 20ºC (68ºF) (EPA 2003; Todd et al. 2008; McCullough 2010), with the differences depending on species, habitat conditions, geographic-specific factors, and the temperature compliance statistic used (e.g., temperature statistics based on mean daily, daily maximum, or mean weekly values).

As part of the Rock Creek–Cresta Project, FERC Project No. 1962, Settlement Agreement, the parties to the agreement adopted a plan to develop operational measures that would seek to maintain mean daily

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[4] Thermographs for 2002-2004 exhibit periods of summer maximum temperatures ranging from 20–90 days from late-June through early-September within the UNFFR Project, Rock Creek–Cresta Project, and Poe Project bypass reaches. Day-to-day mean temperatures vary over a fairly narrow range of 2–3ºC during this period (Stetson Engineers 2009).

temperatures of 20ºC (68ºF) or less to better protect cold freshwater habitat uses (PG&E 2005). PG&E sponsored considerable monitoring and research into water temperature management for the NFFR since the 1980s, which determined that the summer temperature regime of the Rock Creek–Cresta Project reaches is primarily controlled by the water temperatures of Lake Almanor and Butt Valley reservoir at the levels of their respective diversion intakes and the non-controllable warm water temperature of the East Branch of the NFFR (PG&E 2000, 2005). In view of this finding and requirements of the Upper North Fork Feather River Project, FERC Project No. 2105, Relicensing Settlement Agreement, dated April 22, 2004 (UNFFR Project Settlement Agreement) concerning the unresolved water temperature issues, PG&E conducted several feasibility studies to determine the level of temperature control achievable with the UNFFR Project features that can be used to better attain protection of cold freshwater habitat uses of the NFFR (PG&E 2005). The results of these PG&E-sponsored water temperature investigations have been considered as part of the State Water Board's independent evaluation of water temperature control measures that may be necessary to bring the UNFFR Project, Rock Creek–Cresta Project, and Poe Project into compliance with the Basin Plan's water temperature objectives for cold freshwater habitat use.

2. Purpose of This Report

The purpose of the analysis presented in this report is to evaluate the potential water temperature control measures addressed in the Stetson Engineers (2009) engineering feasibility report relative to biological temperature criteria to determine the potential levels of protectiveness achievable for cold freshwater habitat uses of the NFFR. The biological water quality benefits and impacts of the alternative temperature control measures identified in this report were used to inform the Environmental Impact Report (EIR) that the State Water Board intends to use for compliance with the California Environmental Quality Act (CEQA) that must accompany issuance of the CWA Section 401 water quality certification.

The Basin Plan requires development and selection of assessment thresholds and analytic tools consistent with water quality objectives to evaluate water quality impairment, so that measures to reduce impairment can be identified and implemented effectively and their performance can be objectively evaluated (State Water Board 2011). As part of its responsibility in issuing a CWA Section 401 water quality certification for the UNFFR Project, the State Water Board independently reviewed, evaluated, and augmented the additional information that PG&E developed on alternative water temperature control measures for the Rock Creek–Cresta Project, which is described in Stetson Engineers' (2009) engineering feasibility analysis of temperature control alternatives to meet water quality objectives and protect cold freshwater habitat along the NFFR.

3. Selected Water Temperature Performance Metrics

Evaluations of water temperature regimes for ecological and water quality management purposes generally use temperature statistics calculated over an averaging period, frequency analysis of the duration of occurrence of various temperature levels, and identification of extreme (maximum and minimum) temperatures (EPA 1977; Armour 1991; Coutant 1999; Sullivan et al. 2000; McCullough 2010). For the purposes of this analysis, three statistical metrics were selected for their value in distinguishing the relative performances of water temperature control measures for better attaining and protecting the cold freshwater habitat use of the NFFR. The temperature statistics selected for this analysis are based on: (1) applicability to UNFFR Project operations and the temperature modeling approach adopted by the State Water Board for evaluation of the UNFFR Project, and for assessing cumulative water temperature effects on the NFFR; (2) commonly used temperature statistics/metrics for coldwater fish protection; and (3) availability of relevant water temperature criteria for coldwater fish species inhabiting the NFFR for use with the selected statistics. The three selected temperature statistics used for our analysis are as follows:

3. *Daily average temperature* – Mean daily water temperature is defined as the average water temperature over the course of a 24-hour day. The daily average temperature is the limit of resolution of the SNTEMP temperature model used to estimate river temperatures (Stetson Engineers 2009). This statistic allows evaluation of relatively short-term extreme thermal exposures and is consistent with the Rock Creek–Cresta Project Relicensing Settlement Agreement's adoption of a <u>mean daily water temperature criterion</u> of 20ºC to protect cold freshwater habitat (FERC 2005).

4. *Maximum weekly average water temperature (MWAT)* – MWAT is defined as the maximum value of seven-day running averages of daily average water temperatures. The MWAT can be computed on annual and monthly bases. Stetson Engineers (2009) provided MWAT on a monthly basis for the period of summer maximum temperatures for each combination of temperature control measures analyzed. MWAT provides one measure of <u>chronic, or cumulative, temperature exposure</u>, when keyed to thermal requirements (temperature limits) for specific life stages of representative species (EPA 1977; Coutant 1999). It has been EPA's primary recommended statistical metric for developing water temperature guidelines, objectives, and standards (EPA 1977), and has been adopted by a number of states for setting temperature standards consistent with CWA Section 304(a). Despite its history of recommendation by the EPA, application of the MWAT for setting temperature standards has been criticized in recent years for not necessarily being fully protective of the most sensitive uses, such as endangered and threatened species (Coutant 1999; McCullough 1999; EPA 2003). Our use of the MWAT statistic for this analysis does not convey or imply imposition of a particular water temperature standard for the NFFR; its use is strictly as an index to compare modeled water temperature conditions provided by alternative temperature control measures to the relevant data on thermal requirements of representative coldwater species.

5. *Diel water temperature variation* – Diel water temperature variation is the total range of temperature fluctuation occurring over a daily cycle. It is expressed as an average or maximum of diel ranges around the daily mean temperature and provides an index of daily <u>acute temperature exposure</u>. The

diel water temperature statistic provides a means of estimating maximum daily water temperatures when using modeled mean daily temperatures.

4. Thermal Requirements for Cold Freshwater Fish and Their Aquatic Habitat

Habitat for coldwater stream fish consists of the physical, chemical, and biological constituents of the stream and adjacent riparian areas that provide for feeding, sheltering, behavioral interactions, reproduction, rearing, and in-river migrations (Bjornn and Reiser 1991; Griffith 1999; McCullough 1999; Moyle 2002). Water quality affects the physical and chemical aspects of aquatic habitat for fish and aquatic invertebrates. Of the many constituents of water quality, water temperature is one of the most important factors determining the geographic distributions, productivity, and survival of fish and aquatic invertebrates (Gerking 1980; Cech et al. 1990; Vannote and Sweeny 1980; Ward and Sanford 1982; and Hawkins et al. 1997).

Water temperature is considered a key environmental factor affecting fish growth, disease-processes, reproduction, and survival. The freshwater life histories of fish are closely tied to the water temperature regime of the water body that they inhabit. For coldwater fish, especially trout and salmon, the timing of reproductive cycles is closely correlated with seasonal water temperature patterns. Thermal tolerances and physiological optimum ranges for growth and survival vary over a species' life cycle and are also partially dependent on an individual's cumulative thermal exposure history and nutrition and health status, but generally are bounded by ultimate lethal maxima and minima (Figure 1) (Brett 1952; Armour 1991; Myrick and Cech 2000a). To help understand these temperature requirements, several concepts and terms associated with the thermal physiology of fishes are diagrammed in Figure 1 and are further defined as follows:

> ***Physiological optimum temperature (PO)***: Temperature range that maximizes the performance of a particular physiological parameter such as growth, swimming stamina, or reproductive output; each physiological function may have different optimal temperatures. Optimal temperatures for growth are strongly influenced by food availability, or ration level, with declining optimal temperatures as ration levels drop below satiation (Brett 1952, 1956; Armour 1991; McCullough 1999).
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> ***Preferred temperature***: A temperature, or temperature range, that individual fish, regardless of prior history of temperature exposures (or acclimation temperatures), will tend to congregate around, when allowed to freely select in a thermal gradient. The preferred temperature usually falls within the physiological optimal range, often similar to the growth optimum (Brett 1956; Armour 1991; Coutant 1999). Both initial and final temperature preferenda values can be found in the literature. Use of preferred temperatures of fish for water quality criteria must be viewed cautiously because a variety of different test procedures have been historically used to derive them. Physiological responses to thermal conditions are considered more reliable and, when

available, should be used to corroborate preferred temperature data for use as water quality criteria (Armour 1991; Sullivan et al. 2000).

Tolerance zone: Temperature range between the incipient lethal level (high-end temperature) and the feeding limit (low-end temperature) (Elliott 1981, as cited by McCullough 1999).

Supra- and sub-optimal temperatures: These are temperatures, within the tolerance zone, above (supra) and below (sub) the physiological optimum temperature range that results in reduced physiological performance, but that are not directly lethal. Growth, swimming stamina, reproductive output, disease-resistance, and other important functions may each exhibit this pattern of declining performance outside their respective optimal temperature ranges, but may have differing supra- and sub-optimal ranges. Chronic exposure to supra- or sub-optimal water temperatures can reduce population viability through increased incidence of disease, increased vulnerability to predation, reduced reproductive capacity, and deleterious outcomes of interspecific competition (Marine 1992; DeStaso and Rahel 1994; Coutant 1999; Dickerson and Vinyard 1999; McCullough 1999; Moyle 2002; Marine and Cech 2004).

Acclimation temperature: Temperature, within the tolerance zone, that test fish are experimentally exposed to for a period of time from several days to months before a thermal tolerance test (Armour 1991).

Upper incipient lethal temperature (UILT): The upper temperature at which typically 50% of a test population can tolerate and survive during a standard 7-day exposure period, given a previous constant acclimation temperature. The UILT increases with acclimation temperature up to a point such that higher acclimation temperatures have no further effect (Brett 1956).

Ultimate upper incipient lethal temperature (UUILT): The highest temperature at which thermal tolerance (as measured using UILT tests) does not increase with increasing acclimation temperature (Brett 1956).

In view of the variability in physiological responses of fish to water temperature, the CWA Section 304(a) guidance on identification of fully protective water quality criteria (40 CFR § 131.11) for aquatic life implies that not only must the water temperature criteria protect the most sensitive aquatic life use from short-term, acute exposure to lethal temperatures (i.e., lethal maxima and/or minima), but also must protect against deleterious effects of chronic exposure to stressful, but sublethal temperatures outside the optimal range and maintain thermal regimes that promote overall health and productivity of populations, including suitable conditions for all life stages and requirements for growth and reproduction.

Some debate exists within the scientific and regulatory communities about the best temperature statistics and criteria to use for evaluating temperature regimes and defining thermal requirements and protective standards for aquatic life uses under the CWA (Armour 1991; Coutant 1999; Sullivan et al. 2000; McCullough et al. 2010). The challenge in evaluating temperature effects on aquatic organisms is that lethal and optimal temperature ranges vary by species, life stage, genetic characteristics, nutritional and health status, ecological conditions, and the timing and duration of temperature exposure (Brett 1952;

Myrick 1998; McCullough 1999; Cech and Myrick 1999; Railsback and Rose 1999; Myrick and Cech 2000a; Sullivan et al. 2000). Generally, biologically relevant temperature ranges or thresholds related directly to the most sensitive aquatic life use during specific seasons and in specific stream segments of concern are identified for evaluation and regulatory compliance purposes (Coutant 1999). Coldwater salmonids are considered a sensitive aquatic species with regard to water temperatures and are a general indicator species of good water quality and aquatic habitat condition. Based on information found in Wixom (1989), State Water Board identified the juvenile and non-spawning adult life stages of rainbow trout (*Oncorhynchus mykiss*) as an appropriate representative coldwater species for this analysis of water temperature requirements during the period of summer maximum temperatures for the NFFR.

We compiled information on the temperature requirements of rainbow trout from a considerable examination of the scientific literature, including comprehensive reviews by Coutant (1977); EPA (1977); Bell (1986); Bjornn and Reiser (1991); McCullough (1999); Sullivan et al. (2000); and McCullough et al. (2001); and relevant regional studies by Cech et al. (1990); Myrick (1998); and Myrick and Cech (2000a,b,c). These temperature requirements are summarized in Table 2.

5. Discussion of the Rationale for Normative, Optimal, Supra-optimal, and Lethal Water Temperature Ranges Identified to Evaluate Performance of Water Quality Measures

Because we are primarily interested in temperature control measures during the period of summer maximum water temperatures in the NFFR, the focus is on the critical upper temperature tolerances and requirements of non-spawning adult and juvenile rainbow trout for this evaluation, since spawning and egg incubation take place earlier in the year before temperatures increase (Figure 2). A normative temperature range for adult and juvenile rainbow trout can be approximated to occur from 10–21ºC (50.0–69.8ºF), where, most life activities may occur with little impairment and, because fish are cold-blooded, overall behavioral and physiological performance generally increases or becomes more efficient with rising temperature (Table 2). Peak performance of most physiological functions occur within the normative temperature range, but the optimal temperatures for each function can differ and vary within this normative range, depending on life stage, season, genetic traits, food availability, nutritional status, and health condition of fish (Myrick 1998; Coutant 1999; McCullough 1999). For example, the optimal temperature promoting maximum growth rates of a variety of salmonids has been demonstrated to shift to cooler temperatures under reduced food rations (Wurtsbaugh and Davis 1977; Brett et al. 1982; McCullough 1999)[5]. Furthermore, stream temperature and ecological interactions can act in combination to affect the microhabitat selection by fish and, depending on the microhabitats selected, the ultimate thermal conditions experienced by stream fish (Baltz et al. 1987).

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[5] It should be noted that Brett et al. (1982) reported that the food conversion efficiency-growth rate relationships of wild juvenile Chinook salmon appeared most similar to juvenile Chinook salmon in a laboratory fed a ration of 60% of maximum for a given water temperature. Similarly, Wurtsbaugh and Davis (1977) reported that estimated consumption rates for wild caught *O. mykiss* were less than maximal (compared to laboratory measurements) over the range of temperatures and seasons sampled.

The lower end of the normative temperature range that we identified for rainbow trout is informed by data reported for aquacultural growth and disease studies (Leitritz and Lewis 1976; Piper et al. 1982), field observations of "normal" growth (Bell 1990; Bjornn and Reiser 1991), metabolic and swimming efficiency studies (Dickson and Kramer 1971; Myrick and Cech 2000a), and preferred temperature ranges (Cherry et al. 1977; Coutant 1977; Raleigh et al. 1984; Sullivan et al. 2000; McCullough et al. 2001). The upper end of the normative temperature range is identified because of the co-occurrence and convergence of several physiological performance thresholds where growth rates, swimming speeds, and metabolic efficiencies tend to begin to decline from maximum levels. These physiological performance thresholds generally occur over a temperature range from 18–21ºC for rainbow trout (Hokanson et al. 1977; Wurtsbaugh and Davis 1977; Bell 1990; McCullough 1999; Myrick and Cech 2000a; Sullivan et al. 2000; McCullough et al. 2001).

Identification of the upper end of the normative temperature range for rainbow trout is further corroborated by a field study of a Sierra Nevada stream by Matthews et al. (1994), who observed that rainbow trout spent a larger proportion of time at 19ºC (the warmest available) than at cooler temperatures (available down to 14.5ºC) in a stratified pool. Relevant to the Feather River watershed, Myrick and Cech (2000c) found that two Central Valley strains of steelhead, *O. mykiss irideus* (namely, "Nimbus" and "Feather River" strains), preferred temperatures ranging from 17–20ºC when presented with a thermal gradient from 10–30ºC. Importantly, this thermal preference range was independent of ration level and rearing acclimation temperatures (11, 15, or 19ºC for the "Nimbus" strain trials) and was higher than reported for other steelhead strains, typically 10–13ºC (Bell 1990; McCullough 1999). In view of these differences, Myrick and Cech posited that trout and steelhead from California, especially the Central Valley watersheds, may prefer and be able to adapt to somewhat higher temperatures than steelhead from more northerly latitudes. In another regionally relevant study, Myrick and Cech (2000a) reported that for California strains of rainbow trout (specifically, "Mt. Shasta" and "Eagle Lake" strains) mean relative growth rates tended to increase with temperature from 10–19ºC and decreased from a peak at 19ºC to near zero at 25ºC. Similarly, gross conversion efficiencies, the rate at which consumed food is converted to tissue mass, showed no clear relationship with temperature between 10 and 22ºC, but gross conversion efficiency significantly decreased between 22 and 25ºC. Similarly, standard metabolic rates and critical swimming velocities did not differ for either strain at temperatures ranging from 10–19ºC; however, metabolic rates began to show variation between strains at 22ºC and higher, indicating a thermal threshold somewhere between 19 and 22ºC. The collective patterns in these physiological performance metrics suggest that an upper threshold above which overall physiological performance begins to significantly fall off likely occurs at about 20ºC for these California rainbow trout/steelhead strains.

At high water temperatures above the normative range, the evidence summarized in Table 2 indicates that California rainbow trout strains can tolerate temperatures from 21ºC to the UUILT of 25ºC; however, behavioral and physiological performance significantly declines in this range, which can lead to sublethal impairment, reducing disease resistance, increasing predation vulnerability, detrimentally altering behavior and ecological interactions, and increasing mortality (Hokanson et al. 1977; McCullough 1999; Winton 2001; Baltz et al. 1987; Cech et al. 1990; Myrick and Cech 2000a). While it may be possible for rainbow trout populations to endure some periodic exposure to seasonally maximum temperatures up to 24ºC and persist with little appreciable loss in population size (Eaton et al. 1995), there is considerable uncertainty and risk concerning the impact of the cumulative effects of chronic sub-lethal exposure to high water temperatures on trout population productivity (Hokanson et al. 1977; Coutant 1999; Sullivan et al. 2000; McCullough et al. 2001; McCullough 2010). Therefore, effective temperature control measures for the UNFFR Project should prevent temperature excursions to 25ºC and above, and eliminate or reduce the frequency of occurrence of temperatures within the supra-optimal range of 21–24ºC during the period of summer maximum temperatures.

In view of this information, a primary thermal threshold criterion of 20°C (68°F) mean daily temperature was selected for this evaluation based on locally-adapted trout temperature tolerances and the typical summer daily temperature fluctuation in the NFFR, which ranges from 1–3ºC. Mean daily temperatures exceeding 20ºC, up to the UUILT for rainbow trout of 25ºC (77ºF), were considered to cause thermal stress, progressively worsening with increasing temperature in this range, and resulting in physiological impairment with a potential to impact survival of coldwater species.

6. Evaluation of the Relative Biological Performance of Alternative Temperature Control Measures for the Upper North Fork Feather River Project

6.1 Analytical Approach and Criteria

The Stetson Engineers (2009) Level 3 engineering feasibility report evaluated seven alternative combinations of temperature control measures, six of which were advanced for detailed performance analysis (Table 3). For each temperature control alternative, exceedance-duration water temperature profiles were modeled for various reaches of the NFFR based on 19 years of hydrological and meteorological data (1984–2002), representing wet, normal, dry, and critical dry water year reservoir discharge temperatures, river flows, and nominally associated weather conditions. The 50% exceedance (normal), 25% exceedance (warm and dry), 10% exceedance (warm and critical dry), and worst-case maximum highest water temperature conditions during the summer for each of the temperature control alternatives were compared to those for the operations proposed under the UNFFR Project Settlement Agreement (also adopted as the FERC staff-recommended alternative in the 2005 EIS for the UNFFR Project license application) and the CEQA Baseline condition, which is the existing UNFFR Project operations.

We subjected the water temperature regimes associated with each Level 3 temperature control alternative to the following biological temperature performance criteria, which are based on the preceding review of rainbow trout temperature requirements.

1. *Examine how well temperature control alternatives avoid temperature fluctuations up to 25ºC and above.*
   The UUILT for rainbow trout is well established to occur near 25ºC. Controllable factors that can prevent stream temperature excursions equal to and above this level are necessary for full protection of cold freshwater habitat. Since the modeled output was daily mean temperature, we examined thermographs for 2002–2004 to determine the magnitude of diel temperature cycles along the NFFR.

Diel temperature data for various reaches of the NFFR provided by Stetson Engineers (2009) were summarized to determine the range of daily temperature fluctuation that may occur in each NFFR reach (Table 4). Diel temperature fluctuation is low near dam release outlets, generally 1ºC or less, and increases along the bypass reaches as atmospheric heating of the water occurs. Mean daily temperature profiles nearing 23ºC were assumed to include a diel cycle that encroached on or exceeded 25ºC for some portion of the time. This approach is consistent with EPA's (1977) national temperature recommendation for calculating protective temperatures for short-term exposure by subtracting 2ºC from the UUILT.

2. *Examine temperature control alternatives for the relative reduction in the exceedance frequencies of mean daily temperatures greater than 20ºC.*
   A mean daily temperature of 20ºC is consistent with an upper threshold for a normative temperature range, including the upper preferred temperatures selected by rainbow trout, and the upper end of a temperature range within which rainbow trout exhibit physiological optima for growth, food conversion efficiency, and maximum swimming speeds. Overall physiological performance significantly declines at temperatures above 20–21ºC. This approach is also consistent with the 20ºC maximum mean daily temperature criterion adopted in the Rock Creek–Cresta Project Settlement Agreement.

3. Examine differences among temperature control alternatives in their relative reduction in the *magnitude and frequency of occurrence of maximum weekly average temperatures greater than 20ºC in July–September.*
   A protective weekly average temperature using the MWAT statistic has been recommended by the EPA (1977) based on the expression,

$$\text{MWAT} = \text{optimal growth temperature} + \frac{\text{UUILT} - \text{optimal growth temperature}}{3}.$$

The EPA-recommended MWAT for rainbow trout is 19ºC (EPA 1977). This was based on a commonly reported optimal growth temperature for the rainbow trout of around 16ºC and an UUILT of 25ºC (Coutant 1999; McCullough 1999; Sullivan et al. 2000). This is likely a protective MWAT for coldwater fishes in the NFFR, too; however, optimal growth temperatures for California rainbow trout appear to be somewhat higher than that used for the EPA recommendation. Optimal growth temperatures ranging from 18–19ºC for juvenile rainbow trout and steelhead stocks from California's Central Valley watersheds, including the Feather River, have been recently reported by Myrick (1998) and Myrick and Cech (2000a, 2000c). Substituting an optimal growth temperature from the mid-point of this range (*i.e.*, 18.5ºC) would yield a regionally-derived protective MWAT of 20.6ºC. In view of this result, 20ºC was selected for both the mean daily temperature criterion and as a conservative MWAT criterion (by rounding down the 20.6°C value to 20°C) for the purposes of this analysis.

6.2 Relative Biological Performance of Water Temperature Control Measures

Thermal profiles of the mean daily temperatures (Figures 3–10) and MWAT (Figures 11–17) during the period of summer maximum temperature modeled under a range of normal to critical dry water year and weather conditions for each of the temperature control alternatives were examined for each of the reaches along the NFFR from Canyon Dam downstream to the Poe Powerhouse. For the purpose of this biological performance analysis, we used the "Baseline" condition as our primary reference condition for comparison of the temperature control alternatives. The "Baseline" also represents the temperatures produced by the "Present Day" alternative[6] for all NFFR reaches downstream of Belden Dam because Stetson Engineers' (2009) analysis determined that this alternative has only a small effect on water temperature (<0.3ºC). The relative biological performances of each temperature control alternative are compared in the following sections.

6.2.1 Baseline Condition and Present Day Alternative

Under the Baseline condition, there is generally less than a 1ºC difference between the modeled mean daily temperatures and MWAT for both July and August under each hydrologic-weather exceedance condition, indicating that day-to-day temperatures are relatively stable within each of these months (Figures 3–11). This suggests that periods of summer maximum temperature are not brief thermal excursions, but extend for significant periods of the summer in the NFFR. The "Baseline"—and all of the temperature control alternatives—maintain July and August water temperatures within the rainbow trout normative range along all of the Seneca Reach. Water temperatures under "Baseline" operations increase from the outlet temperature, at the base of Canyon Dam, throughout the Seneca Reach, but remain below 20ºC, even under critical dry and warm conditions. "Baseline" July and August thermal conditions remain near optimal for rainbow trout growth throughout the lower half of the Seneca Reach under all hydrologic-weather conditions.

Figures 3–11 show that "Baseline" mean daily and MWAT water temperatures exceed 20ºC in July and August throughout all of the NFFR reaches downstream of Belden Dam, except for a 1-mile-long segment between Bucks Creek powerhouse and Cresta Dam during normal and wetter water years, when the Bucks Creek powerhouse discharge reduces temperatures below 20ºC to Cresta Dam. The confluence of the East Branch of the Feather River (EBFR), at the lower end of the Belden Reach, can increase temperatures by up to 1.5ºC due to its warmer water, although this effect is less noticeable in dry and critical dry water years, when the EBFR warm water contrasts less with Belden Reach water temperature. Water temperature profiles within each of the NFFR downstream reaches are fairly similar down to the lower 5 miles of the Poe Reach, where mean daily and MWAT water temperatures increase most rapidly and can encroach on 25ºC, the UUILT for rainbow trout, especially in warm, dry years (represented by the 25% exceedance) and in warm, critical dry years (represented by both the 10% and worst-case maximum exceedances). Under the "Baseline," trout growth in the Belden, Rock Creek, and Cresta reaches may not be greatly affected in normal and wetter water years, when mean daily temperatures stay within about 1ºC of the 20ºC threshold; however, alterations in behavior, increased predation vulnerability, and certain diseases may increase even at these near threshold warmer conditions. In warm,

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[6] The "Present Day" alternative is the operation proposed by PG&E in its license application and also the FERC staff–recommended project alternative in the EIS, which increases the Canyon Dam releases to those given in the UNFFR Project Settlement Agreement (FERC 2005; Stetson Engineers 2009).

dry and warm, critical dry years, mean daily and MWAT temperatures range from 22–23ºC in these same NFFR reaches, which suggests that daily maximum temperatures can encroach on the rainbow trout UUILT, with mean diel fluctuations of about ±2ºC (see Table 4). Thermal conditions throughout most of the Poe Reach under the "Baseline" operations, in normal to critical dry water years, appear to significantly exceed the rainbow trout normative temperature range and can exceed lethal levels for protracted periods in July and August, especially in dry and critical dry years, which prevents maintenance of suitable over-summering habitat for coldwater fishes.

6.2.2 Alternative 3

Alternative 3 represents a combination of temperature control measures, including use of a thermal curtain at the Prattville intake with removal of submerged levees in Lake Almanor, use of a thermal curtain in Butt Valley reservoir near the Caribou intakes, and an increased Canyon Dam release of 250 cfs during July and August (Table 3). This alternative results in significantly cooler (2.5ºC reduction) July water temperatures in the Seneca Reach, which would result in somewhat slower growth rates than the "Baseline" operation but would remain within the rainbow trout normative range. This alternative would also increase Seneca Reach flow levels to 250 cfs during July and August, which would affect predicted suitable habitat area for rainbow trout compared to the minimum instream flow (MIF) schedule proposed under the "Present Day" alternative (Table 5). In general, the 250 cfs release would increase suitable habitat for adult trout (19–58% increase in area), but reduce it for juvenile trout (10–17% decrease in area), compared to the "Present Day" UNFFR Project Settlement Agreement MIFs.

Figures 3–10 and Figure 12 show that Alternative 3 mean daily and MWAT water temperatures remain below 20ºC, and 3ºC below "Baseline" in July and August in the Belden Reach, except for a 0.7-mile segment between the EBFR confluence and Belden powerhouse, where the EBFR discharge warms the NFFR by about 3ºC up to 21–22ºC in all water year types (Tables 6 and 7). Alternative 3 generally maintains mean daily and MWAT temperatures in the Rock Creek and Cresta reaches near or below 20ºC in normal to dry water years, but exceeds 20ºC along some or all of these reach segments in critical dry and warm conditions. These temperatures are 2–2.5ºC cooler than under the "Baseline" in these reaches. Similarly, Alternative 3 reduces water temperatures in the Poe Reach by 1–2ºC, but more than half of the reach remains above 20ºC during July and August. The magnitude of these temperature reductions are sufficient, though, to reduce the frequency of diel fluctuations reaching and exceeding 25ºC, the rainbow trout UUILT. The overall effect of the July to August temperature reductions under Alternative 3 compared to the "Baseline" would be to prevent thermal conditions from exceeding rainbow trout normative temperatures throughout much of the NFFR segments downstream through the Cresta Reach. Growth, disease resistance, and ecological interactions contributing to survival would be expected to significantly improve compared to "Baseline."

6.2.3 Alternative 3x

Alternative 3x represents a combination of temperature control measures, including use of a thermal curtain at the Prattville intake with removal of submerged levees in Lake Almanor, an increased Canyon Dam release of 600 cfs during July and August, and preferential operation of Caribou No. 1 over Caribou No. 2 powerhouses[7] (Table 3). This alternative results in the most significant cooling along the entire

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[7] In this case, "preferential use" of the Caribou No. 1 powerhouse intake, which is located deeper in Butt Valley reservoir than the Caribou No. 2 intake, would provide colder water for discharge in the Belden forebay and to the NFFR downstream.

NFFR (Figures 3–10; Figure 13). July and August water temperatures in the Seneca Reach could range as much as 3.5ºC cooler than "Baseline," which could result in significantly slower growth rates but remain within the rainbow trout normative range. This alternative would also increase Seneca Reach flow levels to 600 cfs during July and August, which would affect predicted suitable habitat area for rainbow trout compared to the MIF schedule proposed under the "Present Day" alternative (Table 5). In general, the 600 cfs release would increase suitable habitat for adult trout (27–69% increase in area), but reduce it for juvenile trout (22–27% decrease in area), compared to the "Present Day" UNFFR Project Settlement Agreement MIFs.

Figures 3–10 and Figure 13 show that Alternative 3x mean daily and MWAT water temperatures remain between 15.5-19ºC, and 3-6ºC below "Baseline" in July and August in the Belden Reach, except for a 0.7-mile segment between the EBFR confluence and Belden powerhouse, where the EBFR discharge warms the NFFR by about 3ºC up to a MWAT of 20–21ºC in all water year types (Figure 13). Alternative 3x generally maintains mean daily and MWAT temperatures in the Rock Creek Reach and most of the Cresta Reach from 16–20ºC in normal to critical dry water years, but exceeds 20ºC by up to 1ºC only in the lower half of the Cresta Reach in critical dry and warm conditions. These temperatures are 2–5ºC cooler than under the "Baseline" in these reaches. Similarly, Alternative 3x reduces water temperatures in the Poe Reach by 2–4ºC, allowing up to half of this segment to remain at or below 20ºC in July of normal years, but more than half of the segment remains above 20ºC during July and August in dry and critical dry and warm years. The magnitude of Alternative 3x temperature reductions in the Poe Reach would be sufficient to significantly reduce the frequency of diel fluctuations reaching and exceeding 25ºC, the rainbow trout UUILT. The overall effect of the July to August temperature reductions under Alternative 3x compared to the "Baseline" would be to prevent thermal conditions from exceeding rainbow trout normative temperatures throughout much of the NFFR segments downstream through the middle of the Poe Reach. Growth, disease resistance, and ecological interactions contributing to survival would be expected to significantly improve compared to "Baseline;" significantly reduce the frequency of temperatures above 20ºC along a longer segment of the NFFR during dry and critical dry and warm years compared to Alternatives 3, 4a, and 4b; and reduce the frequency of temperature fluctuations near and above lethal levels for rainbow trout in portions of the Poe Reach compared to Alternatives 3, 4a, and 4b.

6.2.4 Alternatives 4a and 4b

The biological performance of temperature control Alternatives 4a and 4b are very similar and are discussed together. Alternatives 4a and 4b represent a combination of temperature control measures, including use of a thermal curtain at the Prattville intake without removal of submerged levees in Lake Almanor, and either a thermal curtain in Butt Valley reservoir (Alternative 4a) or preferential operation of Caribou #1 over Caribou #2 powerhouses (Alternative 4b) (Table 3). These alternatives adopt the Canyon Dam release schedule proposed in the UNFFR Project Settlement Agreement ("Present Day" Alternative), which would result in somewhat cooler water temperature profiles during all water years in the Seneca Reach compared to the "Baseline" operation (Figures 3–10; Figures 14 and 15). The result is 1.5ºC or less cooling along the Seneca Reach and since daily mean temperatures remain between 14 and 16ºC, no significant differences in trout growth or survival would be expected compared to the "Baseline" operation.

Figures 3–10 and Figures 14 and 15 show that mean daily and MWAT water temperatures under Alternatives 4a and 4b remain below 20ºC, and 1.5–3ºC below "Baseline," in July and August of normal water years in the Belden Reach, except for a 0.7-mile segment between the EBFR confluence and Belden powerhouse, where the EBFR discharge warms the NFFR by about 2ºC up to 20.2–21.5ºC in normal and dry water year types (Tables 6 and 7). Alternative 4b is 0.5–1ºC cooler than Alternative 4a, and both alternatives generally maintain mean daily and MWAT temperatures in the Rock Creek and Cresta reaches near or below 20ºC in normal water years, but exceed 20ºC, up to about 21ºC, along most of these reach segments in dry and critical dry and warm conditions. These temperatures are 1–2ºC cooler than under the "Baseline" in these NFFR reaches. Similarly, Alternatives 4a and 4b reduce water temperatures in the Poe Reach by 0.6–2ºC compared to "Baseline;" however, more than half of the reach remains above 20ºC during July and August in normal years, and the entire reach exceeds 20ºC in dry and critical dry years. Alternatives 4a and 4b temperature reductions along the Poe Reach are sufficient only in the upper half of the segment to reduce the frequency of diel fluctuations reaching and exceeding 25ºC, the rainbow trout UUILT in most water years. The overall effect of Alternatives 4a and 4b on July to August temperatures compared to the "Baseline" would be to prevent thermal conditions from exceeding rainbow trout normative temperatures throughout much of the NFFR segments downstream through the Cresta Reach in normal years. In dry and critical dry and warm years, Alternatives 4a and 4b prevent mean daily temperatures and MWAT from excursions that could allow diel fluctuations to encroach on lethal levels in the Rock Creek and Cresta reaches and exceed lethal levels in the Poe Reach. Growth, disease resistance, and ecological interactions contributing to survival would be expected to be somewhat improved compared to "Baseline."

6.2.5 Alternatives 4c and 4d

The biological performance of temperature control Alternatives 4c and 4d are very similar and are discussed together. Alternatives 4c and 4d represent a combination of temperature control measures, including an increased Canyon Dam release of 600 cfs during July and August, and preferential operation of Caribou #1 over Caribou #2 powerhouses (Alternative 4c) or use of a thermal curtain in Butt Valley reservoir near the Caribou intakes (Alternative 4d) (Table 3). Except for Alternative 3x, these alternatives result in the most significant cooling along the entire NFFR (Figures 3–10; Figures 16 and 17). The thermal effects on the Seneca Reach are similar to those of Alternative 3x, with water temperatures ranging as much as 3.5ºC cooler than "Baseline," and the consequent effects of slowing trout growth. The 600 cfs release at Canyon Dam would have effects similar to Alternative 3x, increasing suitable habitat for adult trout (27–69% increase in area), but reducing it for juvenile trout (22–27% decrease in area) compared to the "Present Day" UNFFR Project Settlement Agreement MIFs.

Figures 3–10 show that Alternatives 4c and 4d mean daily water temperatures in the Belden Reach remain between 17–19ºC in July and 18.5–20.5ºC in August, and 3-5ºC below "Baseline", except for a 0.7-mile segment between the EBFR confluence and Belden powerhouse, where the EBFR discharge warms the NFFR by about 2.5–3ºC up to a MWAT of 20.5–21ºC in all water year types (Figures 16 and 17). Alternatives 4c and 4d generally maintain MWAT temperatures in the Belden, Rock Creek Reach, and most of the Cresta Reach from 17–20ºC in normal and dry water years during July and August, but exceed 20ºC by up to 1ºC in all three reaches during critical dry and warm conditions. These temperatures remain 2–3ºC cooler than under the "Baseline" in these reaches during the dry and critical dry water years. Similarly, both alternatives reduce water temperatures in the Poe Reach by 1–3ºC, allowing up to half of this segment to remain at or below 20ºC in July of normal years, but more than half of this segment remains above 20ºC during July and August in dry and critical dry and warm years (Tables 6 and 7). Similar to Alternative 3x, temperature reductions in the Poe Reach would be sufficient to significantly reduce the frequency of diel fluctuations reaching and exceeding 25ºC, the rainbow trout UUILT. The overall effect of the July and August temperature reductions under Alternatives 4c and 4d compared to the "Baseline" would be to prevent thermal conditions from exceeding rainbow trout normative temperatures throughout much of the NFFR segments downstream through the middle of the Rock Creek and Cresta reaches. However, Alternatives 4c and 4d do not sufficiently cool temperatures throughout the Poe Reach, especially in dry and critical dry years, to prevent mean daily temperature excursions, where diel fluctuations would exceed 25ºC during July and August maximum temperature periods in a large portion of this segment. Growth, disease resistance, and ecological interactions contributing to survival would be expected to significantly improve compared to "Baseline;" significantly reduce the frequency of temperatures above 20ºC along a longer segment of the NFFR during normal and dry and warm years compared to Alternatives 3, 4a, and 4b; and reduce the frequency of temperature fluctuations near and above lethal levels in normal and dry years for rainbow trout in portions of the Poe Reach compared to Alternatives 3, 4a, and 4b.

A unique difference of Alternatives 4c and 4d is that September temperatures in the Belden and Rock Creek reaches, in particular, increase significantly from August, by up to 2ºC, compared to the other temperature control alternatives (Figures 16 and 17). This is a function of termination of the 600 cfs Canyon Dam releases in September and lack of a thermal curtain at the Prattville intake, which together would result in warmer surface water released from Lake Almanor during this period, which is the cause of downstream warming under these alternatives. This feature of Alternatives 4c and 4d could effectively extend the duration of water temperatures exceeding 20ºC well into September. Extension of the seasonal period of maximum temperature exposure would be undesirable and could reduce the period of favorable temperatures for recovery and growth during the fall months prior to the onset of colder winter water temperatures.

6.2.6 Overall Ranking of Biological Performance of Temperature Control Alternatives

Each of the temperature control alternatives was ranked for its biological performance according to the preceding analysis. This biological performance ranking was integrated with the engineering feasibility ranking provided in Stetson Engineers (2009) to select the range of reasonable temperature control alternatives for better attaining the water temperature objectives for the NFFR and advancement of temperature control measures for analysis in the EIR. The following describes, in order of greatest to least net benefit for coldwater fish habitat, the rationale for biological performance rankings of each temperature control alternative.

1. **Alternative 3x** – would reduce monthly MWAT by about 4.5º, 3.2º, 2.9º, and 2.0ºC in July and 3º, 2.5º, 2.3º, and 2.2ºC in August, on average, at the lower end of the Belden Reach above the EBFR, Rock Creek Reach above Bucks Creek, Cresta Reach above Cresta Powerhouse, and Poe Reach above Poe Powerhouse, respectively (Tables 8–11). Alternative 3x would prevent thermal conditions from exceeding rainbow trout normative temperatures throughout much of the NFFR segments downstream through the middle of the Poe Reach. Under Alternative 3x, growth, disease resistance, and ecological interactions contributing to survival would be expected to significantly improve compared to "Baseline;" significantly reduce the frequency of temperatures above 20ºC along a

longer segment of the NFFR during dry and critical dry and warm years compared to Alternatives 3, 4a, and 4b; and reduce the frequency of temperature fluctuations near and above lethal levels for rainbow trout in portions of the Poe Reach compared to Alternatives 3, 4a, and 4b. However, increasing Canyon Dam releases to 600 cfs under this alternative would decrease juvenile rainbow trout habitat by up to 22–27% and increase adult trout habitat area by up to 27–69% in the Seneca Reach compared to the UNFFR Project Settlement Agreement MIFs, and decrease summer temperatures in this segment relative to the "Baseline," resulting in somewhat slower growth rates for rainbow trout.

2. **Alternative 3** – would reduce monthly MWAT by about 2.9º, 2.1º, 1.9º, and 1.3ºC in July and 2.8º, 2.3º, 2.1º, and 2.0ºC in August, on average, at the lower end of the Belden Reach above the EBFR, Rock Creek Reach above Bucks Creek, Cresta Reach above Cresta Powerhouse, and Poe Reach above Poe Powerhouse, respectively (Tables 8–11). Alternative 3 would prevent thermal conditions from exceeding rainbow trout normative temperatures throughout much of the NFFR segments downstream through the Cresta Reach. While July to August temperatures through much of the Poe Reach would exceed 20ºC in most years, Alternative 3 would reduce the frequency of occurrence of diel fluctuations that exceed the UUILT of 25ºC. Growth, disease resistance, and ecological interactions contributing to survival would be expected to significantly improve compared to "Baseline" and Alternatives 4a and 4b along the NFFR to the middle of the Cresta Reach. The provision of increasing Canyon Dam releases to 250 cfs during July and August would increase suitable habitat area for adult trout by up to19–58%, but reduce it for juvenile trout by 10–17%, compared to the UNFFR Project Settlement Agreement MIFs, and decrease summer temperatures in this segment relative to the "Baseline," resulting in somewhat slower growth rates for rainbow trout.

3. **Alternatives 4a and 4b** – would reduce monthly MWAT by about 2.2–2.3º, 1.6º, 1.5º, and 1.0–1.1ºC in July and 2.1º, 1.6–1.7º, 1.5º, and 1.0–1.1ºC in August, on average, at the lower end of the Belden Reach above the EBFR, Rock Creek Reach above Bucks Creek, Cresta Reach above Cresta Powerhouse, and Poe Reach above Poe Powerhouse, respectively (Tables 8–11). Alternatives 4a and 4b would prevent thermal conditions from exceeding rainbow trout normative temperatures throughout much of the NFFR segments downstream through the Cresta Reach in normal years. In dry and critical dry and warm years, Alternatives 4a and 4b would prevent mean daily temperatures and MWAT from excursions that could allow diel fluctuations to encroach on lethal levels in the Rock Creek and Cresta reaches and exceed lethal levels in the Poe Reach. Growth, disease resistance, and ecological interactions contributing to survival would be expected to be somewhat improved compared to "Baseline." While July to August temperatures through much of the Poe Reach would exceed 20ºC in most years, Alternatives 4a and 4b would reduce the frequency of occurrence and magnitude of diel fluctuations that exceed the UUILT of 25ºC. Growth, disease resistance, and ecological interactions contributing to survival would be expected to significantly improve compared to "Baseline" along the NFFR downstream through the middle of the Cresta Reach in most years.

4. **Alternatives 4c and 4d** – would reduce monthly MWAT by about 3.4–3.9º, 2.5–2.8º, 2.3–2.5º, and 1.6–1.8ºC in July and 2.4º, 1.9–2.0º, 1.8º, and 1.8ºC in August, on average, at the lower end of the Belden Reach above the EBFR, Rock Creek Reach above Bucks Creek, Cresta Reach above Cresta Powerhouse, and Poe Reach above Poe Powerhouse, respectively (Tables 8–11). While Alternatives 4c and 4d would prevent thermal conditions from exceeding rainbow trout normative temperatures throughout much of the NFFR segments downstream through the middle of the Rock Creek and

Cresta reaches in most years, the use of the 600 cfs Canyon Dam release in July and August would have similar effects as Alternative 3x on increasing suitable habitat for adult trout and reducing it for juvenile trout. Additionally, September temperatures in the Belden and Rock Creek reaches, in particular, would increase significantly from August, by up to 2ºC, compared to the other temperature control alternatives. While in most years it appears that temperatures would not exceed 20ºC for long in September, they would remain higher for longer into the month than the other alternatives.

7. Potential Consequences of River Temperature Management Measures on Water Quality of Lake Almanor and Butt Valley Reservoir

7.1 Limiting Factors and the Mechanisms of Environmental Impact

Lake Almanor serves as the main water storage reservoir for the UNFFR Project and all of PG&E's downstream hydroelectric projects on the NFFR (PG&E 2005; Stetson Engineers 2009). The Basin Plan lists the designated beneficial uses of the waters of Lake Almanor to include hydropower generation, warm freshwater habitat, cold freshwater habitat, spawning habitat for warmwater fish, water-dependent wildlife, and contact recreation. The proposed temperature control measures for the NFFR could potentially affect these beneficial uses through (1) alteration of the thermodynamics of Lake Almanor, which may affect changes to cold and warm freshwater habitat; (2) a reduction in fish entrainment at the Prattville intake; and (3) temporary impacts to water quality in the vicinity of in-water construction activities associated with installation of temperature control features (i.e., thermal curtain). Specifically, operation of a thermal curtain at the Prattville intake, increased selective discharge of cold hypolimnetic water from Lake Almanor at Canyon Dam, and operation of a thermal curtain near the Caribou intakes or preferential operation of Caribou No. 1 powerhouse over Caribou No. 2 powerhouse in Butt Valley reservoir, have the potential to affect water quality and fish habitat, especially during July and August, particularly for cold freshwater habitat and the trout fishery of Lake Almanor.

At normal maximum pool, Lake Almanor stores approximately 1,142,000 acre-feet, with an average depth of about 40 feet and a maximum surface area of 26,275 acres, at an elevation of about 4,500 feet above mean sea level (California Department of Water Resources (CDWR) 1974; Jones and Stokes 2004; Stetson Engineers 2009). Lake Almanor generally reaches its highest seasonal elevation around the end of May and declines through the summer as water is released for hydroelectric generation (California Department of Water Resources 1974; Gast 2004). Lake Almanor stratifies during the summer months, forming a warm surface layer (epilimnion) and colder bottom layer (hypolimnion), usually beginning in mid-May, with a deepening of the epilimnion and maximum heat storage achieved around mid-August (California Department of Water Resources 1974; Stetson Engineers 2009). Thermal stratification begins declining with cooling nighttime temperatures during September and the temperature profile through the depths of Lake Almanor becomes nearly homogeneous in the fall months (Jones and Stokes 2004; Stetson Engineers 2009). During the period of summer thermal stratification, DO concentrations in the hypolimnion can decline to near zero in the deepest portions of the lake, especially in the vicinity of Canyon Dam (CDWR 1974; Jones and Stokes 2004; Stetson Engineers 2009).

Lake Almanor supports popular coldwater and warmwater fisheries (PG&E 2002; Gast 2004; Basin Plan). Historically, catch rates of trout and warmwater fish were relatively low (CDWR 1974) and PG&E's 2001 relicensing study reported that contemporary angler catch rates are around 0.25 fish per hour for coldwater and warmwater species combined (EA Engineering 2001). Since the raising of Canyon Dam in 1927, coldwater fishery management has been challenged by balancing reservoir operations; competition with non-game species, such as carp (*Cyprinus carpio*); and selecting and balancing compatible populations of forage fish with trout and salmon species (CDWR 1974). Thermal stratification, along with its warm surface temperatures and associated effects on DO profiles during the summer, has long been thought to be a limiting factor for the coldwater fishery in Lake Almanor (CDWR 1974); however, no definitive studies or information are available on the seasonal distributions and other factors that may be limiting coldwater fish in the lake (CDWR 1974; Gast 2004).

Currently, the coldwater fishery includes Eagle Lake strain rainbow trout, brown trout (*Salmo trutta*), and Chinook salmon (*Oncorhynchus tshawytscha*) , which are stocked in Lake Almanor by the California Department of Fish and Game and a non-profit sportfishing association (PG&E 2002; Gast 2004; CDFG, unpublished data). Annual stocking of catchable and sub-catchable trout and fingerling salmon, in combination, has ranged from 150,340–323,500 since 2001 (Table 12). Butt Valley reservoir, which receives water from Lake Almanor through the Prattville diversion, also supports coldwater and warmwater fishes (PG&E 2002). A "trophy" trout fishery that occurs in Butt Valley reservoir is attributed to the wakasagi (*Hypomesus nipponensis*), a non-native, introduced forage fish, entrained into the Prattville intake from Lake Almanor and discharged at the Butt Valley Powerhouse (PG&E 2002). The primary warmwater fishery in both reservoirs is for smallmouth bass (*Micropterus dolomeiu*) and largemouth bass (*Micropterus salmoides*) (PG&E 2002). These warmwater sport fish were first introduced in the 1950s and 1960s to diversify the fishery and as an attempt to compensate for the largely unsuccessful stocking effort at that time to revitalize a robust trout fishery (CDWR 1974).

The physical habitat in Lake Almanor varies throughout the year for both warm and coldwater fish. During most of the year water temperatures and DO levels are within normative ranges for coldwater fish (CDWR 1974). Suitable conditions exist for reproduction of warmwater fish within the epilimnion (warm surface layer) along littoral (near shore) zones of the lake, when surface water temperatures warm during the spring and summer months. In fact, smallmouth bass dominated the fish community, especially in the littoral zone of the lake, as reported by PG&E during relicensing studies in August 2000 (PG&E 2002). During the peak of the summer, though, high water temperatures may limit trout distributions in the epilimnion and low DO may limit their distribution in the hypolimnion, effectively restricting the zone of preferred and suitable temperature and DO conditions to the narrow depth zone between the epilimnion and hypolimnion (Olson et al. 1988; Rowe and Chisnall 1995; Baldwin et al. 2002; Barwick et al. 2004). Lake Almanor's large underwater springs have also been anecdotally reported to be localities where trout and salmon may congregate during the summer period of limited coldwater habitat in the lake; however, it is not known what portion of the lake's coldwater fish population may use these areas as a thermal refuge (Gast 2004).

Trout and salmon inhabiting lakes are commonly reported to congregate at depths usually associated with the thermocline[8] and deeper during the summer months (Olson et al. 1988; Stables and Thomas 1992; Rowe and Chisnall 1995; Nowack and Quinn 2002; Haddix and Budy 2005; Quinn 2005). Such stratified vertical distributions are widely believed to be based on preferences of salmonids for temperature, oxygen, and light levels (Rowe and Chisnall 1995), but prey distributions, competition, and predation risks also affect the summer depth distributions of trout in lakes (Olson et al. 1988; Tabor and Wurtsbaugh 1991; Quinn 2005; Bergstedt et al. 2012). In lakes, rainbow trout have been reported to forage for prey in warm surface waters at temperatures up to 24ºC, then retreat to cold hypolimnetic waters where DO concentrations were as low as about 3 mg/L, presumably to balance feeding opportunity in the surface waters with energetic efficiencies obtained in cooler deep waters (Rowe and Chisnall 1995; Barwick et al. 2004; Haddix and Budy 2005). While these studies indicate that trout will tolerate short-term exposures to warm water temperatures and low DO concentrations as a function of available habitat and ecological interactions, the weight of evidence indicates that most trout and salmon species exhibit specific preferences and will seek and congregate in water that is 20ºC or cooler and contains DO concentrations of 5 mg/L and greater, when available (Davis 1975; Rowe and Chisnall 1995; Myrick 1998; Myrick and Cech 2000a; Barwick et al. 2004; Haddix and Budy 2005; Quinn 2005).

7.2 Analytic Approach and Metrics for Evaluating Impacts on Project Reservoirs

In view of the important public value of the multiple beneficial uses of Lake Almanor, the State Water Board conducted an independent evaluation of the potential effects that the NFFR temperature control alternatives may have on these uses, with emphasis on the cold freshwater habitat.

The Stetson Engineers (2009) Level 3 engineering feasibility evaluation modeled water temperature and DO distributions in Lake Almanor and Butt Valley reservoir that would occur using the alternative combinations of temperature control measures for the NFFR, under two contrasting water years, 2000 (a normal hydrologic year) and 2001 (a critical dry hydrologic year). A subset of three out of the six temperature control alternatives analyzed for the NFFR were evaluated for their effects on the reservoir water quality because this subset of alternatives contained the full range of temperature management features and exhibited the full range of effects on the reservoir water quality (Stetson Engineers 2009). The temperature control alternatives used for the reservoir impact analysis were as follows:

Alternative 3x was used to represent Alternatives 3 and 3x because both use thermal curtains, remove submerged levees, modify and increase Canyon Dam releases at Lake Almanor in July and August, and have similar effects. Although Alternative 3 would have somewhat less impact on Lake Almanor coldwater habitat due to a lesser Canyon Dam discharge level.

Alternative 4a was used to represent Alternatives 4a and 4b because both use thermal curtains and do not remove submerged levees in Lake Almanor. This alternative was used to evaluate the most extreme effect of use of thermal curtains at the Prattville intake on Butt Valley reservoir.

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[8] The "thermocline" is the zone of depth exhibiting the most rapid rate of temperature change in thermally stratified lakes, typically a rate of change in temperature of ≥ 0.5º-1ºC/meter of depth (Wetzel 1983). In Lake Almanor, the thermocline layer varies from about 5 to 18 feet in thickness, depending on the time of year and its state of development.

Alternative 4c was used to represent Alternatives 4c and 4d because both modify and increase the Canyon Dam discharge to 600 cfs from Lake Almanor in July and August.

The effects of the temperature control alternatives were compared to the model-fitted Baseline condition, which was the existing condition in the two years used for this analysis, 2000 and 2001, and the modeled UNFFR Project Settlement Agreement "Present Day" alternative since it would have some effects on coldwater habitat conditions in Lake Almanor (Stetson Engineers 2009).

Two types of metrics were used to evaluate the potential effects of water temperature control alternatives on suitable cold freshwater habitat conditions in Lake Almanor and Butt Valley reservoir.

1. *Cold freshwater habitat (thermal refuge) volume*
   Cold freshwater habitat volume is defined as the lake-wide volume of water meeting specified temperature and DO criteria. This metric was used as an index of available thermal refugial habitat for trout and other coldwater species in Lake Almanor and Butt Valley reservoir during summer, the period of limited cold freshwater habitat, and is based on the reported tendency for trout to congregate at depths possessing preferred temperatures and DO concentrations. Temperatures preferred by rainbow trout are commonly reported to be 20ºC and less and this temperature was used as a primary criterion for the NFFR temperature control analysis. Additionally, 21º, and 22ºC were selected as secondary thermal refuge criteria for this evaluation because suitable habitat meeting the 20°C primary criteria and containing sufficient DO can be absent at times in Lake Almanor even under the existing condition (Jones and Stokes 2004). Use of 21° and 22°C as secondary temperature criteria is also supported by the finding of Myrick and Cech (2000a), who reported that Eagle Lake rainbow trout, the trout strain that is used to stock Lake Almanor, exhibits similar physiological performances for growth and metabolism over the temperature range 19º–22ºC, suggesting a higher temperature tolerance than some other rainbow trout strains. A DO threshold of 5 mg/L was selected based on the recommendation of Jones and Stokes (2004) that DO thresholds greater than 5 mg/L often resulted in the absence of suitable thermal refuge habitat in Lake Almanor during the summer. Additionally, the DO at depths in lakes where trout are distributed during periods of summer thermal stratification are often reported to be as low as about 5 mg/L (Rowe and Chisnall 1995; Barwick et al. 2004). Based on this information relevant to rainbow trout stocked in Lake Almanor, three different DO-temperature threshold criteria were used for our analysis:

   a) temperature ≤ 20°C and DO ≥ 5mg/L
   b) temperature ≤ 21°C and DO ≥ 5mg/L
   c) temperature ≤ 22°C and DO ≥ 5mg/L

2. *Top of thermocline elevation/metalimnion surface area*
   Top of thermocline is defined as the shallowest depth or highest elevation where the greatest temperature gradient begins to occur. Metalimnion surface area is defined as the lake-wide surface area at the top of the thermocline. This metric was included to augment the coldwater refuge volume metric as a spatial index of the depth strata associated with the thermocline, where trout have been reported to congregate within a narrow depth range with the most preferred available combination of temperature and DO conditions that may occur during summer thermal stratification. The importance of the surface area of the thermocline as an indicator of limiting, suitable, coldwater habitat may be similar or greater than that of the cold freshwater habitat volume, since trout tend to use this narrow

water stratum principally as a thermal refuge from which to forage into the warm epilimnion, where most of their prey occur, during the summer (Rowe and Chisnall 1995; Quinn 2005)

Cold freshwater habitat volume and top of thermocline elevation/metalimnion surface area for Lake Almanor were computed approximately bi-weekly for the years 2000 and 2001 (normal hydrologic year and critical dry year, respectively). This modeling time-step allowed for better evaluation of the durations of exposure to the dynamic environmental conditions that occur during thermal stratification of Lake Almanor (Jones and Stokes 2004).

For Butt Valley reservoir, only the cold freshwater habitat volume metric was used to evaluate the potential effect of temperature control alternatives on reservoir coldwater habitat. Metalimnion surface area was not applied to this reservoir because reservoir stratification is not strong enough to develop a strong thermocline due to Butt Valley reservoir's relatively small storage volume, shallow depth, and relatively short hydraulic residence time (about 2 weeks) (Stetson Engineers 2009).

7.3 Effects on Lake Almanor

7.3.1 Warm and Cold Freshwater Habitat

All of the representative temperature control alternatives (Alternatives 3x, 4a, and 4c) analyzed have relatively similar effects on the warmwater and coldwater habitat conditions in Lake Almanor during the period of summer thermal stratification; the differences among the alternatives are minor. Stetson Engineers (2009) described the physical effects of hypolimnetic water withdrawal, the main feature of all the alternatives, as reducing the coldwater volume in the hypolimnion, while at the same time inducing a small amount of hypolimnetic water movement, resulting in mixing at the interface of the hypolimnion and thermocline water strata that, in turn, can increase the depth of the thermocline and increase the DO levels in the hypolimnion. These processes would similarly occur, whether releasing water from the Canyon Dam low level outlet or by withdrawing water at the Prattville intake through use of a thermal curtain. The consequences of this process are that the cold hypolimnetic volume of the lake decreases, though much of this cold water is not habitable by fish because of very low DO concentrations, and temperature and DO depth profiles can change relative to the Baseline (no action) condition with hypolimnetic releases from the lake.

The relative effects of the representative temperature control alternatives on Lake Almanor thermocline elevations are compared to the Baseline and UNFFR Project Settlement Agreement (Present Day) alternative in Tables 13 and 14 and Figures 18 and 19. The thermocline is the important feature in creating a lake's thermal structure and DO profiles and was used to define limiting summer coldwater habitat. Each of the alternatives increases the depth of the thermocline (reduces the elevation) by 3 feet compared to the Baseline and Present Day alternative during one or two biweekly periods from July through August, in both normal and critical dry water years. Thermocline elevations decrease again in September by up to 7–10 feet in September and October of both water year types; however, this seasonal effect is more related to surface water cooling. As water temperatures decline to 20ºC or less, and the thermocline turnover begins in the fall, the elevation of the thermocline declines (see Appendices C and D in Stetson Engineers 2009).

A periodic increase in the depth of the thermocline during July and August would increase the depth of the warm epilimnion and effectively increase the area of littoral habitat, with temperatures preferred by warmwater fish. Since smallmouth and largemouth bass, the predominant warmwater species in Lake Almanor, typically spawn before mid-July, the primary effect of increased thermocline depth would be a transient increase in preferred temperature habitat for rearing and foraging by bass. However, warmwater rearing and foraging habitat has not been identified as limited in Lake Almanor, so there is no evidence that such modest increases in preferred temperature habitat in the mid- to late-summer would significantly affect warmwater species.

A biweekly time series of suitable coldwater habitat volumes computed using the three temperature criteria for each of the temperature control alternatives are compared to the Baseline and Present Day alternative in Tables 15–20 and Figures 20–25. Similarly, biweekly metalimnion surface areas for each temperature control alternative are compared to the Baseline and Present Day alternative in Tables 20 and 22 and Figures 26 and 27. Examination of both of these metrics together provides a more complete characterization of the effects of the temperature control alternatives on the metalimnetic coldwater refuge during the months of July and August.

In a normal water year, suitable coldwater habitat volumes, using the 20ºC criterion, are similar for all the temperature control alternatives and the Baseline and Present Day conditions, except for about a 2-week period in mid-August, when the lake-wide coldwater volume metric decreases a small amount to 4% for Alternatives 3x, 4a, and 4c compared to 5% for the Baseline (Table 15 and Figure 20). During the same general period of August, the metalimnion surface area ratio for the alternatives are very similar to the Baseline and Present Day, with only a 3% lower value for Alternatives 3x and 4a for two weeks in August, with an overall metalimnion surface area ratio of about 60% (Table 21 and Figure 26). Differences in the metalimnion surface area ratios between the Baseline and alternatives also occur in September and October, but do not indicate an impact on coldwater habitat because water temperatures in the epilimnion have cooled into the suitable range by this time of year and suitable coldwater habitat is not restricted to the thermocline. Therefore, the effects of the temperature control alternatives would be considered a minor and short-term impact on the availability of suitable coldwater thermal refugia in Lake Almanor in a normal water year.

In a critical water year, suitable coldwater habitat volumes, using the 20ºC criterion, become severely limited by mid-July and decline to zero during much of August for the Present Day and temperature control alternatives. Coldwater habitat also declines to zero under the Baseline (no action) condition, too, but not quite as rapidly as for the alternatives (Table 18 and Figure 23). In such a case, only marginal coldwater refugial habitat would remain available even under the Baseline condition and would be restricted to water strata of 21º and 22ºC with DO concentrations of 5mg/L and greater (Tables 19 and 20 and Figures 24 and 25). Using these temperature criteria, coldwater refugial volumes for the temperature control alternatives would be less than the Baseline condition for only about two weeks in late August of a critical dry year. On a lake-wide basis, using the 21°C criteria in a critical dry year, the alternatives would reduce the percentage of coldwater refugia in Lake Almanor, relative to the Baseline, from 11% to 10% on July 20; from 8% to 6% (Alternatives 3x and 4a), and from 8% to 7% (Alternative 4c), on August 9; and from 4% to 1% (Alternative 3x), and from 4% to 2% (Alternatives 4a and 4c), on August 17. Similar proportional differences among the Baseline and alternatives exists for coldwater refugia volume computed using the 22ºC criterion.

The temperature at the top of the thermocline in the critical dry year of 2001 was about 21ºC in July and 21.5º–22ºC in August (Appendix C in Stetson Engineers 2009), so the metalimnion surface area would reflect the available thermal refugial area in this case as well. The metalimnion surface area ratio under the temperature control alternatives varies from 0–6% less than that of the Baseline during July and August 2001, a critical dry year (Table 22 and Figure 27). In the worst case, these differences result in a decrease in the ratio of metalimnion surface to total lake surface area from 63% under Baseline condition to 57% for Alternatives 3x and 4c on August 17, 2001, with a temperature at the top of the thermocline of 22ºC. The temperature control alternatives, especially Alternative 3x, would further restrict the already marginal coldwater refugial habitat in a critical dry water year. Alternatives 4a and 4c would have the least effect on coldwater habitat volume, with about 50% of the Baseline volume during the most temperature limiting 2-week period in August.

7.3.2 Fish Entrainment at Prattville Intake

Gast (2004) identified reduction in wakasagi entrainment as a potential impact of installation of a thermal curtain device at the Prattville intake in Lake Almanor. Large numbers of wakasagi, but very few other species, are currently entrained at the Prattville intake, with subsequent passage through to the Butt Valley Powerhouse (PG&E 2002). The entrainment of non-native wakasagi is thought to support the presence of a “trophy” trout fishery, which preys on the wakasagi, in the Butt Valley powerhouse tailrace and reservoir (PG&E 2002). Gast (2004) hypothesized that installation of a thermal curtain may reduce entrainment of wakasagi at the Prattville intake, reducing the prey base in Butt Valley reservoir for “trophy” trout and increasing the wakasagi abundance in Lake Almanor. He subjected this hypothesis to a modeling exercise that used simple assumptions on wakasagi distribution and vulnerability to entrainment along with PG&E data and modeling on withdrawal strata profiles, with and without a thermal curtain, to determine relative differences in wakasagi entrainment under these scenarios. In the absence of definitive data on wakasagi distributions and associated environmental conditions for Lake Almanor, he made a reasonable assumption that wakasagi are distributed throughout water strata with suitable temperatures and DO concentrations and are entrained in proportion to volumes of water containing wakasagi withdrawn into the intake. He adopted a maximum temperature threshold of 22ºC and minimum DO thresholds of 5 mg/L and 6 mg/L, which confined the wakasagi to the metalimnion and much of the epilimnion for the summer period. This modeling concluded that, in normal water years, wakasagi entrainment could be reduced by up to 95–99%, in July and August, and by less than 30% in June and September. In critical dry water years, entrainment could be reduced by 86–99% from June to September. Using suitability index analysis, the same monthly patterns resulted with slightly lower entrainment levels.

There is not adequate evidence for or against Gast’s hypothesis concerning the potential for a significant change in wakasagi entrainment at the Prattville intake or its impact on the Butt Valley reservoir fishery in documents reviewed as part of the relicensing record. The only available data on wakasagi depth distributions in the vicinity of the Prattville intake is from PG&E (2002), which was obtained using hydroacoustic surveys in August 2001 as part of the relicensing studies, indicating that wakasagi schools occurred at depths from 10–14 meters (33–46 feet), and mostly near the lake bottom (Gast 2004). This depth would place fish within the withdrawal zone of the thermal curtain. However, at the time of this hydroacoustic survey, low lake levels put the top of the thermocline near the elevation of the thermal curtain opening, which may have affected fish distribution (Gast 2004). This would be consistent with observations of wakasagi congregating in and just below the thermocline in Lake Oroville (D. Lee, California Department of Fish and Game, personal communication, as cited in FERC 2005). Additionally, wakasagi have spread and are abundant throughout the entire NFFR system from Lake Almanor to Lake Oroville, including Butt Valley reservoir. Wakasagi populations in all reservoirs along the NFFR have increased dramatically since their initial stocking in Lake Almanor in 1972–73 (Moyle 2002). Their broad thermal and salinity tolerance and ability to spawn in sand and small gravel on the beds of feeder streams and along the shorelines of ponds, lakes, and reservoirs has likely led to their adaptability and expanding range throughout California (Moyle 2002). We found no information to the contrary in the relicensing record, nor is there any reason to expect that wakasagi have not similarly established self-sustaining populations in Butt Valley reservoir. Therefore, there is little evidence that reducing wakasagi entrainment at the Prattville intake will have a significant effect on presence of a suitable forage fish in the Butt Valley reservoir.

7.3.3 In-Water Construction Impacts

Stetson Engineers (2009) provides a detailed description of the features and construction activities required for various elements of the temperature control alternatives. The primary in-water construction activities that could affect aquatic resources in Lake Almanor include installation of a thermal curtain in the vicinity of the Prattville intake, dredging of the lake bottom to remove submerged levees to enhance the flow of cold water into the intake, and modification and repair of two of the three low-level outlets on the Canyon Dam release tower.

Installation of the thermal curtain includes construction of galvanized steel bin-type walls that would extend 300 feet offshore and connect to the curtain endpoints. The bin walls would be installed on a one-foot foundation of fill material placed on a geotextile fabric to limit turbidity from disturbance of the lake bed. Construction of the bin walls would result in long-term loss of lake bed littoral habitat in the vicinity of the Prattville intake tower; however, available fish habitat maps do not indicate the presence of concentrated warmwater fish spawning habitat at this location and it would be a very small area of lake bed relative to the whole of Lake Almanor; so, bin wall construction would not be expected to significantly affect warmwater spawning habitat.

Localized and temporary increases in turbidity and resuspension of lake bed sediment could occur during installation of the bin-type walls and dredging of the submerged levees. The turbidity of a water body is related to the concentration of suspended solids. Suspended solids and turbidity generally do not acutely affect aquatic organisms unless they reach extremely high levels (i.e., levels of suspended solids reaching 25 milligrams per liter) (Alabaster and Lloyd 1980). At these high levels, suspended solids can adversely affect the physiology and behavior of aquatic organisms and may suppress photosynthetic activity at the base of food webs, affecting aquatic organisms either directly or indirectly (Cordone and Kelley 1961; Iwamoto et al. 1978; Alabaster and Lloyd 1980). Construction activities will likely have to comply with Basin Plan turbidity objectives that limits turbidity increases from dredging and construction generally to less than 20% of background levels to protect beneficial uses, which along with the size of Lake Almanor, a turbidity barrier is not expected to form or impede fish migration through the project area, nor would the suspended sediment be expected to significantly affect primary production or settle on spawning beds.

Modification and repair of the Canyon Dam outlet tower gates would be accomplished using divers and underwater construction techniques, including a barge-mounted crane and diving platform or floating walkway to install prefabricated steel bulkheads with built-in slide gates to the existing outlet tower. This activity would be confined to the vicinity of the outlet tower, which is located in deep water (> 80 feet) near the dam. Fish and other aquatic organisms would be minimally disturbed by this activity and any fish in the vicinity would likely disperse away from the area during most construction activities. Spills of fuels, lubricants, and hydraulic fluids could occur on the crane barge. These materials are hazardous to aquatic life and could cause adverse effects if even small quantities were to enter the lake. Construction site best management practices to prevent and manage spills to ensure rapid and effective clean up and abatement of any spilled hazardous substances would be required. If the Canyon Dam outlet tunnel would need to be closed during installation of a bulkhead, a pipeline and pump or siphon would be used to maintain minimum instream flows of 35–60 cfs in the NFFR below the dam. To prevent fish entrainment through the pump or siphon, fish screens of a compatible design and of appropriate mesh size (to preclude small fish) would need to be fitted to the pump or siphon.

7.4 Effects on Butt Valley Reservoir

7.4.1 Cold Freshwater Habitat

Butt Valley reservoir is an impoundment on Butt Creek, which is a tributary of the NFFR, and is subject to the same beneficial uses. Cold freshwater habitat in Butt Valley reservoir is the primary beneficial use that would potentially be affected by UNFFR Project temperature control alternatives. Little information on the fishery or fish populations of Butt Valley reservoir was found in the relicensing record. Entrainment monitoring at the Butt Valley powerhouse by PG&E (2002) indicated that large numbers of wakasagi, along with small numbers of other species, including both warmwater and coldwater fishes, pass from Lake Almanor to Butt Valley reservoir. No fish population data were collected on Butt Valley reservoir by PG&E (2002). However, a small fishery for trophy-sized rainbow and brown trout was documented by a creel survey conducted in 2000 by PG&E (2002). The Butt Valley powerhouse tailrace was reported as a focus location for this fishery (Stuart Running, PG&E, personal communication).

Both the water temperature and DO concentration of the Butt Valley powerhouse discharge would be affected by use of a thermal curtain at the Prattville intake during the summer months (Figures 28–31). Water temperatures and DO would decrease in the Butt Valley powerhouse discharge, with DO levels declining well below the typical Baseline (no action) condition minimum levels of about 5–6 mg/L from June through August in both normal and critical dry water years. A trout fishery in the powerhouse tailrace could be affected by reductions in DO concentration from 5–6 mg/L to 2–3 mg/L in July and August. A likely response would be for trout to either disperse from the immediate vicinity of the powerhouse tailrace to areas of higher DO levels or make brief forays into the tailrace to feed and then return to adjacent areas with higher DO levels. This impact would be significant because it would adversely affect water quality and likely change the fishery utilization at this location. Aeration to increase DO levels of the diverted water would serve to alleviate this impact. Several aeration and reoxygenation technologies are potentially available to mitigate this impact, such as passive venturi tube aeration in the Butt Valley tunnel and penstock and Speece cone reoxygenation.

The changes in temperature and DO concentrations of the powerhouse discharge, in turn, would also alter the amount of suitable coldwater habitat through subsequent effects on the temperature and DO profiles of Butt Valley reservoir (Stetson Engineers 2009). The degree to which the availability of suitable coldwater habitat during the summer is limiting cold freshwater habitat uses and a trout fishery in Butt Valley reservoir is not completely known, but has not been reported to be a problem. The overall effect of the Prattville thermal curtain on coldwater habitat in Butt Valley reservoir would be to reduce the frequency of occurrence of water temperatures greater than 20ºC, but increase the frequency of occurrence of DO levels less than 5mg/L. Coldwater habitat is limited by the lower DO levels of the powerhouse discharge under Alternative 4a compared to the Baseline condition in normal water years during late June and early July; however, later in the summer powerhouse discharges provide a greater amount of habitat at temperatures ≤ 20ºC, with adequate DO levels, than the Baseline condition (Table 23 and Figure 32). In critical dry water years, coldwater habitat volume under Alternative 4a, defined by the ≤ 20ºC and ≥ 5mg/L DO criteria, is slightly greater in late June and nearly twice the volume of the Baseline during July, before the availability of ≤ 20ºC from Lake Almanor, via a thermal curtain withdrawal, declines to nearly zero in August (Table 26 and Figure 35). Coldwater habitat volumes defined by the higher temperature criteria, 21º and 22ºC, under Alternative 4a are generally less than or equal to the Baseline condition because less of the water diverted from Lake Almanor is at these temperatures (Tables 24 and 25 and 27 and 28; Figures 33 and 34 and 36 and 37). The overall effect of Alternative 4a would be to increase suitable coldwater habitat during mid- to late-summer in most water years, with the least effect in critical dry years. Other temperature control alternatives using a thermal curtain at the Prattville intake would exhibit similar to lesser increases of suitable coldwater habitat, with temperatures ≤ 20ºC and DO levels ≥ 5mg/L, depending on the balance of water released from Lake Almanor via the Canyon Dam outlet and the Prattville intake. Aeration could be used to increase DO levels of the diverted water to further increase the coldwater habitat volume benefit to Butt Valley reservoir under the UNFFR Project temperature control alternatives that use a thermal curtain at the Prattville intake.

7.4.2 In-Water Construction Impacts

Stetson Engineers (2009) provides a detailed description of the features and construction activities required for installation of a thermal curtain near the Caribou intakes, the primary in-water construction activity that could affect aquatic resources in Butt Valley reservoir.

Similar to the Prattville intake at Lake Almanor, installation of the thermal curtain in Butt Valley reservoir would include construction of galvanized steel bin-type walls that would extend about 200 feet offshore and connect to the curtain endpoints. The bin walls would be installed on a 1-foot foundation of fill material placed on a geotextile fabric to limit impacts of turbidity from disturbance of the lake bed. This construction activity would result in loss of lake bed; however, because of the steepness of this near-shore zone in Butt Valley reservoir, it is not considered suitable littoral habitat for warmwater fishes (FERC 2005). Therefore, no significant adverse impact to fish habitat would be expected from installation of the bin walls.

Localized and temporary increases in turbidity and resuspension of lake bed sediment could occur during installation of the bin-type walls. However, because construction activities will likely have to comply with Basin Plan turbidity objectives that limits turbidity increases from dredging and construction generally to less than 20% of background levels to protect beneficial uses, and use of geotextile fabric laid on the lake bed and clean fill to create the foundation for the bin walls, resuspension of sediment and turbidity would be minimized. No significant effects from the minimal sediment disturbance and turbidity during this activity are expected on primary production, fish migration, or fish spawning habitat.

8. Conclusions and Summary of Recommended Mitigation

This analysis determined the relative biological performance of a range of alternative temperature control measures proposed for the UNFFR Project to improve attainment of temperature objectives for designated aquatic life uses of the NFFR, primarily cold freshwater habitat. Following is a brief recap and summary of the key biological differences, similarities, and performance ranking among the temperature control alternatives.

1. **Alternative 3x** – incorporates the full range of the most effective measures for reducing temperatures in downstream river reaches and reduces water temperatures by the greatest amount, on average, throughout all reaches of the NFFR. Alternative 3x includes: a thermal curtain at the Prattville intake; removal of submerged levees in Lake Almanor; increasing Canyon Dam releases by up to 600 cfs, with commensurate reductions at the Prattville intake; and preferential operation of Caribou No. 1 intake. Alternative 3x would prevent thermal conditions from exceeding rainbow trout normative temperatures throughout much of the NFFR segments downstream through the middle of the Poe Reach. Growth, disease resistance, and ecological interactions contributing to survival would be expected to significantly improve compared to the Baseline (no action) condition and the frequency of temperature fluctuations near and above lethal levels for rainbow trout would be reduced in the Poe Reach. However, this alternative includes increasing Canyon Dam releases by up to 600 cfs, which would decrease juvenile rainbow trout habitat in the Seneca Reach and decrease summer temperatures relative to Baseline conditions, resulting in somewhat slower growth rates for rainbow trout.

2. **Alternative 3** – incorporates a range of effective measures for reducing temperatures in downstream river reaches, including thermal curtains at the Prattville and Caribou intakes, removal of submerged levees in Lake Almanor, and increasing Canyon Dam releases by up to 250 cfs, with commensurate reductions at the Prattville intake. Alternative 3 results in 90–95% of the cooling achieved by Alternative 3x. Alternative 3 would prevent thermal conditions from exceeding rainbow trout normative temperatures throughout much of the NFFR segments downstream through the Cresta Reach. Although it would not prevent exceedance of mean daily temperatures of 20ºC in the Poe Reach during most years, Alternative 3 would reduce the frequency of occurrence of diel fluctuations that exceed the UUILT of 25ºC. Growth, disease resistance, and ecological interactions contributing to survival would be expected to significantly improve compared to the Baseline condition along the NFFR to the middle of the Cresta Reach. The provision of increasing Canyon Dam releases to 250 cfs during July and August would reduce habitat for juvenile trout in the Seneca Reach and decrease summer temperatures in this segment, also resulting in somewhat slower growth rates for rainbow trout, but not to the extent of Alternative 3x.

3. **Alternatives 4a and 4b** – are similar in temperature reduction performance. Both alternatives incorporate a thermal curtain at the Prattville intake, but do not remove the submerged levees in Lake Almanor; however they differ in that Alternative 4a uses a thermal curtain near the Caribou intakes and Alternative 4b uses preferential operation of Caribou No. 1 intake. Alternatives 4a and 4b result in 50–75% of the cooling achieved by Alternative 3x. Alternatives 4a and 4b would prevent thermal conditions, on average, from exceeding the rainbow trout normative temperature range throughout

much of the NFFR segments downstream through the Cresta Reach in normal years. In warm, dry and critical dry years, these alternatives maintain diel fluctuations below lethal levels in the Rock Creek and Cresta reaches and prevent temperature fluctuations from exceeding lethal levels in the Poe Reach. Growth, disease resistance, and ecological interactions contributing to survival would be expected to significantly improve compared to Baseline conditions along the NFFR downstream through the middle of the Cresta Reach in most years. Although Alternatives 4a and 4b would not prevent exceedance of 20ºC in the Poe Reach, they would reduce the frequency of occurrence of diel fluctuations that exceed the UUILT of 25ºC.

4. **Alternatives 4c and 4d** – are similar in temperature reduction performance and both incorporate increasing Canyon Dam releases by up to 600 cfs, with commensurate reduction at the Prattville intake; however, they differ in that Alternative 4c uses preferential operation of Caribou No.1 intake and Alternative 4d uses a thermal curtain near the Caribou intakes. Alternatives 4c and 4d result in 80–90% of the cooling achieved by Alternative 3x, which is cooler than Alternatives 4a and 4b. While Alternatives 4c and 4d would prevent thermal conditions from exceeding the rainbow trout normative temperature range throughout much of the NFFR segments downstream through the middle of the Rock Creek and Cresta reaches in most years, the use of the 600 cfs Canyon Dam release would reduce habitat for juvenile trout and trout growth rates in the Seneca Reach. Additionally, September temperatures in the Belden and Rock Creek reaches, in particular, would increase significantly from those in August, by up to 2ºC, compared to the other temperature control alternatives. For these reasons, Alternatives 4c and 4d were ranked lower than Alternatives 4a and 4b in overall biological performance.

While each of the alternative combinations of temperature control measures analyzed for the UNFFR Project provides a range of temperature benefits for aquatic habitat uses in the NFFR compared to the Baseline (no action) condition, a number of potential impacts to Lake Almanor and Butt Valley reservoir may occur during construction and operation of temperature control features. The potential for and degree of significance of impacts on aquatic resources in UNFFR Project reservoirs vary among the temperature control alternatives. Tables 29 and 30 list and summarize the potential impacts and effects of the alternative measures on aquatic resources. Each of the temperature control features that are identified to have a potential significant impact on aquatic resources or requiring mitigation during construction or operation is included in Tables 29 and 30, along with associated recommendations.

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ATTACHMENT A. TABLES AND FIGURES

Table 1. Beneficial uses of the North Fork Feather River (Central Valley RWQCB 2009)

BENEFICIAL USE	DESCRIPTION
Municipal and Domestic Supply	Uses of water for community, military, and individual water supply systems, including, but not limited to drinking water supply.
Hydropower Generation	Uses of water for hydropower generation.
Water Contact Recreation	Uses of water for recreational activities involving body contact, where ingestion of water is reasonably possible. These uses include but are not limited to swimming, wading, water-skiing, skin and SCUBA diving, surfing, white-water activities, fishing, and use of natural hot springs.
Non-contact Water Recreation	Uses of water for recreational activities involving proximity to water, but where there is generally no body contact with water, nor any likelihood of ingestion of water. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tide pool and marine life study, hunting, sightseeing, or aesthetic enjoyment in connection with the above activities.
Cold Freshwater Habitat	Uses of water that support coldwater ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
Spawning, Reproduction, and Early Development (coldwater fisheries)	Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.
Wildlife Habitat	Uses of water that support terrestrial or wetland ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats or wetlands, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

Table 2. A compilation and summary of published information on the observed relationships and effects of water temperature on the non-spawning adult and juvenile life stages of rainbow trout, with inferences on the sub-lethal temperature ranges

TEMPERATURE RANGE	EFFECTS OF TEMPERATURE ON NON-SPAWNING ADULT AND JUVENILE LIFE STAGES OF RAINBOW TROUT	SOURCES OF INFORMATION
< 6ºC	Reduced and cease feeding; no or negative growth can occur; seek cover in deep pools, undercuts, and within streambed cobbles; seasonal periods of temperatures below 6ºC are endured without significant mortality as long as hypoxia does not co-occur.	Everest and Chapman (1972); Leitritz and Lewis (1976); Piper et al. (1982); Bell (1990); Bjornn and Reiser (1991)
6ºC – 9ºC	Inferred range of sub-optimal temperatures; reduced feeding and food conversion efficiency; greatly reduced growth rates; and increased virulence of coldwater viruses for some salmonids.	Leitritz and Lewis (1976); EPA (1977); Wurtsbaugh and Davis (1977); Piper et al. (1982); Post (1987); Bell (1990); Bjornn and Reiser (1991)
10ºC – 21ºC	Integrated normative range for reported observations of maximal field abundance and survival; preferred temperatures; and optimal or near-optimal growth over a range of ration levels, metabolic efficiency, feeding efficiency, swimming performance; 16-20ºC is sub-range of most often reported maximum growth rates, when fed to repletion, and maximum swimming speeds; growth rates tend to decline above 17ºC, when fed approximately 60% of satiation diet (similar to field measurements).	Dickson and Kramer (1971); Leitritz and Lewis (1976); Cherry et al. (1977); Coutant (1977, 1999); EPA (1977); Hokanson et al. (1977); Wurtsbaugh and Davis (1977); Piper et al. (1982); Raleigh et al. (1984); Bell (1990); Cech et al. (1990); Bjornn and Reiser (1991); Matthews et al. (1994); McCullough (1999); Myrick and Cech (2000a,c); McCullough et al. (2001)
19ºC – 24ºC	Inferred range of supra-optimal temperatures; significantly reduced food conversion efficiency and growth rates; decreased resistance to some diseases; altered behaviors; increased vulnerability to predation; deleterious outcomes of interspecific competition; direct and indirect mortality rates tend to increase within this range up to the ultimate upper incipient lethal temperature (UUILT) of 25ºC; trout population productivity declines rapidly in this range (zero biomass gain at 23ºC).	Dickson and Kramer (1971); Leitritz and Lewis (1976); Cherry et al. (1977); Hokanson et al. (1977); Wurtsbaugh and Davis (1977); Piper et al. (1982); Schneider and Connors (1982); Baltz et al. (1987); Bell (1990); Eaton et al. (1995); Myrick (1998); McCullough (1999); McCullough et al. (2001); Myrick and Cech (2000a,c); Winton (2001)
25ºC – 30ºC	Upper lethal temperature range; 25ºC is a consensus UUILT for rainbow trout/steelhead; thermal resistance and time to death decline rapidly above incipient lethal temperature; death is nearly instantaneous for exposures >30ºC.	Brett (1956); Cherry et al. (1975); EPA (1977); Hokanson et al. (1977); Bell (1990) Alabaster and Downing (1966), as cited in Sullivan et al. (2000); McCullough (1999); McCullough et al. (2001)

Table 3. Summary of the Upper North Fork Feather River Project (FERC No. 2105) temperature control measure combinations (Alternatives) formulated and evaluated in the Stetson Engineers (2009) Level 3 analysis

ALTERNATIVES	MEASURES INCLUDED IN THE UNFFR PROJECT-ONLY ALTERNATIVES
Baseline	▪ No action. Existing UNFFR Project operations.
"Present Day" UNFFR Project Settlement Agreement	▪ Increase Canyon Dam release as provided in the UNFFR Project Settlement Agreement (and decrease Prattville Intake release commensurately).
Alternative 3	▪ Install Prattville Intake thermal curtain and remove submerged levees in Lake Almanor near the Intake; ▪ Modify Canyon Dam low-level outlet and increase release to 250 cfs (in July and August and decrease Prattville Intake release commensurately); and ▪ Install a single thermal curtain in Butt Valley reservoir near Caribou No.1 and No. 2 Intakes.
Alternative 3x [a]	▪ Install Prattville Intake thermal curtain and remove submerged levees in Lake Almanor near the Intake; ▪ Modify Canyon Dam low-level outlet and increase release to 600 cfs (in July and August) and decrease Prattville Intake release commensurately; and ▪ Operate Caribou No. 1 preferentially over Caribou No. 2.
Alternative 3a [b]	▪ Install Prattville Intake thermal curtain and remove submerged levees in Lake Almanor near the Intake; ▪ Install a single thermal curtain near Caribou No. 1 and No. 2 Intakes.
Alternative 4a	▪ Install Prattville Intake thermal curtain (without removal of submerged levees in Lake Almanor near the Intake); and ▪ Install a single thermal curtain near Caribou #1 and #2 Intakes.
Alternative 4b	▪ Install Prattville Intake thermal curtain (without removal of submerged levees in Lake Almanor near the Intake); and ▪ Operate Caribou #1 preferentially over Caribou #2.
Alternative 4c	▪ Modify Canyon Dam low-level outlet and increase release to 600 cfs (in July and August) and decrease Prattville Intake release commensurately; and ▪ Operate Caribou #1 preferentially over Caribou #2.
Alternative 4d	▪ Modify Canyon Dam low-level outlet and increase release to 600 cfs (in July and August) and decrease Prattville Intake release commensurately; and ▪ Install a single thermal curtain near Caribou #1 and #2 Intakes.

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[a] This alternative results in most significant cooling along entire NFFR. However, the elevated Seneca reach flows reduces juvenile trout rearing habitat area in that reach and water temperatures are reduced sufficiently to slow trout growth in the Seneca reach, too, which results in a greater impact than the other alternative water quality measures in relation to overall ecological benefits..

[b] Alternative 3a was used to compare to Alternative 4a to evaluate the effect of levee removal on release temperature. Levee removal provided only a 0.3-0.6ºC decrease at end of Belden reach.

Table 4. Diel temperature cycle (daily range, in ºC) statistics for North Fork Feather River gaging stations, 2002-2004 (adapted from data in Stetson Engineers 2009)

			AVERAGE RANGE (ºC)		
REACH	**STATION**	**MONTH**	**MAX**	**MIN**	**MEAN**
Belden Reach	NF5	June	1.4	0.2	0.6
		July	2.2	0.3	0.6
		Aug	1.9	0.2	0.5
		Sep	2.8	0.3	0.6
		Average	2.1	0.3	0.6
	NF6	June	3.9	1.2	3.2
		July	4.2	2.5	3.2
		Aug	3.9	0.5	2.7
		Sep	4.7	1.7	3.3
		Average	4.2	1.5	3.1
	NF7	June	5.7	1.5	4.8
		July	6.0	3.3	4.8
		Aug	5.4	0.6	4.1
		Sep	5.5	2.1	4.1
		Average	5.7	1.9	4.5
	NF8	June	5.2	1.5	4.3
		July	5.3	3.1	4.5
		Aug	5.2	0.8	4.1
		Sep	4.5	1.8	3.3
		Average	5.1	1.8	4.0
Rock Creek Reach	NF10	June	3.7	0.5	1.8
		July	2.5	0.5	1.4
		Aug	2.0	0.4	1.2
		Sep	1.4	0.3	1.0
		Average	2.4	0.4	1.4
	NF11	June	5.1	1.8	3.8
		July	4.3	2.3	3.5
		Aug	4.1	0.8	3.1
		Sep	3.5	0.8	2.6
		Average	4.3	1.4	3.3
	NF12	June	5.2	1.7	3.6
		July	3.8	1.9	3.1
		Aug	3.6	0.9	2.7
		Sep	3.7	1.1	2.5
		Average	4.1	1.4	3.0
	NF13	June	4.6	1.2	2.8
		July	4.6	1.3	2.7
		Aug	5.3	0.9	2.7
		Sep	4.5	1.1	2.5
		Average	4.8	1.1	2.7

Table 4. Diel temperature cycle (daily range, in ºC) statistics for North Fork Feather River gaging stations, 2002-2004 (adapted from data in Stetson Engineers 2009)

			AVERAGE RANGE (ºC)		
REACH	**STATION**	**MONTH**	**MAX**	**MIN**	**MEAN**
Cresta Reach	NF14	June	1.8	0.6	1.1
		July	1.6	0.5	1.0
		Aug	1.6	0.3	1.0
		Sep	1.7	0.3	0.9
		Average	1.7	0.4	1.0
	NF15	June	3.3	1.0	2.6
		July	3.2	1.6	2.5
		Aug	3.1	0.6	2.3
		Sep	4.8	0.6	2.4
		Average	3.6	1.0	2.5
	NF16	June	3.7	1.8	2.9
		July	3.7	2.1	2.8
		Aug	3.2	0.6	2.5
		Sep	3.0	0.7	2.0
		Average	3.4	1.3	2.6
Poe Reach	NF17	June	1.8	0.2	1.1
		July	1.6	0.2	0.9
		Aug	1.7	0.2	0.8
		Sep	1.6	0.2	0.7
		Average	1.7	0.2	0.9
	NF18	June	3.7	2.2	3.2
		July	3.6	2.2	3.1
		Aug	3.4	0.6	2.7
		Sep	3.0	1.1	2.4
		Average	3.4	1.5	2.8

Table 5. Flow-dependent suitable habitat area relationships for adult and juvenile life stages of rainbow trout in the Seneca Reach of the North Fork Feather River relative to Canyon Dam releases associated with various temperature control alternatives. Data are adapted from PG&E (2002).

FLOW[B] (CFS)	ONE VELOCITY CALIBRATION[A]				DEPTH CALIBRATION[A]			
	RAINBOW TROUT JUVENILE		RAINBOW TROUT ADULT		RAINBOW TROUT JUVENILE		RAINBOW TROUT ADULT	
	AREA (FT^2)	% OF MAX	AREA (FT^2)	% OF MAX	AREA (FT^2)	% OF MAX	AREA (FT^2)	% OF MAX
60	19,492	99	7,168	58	19,196	94	7,600	71
125	18,150	92	9,564	77	16,683	82	9,589	89
250	16,185	82	11,383	92	14,330	71	10,759	100
600	14,116	72	12,231	98	11,995	59	8,499	79
Max area (ft^2)	19,695	100	12,400	100	20,268	100	10,759	100

[a] Calibration methods refer to hydraulic simulation models used for development of the flow-physical habitat relationships in PG&E (2002).

[b] Flow levels are associated with Canyon Dam releases under the UNFFR Project Settlement Agreement “Present Day” Alternative (60cfs-dry/critical dry; 125cfs-normal/wet), Alternative 3 (250cfs), and Alternatives 3x, 4c, and 4d (600 cfs) operational scenarios for the Upper North Fork Feather River Project (FERC Project No. 2105).

Table 6. Summary of mean daily water temperature profiles for different temperature control alternatives – July (from Stetson Engineers 2009)

		BELDEN REACH (REACH LENGTH = 8.8 MILES)		ROCK CREEK REACH (REACH LENGTH = 7.9 MILES)		CRESTA REACH (REACH LENGTH = 4.7 MILES)		POE REACH (REACH LENGTH = 7.5 MILES)	
ALT.	**EXCEEDANCE LEVEL**	**REACH LENGTH THAT EXCEEDS 20°C (MILE)**	**TEMPERATURE RANGE ALONG THE REACH**	**REACH LENGTH THAT EXCEEDS 20°C (MILE)**	**TEMPERATURE RANGE ALONG THE REACH**	**REACH LENGTH THAT EXCEEDS 20°C (MILE)**	**TEMPERATURE RANGE ALONG THE REACH**	**REACH LENGTH THAT EXCEEDS 20°C (MILE)**	**TEMPERATURE RANGE ALONG THE REACH**
Baseline	Maximum	Entire reach	23.2-23.6°C	Entire reach	23.3-23.7°C	Entire reach	23.1-23.8°C	Entire reach	23.3-25.7°C
	10% Exceedance	Entire reach	22.2-23.0°C	Entire reach	22.4-23.0°C	Entire reach	22.3-23.2°C	Entire reach	22.5-25.3°C
	25% Exceedance	Entire reach	21.7-22.7°C	Entire reach	21.9-22.7°C	Entire reach	22.0-22.8°C	Entire reach	22.1-25.1°C
	50% Exceedance	Entire reach	20.4-21.9°C	6.9	18.6-21.1°C	Entire reach	20.1-20.8°C	Entire reach	20.2-23.2°C
Alt. 3	Maximum	Entire reach	21.0-22.7°C	Entire reach	21.4-22.4°C	Entire reach	21.5-22.7°C	Entire reach	21.6-24.8°C
	10% Exceedance	1.6	19.0-22.1°C	7.1	19.7-21.3°C	Entire reach	20.0-21.7°C	Entire reach	20.2-24.1°C
	25% Exceedance	1.6	18.3-21.2°C	4.7	19.2-20.7°C	3.1	19.5-20.8°C	7.0	19.8-23.9°C
	50% Exceedance	0.7	17.0-20.2°C	0	17.5-19.0°C	0	17.9-18.8°C	4.0	18.2-22.1°C
Alt. 4a	Maximum	Entire reach	21.0-22.7°C	Entire reach	21.3-22.3°C	Entire reach	21.5-22.6°C	Entire reach	21.6-24.8°C
	10% Exceedance	Entire reach	20.0-22.4°C	Entire reach	20.6-21.8°C	Entire reach	20.7-22.2°C	Entire reach	20.9-24.5°C
	25% Exceedance	1.6	19.1-21.5°C	7.2	19.9-21.1°C	Entire reach	20.1-21.3°C	Entire reach	20.4-24.2°C
	50% Exceedance	1.6	17.9-20.6°C	0	17.9-19.6°C	0	18.5-19.3°C	4.8	18.7-22.4°C
Alt. 4b	Maximum	Entire reach	20.6-22.6°C	Entire reach	21.0-22.0°C	Entire reach	21.2-22.5°C	Entire reach	21.3-24.7°C
	10% Exceedance	1.6	19.1-22.1°C	7.4	19.9-21.4°C	Entire reach	20.1-21.8°C	Entire reach	20.3-24.2°C
	25% Exceedance	1.6	18.5-21.2°C	5.3	19.4-20.8°C	3.5	19.7-20.9°C	Entire reach	19.9-24.0°C
	50% Exceedance	0.7	17.0-20.2°C	0	17.5-19.0°C	0	18.0-18.8°C	4.0	18.2-22.1°C
Alt. 4c	Maximum	1.6	18.8-22.1°C	6.6	19.6-21.2°C	4.2	19.8-21.6°C	Entire reach	20.0-24.0°C
	10% Exceedance	1.6	17.4-21.6°C	2.9	18.4-20.5°C	2.5	18.7-20.9°C	6.1	19.0-23.5°C
	25% Exceedance	1.1	16.5-20.3°C	0	17.8-19.7°C	0	18.1-19.7°C	4.8	18.4-23.2°C
	50% Exceedance	0	15.3-19.4°C	0	16.7-18.0°C	0	16.8-17.9°C	2.9	17.0-21.5°C
Alt. 4d	Maximum	2.2	19.2-22.2°C	7.6	19.9-21.4°C	Entire reach	20.1-21.8°C	Entire reach	20.3-24.2°C
	10% Exceedance	1.6	17.9-21.8°C	4.1	18.8-20.8°C	3.1	19.1-21.1°C	6.5	19.3-23.7°C
	25% Exceedance	1.6	17.4-20.7°C	0.5	18.4-20.2°C	0.3	18.7-20.2°C	6.1	19.0-23.5°C
	50% Exceedance	0	16.4-19.9°C	0	17.2-18.6°C	0	17.5-18.4°C	3.8	17.7-21.2°C

Notes: The State Water Board has determined that the Seneca Reach is not impaired for water temperature, therefore it is excluded from this table.

The length of the lower Belden Reach below East Branch = 1.6 miles.

The length of the lower Rock Creek Reach below Bucks Creek = 1.2 miles.

Table 7. Summary of mean daily water temperature profiles for different temperature control alternatives – August (from Stetson Engineers 2009)

		BELDEN REACH (REACH LENGTH = 8.8 MILES)		ROCK CREEK REACH (REACH LENGTH = 7.9 MILES)		CRESTA REACH (REACH LENGTH = 4.7 MILES)		POE REACH (REACH LENGTH = 7.5 MILES)	
ALT.	EXCEEDANCE LEVEL	REACH LENGTH THAT EXCEEDS 20°C (MILE)	TEMPERATURE RANGE ALONG THE REACH	REACH LENGTH THAT EXCEEDS 20°C (MILE)	TEMPERATURE RANGE ALONG THE REACH	REACH LENGTH THAT EXCEEDS 20°C (MILE)	TEMPERATURE RANGE ALONG THE REACH	REACH LENGTH THAT EXCEEDS 20°C (MILE)	TEMPERATURE RANGE ALONG THE REACH
Baseline	Maximum	Entire reach	22.8-23.8°C	Entire reach	23.0-23.3°C	Entire reach	22.9-23.2°C	Entire reach	23.1-24.9°C
	10% Exceedance	Entire reach	22.1-22.7°C	Entire reach	22.3-22.6°C	Entire reach	22.2-22.6°C	Entire reach	22.3-24.5°C
	25% Exceedance	Entire reach	21.7-22.0°C	Entire reach	21.8-22.2°C	Entire reach	21.8-22.3°C	Entire reach	21.9-24.2°C
	50% Exceedance	Entire reach	20.7-21.2°C	6.9	18.0-20.9°C	Entire reach	20.0-20.4°C	Entire reach	20.1-22.5°C
Alt. 3	Maximum	Entire reach	20.7-21.6°C	Entire reach	21.1-21.7°C	Entire reach	21.1-21.9°C	Entire reach	21.3-23.9°C
	10% Exceedance	1.6	19.6-21.1°C	Entire reach	20.0-20.9°C	Entire reach	20.1-21.2°C	Entire reach	20.3-23.4°C
	25% Exceedance	1.6	19.0-20.6°C	3.8	19.4-20.4°C	2.5	19.6-20.5°C	6.8	19.8-23.1°C
	50% Exceedance	0	18.2-19.8°C	0	17.2-19.1°C	0	18.2-18.8°C	3.3	18.3-21.5°C
Alt. 4a	Maximum	Entire reach	21.5-22.5°C	Entire reach	22.2-22.5°C	Entire reach	22.0-22.6°C	Entire reach	22.3-24.4°C
	10% Exceedance	Entire reach	20.6-21.5°C	Entire reach	20.0-21.6°C	Entire reach	21.0-21.8°C	Entire reach	21.1-23.8°C
	25% Exceedance	Entire reach	20.0-21.1°C	Entire reach	20.4-21.0°C	Entire reach	20.5-21.2°C	Entire reach	20.6-23.6°C
	50% Exceedance	1.6	19.1-20.2°C	0	17.6-19.7°C	0	18.8-19.3°C	4.3	18.9-21.9°C
Alt. 4b	Maximum	Entire reach	21.6-22.6°C	Entire reach	22.3-22.5°C	Entire reach	22.1-22.6°C	Entire reach	22.3-24.4°C
	10% Exceedance	Entire reach	20.6-21.5°C	Entire reach	21.0-21.6°C	Entire reach	21.1-21.9°C	Entire reach	21.2-23.8°C
	25% Exceedance	4.6	20.0-21.0°C	Entire reach	20.3-21.0°C	Entire reach	20.4-21.1°C	Entire reach	20.5-23.5°C
	50% Exceedance	1.6	19.0-20.2°C	0	17.5-19.6°C	0	18.8-19.3°C	4.2	18.9-21.8°C
Alt. 4c	Maximum	Entire reach	20.2-21.3°C	Entire reach	20.6-21.3°C	Entire reach	20.6-21.6°C	Entire reach	20.8-23.6°C
	10% Exceedance	1.6	19.1-20.9°C	5.3	19.5-20.6°C	3.3	19.6-20.9°C	6.8	19.7-23.1°C
	25% Exceedance	1.1	18.5-20.3°C	0	18.9-20.0°C	0.3	19.1-20.1°C	5.9	19.3-22.9°C
	50% Exceedance	0	17.8-19.6°C	0	17.0-18.8°C	0	17.9-18.6°C	3.3	18.0-21.4°C
Alt. 4d	Maximum	Entire reach	20.7-21.5°C	Entire reach	21.1-21.7°C	Entire reach	21.1-21.9°C	Entire reach	21.3-23.9°C
	10% Exceedance	1.6	19.1-20.9°C	5.3	19.5-20.6°C	3.3	19.6-20.9°C	6.8	19.8-23.1°C
	25% Exceedance	1.6	18.6-20.4°C	0.8	19.1-20.1°C	0.6	19.2-20.2°C	6.1	19.4-22.9°C
	50% Exceedance	0	17.9-19.6°C	0	17.0-18.9°C	0	18.0-18.6°C	3.3	18.1-21.4°C

Notes: The State Water Board has determined that the Seneca Reach is not impaired for water temperature; therefore, it is excluded from this table.
The length of the lower Belden Reach below East Branch = 1.6 miles.
The length of the lower Rock Creek Reach below Bucks Creek = 1.2 miles.

Table 8. Comparison of monthly (Jul, Aug, Sep) and annual MWAT (°C) in Belden Reach above East Branch Feather River (NF7) between temperature control alternatives (from Stetson Engineers 2009)

		BASELINE				PRESENT DAY				ALTERNATIVE 3				ALTERNATIVE 3X			
WY	**TYPE**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**
1984	W	19.6	19.7	19.4	19.7	19.4	19.6	19.4	19.6	17.3	17.6	17.8	17.8	16.3	17.7	18.6	18.6
1985	D	21.7	21.2	19.7	21.7	21.5	20.8	19.3	21.5	18.5	18.5	18.7	18.7	17.7	17.9	19.2	19.2
1986	W	20.6	20.8	20.2	20.8	20.5	20.7	20.3	20.7	17.6	18.5	18.5	18.5	17.0	18.4	19.4	19.4
1987	CD	20.5	20.4	19.3	20.5	18.9	19.7	18.7	19.7	17.2	18.2	18.0	18.2	16.0	17.6	18.7	18.7
1988	CD	23.1	22.9	22.3	23.1	22.6	21.9	21.6	22.6	19.8	20.6	20.2	20.6	15.6	20.1	21.7	21.7
1989	N	20.7	20.3	18.8	20.7	20.5	20.1	18.6	20.5	17.7	17.9	18.2	18.2	16.2	17.5	18.6	18.6
1990	CD	21.7	21.8	19.1	21.8	21.3	21.3	18.5	21.3	18.9	17.8	18.1	18.9	17.2	17.6	18.4	18.4
1991	CD	22.1	21.8	20.4	22.1	21.7	21.2	19.7	21.7	19.2	19.2	19.5	19.5	18.1	19.0	19.8	19.8
1992	CD	21.8	22.3	19.9	22.3	21.3	21.7	19.1	21.7	19.0	18.6	18.3	19.0	13.9	18.4	18.6	18.6
1993	W	21.3	21.6	21.2	21.6	21.2	21.5	21.1	21.5	18.2	19.1	19.4	19.4	17.7	19.1	20.2	20.2
1994	CD	22.2	22.1	20.4	22.2	21.7	21.5	19.7	21.7	19.3	19.1	19.3	19.3	16.4	18.8	19.7	19.7
1995	W	19.3	19.6	18.8	19.6	19.1	19.5	18.7	19.5	17.0	17.0	17.2	17.2	16.7	17.0	17.8	17.8
1996	W	20.2	20.6	19.6	20.6	20.0	20.6	19.6	20.6	17.5	18.1	17.6	18.1	16.7	17.9	18.4	18.4
1997	W	22.0	22.0	20.5	22.0	21.7	21.8	20.4	21.8	18.7	19.2	19.5	19.5	17.5	19.0	20.2	20.2
1998	W	20.2	21.3	21.2	21.3	20.0	21.2	21.1	21.2	18.0	18.5	18.0	18.5	17.6	18.7	19.5	19.5
1999	N	20.7	20.7	19.2	20.7	20.6	20.6	19.1	20.6	18.1	17.6	17.6	18.1	17.4	17.5	18.2	18.2
2000	N	21.6	21.6	18.0	21.6	21.5	21.5	18.0	21.5	18.3	17.9	18.2	18.3	17.7	17.4	18.6	18.6
2001	CD	22.6	23.0	21.9	23.0	21.8	22.3	21.1	22.3	19.6	20.6	19.7	20.6	18.2	20.1	20.0	20.1
2002	D	22.0	22.2	20.3	22.2	21.7	21.9	20.1	21.9	19.0	19.3	18.9	19.3	15.9	19.2	19.5	19.5
Mean		**21.3**	**21.4**	**20.0**	**21.4**	**20.9**	**21.0**	**19.7**	**21.2**	**18.4**	**18.6**	**18.6**	**18.8**	**16.8**	**18.4**	**19.2**	19.2

		ALTERNATIVE 4A				ALTERNATIVE 4B				ALTERNATIVE 4C				ALTERNATIVE 4D			
WY	**TYPE**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**
1984	W	17.8	17.9	17.9	17.9	17.7	18.2	18.4	18.4	16.7	18.5	19.7	19.7	16.9	18.4	19.5	19.5
1985	D	19.3	19.4	19.0	19.4	19.3	19.5	19.0	19.5	18.9	18.0	19.3	19.3	18.9	18.0	19.3	19.3
1986	W	18.1	18.9	18.7	18.9	18.2	19.0	19.1	19.1	18.2	19.4	20.5	20.5	18.3	19.4	20.1	20.1
1987	CD	18.6	19.3	18.0	19.3	17.6	18.9	18.7	18.9	16.0	17.6	18.9	18.9	16.4	17.5	18.2	18.2

		ALTERNATIVE 4A				**ALTERNATIVE 4B**				**ALTERNATIVE 4C**				**ALTERNATIVE 4D**			
WY	**TYPE**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**
1988	CD	21.2	21.3	20.4	21.3	20.9	21.5	21.4	21.5	15.6	20.1	21.8	21.8	17.5	20.3	21.2	21.2
1989	N	18.7	19.0	18.4	19.0	18.4	18.8	18.5	18.8	17.2	17.7	18.7	18.7	17.3	17.6	18.6	18.6
1990	CD	19.8	19.6	18.2	19.8	19.7	19.0	18.1	19.7	17.2	17.8	18.6	18.6	17.7	17.8	18.7	18.7
1991	CD	20.0	19.7	19.7	20.0	20.0	19.9	19.7	20.0	18.4	19.3	20.1	20.1	18.5	19.3	20.2	20.2
1992	CD	19.9	19.5	18.7	19.9	19.6	19.1	18.8	19.6	13.9	18.8	19.1	19.1	15.7	18.9	19.1	19.1
1993	W	18.7	19.5	19.6	19.6	18.8	19.8	19.9	19.9	19.2	20.1	21.1	21.1	19.2	19.9	21.2	21.2
1994	CD	20.4	19.7	19.4	20.4	20.2	19.8	19.5	20.2	16.4	18.9	19.9	19.9	17.7	18.9	19.8	19.8
1995	W	17.2	17.2	17.3	17.3	17.4	17.3	17.7	17.7	17.5	18.2	19.0	19.0	17.5	18.3	18.9	18.9
1996	W	18.1	18.6	18.0	18.6	17.9	18.9	18.6	18.9	17.7	19.0	19.3	19.3	17.9	18.8	19.1	19.1
1997	W	19.3	19.9	19.9	19.9	19.1	20.1	20.2	20.2	17.9	19.8	20.7	20.7	18.1	19.7	20.8	20.8
1998	W	18.3	18.8	18.2	18.8	18.5	19.1	19.1	19.1	18.2	20.3	21.3	21.3	18.3	20.2	21.0	21.0
1999	N	18.5	18.4	17.7	18.5	18.5	18.3	17.8	18.5	18.4	18.6	19.1	19.1	18.5	18.6	19.2	19.2
2000	N	18.8	18.8	18.5	18.8	19.2	18.9	18.5	19.2	19.2	18.8	18.7	19.2	19.2	18.8	18.7	19.2
2001	CD	20.6	21.5	20.9	21.5	20.5	21.5	20.9	21.5	18.3	20.2	20.1	20.2	18.6	20.2	20.1	20.2
2002	D	20.0	19.7	19.1	20.0	19.7	20.0	19.5	20.0	15.9	19.7	20.1	20.1	17.8	19.7	20.1	20.1
Mean		**19.1**	**19.3**	**18.8**	**19.4**	**19.0**	**19.3**	**19.1**	**19.5**	**17.4**	**19.0**	**19.8**	**19.8**	**17.9**	**19.0**	**19.7**	19.7

Table 9. Comparison of monthly (Jul, Aug, Sep) and annual MWAT (°C) in Rock Creek Reach above Bucks Creek (NF12) between temperature control alternatives (from Stetson Engineers 2009)

		BASELINE				PRESENT DAY				ALTERNATIVE 3				ALTERNATIVE 3X			
WY	TYPE	JUL	AUG	SEP	ANNUAL	JUL	AUG	SEP	ANNUAL	JUL	AUG	SEP	ANNUAL	JUL	AUG	SEP	ANNUAL
1984	W	20.3	20.1	19.7	20.3	20.2	20.0	19.6	20.2	18.7	18.4	18.2	18.7	18.1	18.6	19.0	19.0
1985	D	22.0	21.4	19.6	22.0	21.8	21.3	19.5	21.8	19.3	19.1	19.1	19.3	18.6	18.6	19.5	19.5
1986	W	20.9	21.0	20.4	21.0	20.8	20.9	20.5	20.9	18.8	19.0	18.8	19.0	18.3	19.0	19.7	19.7
1987	CD	21.4	20.3	19.3	21.4	20.1	20.1	19.2	20.1	19.9	19.0	18.6	19.9	18.5	18.4	19.3	19.3
1988	CD	23.2	22.9	22.2	23.2	23.0	22.3	22.1	23.0	21.0	21.3	20.7	21.3	18.2	20.9	22.2	22.2
1989	N	20.9	20.5	18.9	20.9	20.8	20.3	18.8	20.8	18.7	18.6	18.3	18.7	17.6	18.2	18.6	18.6
1990	CD	22.0	22.0	19.3	22.0	21.8	21.9	19.2	21.9	19.9	18.7	18.8	19.9	18.6	18.5	19.1	19.1
1991	CD	22.3	22.0	20.5	22.3	22.2	21.8	20.4	22.2	20.0	20.0	20.2	20.2	19.1	19.7	20.5	20.5
1992	CD	22.0	22.4	19.9	22.4	21.8	22.3	19.8	22.3	20.0	19.3	19.0	20.0	16.6	19.2	19.3	19.3
1993	W	21.4	21.7	21.3	21.7	21.4	21.6	21.3	21.6	19.2	19.6	19.6	19.6	18.8	19.6	20.4	20.4
1994	CD	22.3	22.1	20.4	22.3	22.1	22.0	20.3	22.1	20.2	19.8	19.9	20.2	18.4	19.5	20.3	20.3
1995	W	19.9	20.0	19.0	20.0	19.7	19.9	19.0	19.9	18.2	17.7	17.6	18.2	18.0	17.7	18.2	18.2
1996	W	20.9	21.0	19.6	21.0	20.7	21.0	19.6	21.0	18.9	18.8	17.9	18.9	18.2	18.6	18.5	18.6
1997	W	22.0	21.9	20.4	22.0	21.9	21.8	20.4	21.9	19.7	19.7	19.6	19.7	18.9	19.5	20.3	20.3
1998	W	20.8	21.4	21.4	21.4	20.6	21.3	21.3	21.3	19.2	19.1	18.4	19.2	18.9	19.3	19.8	19.8
1999	N	21.2	21.0	19.1	21.2	21.0	20.9	19.1	21.0	19.0	18.1	17.8	19.0	18.5	18.0	18.3	18.5
2000	N	21.6	21.6	18.1	21.6	21.6	21.6	18.1	21.6	19.1	18.3	18.6	19.1	18.6	17.8	18.9	18.9
2001	CD	22.4	22.9	21.6	22.9	22.2	22.7	21.5	22.7	20.4	21.1	19.9	21.1	19.2	20.7	20.1	20.7
2002	D	22.4	22.4	20.5	22.4	22.2	22.2	20.4	22.2	20.2	19.8	19.3	20.2	18.5	19.8	19.9	19.9
Mean		**21.6**	**21.5**	**20.1**	**21.7**	**21.4**	**21.4**	**20.0**	**21.5**	**19.5**	**19.2**	**19.0**	**19.6**	**18.4**	**19.0**	**19.6**	**19.6**

		ALTERNATIVE 4A				ALTERNATIVE 4B				ALTERNATIVE 4C				ALTERNATIVE 4D			
WY	TYPE	JUL	AUG	SEP	ANNUAL	JUL	AUG	SEP	ANNUAL	JUL	AUG	SEP	ANNUAL	JUL	AUG	SEP	ANNUAL
1984	W	19.0	18.7	18.4	19.0	19.0	18.9	18.8	19.0	18.3	19.2	19.9	19.9	18.4	19.0	19.7	19.7
1985	D	20.0	19.8	19.2	20.0	20.0	19.9	19.3	20.0	19.6	18.7	19.5	19.6	19.6	18.7	19.5	19.6
1986	W	19.1	19.3	19.0	19.3	19.1	19.4	19.4	19.4	19.2	19.8	20.7	20.7	19.2	19.8	20.3	20.3
1987	CD	20.1	20.1	18.6	20.1	19.7	19.5	19.3	19.7	18.5	18.4	19.4	19.4	18.7	18.3	18.8	18.8

		ALTERNATIVE 4A				ALTERNATIVE 4B				ALTERNATIVE 4C				ALTERNATIVE 4D			
WY	**TYPE**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**
1988	CD	21.9	21.9	20.9	21.9	21.7	22.1	22.0	22.1	18.2	20.9	22.3	22.3	19.2	21.0	21.7	21.7
1989	N	19.3	19.4	18.5	19.4	19.1	19.2	18.7	19.2	18.3	18.4	18.7	18.7	18.4	18.3	18.6	18.6
1990	CD	20.7	20.4	18.9	20.7	20.6	19.8	18.8	20.6	18.6	18.7	19.3	19.3	19.0	18.7	19.4	19.4
1991	CD	20.8	20.5	20.4	20.8	20.7	20.5	20.4	20.7	19.4	20.0	20.8	20.8	19.5	20.0	20.8	20.8
1992	CD	20.6	20.1	19.4	20.6	20.5	19.8	19.5	20.5	16.6	19.6	19.7	19.7	17.4	19.6	19.8	19.8
1993	W	19.5	20.0	19.8	20.0	19.6	20.2	20.1	20.2	19.9	20.5	21.2	21.2	19.9	20.3	21.3	21.3
1994	CD	21.1	20.3	20.1	21.1	20.9	20.4	20.1	20.9	18.4	19.6	20.5	20.5	19.0	19.7	20.5	20.5
1995	W	18.3	17.9	17.7	18.3	18.5	17.9	18.1	18.5	18.6	18.7	19.3	19.3	18.6	18.7	19.2	19.2
1996	W	19.4	19.2	18.2	19.4	19.2	19.4	18.7	19.4	18.9	19.5	19.3	19.5	19.0	19.3	19.1	19.3
1997	W	20.1	20.2	20.0	20.2	20.0	20.4	20.3	20.4	19.2	20.1	20.7	20.7	19.3	20.1	20.7	20.7
1998	W	19.4	19.3	18.6	19.4	19.5	19.5	19.6	19.6	19.3	20.6	21.4	21.4	19.4	20.5	21.2	21.2
1999	N	19.4	18.9	17.9	19.4	19.4	18.7	18.0	19.4	19.3	19.0	19.0	19.3	19.4	19.0	19.1	19.4
2000	N	19.5	19.0	18.9	19.5	19.8	19.1	18.9	19.8	19.8	19.1	19.1	19.8	19.8	19.0	19.1	19.8
2001	CD	21.2	22.0	21.3	22.0	21.1	22.0	21.3	22.0	19.3	20.9	20.2	20.9	19.5	20.8	20.2	20.8
2002	D	20.9	20.2	19.5	20.9	20.7	20.4	19.8	20.7	18.5	20.2	20.4	20.4	19.3	20.2	20.4	20.4
Mean		**20.0**	**19.9**	**19.2**	**20.1**	**20.0**	**19.8**	**19.5**	**20.1**	**18.8**	**19.6**	**20.1**	**20.2**	**19.1**	**19.5**	**20.0**	**20.1**

Table 10. Comparison of monthly (Jul, Aug, Sep) and annual MWAT (°C) in Cresta Reach above Cresta Powerhouse (NF16) between temperature control alternatives (from Stetson Engineers 2009)

		BASELINE				PRESENT DAY				ALTERNATIVE 3				ALTERNATIVE 3X			
WY	**TYPE**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**
1984	W	20.3	19.7	19.1	20.3	19.9	19.6	19.0	19.9	18.6	18.3	17.8	18.6	18.0	18.4	18.4	18.4
1985	D	22.0	21.5	19.0	22.0	21.9	21.3	18.9	21.9	19.4	19.2	18.6	19.4	18.8	18.8	18.9	18.9
1986	W	20.8	20.5	19.9	20.8	20.6	20.4	19.9	20.6	18.7	18.8	18.4	18.8	18.3	18.8	19.2	19.2
1987	CD	21.6	20.4	18.8	21.6	20.4	20.3	18.8	20.4	20.4	19.3	18.3	20.4	19.2	18.7	18.8	19.2
1988	CD	23.2	22.9	21.6	23.2	23.0	22.3	21.5	23.0	21.4	21.5	20.2	21.5	18.9	21.1	21.6	21.6
1989	N	20.5	19.8	18.0	20.5	20.3	19.7	17.9	20.3	18.5	18.2	17.5	18.5	17.5	17.9	17.7	17.9
1990	CD	22.0	22.0	18.8	22.0	21.8	21.9	18.7	21.9	20.2	18.8	18.4	20.2	19.1	18.6	18.6	19.1
1991	CD	22.3	21.9	19.9	22.3	22.2	21.8	19.9	22.2	20.4	20.0	19.8	20.4	19.6	19.8	20.1	20.1
1992	CD	21.9	22.4	19.4	22.4	21.8	22.3	19.3	22.3	20.3	19.5	18.6	20.3	17.4	19.3	18.8	19.3
1993	W	21.3	21.2	20.5	21.3	21.1	21.1	20.5	21.1	19.1	19.4	18.9	19.4	18.7	19.3	19.7	19.7
1994	CD	22.3	22.0	19.7	22.3	22.2	21.9	19.6	22.2	20.6	19.8	19.3	20.6	19.1	19.6	19.6	19.6
1995	W	19.9	19.8	18.5	19.9	19.6	19.7	18.5	19.7	18.2	17.6	17.3	18.2	18.0	17.6	17.8	18.0
1996	W	20.9	20.6	18.9	20.9	20.5	20.5	18.9	20.5	18.9	18.5	17.4	18.9	18.2	18.4	17.9	18.4
1997	W	21.7	21.2	19.5	21.7	21.5	21.1	19.5	21.5	19.5	19.3	18.8	19.5	18.8	19.2	19.4	19.4
1998	W	20.8	21.0	20.8	21.0	20.4	20.9	20.7	20.9	19.1	18.9	18.0	19.1	18.8	19.1	19.4	19.4
1999	N	21.0	20.7	18.4	21.0	20.7	20.6	18.4	20.7	18.9	17.9	17.2	18.9	18.4	17.8	17.5	18.4
2000	N	21.6	21.4	17.7	21.6	21.4	21.3	17.7	21.4	19.0	18.2	18.1	19.0	18.6	17.7	18.4	18.6
2001	CD	22.3	22.7	20.8	22.7	22.1	22.6	20.7	22.6	20.6	21.2	19.2	21.2	19.6	20.8	19.3	20.8
2002	D	22.5	22.4	20.0	22.5	22.3	22.2	19.9	22.3	20.4	19.9	18.9	20.4	18.9	19.8	19.4	19.8
Mean		**21.5**	**21.3**	**19.4**	**21.6**	**21.2**	**21.1**	**19.4**	**21.3**	**19.6**	**19.2**	**18.5**	**19.6**	**18.6**	**19.0**	**19.0**	**19.3**

		ALTERNATIVE 4A				ALTERNATIVE 4B				ALTERNATIVE 4C				ALTERNATIVE 4D			
WY	**TYPE**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**
1984	W	18.9	18.6	18.0	18.9	18.9	18.7	18.3	18.9	18.2	19.0	19.3	19.3	18.4	18.9	19.1	19.1
1985	D	20.1	19.9	18.6	20.1	20.1	20.0	18.6	20.1	19.8	18.9	19.0	19.8	19.7	18.8	18.9	19.7
1986	W	19.0	19.1	18.6	19.1	19.0	19.2	18.9	19.2	19.0	19.5	20.1	20.1	19.1	19.5	19.7	19.7
1987	CD	20.3	20.3	18.3	20.3	20.1	19.7	18.8	20.1	19.2	18.8	19.0	19.2	19.4	18.7	18.4	19.4

		ALTERNATIVE 4A				ALTERNATIVE 4B				ALTERNATIVE 4C				ALTERNATIVE 4D			
WY	TYPE	JUL	AUG	SEP	ANNUAL	JUL	AUG	SEP	ANNUAL	JUL	AUG	SEP	ANNUAL	JUL	AUG	SEP	ANNUAL
1988	CD	22.2	22.1	20.4	22.2	22.0	22.2	21.4	22.2	18.9	21.1	21.6	21.6	19.9	21.3	21.1	21.3
1989	N	19.0	18.9	17.6	19.0	18.9	18.8	17.8	18.9	18.1	18.0	17.8	18.1	18.2	18.0	17.7	18.2
1990	CD	20.9	20.5	18.4	20.9	20.8	19.9	18.4	20.8	19.1	18.8	18.8	19.1	19.4	18.8	18.8	19.4
1991	CD	21.0	20.5	20.0	21.0	20.9	20.5	20.0	20.9	19.9	20.1	20.4	20.4	19.9	20.1	20.4	20.4
1992	CD	20.9	20.1	19.0	20.9	20.7	19.7	19.0	20.7	17.4	19.7	19.2	19.7	18.1	19.7	19.2	19.7
1993	W	19.4	19.7	19.1	19.7	19.5	19.8	19.5	19.8	19.7	20.1	20.4	20.4	19.7	20.0	20.5	20.5
1994	CD	21.3	20.3	19.4	21.3	21.1	20.3	19.5	21.1	19.1	19.7	19.8	19.8	19.5	19.7	19.8	19.8
1995	W	18.3	17.8	17.4	18.3	18.5	17.8	17.8	18.5	18.5	18.5	18.8	18.8	18.5	18.6	18.7	18.7
1996	W	19.3	18.9	17.6	19.3	19.2	19.1	18.0	19.2	18.9	19.2	18.5	19.2	19.0	19.1	18.3	19.1
1997	W	19.9	19.7	19.1	19.9	19.7	19.8	19.4	19.8	19.0	19.7	19.7	19.7	19.2	19.6	19.8	19.8
1998	W	19.3	19.1	18.1	19.3	19.4	19.3	19.1	19.4	19.2	20.3	20.8	20.8	19.3	20.2	20.6	20.6
1999	N	19.2	18.7	17.4	19.2	19.2	18.5	17.5	19.2	19.1	18.6	18.1	19.1	19.2	18.7	18.1	19.2
2000	N	19.4	18.8	18.4	19.4	19.7	18.9	18.4	19.7	19.7	18.9	18.5	19.7	19.7	18.8	18.5	19.7
2001	CD	21.3	22.0	20.5	22.0	21.1	22.0	20.6	22.0	19.7	21.0	19.4	21.0	19.8	21.0	19.4	21.0
2002	D	21.1	20.3	19.0	21.1	20.9	20.5	19.4	20.9	18.9	20.3	19.9	20.3	19.6	20.3	19.9	20.3
Mean		**20.0**	**19.8**	**18.7**	**20.1**	**20.0**	**19.7**	**19.0**	**20.1**	**19.0**	**19.5**	**19.4**	**19.8**	**19.2**	**19.5**	**19.3**	**19.8**

Table 11. Comparison of monthly (Jul, Aug, Sep) and annual MWAT (°C) in Poe Reach above Poe Powerhouse (NF18) between temperature control alternatives (from Stetson Engineers 2009)

		BASELINE				PRESENT DAY				ALTERNATIVE 3				ALTERNATIVE 3X			
WY	**TYPE**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**
1984	W	22.5	21.8	21.1	22.5	22.4	21.9	21.1	22.4	21.5	20.8	20.1	21.5	21.2	20.8	20.8	21.2
1985	D	23.8	23.2	20.7	23.8	23.8	23.1	20.6	23.8	21.7	21.1	20.2	21.7	21.3	20.8	20.4	21.3
1986	W	22.9	22.6	21.9	22.9	22.8	22.5	22.0	22.8	21.6	21.2	20.5	21.6	21.4	21.2	21.5	21.5
1987	CD	23.8	22.8	20.4	23.8	22.6	22.6	20.4	22.6	22.8	21.1	20.0	22.8	21.8	20.7	20.4	21.8
1988	CD	25.0	24.8	23.3	25.0	24.9	24.1	23.3	24.9	23.7	23.5	22.0	23.7	21.7	23.2	23.3	23.3
1989	N	22.4	21.8	20.0	22.4	22.3	21.7	20.0	22.3	21.0	20.3	19.6	21.0	20.5	20.1	19.8	20.5
1990	CD	23.9	23.8	20.6	23.9	23.8	23.7	20.6	23.8	22.5	20.5	20.3	22.5	21.7	20.3	20.5	21.7
1991	CD	24.1	23.7	21.7	24.1	24.0	23.6	21.7	24.0	22.6	21.8	21.5	22.6	22.0	21.6	21.8	22.0
1992	CD	23.8	24.2	20.9	24.2	23.7	24.1	20.9	24.1	22.6	21.1	20.3	22.6	19.6	21.0	20.4	21.0
1993	W	23.5	23.5	22.5	23.5	23.5	23.5	22.5	23.5	22.2	21.9	20.9	22.2	22.0	21.9	21.8	22.0
1994	CD	24.1	23.9	21.5	24.1	24.0	23.8	21.4	24.0	22.8	21.6	21.2	22.8	21.8	21.4	21.4	21.8
1995	W	22.3	21.8	20.3	22.3	22.2	21.8	20.3	22.2	21.3	19.9	19.2	21.3	21.2	19.9	20.0	21.2
1996	W	23.1	22.8	21.0	23.1	22.8	22.8	21.0	22.8	21.6	21.0	19.5	21.6	21.2	21.0	19.8	21.2
1997	W	24.1	23.5	21.5	24.1	24.0	23.5	21.5	24.0	22.2	21.5	20.8	22.2	21.7	21.5	21.4	21.7
1998	W	23.3	23.2	22.8	23.3	23.3	23.2	22.7	23.3	22.5	21.9	20.1	22.5	22.3	22.0	21.9	22.3
1999	N	23.3	22.5	19.9	23.3	23.2	22.4	19.9	23.2	22.1	20.0	19.4	22.1	21.8	19.9	19.7	21.8
2000	N	23.9	23.7	18.7	23.9	23.8	23.7	18.7	23.8	22.5	19.9	19.9	22.5	22.2	19.2	20.4	22.2
2001	CD	24.2	24.6	22.6	24.6	23.9	24.5	22.5	24.5	22.7	23.1	21.0	23.1	22.0	22.8	21.1	22.8
2002	D	24.4	24.2	21.9	24.4	24.3	24.1	21.8	24.3	23.2	22.1	20.6	23.2	22.4	22.0	21.0	22.4
Mean		**23.6**	**23.3**	**21.2**	**23.6**	**23.4**	**23.2**	**21.2**	**23.5**	**22.3**	**21.3**	**20.4**	**22.3**	**21.6**	**21.1**	**20.9**	**21.8**

		ALTERNATIVE 4A				ALTERNATIVE 4B				ALTERNATIVE 4C				ALTERNATIVE 4D			
WY	**TYPE**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**
1984	W	21.7	20.9	20.2	21.7	21.7	21.0	20.7	21.7	21.3	21.2	21.3	21.3	21.4	21.1	21.0	21.4
1985	D	22.1	21.8	20.5	22.1	22.2	21.9	20.5	22.2	22.0	20.9	20.5	22.0	21.9	20.8	20.5	21.9
1986	W	21.8	21.4	20.6	21.8	21.9	21.4	21.2	21.9	21.9	21.6	22.1	22.1	21.9	21.6	21.5	21.9
1987	CD	22.5	22.8	20.0	22.8	22.3	21.5	20.4	22.3	21.8	20.7	20.5	21.8	21.9	20.7	20.0	21.9

		ALTERNATIVE 4A				ALTERNATIVE 4B				ALTERNATIVE 4C				ALTERNATIVE 4D			
WY	**TYPE**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**	**JUL**	**AUG**	**SEP**	**ANNUAL**
1988	CD	24.3	23.9	22.2	24.3	24.2	24.0	23.2	24.2	21.7	23.2	23.4	23.4	22.6	23.3	22.8	23.3
1989	N	21.3	21.2	19.7	21.3	21.2	20.7	19.9	21.2	21.0	20.2	19.8	21.0	21.0	20.1	19.7	21.0
1990	CD	23.0	22.4	20.3	23.0	23.0	21.5	20.2	23.0	21.7	20.5	20.6	21.7	21.9	20.5	20.7	21.9
1991	CD	23.1	22.1	21.8	23.1	23.0	22.4	21.7	23.0	22.2	21.8	22.0	22.2	22.2	21.8	22.0	22.2
1992	CD	23.0	22.1	20.6	23.0	22.9	21.5	20.7	22.9	19.6	21.3	20.7	21.3	20.9	21.3	20.8	21.3
1993	W	22.4	22.1	21.0	22.4	22.5	22.2	21.6	22.5	22.6	22.4	22.3	22.6	22.6	22.3	22.3	22.6
1994	CD	23.4	22.0	21.3	23.4	23.2	22.1	21.3	23.2	21.8	21.5	21.5	21.8	22.0	21.5	21.5	22.0
1995	W	21.4	20.0	19.3	21.4	21.5	20.0	19.9	21.5	21.5	20.5	20.7	21.5	21.5	20.5	20.5	21.5
1996	W	21.9	21.3	19.6	21.9	21.8	21.4	19.9	21.8	21.6	21.4	20.2	21.6	21.6	21.4	20.1	21.6
1997	W	22.4	21.8	21.0	22.4	22.3	21.9	21.4	22.3	21.9	21.8	21.7	21.9	22.0	21.8	21.7	22.0
1998	W	22.6	22.1	20.2	22.6	22.7	22.2	21.7	22.7	22.6	22.8	22.7	22.8	22.6	22.7	22.3	22.7
1999	N	22.3	20.8	19.3	22.3	22.3	20.4	19.3	22.3	22.3	20.4	20.0	22.3	22.3	20.4	20.0	22.3
2000	N	22.7	20.8	20.3	22.7	22.9	21.5	20.3	22.9	22.7	21.5	20.4	22.7	22.8	21.6	20.4	22.8
2001	CD	23.3	23.8	22.4	23.8	23.2	23.8	22.5	23.8	22.0	22.9	21.2	22.9	22.2	22.9	21.2	22.9
2002	D	23.7	22.3	20.7	23.7	23.4	22.4	21.2	23.4	22.4	22.3	21.3	22.4	22.6	22.3	21.3	22.6
Mean		**22.6**	**21.9**	**20.6**	**22.6**	**22.5**	**21.8**	**20.9**	**22.6**	**21.8**	**21.5**	**21.2**	**22.1**	**22.0**	**21.5**	**21.1**	**22.1**

Table 12. Fish stocking records for Lake Almanor, 2001 and 2011.

		YEAR											
Species	**Size**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Total**
Brown Trout	Catchable	64,100	44,240	59,000	32,860	19,200	39,000	38,000	41,600	62,670	57,195	30,400	**488,265**
	Subcatchable	0	0	0	0	0	0	0	0	0	21,350	0	**21,350**
	Fingerling	0	0	0	0	0	0	0	0	0	0	0	**0**
	Subtotal	**64,100**	**44,240**	**59,000**	**32,860**	**19,200**	**39,000**	**38,000**	**41,600**	**62,670**	**78,545**	**30,400**	**509,615**
Chinook Salmon	Catchable	0	0	0	0	0	0	0	0	0	0	0	**0**
	Subcatchable	0	0	0	0	0	0	0	0	0	0	0	**0**
	Fingerling	163,800	100,008	0	176,100	60,420	43,560	60,270	59,994	33,792	60,000	65,030	**822,974**
	Subtotal	**163,800**	**100,008**	**0**	**176,100**	**60,420**	**43,560**	**60,270**	**59,994**	**33,792**	**60,000**	**65,030**	**822,974**
Eagle Lake Rainbow Trout	Catchable	95,600	36,400	40,055	55,460	70,800	35,400	56,100	65,960	54,690	57,750	52,400	**620,615**
	Subcatchable	0	50,556	36,875	49,781	50,295	50,229	49,992	50,400	49,970	49,979	34,450	**472,527**
	Fingerling	0	0	14,410	0	0	0	0	0	0	0	0	**14,410**
	Subtotal	95,600	86,956	91,340	105,241	121,095	85,629	106,092	116,360	104,660	107,729	86,850	**1,107,552**
Rainbow Trout (var)	Catchable	0	0	0	0	0	0	0	0	0	24,047	0	**24,047**
	Subcatchable	0	0	0	0	0	0	0	0	0	0	0	**0**
	Fingerling	0	0	0	0	0	0	0	0	0	0	0	**0**
	Subtotal										**24,047**		**24,047**
TOTAL		**323,500**	**231,204**	**150,340**	**314,201**	**200,715**	**168,189**	**204,362**	**217,954**	**201,122**	**270,321**	**182,280**	**2,464,188**

Source: Linda Radford, California Department of Fish and Game, Statewide Hatchery Database – Provisional data, which subject to change

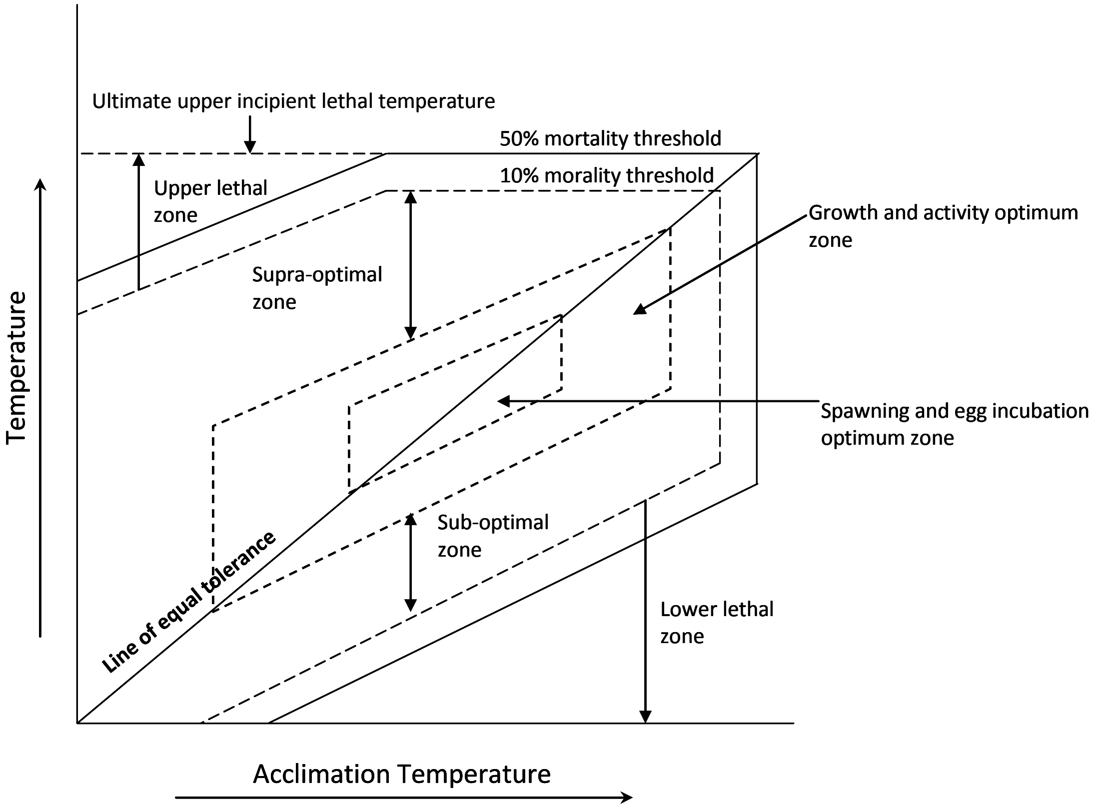
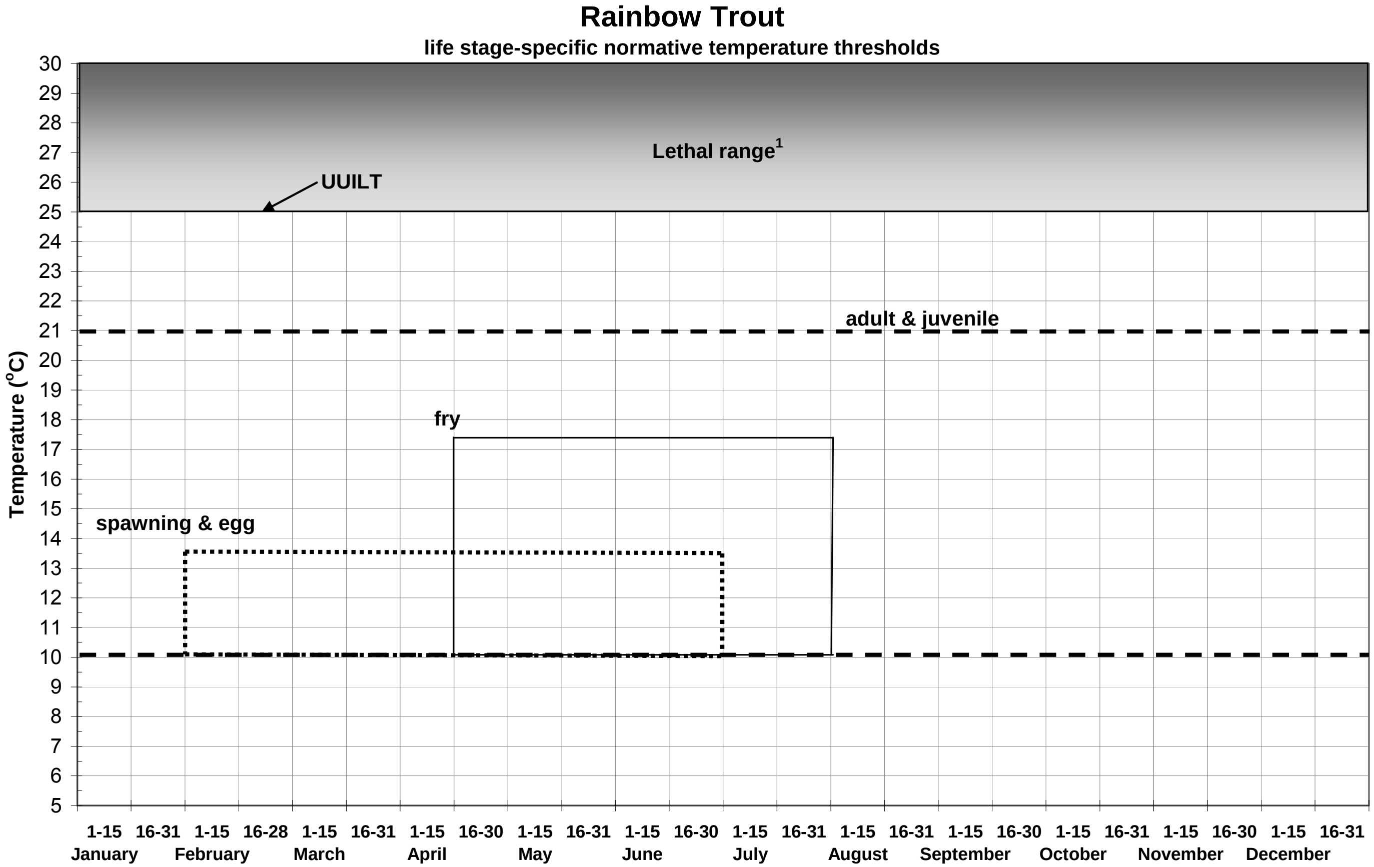


Figure 1. Typical relationships for fish between the zones of thermal optima for various life cycle activities and sublethal and lethal temperatures for fish relative to acclimation temperature. Note that normal reproduction occurs within a narrow range of temperatures compared to the optimal range of temperatures for rearing and growing fish (adapted from Brett 1960, as cited in Armour 1991).



1 Range between ultimate upper incipient lethal temperature and critical thermal maximum

Sources: Moyle 2002; Bjornn and Reiser 1991; U.S. Environmental Protection Agency 1999; Myrick 1998; Myrick and Cech 2000

Figure 2. Typical life cycle timing for rainbow trout in streams draining the west slope of the Sierra Nevada, with temperature requirements derived from the literature (temperature requirement data used are from Leitritz and Lewis 1976, Piper et al. 1982, Wixom 1989, Bell 1990, Bjornn and Reiser 1991, McCullough 1999, Myrick and Cech 2000a, Moyle 2002).

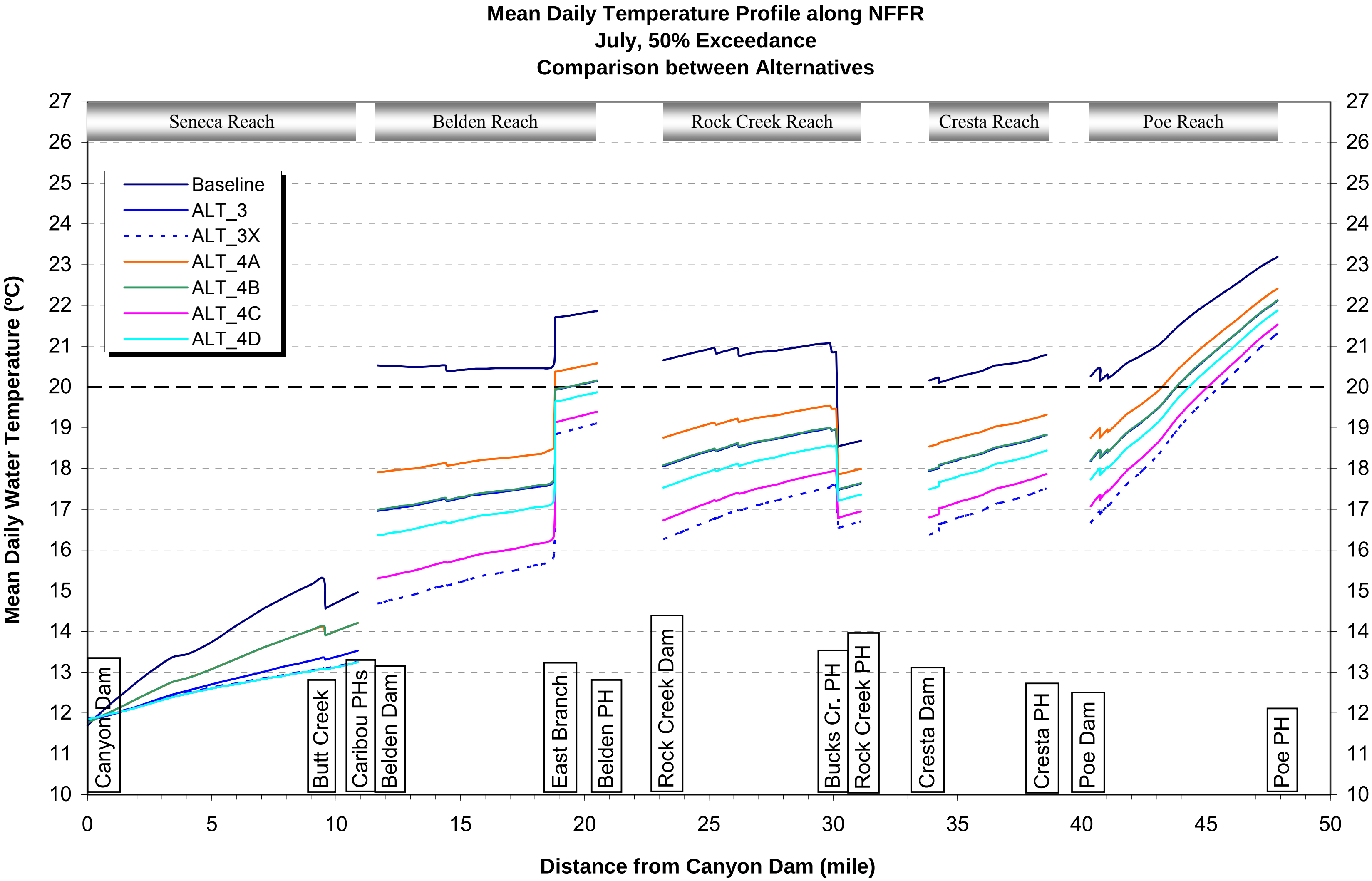


Figure 3. Comparison of NFFR water temperature longitudinal profiles between alternatives — July, 50% exceedance (from Stetson Engineers 2009). (Note: The added Alternative 4D is similar to Alternative 4C, except that the measure of preferential use of Caribou #1 is changed to installation of thermal curtain near Caribou Intake)

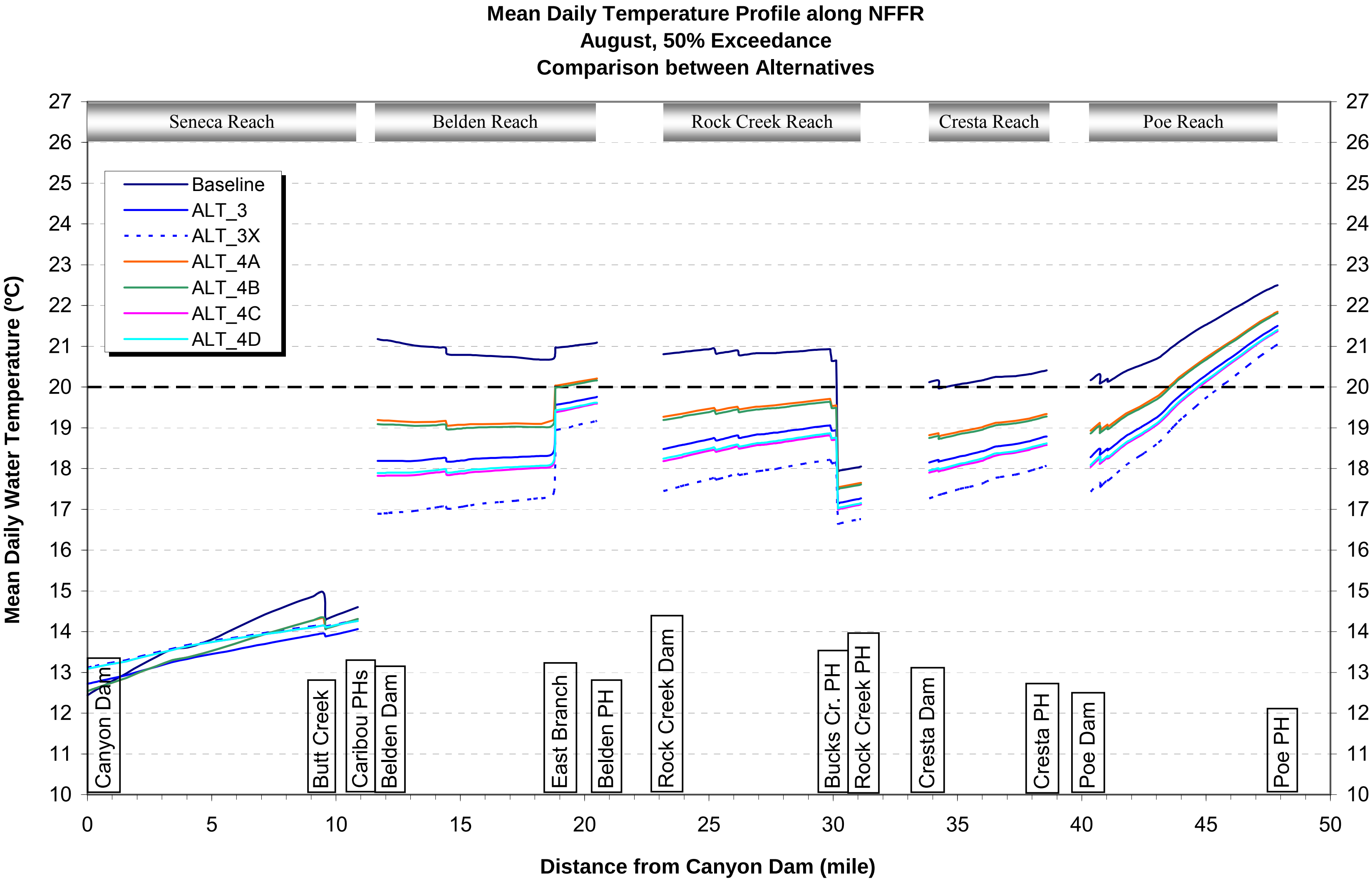


Figure 4. Comparison of NFFR water temperature longitudinal profiles between alternatives — August, 50% exceedance (from Stetson Engineers 2009).

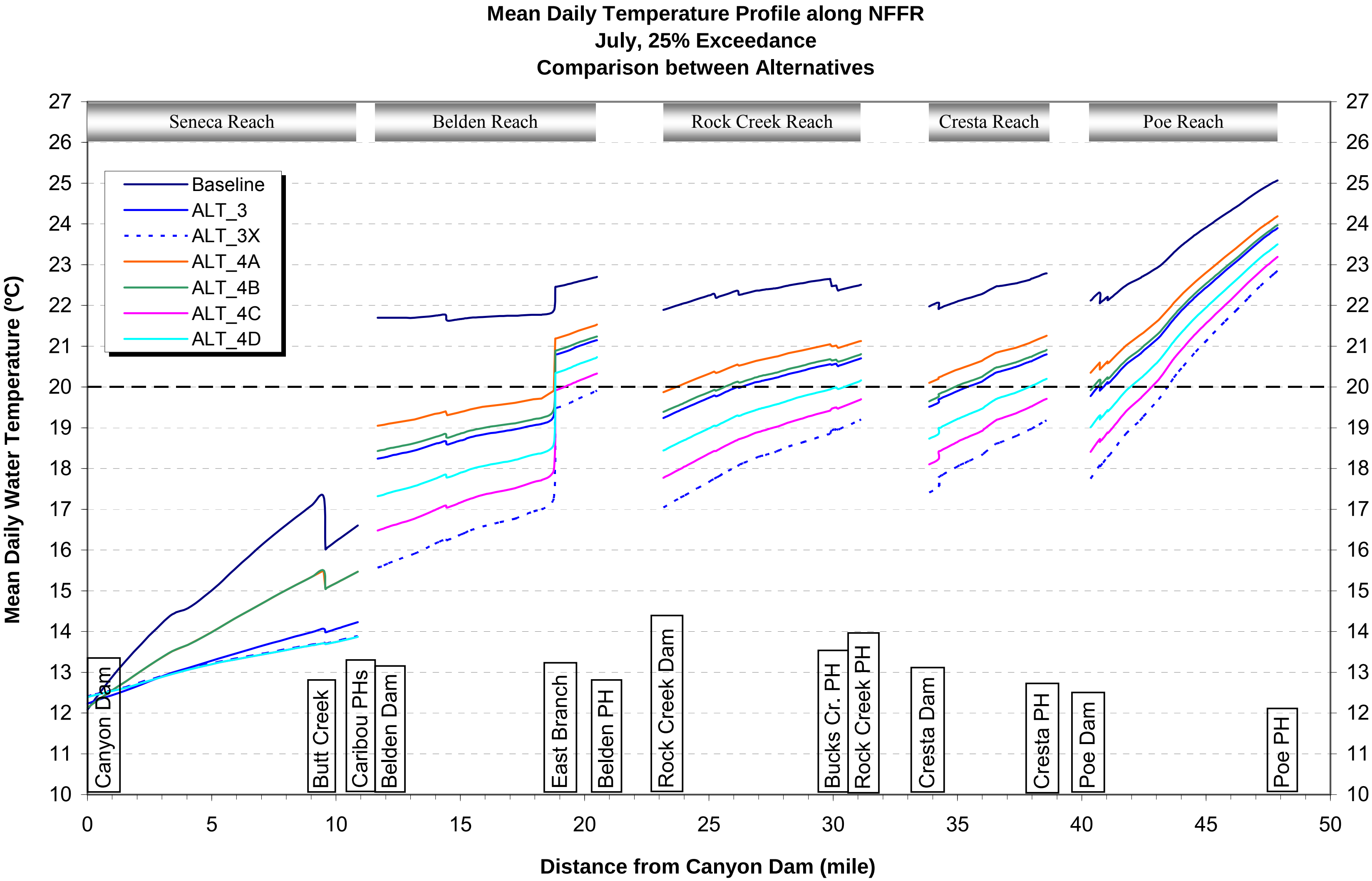


Figure 5. **Comparison of NFFR water temperature longitudinal profiles between alternatives — July, 25% exceedance (from Stetson Engineers 2009).**

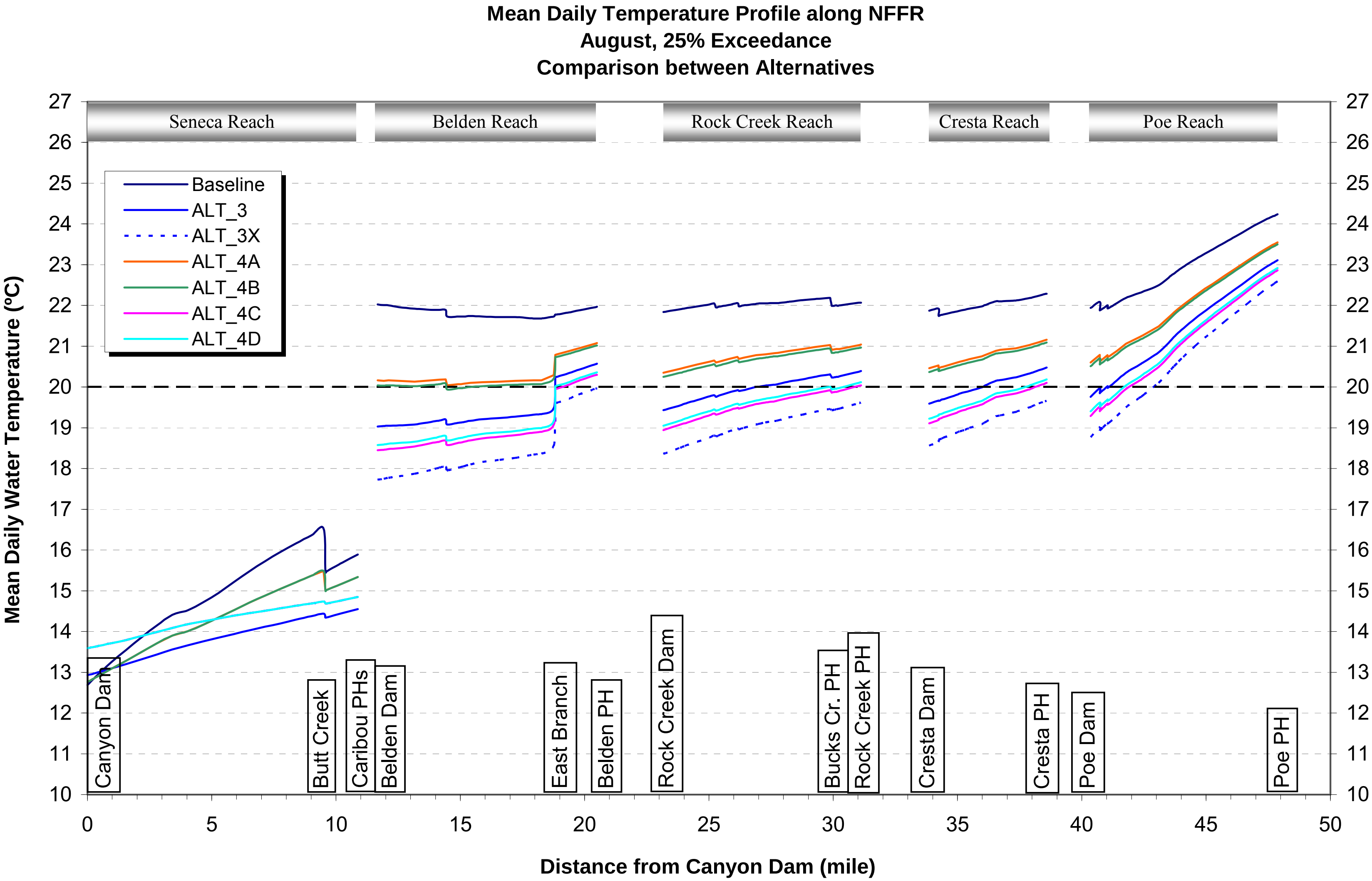


Figure 6. Comparison of NFFR water temperature longitudinal profiles between alternatives — August, 25% exceedance (from Stetson Engineers 2009).

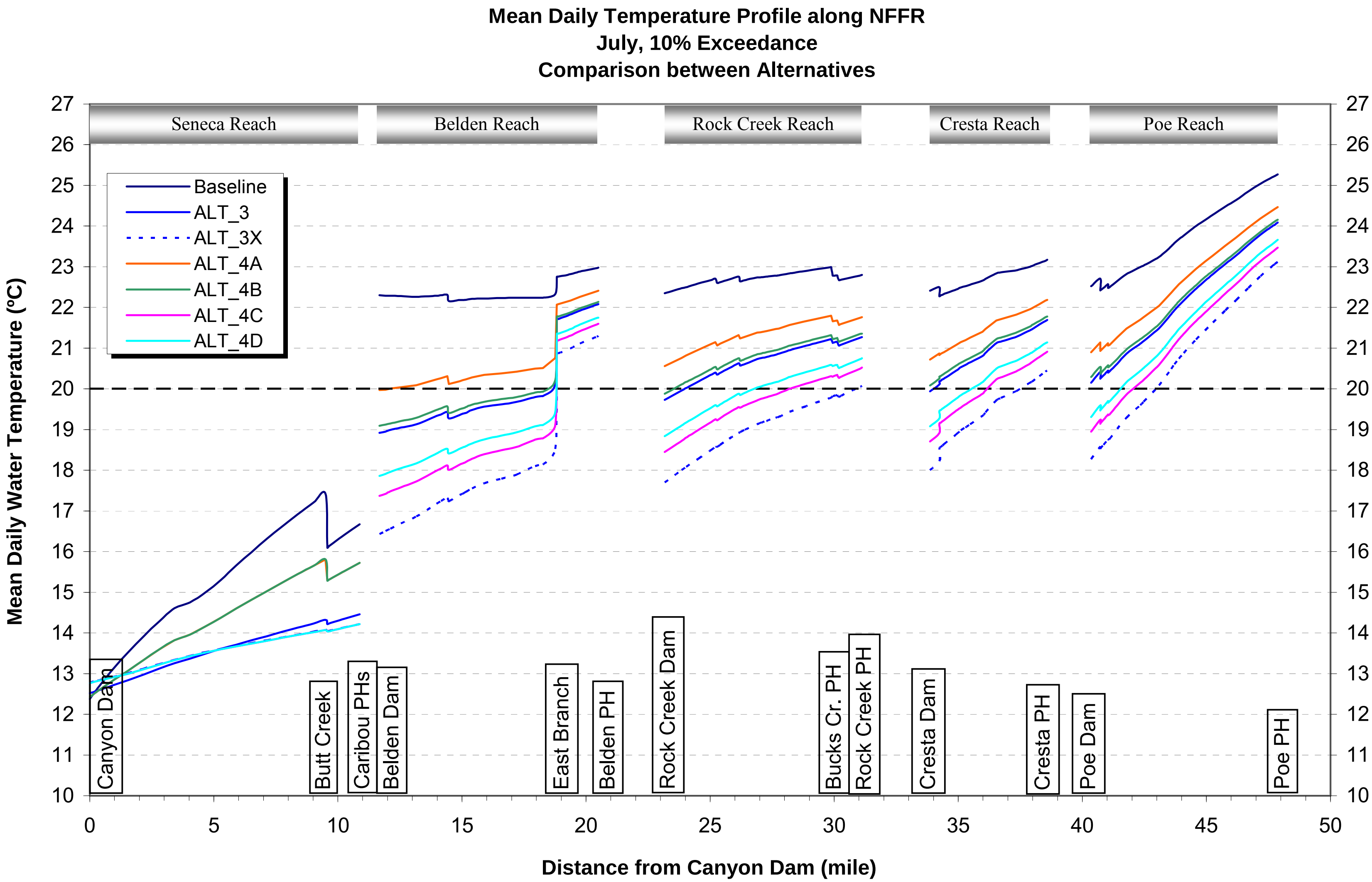


Figure 7. Comparison of NFFR water temperature longitudinal profiles between alternatives — July, 10% exceedance (from Stetson Engineers 2009).

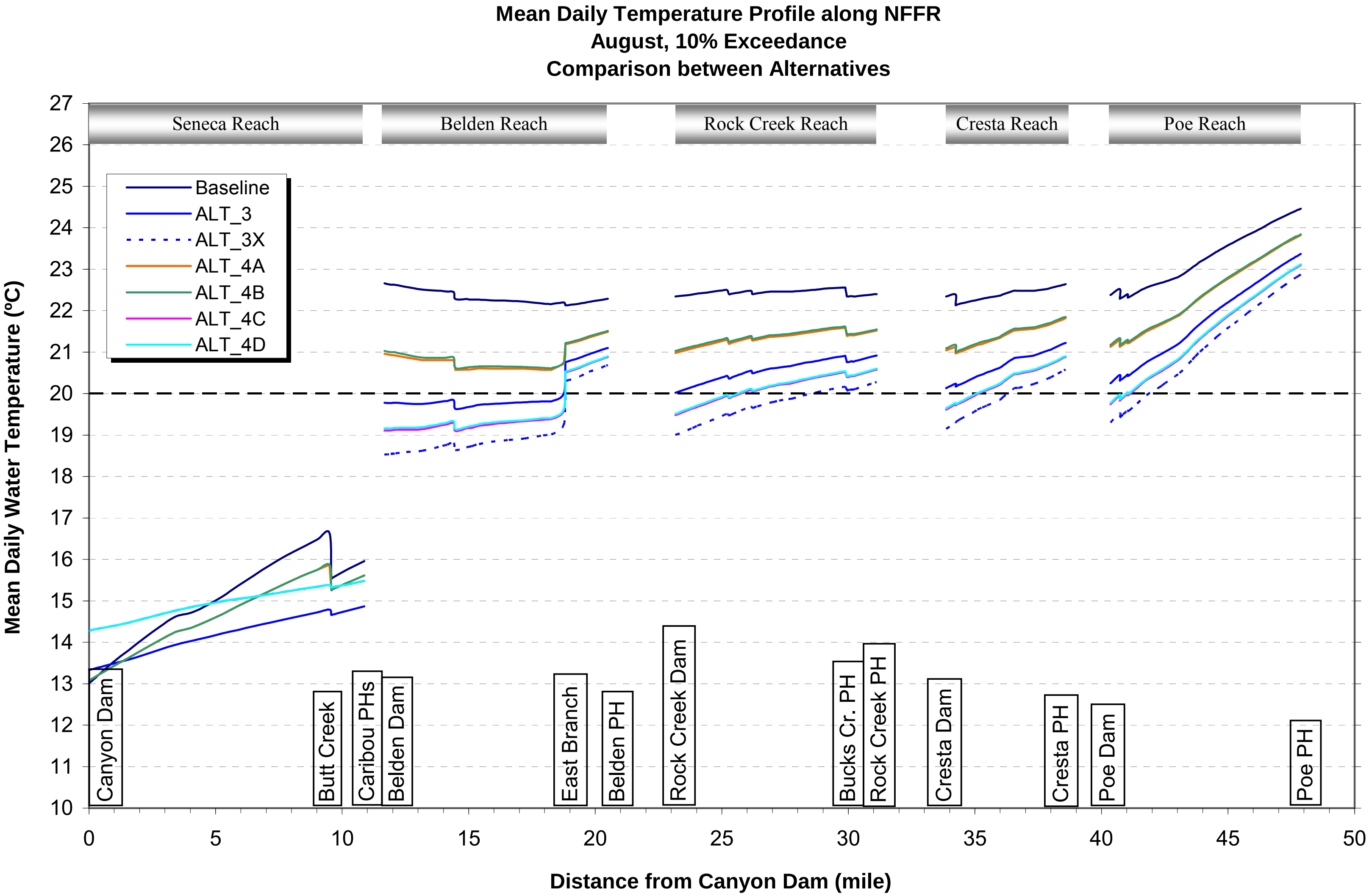


Figure 8. **Comparison of NFFR water temperature longitudinal profiles between alternatives — August, 10% exceedance (from Stetson Engineers 2009).**

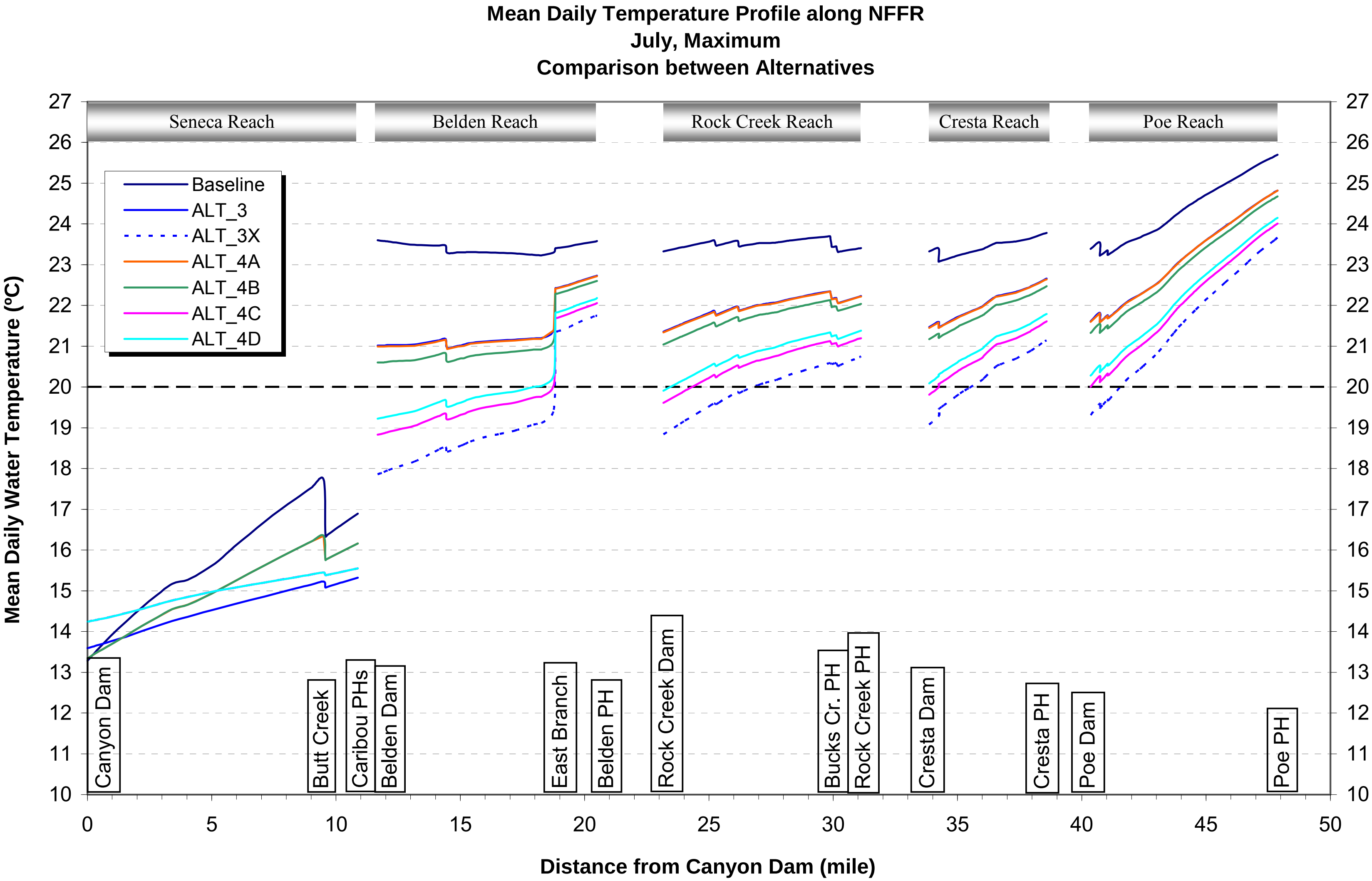


Figure 9. Comparison of NFFR water temperature longitudinal profiles between alternatives — July, maximum (from Stetson Engineers 2009).

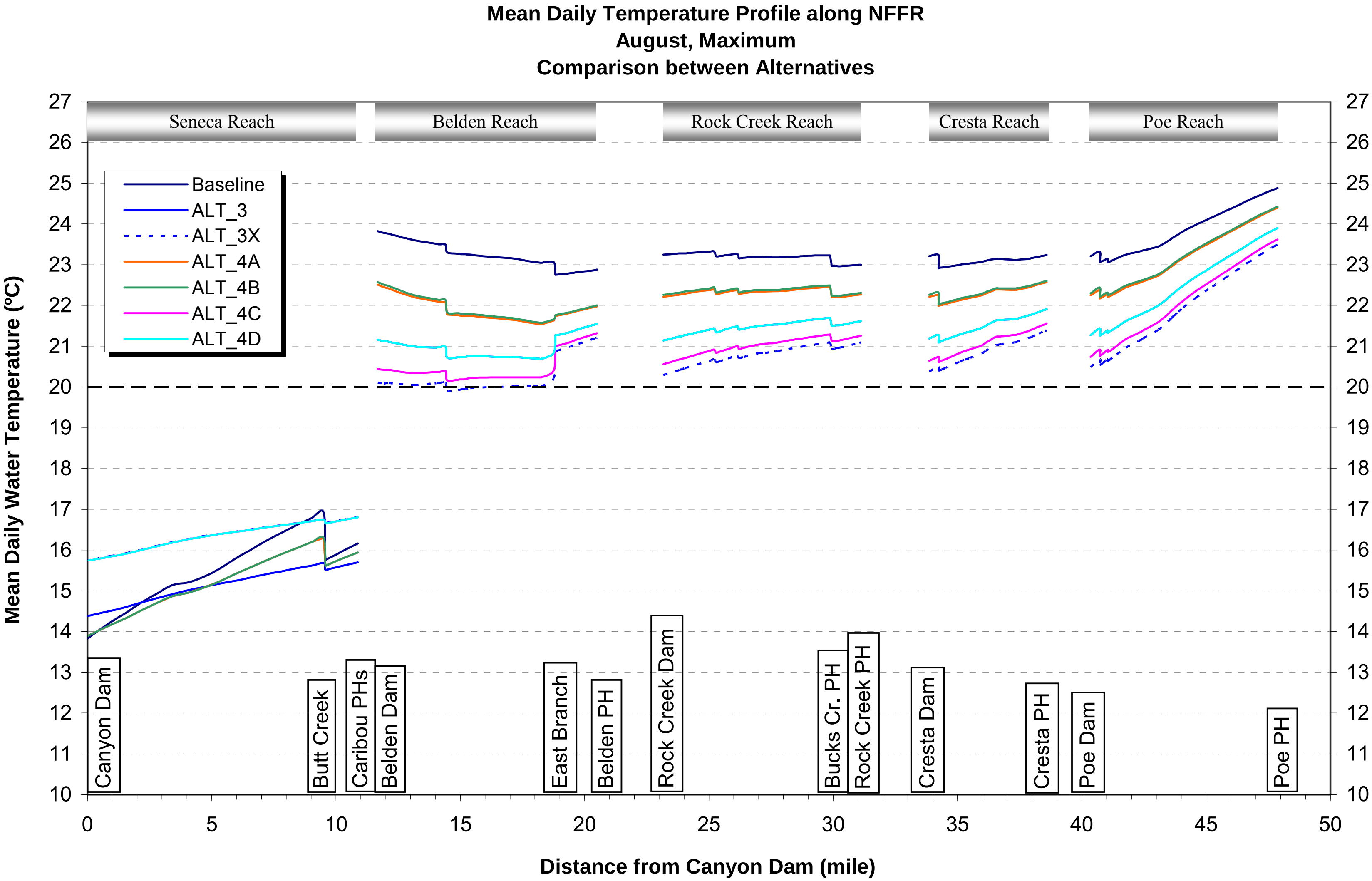
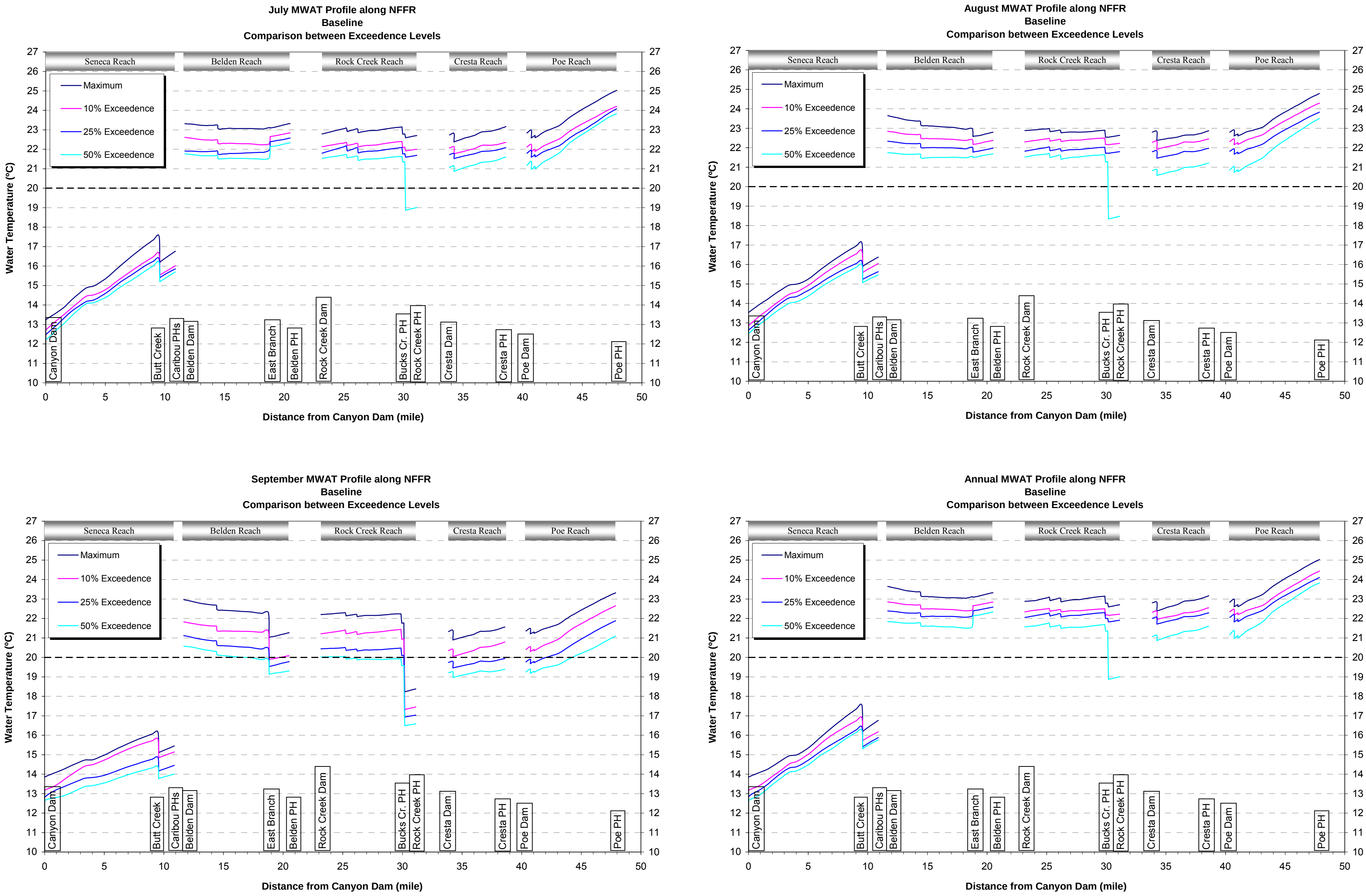


Figure 10. Comparison of NFFR water temperature longitudinal profiles between alternatives — August, maximum (from Stetson Engineers 2009).



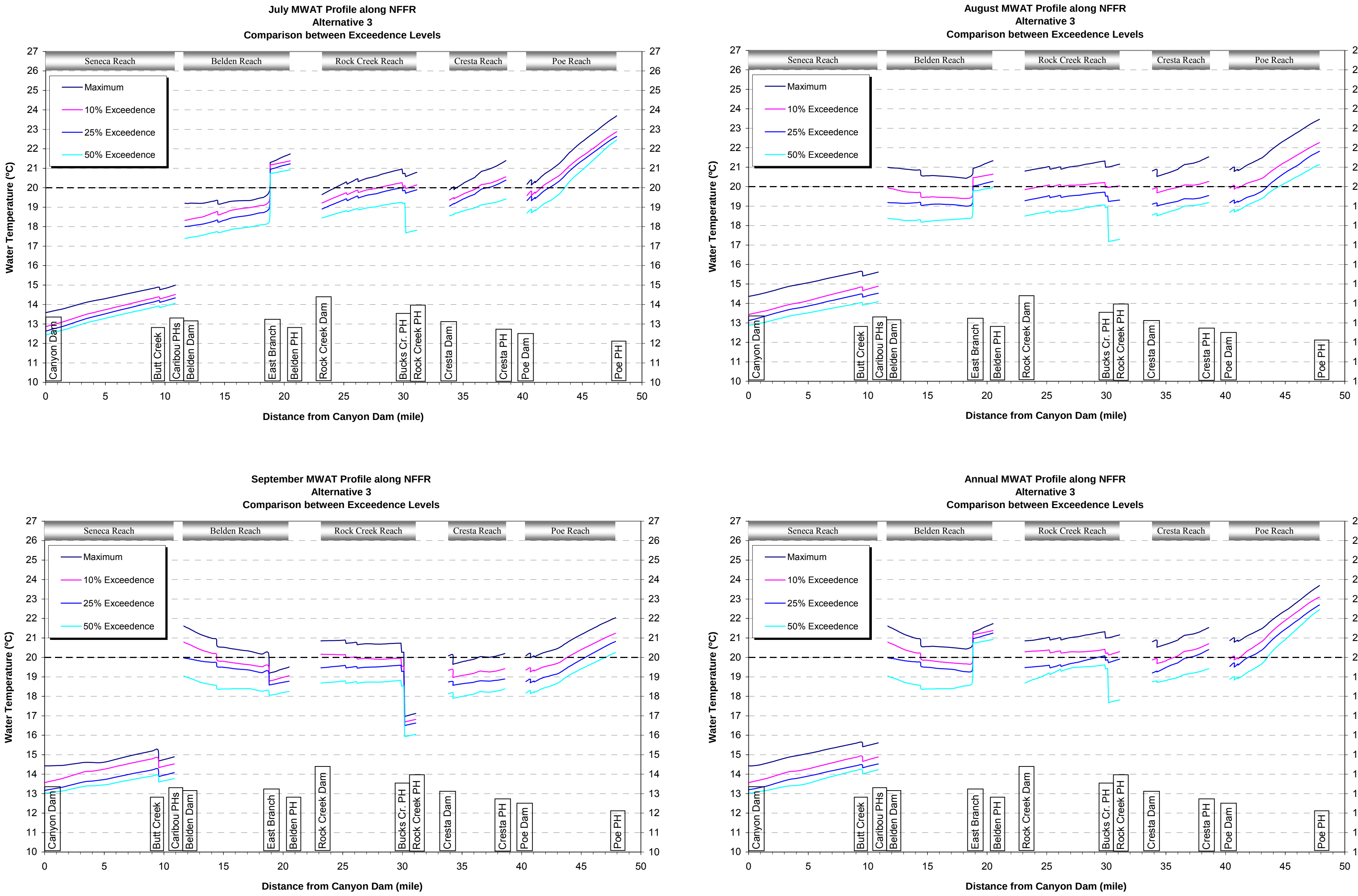
July MWAT Profile along NFFR
Baseline
Comparison between Exceedence Levels

August MWAT Profile along NFFR
Baseline
Comparison between Exceedence Levels

September MWAT Profile along NFFR
Baseline
Comparison between Exceedence Levels

Annual MWAT Profile along NFFR
Baseline
Comparison between Exceedence Levels

Figure 11. Monthly (July, Aug, Sep) and annual MWAT profiles along NFFR – Baseline (from Stetson Engineers 2009).


July MWAT Profile along NFFR
Alternative 3
Comparison between Exceedence Levels

August MWAT Profile along NFFR
Alternative 3
Comparison between Exceedence Levels

September MWAT Profile along NFFR
Alternative 3
Comparison between Exceedence Levels

Annual MWAT Profile along NFFR
Alternative 3
Comparison between Exceedence Levels

Figure 12. Monthly (July, Aug, Sep) and annual MWAT profiles along NFFR – Alternative 3 (from Stetson Engineers 2009).

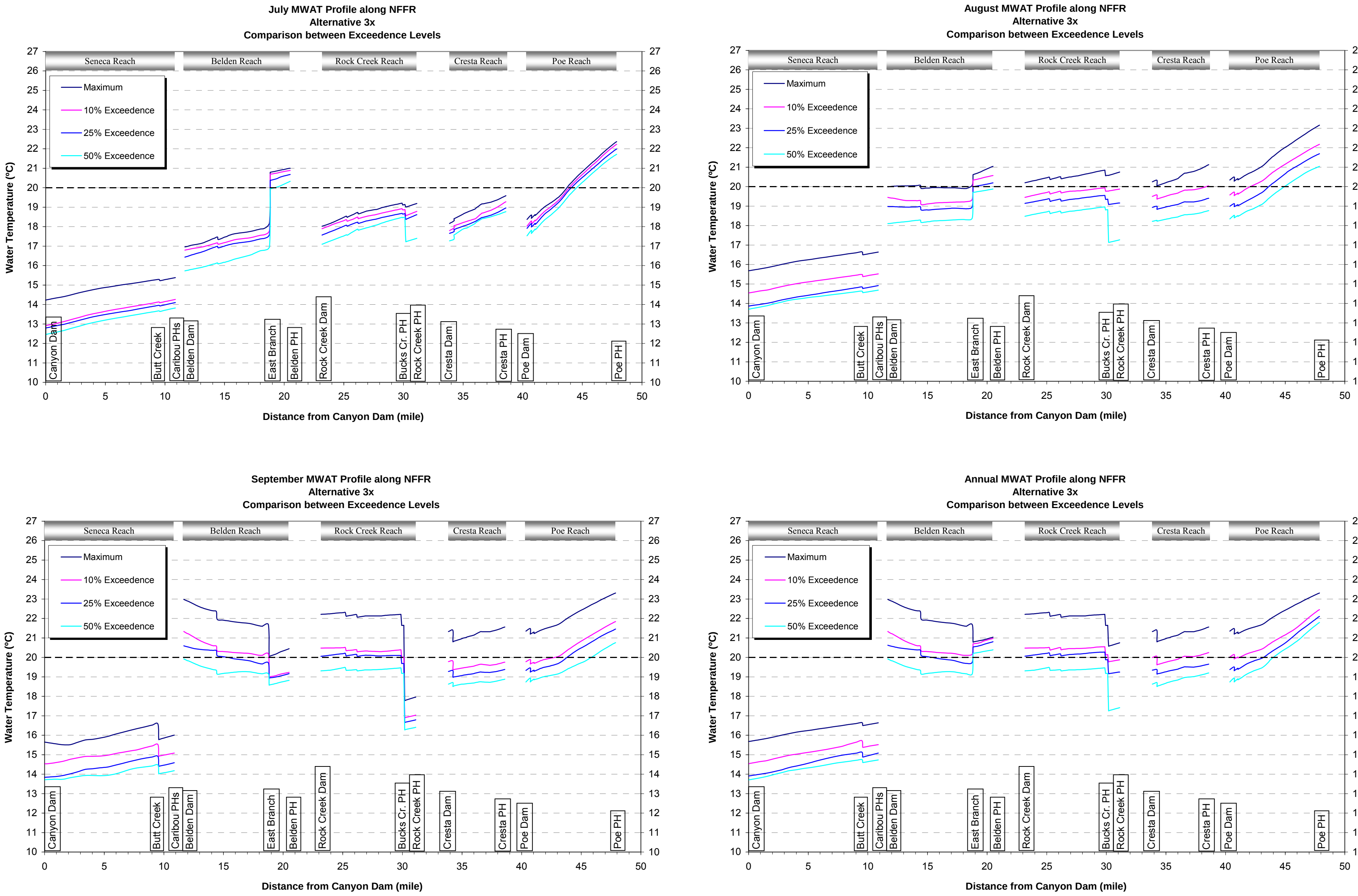


Figure 13. Monthly (July, Aug, Sep) and annual MWAT profiles along NFFR – Alternative 3x (from Stetson Engineers 2009).

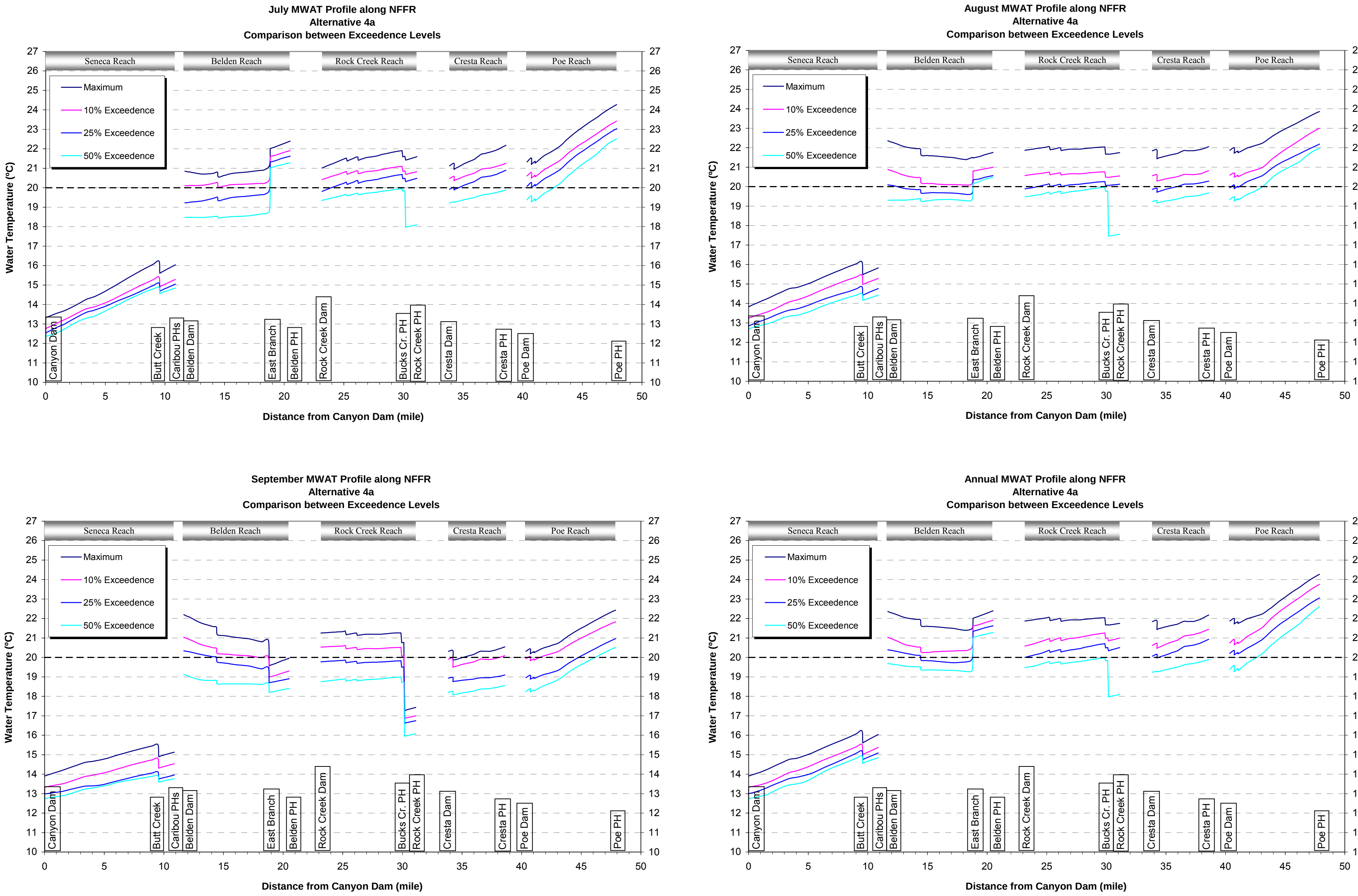


Figure 14. Monthly (July, Aug, Sep) and annual MWAT profiles along NFFR – Alternative 4a (from Stetson Engineers 2009).

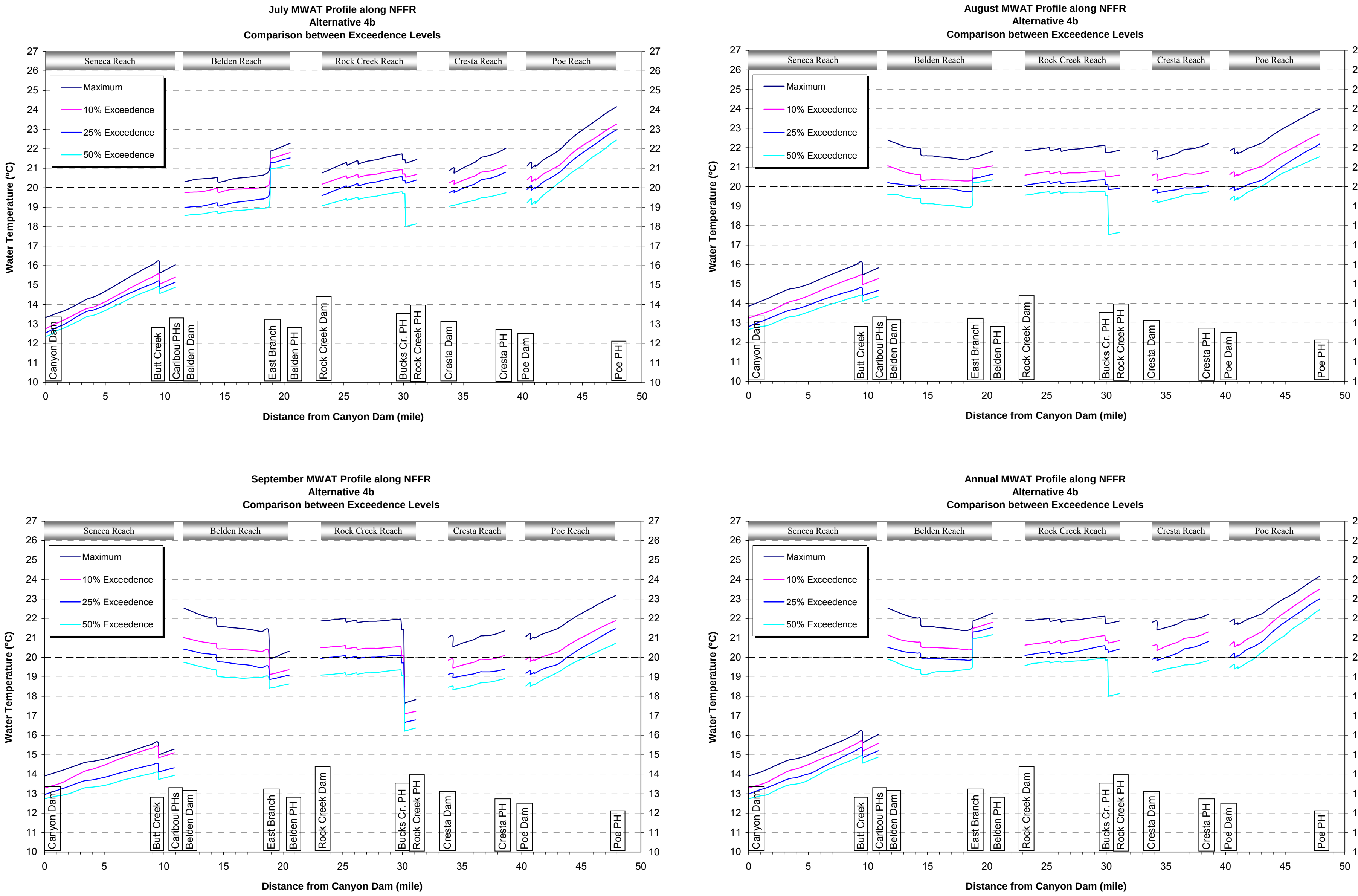


Figure 15. Monthly (July, Aug, Sep) and annual MWAT profiles along NFFR – Alternative 4b (from Stetson Engineers 2009).

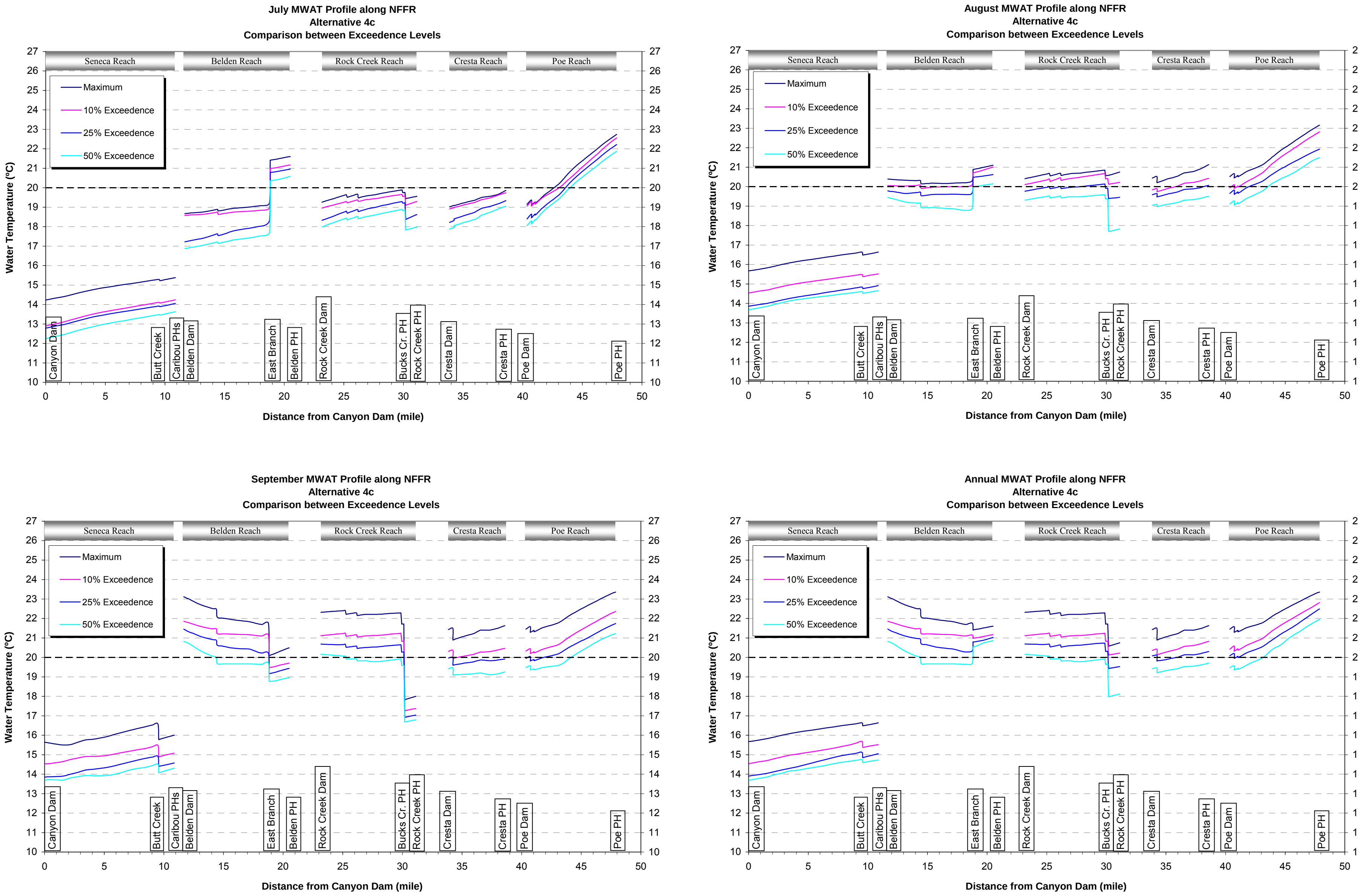
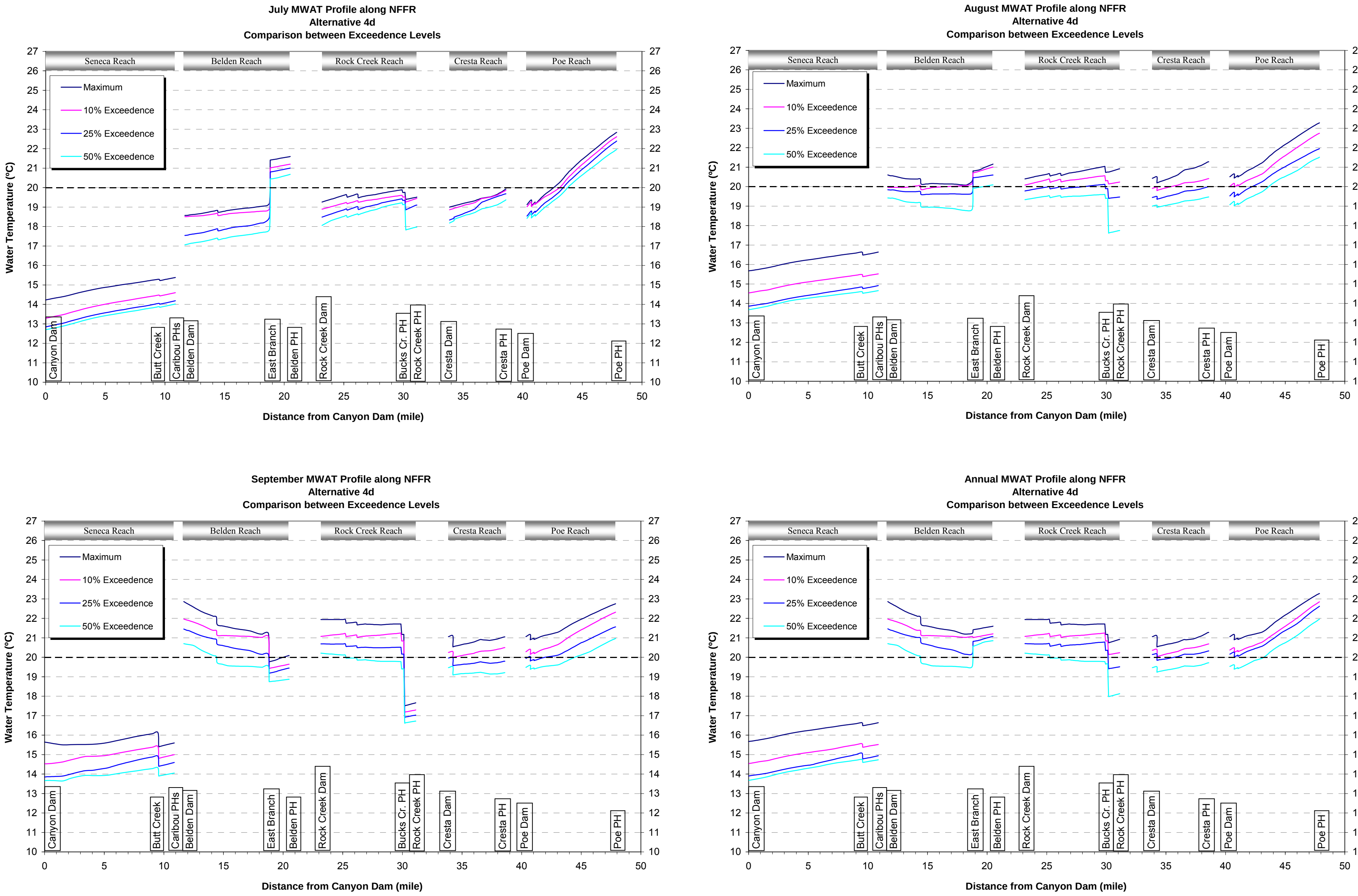


Figure 16. Monthly (July, Aug, Sep) and annual MWAT profiles along NFFR – Alternative 4c (from Stetson Engineers 2009).



July MWAT Profile along NFFR
Alternative 4d
Comparison between Exceedence Levels

August MWAT Profile along NFFR
Alternative 4d
Comparison between Exceedence Levels

September MWAT Profile along NFFR
Alternative 4d
Comparison between Exceedence Levels

Annual MWAT Profile along NFFR
Alternative 4d
Comparison between Exceedence Levels

Figure 17. Monthly (July, Aug, Sep) and annual MWAT profiles along NFFR – Alternative 4d (from Stetson Engineers 2009).

Table 13. Summary of simulated Lake Almanor thermocline elevations for different alternatives and change in thermocline elevation relative to baseline condition (2000, Normal Hydrologic Year) (from Stetson Engineers 2009)

DATE	WATER SURFACE ELEVATION	SIMULATED THERMOCLINE ELEVATION (FEET IN USGS DATUM)					CHANGE IN THERMOCLINE ELEVATION RELATIVE TO BASELINE CONDITION (FT)			
		BASELINE	PRESENT DAY	ALT 3X	ALT 4A	ALT 4C	PRESENT DAY	ALT 3X	ALT 4A	ALT 4C
5/15/2000	4,500.2									
6/7/2000	4,500.3	4,473.8	4,473.8	4,473.8	4,473.8	4,473.8	0	0	0	0
6/22/2000	4,500.1	4,480.3	4,480.3	4,480.3	4,480.3	4,480.3	0	0	0	0
7/7/2000	4,499.5	4,463.9	4,463.9	4,463.9	4,463.9	4,463.9	0	0	0	0
7/20/2000	4,497.2	4,467.2	4,467.2	4,463.9	4,463.9	4,463.9	0	-3	-3	-3
8/7/2000	4,496.2	4,467.2	4,467.2	4,463.9	4,463.9	4,467.2	0	-3	-3	0
8/17/2000	4,493.9	4,460.7	4,460.7	4,460.7	4,460.7	4,460.7	0	0	0	0
9/7/2000	4,492.9	4,454.1	4,454.1	4,447.5	4,450.8	4,450.8	0	-7	-3	-3
9/28/2000	4,490.3	4,454.1	4,454.1	4,447.5	4,447.5	4,450.8	0	-7	-7	-3
10/15/2000	4,489.6	4,444.3	4,441.0	4,437.7	4,441.0	4,441.0	-3	-7	-3	-3

Note: The bold dates represent observed profiles.

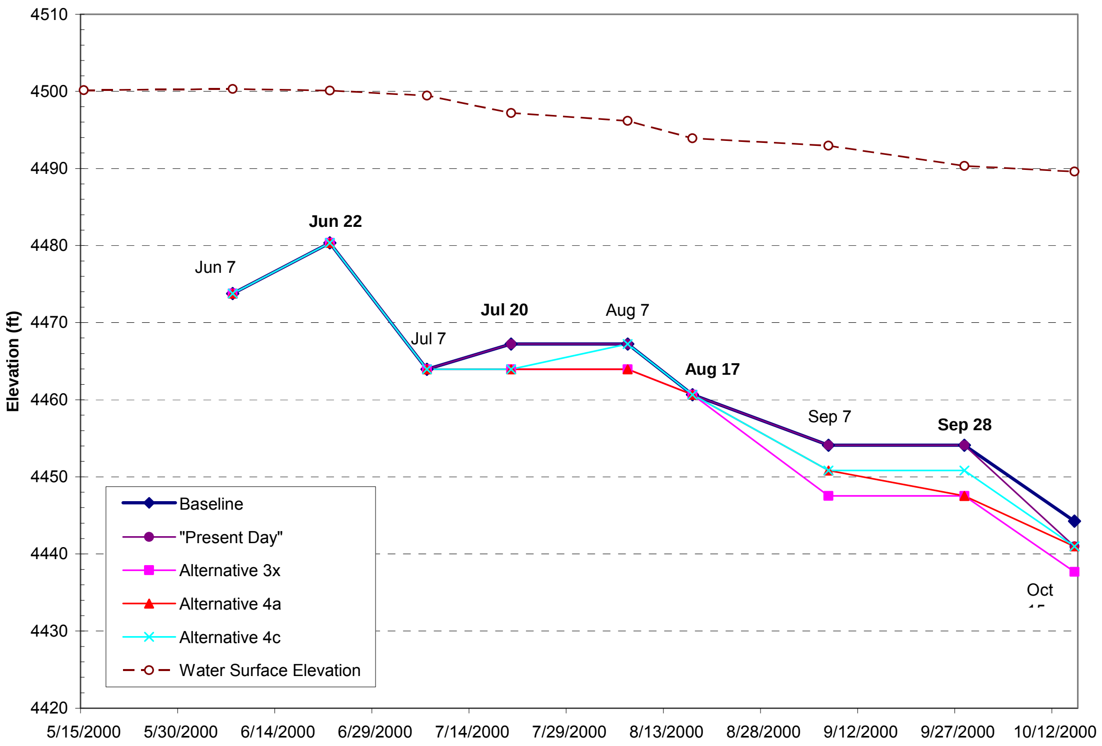


Figure 18. Comparison of simulated Lake Almanor thermocline elevation for different alternatives (2000, Normal Hydrologic Year) (from Stetson Engineers 2009). Note: The lake bed topography varies throughout the lake; the highest elevations, or shallowest areas, occur in the northern end of the lake and the lowest elevations, or deepest channels, occur from near the Prattville intake and throughout the eastern arm of the lake (4,430 feet) to near Canyon dam (4,410 feet). However, it is reported that accumulated sediment depths near the Canyon dam tower are approximately 20 feet .

Table 14. Summary of simulated Lake Almanor thermocline elevations for different alternatives and change in thermocline elevation relative to baseline condition (2001, Critical Dry Year) (from Stetson Engineers 2009)

		SIMULATED THERMOCLINE ELEVATION (FEET IN USGS DATUM)					CHANGE IN THERMOCLINE ELEVATION RELATIVE TO BASELINE CONDITION (FT)			
DATE	WATER SURFACE ELEVATION	BASELINE	PRESENT DAY	ALT 3X	ALT 4A	ALT 4C	PRESENT DAY	ALT 3X	ALT 4A	ALT 4C
5/15/2001	4,487.6	4,450.8	4,450.8	4,450.8	4,450.8	4,450.8	0	0	0	0
6/6/2001	4,487.8	4,467.2	4,467.2	4,467.2	4,467.2	4,467.2	0	0	0	0
6/22/2001	4,487.5	4,470.5	4,470.5	4,470.5	4,470.5	4,470.5	0	0	0	0
7/10/2001	4,486.9	4,457.4	4,457.4	4,454.1	4,454.1	4,454.1	0	-3	-3	-3
7/20/2001	4,486.6	4,463.9	4,463.9	4,463.9	4,460.7	4,463.9	0	0	-3	0
8/9/2001	4,484.3	4,457.4	4,457.4	4,457.4	4,457.4	4,457.4	0	0	0	0
8/17/2001	4,484.0	4,457.4	4,457.4	4,454.1	4,457.4	4,454.1	0	-3	0	-3
9/12/2001	4,483.6	4,444.3	4,444.3	4,441.0	4,444.3	4,441.0	0	-3	0	-3
9/28/2001	4,483.2	4,447.5	4,444.3	4,437.7	4,444.3	4,437.7	-3	-10	-3	-10
10/15/2001	4,480.8	4,427.9	4,424.6	4,421.3	4,424.6	4,421.3	-3	-7	-3	-7

Note: The bold dates represent observed profiles.

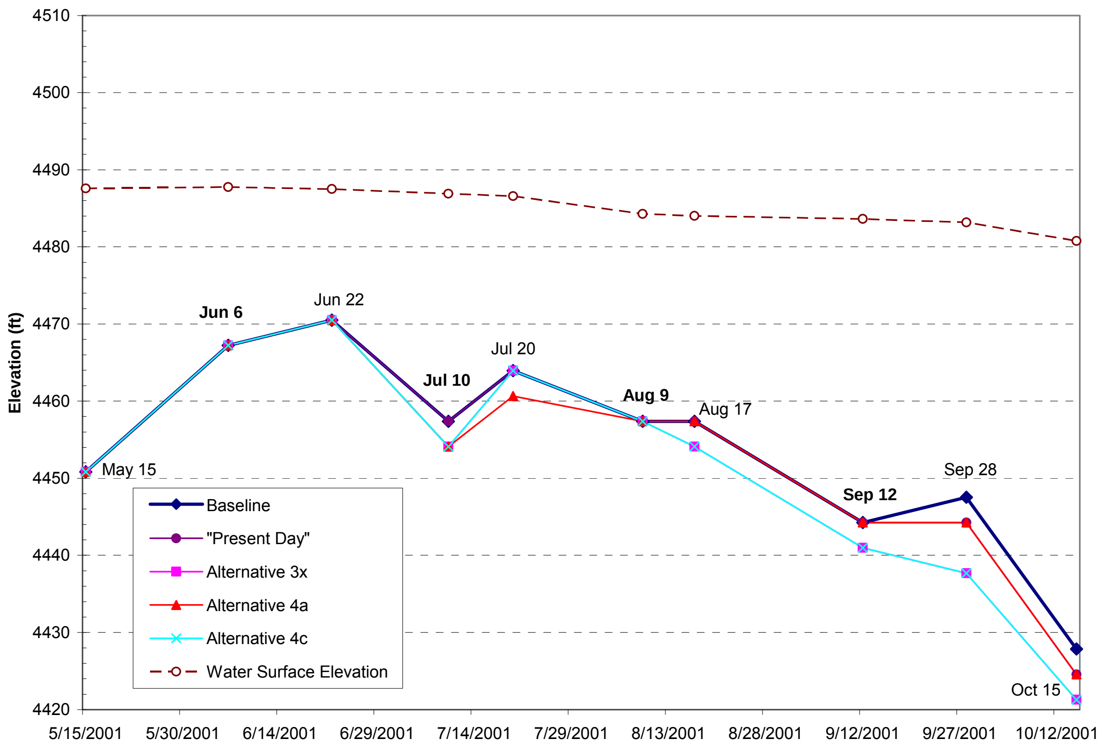


Figure 19. Comparison of simulated Lake Almanor thermocline elevation for different alternatives (2001, Critical Dry Year) (from Stetson Engineers 2009). Note: The lake bed topography varies throughout the lake; the highest elevations, or shallowest areas, occur in the northern end of the lake and the lowest elevations, or deepest channels, occur from near the Prattville intake and throughout the eastern arm of the lake (4430 feet) to near Canyon dam (4410 feet). However, it is reported that accumulated sediment depths near the Canyon dam tower are approximately 20 feet .

Table 15. Summary of simulated Lake Almanor habitat volume (acre-ft) with water temperature ≤ 20°C and DO ≥ 5 mg/L for different alternatives and the change in suitable coldwater habitat volume relative to baseline condition (2000, normal year) (from Stetson Engineers 2009)

		Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage				
Date	**Total Reservoir Storage (acre-ft)**	**Baseline**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**	**Base line**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**
May 15	1,011,490	993,600	989,670	989,110	989,110	989,670	-3,930	-4,490	-4,490	-3,930	98%	98%	98%	98%	98%
June 7	1,015,410	876,500	874,470	883,350	881,800	874,470	-2,030	6,850	5,300	-2,030	86%	86%	87%	87%	86%
Jun 22	1,010,250	452,400	449,750	465,600	462,510	449,750	-2,650	13,200	10,110	-2,650	45%	45%	46%	46%	45%
July 7	993,780	216,200	214,940	230,770	227,740	214,950	-1,260	14,570	11,540	-1,250	22%	22%	23%	23%	22%
Jul 20	938,020	145,600	143,790	151,770	148,400	145,040	-1,810	6,170	2,800	-560	16%	15%	16%	16%	15%
Aug 7	913,180	65,000	63,690	63,410	61,150	63,110	-1,310	-1,590	-3,850	-1,890	7%	7%	7%	7%	7%
Aug 17	859,160	44,400	40,910	32,490	35,030	38,240	-3,490	-11,910	-9,370	-6,160	5%	5%	4%	4%	4%
Sep 7	836,720	636,600	639,480	698,340	683,250	661,180	2,880	61,740	46,650	24,580	76%	76%	83%	82%	79%
Sep 28	777,330	607,400	609,130	663,450	649,750	622,960	1,730	56,050	42,350	15,560	78%	78%	85%	84%	80%
Oct 15	761,020	676,200	678,940	712,080	702,680	694,830	2,740	35,880	26,480	18,630	89%	89%	94%	92%	91%

Note: The bold dates represent observed profiles.

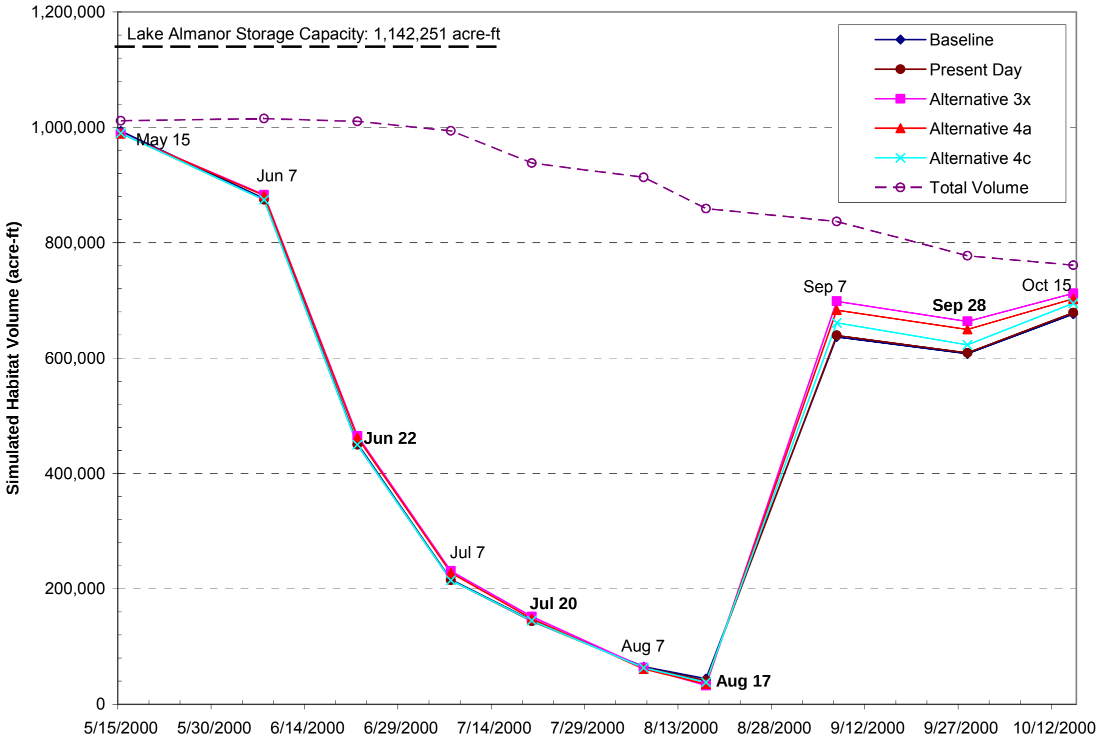


Figure 20. Comparison of simulated Lake Almanor habitat volume having water temperature ≤ 20°C and DO ≥ 5 mg/L for different alternatives (2000, normal year) (from Stetson Engineers 2009).

Table 16. Summary of simulated Lake Almanor habitat volume (acre-ft) with water temperature ≤ 21°C and DO ≥ 5 mg/L for different alternatives and the change in suitable coldwater habitat volume relative to baseline condition (2000, normal year) (from Stetson Engineers 2009)

	Total Reservoir Storage (acre-ft)	Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage				
Date		Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Present Day	Alt 3x	Alt 4a	Alt 4c
May 15	1,011,490	993,550	989,670	989,110	989,110	989,670	-3,880	-4,440	-4,440	-3,880	98%	98%	98%	98%	98%
June 7	1,015,410	876,510	874,470	883,350	881,800	874,470	-2,040	6,840	5,290	-2,040	86%	86%	87%	87%	86%
Jun 22	1,010,250	669,500	659,150	673,510	670,150	659,150	-10,350	4,010	650	-10,350	66%	65%	67%	66%	65%
July 7	993,780	584,410	585,350	598,010	594,810	587,100	940	13,600	10,400	2,690	59%	59%	60%	60%	59%
Jul 20	938,020	228,530	223,930	231,700	227,170	222,930	-4,600	3,170	-1,360	-5,600	24%	24%	25%	24%	24%
Aug 7	913,180	97,120	95,040	98,350	94,350	96,170	-2,080	1,230	-2,770	-950	11%	10%	11%	10%	11%
Aug 17	859,160	69,040	66,590	58,970	58,750	63,710	-2,450	-10,070	-10,290	-5,330	8%	8%	7%	7%	7%
Sep 7	836,720	636,600	639,480	698,340	683,250	661,180	2,880	61,740	46,650	24,580	76%	76%	83%	82%	79%
Sep 28	777,330	607,380	609,130	663,450	649,750	622,960	1,750	56,070	42,370	15,580	78%	78%	85%	84%	80%
Oct 15	761,020	676,160	678,940	712,080	702,680	694,830	2,780	35,920	26,520	18,670	89%	89%	94%	92%	91%

Note: The bold dates represent observed profiles.

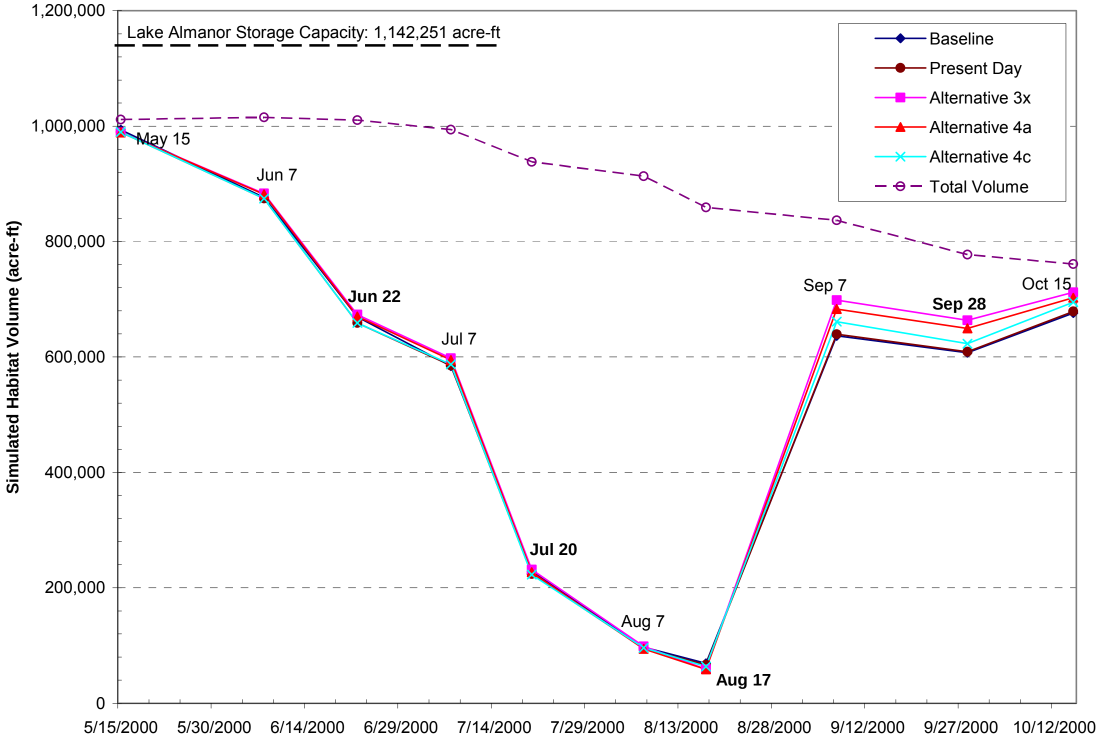


Figure 21. Comparison of simulated Lake Almanor habitat volume having water temperature ≤ 21°C and DO ≥ 5 mg/L for different alternatives (2000, normal year) (from Stetson Engineers 2009).

Table 17. Summary of simulated Lake Almanor habitat volume (acre-ft) with water temperature ≤ 22°C and DO ≥ 5 mg/L for different alternatives and the change in suitable coldwater habitat volume relative to baseline condition (2000, normal year) (from Stetson Engineers 2009)

Date	Total Reservoir Storage (acre-ft)	Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage				
		Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Present Day	Alt 3x	Alt 4a	Alt 4c
May 15	1,011,490	993,550	989,670	989,110	989,110	989,670	-3,880	-4,440	-4,440	-3,880	98%	98%	98%	98%	98%
June 7	1,015,410	876,510	874,470	883,350	881,800	874,470	-2,040	6,840	5,290	-2,040	86%	86%	87%	87%	86%
Jun 22	1,010,250	798,650	798,700	818,190	815,210	798,700	50	19,540	16,560	50	79%	79%	81%	81%	79%
July 7	993,780	743,860	745,570	778,400	775,130	748,270	1,710	34,540	31,270	4,410	75%	75%	78%	78%	75%
Jul 20	938,020	632,400	631,140	661,580	657,470	638,300	-1,260	29,180	25,070	5,900	67%	67%	71%	70%	68%
Aug 7	913,180	144,170	143,320	155,090	149,440	147,300	-850	10,920	5,270	3,130	16%	16%	17%	16%	16%
Aug 17	859,160	458,170	440,650	345,350	342,380	406,800	-17,520	-112,820	-115,790	-51,370	53%	51%	40%	40%	47%
Sep 7	836,720	636,600	639,480	698,340	683,250	661,180	2,880	61,740	46,650	24,580	76%	76%	83%	82%	79%
Sep 28	777,330	607,380	609,130	663,450	649,750	622,960	1,750	56,070	42,370	15,580	78%	78%	85%	84%	80%
Oct 15	761,020	676,160	678,940	712,080	702,680	694,830	2,780	35,920	26,520	18,670	89%	89%	94%	92%	91%

Note: The bold represent have observed profiles.

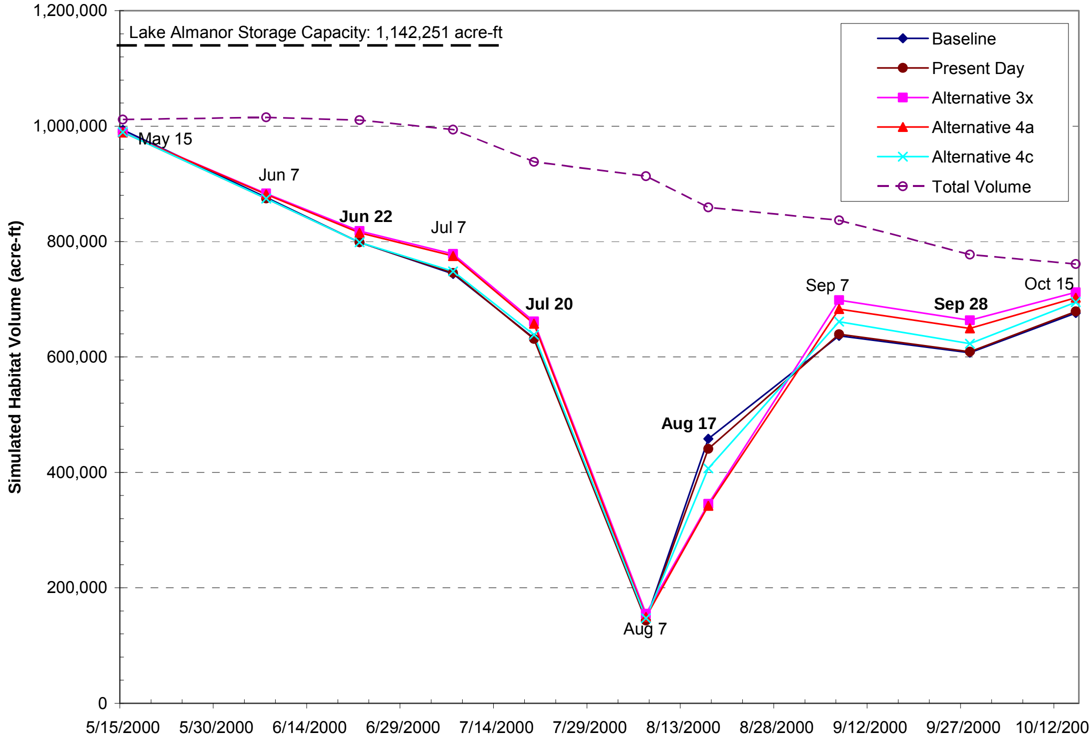


Figure 22. Comparison of simulated Lake Almanor habitat volume having water temperature ≤ 22°C and DO ≥ 5 mg/L for different alternatives (2000, normal year) (from Stetson Engineers 2009).

Table 18. Summary of simulated Lake Almanor habitat volume (acre-ft) with water temperature ≤ 20°C and DO ≥ 5 mg/L for different alternatives and the change in suitable coldwater habitat volume relative to baseline condition (2001, critical dry year) (from Stetson Engineers 2009)

		Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage				
Date	**Total Reservoir Storage (acre-ft)**	**Baseline**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**	**Base line**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**
May 15	717,310	712,230	709,010	709,010	709,010	709,010	-3,220	-3,220	-3,220	-3,220	99%	99%	99%	99%	99%
June 6	721,260	588,900	585,970	590,050	589,390	585,970	-2,930	1,150	490	-2,930	82%	81%	82%	82%	81%
Jun 22	715,340	210,900	207,400	210,310	207,520	207,400	-3,500	-590	-3,380	-3,500	29%	29%	29%	29%	29%
July 10	702,590	85,420	82,720	84,830	82,900	84,240	-2,700	-590	-2,520	-1,180	12%	12%	12%	12%	12%
Jul 20	695,920	40,870	39,070	35,640	37,090	37,770	-1,800	-5,230	-3,780	-3,100	6%	6%	5%	5%	5%
Aug 9	648,010	360	0	0	0	0	-360	-360	-360	-360	0%	0%	0%	0%	0%
Aug 17	642,460	0	0	0	0	0	0	0	0	0	0%	0%	0%	0%	0%
Sep 12	634,800	490,230	493,040	352,170	463,000	442,000	2,810	-138,060	-27,230	-48,230	77%	78%	55%	73%	70%
Sep 28	625,800	543,700	545,630	575,920	558,700	565,360	1,930	32,220	15,000	21,660	87%	87%	92%	89%	90%
Oct 15	578,400	544,160	541,910	547,750	542,930	547,790	-2,250	3,590	-1,230	3,630	94%	94%	95%	94%	95%

Note: The bold dates represent observed profiles.

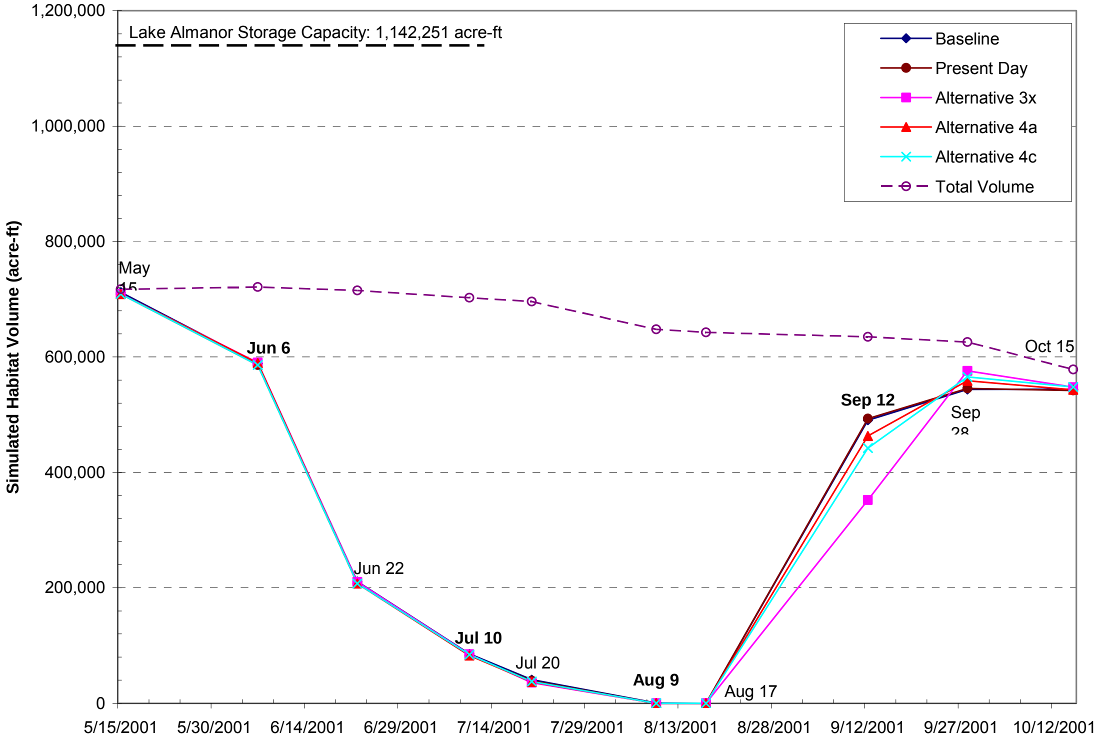


Figure 23. Comparison of simulated Lake Almanor habitat volume having water temperature ≤ 20°C and DO ≥ 5 mg/L for different alternatives (2001, critical dry year) (from Stetson Engineers 2009).

Table 19. Summary of simulated Lake Almanor habitat volume (acre-ft) with water temperature ≤ 21°C and DO ≥ 5 mg/L for different alternatives and the change in habitat volume relative to baseline condition (2001, critical dry year) (from Stetson Engineers 2009)

		Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage				
Date	Total Reservoir Storage (acre-ft)	Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Present Day	Alt 3x	Alt 4a	Alt 4c
May 15	717,310	712,230	709,010	709,010	709,010	709,010	-3,220	-3,220	-3,220	-3,220	99%	99%	99%	99%	99%
June 6	721,260	588,900	585,970	590,050	589,390	585,970	-2,930	1,150	490	-2,930	82%	81%	82%	82%	81%
Jun 22	715,340	326,300	324,330	329,610	326,170	324,330	-1,970	3,310	-130	-1,970	46%	45%	46%	46%	45%
July 10	702,590	137,960	134,360	137,910	134,680	136,420	-3,600	-50	-3,280	-1,540	20%	19%	20%	19%	19%
Jul 20	695,920	74,230	73,060	69,690	68,900	72,360	-1,170	-4,540	-5,330	-1,870	11%	10%	10%	10%	10%
Aug 9	648,010	51,900	49,850	37,100	41,050	43,090	-2,050	-14,800	-10,850	-8,810	8%	8%	6%	6%	7%
Aug 17	642,460	23,260	20,250	8,160	14,730	12,930	-3,010	-15,100	-8,530	-10,330	4%	3%	1%	2%	2%
Sep 12	634,800	505,370	509,840	545,620	524,010	533,150	4,470	40,250	18,640	27,780	80%	80%	86%	83%	84%
Sep 28	625,800	543,700	545,630	575,920	558,700	565,360	1,930	32,220	15,000	21,660	87%	87%	92%	89%	90%
Oct 15	578,400	544,160	541,910	547,750	542,930	547,790	-2,250	3,590	-1,230	3,630	94%	94%	95%	94%	95%

Note: The bold dates represent observed profiles.

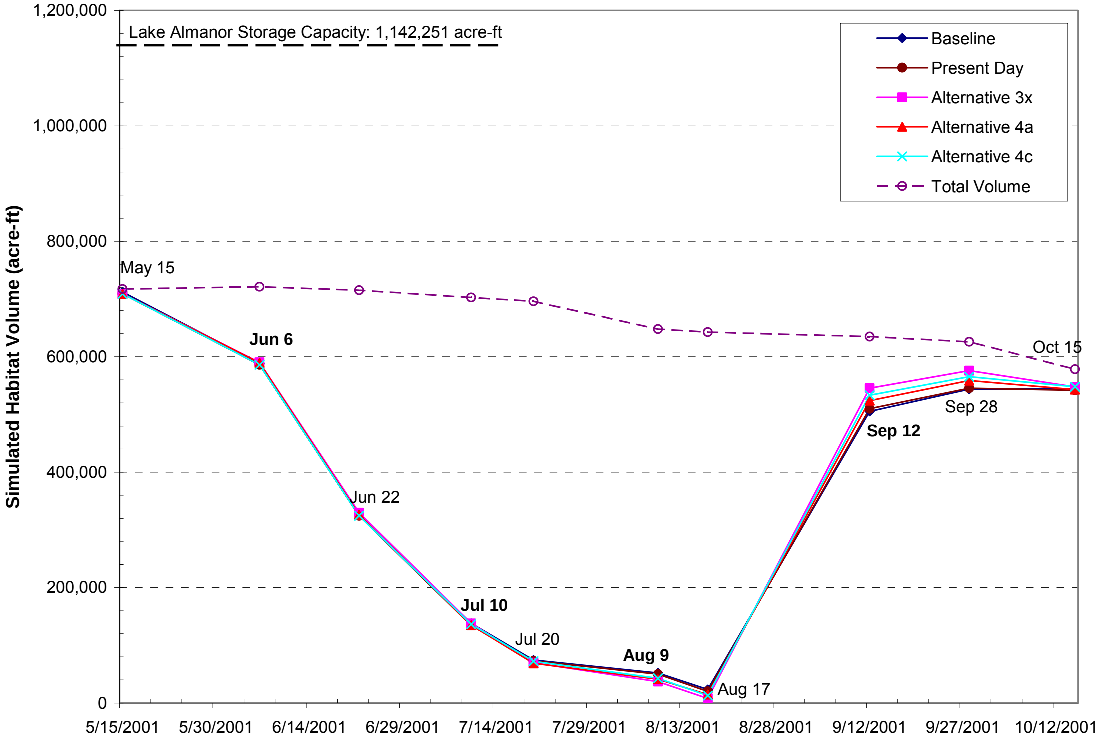


Figure 24. Comparison of simulated Lake Almanor habitat volume having water temperature ≤ 21°C and DO ≥ 5 mg/L for different alternatives (2001, critical dry year) (from Stetson Engineers 2009).

Table 20. Summary of simulated Lake Almanor habitat volume (acre-ft) with water temperature ≤ 22°C and DO ≥ 5 mg/L for different alternatives and the change in habitat volume relative to baseline condition (2001, critical dry year) (from Stetson Engineers 2009)

		Simulated Habitat Volume (acre-ft)					Change in Habitat Volume Relative to Baseline Condition (acre-ft)				% of Habitat Volume to Total Reservoir Storage				
Date	Total Reservoir Storage (acre-ft)	Baseline	Present Day	Alt 3x	Alt 4a	Alt 4c	Present Day	Alt 3x	Alt 4a	Alt 4c	Base line	Present Day	Alt 3x	Alt 4a	Alt 4c
May 15	717,310	712,230	709,010	709,010	709,010	709,010	-3,220	-3,220	-3,220	-3,220	99%	99%	99%	99%	99%
June 6	721,260	588,900	585,970	590,050	589,390	585,970	-2,930	1,150	490	-2,930	82%	81%	82%	82%	81%
Jun 22	715,340	544,990	542,240	553,650	550,580	542,240	-2,750	8,660	5,590	-2,750	76%	76%	77%	77%	76%
July 10	702,590	427,730	428,850	426,390	420,380	435,440	1,120	-1,340	-7,350	7,710	61%	61%	61%	60%	62%
Jul 20	695,920	420,180	421,170	410,020	405,990	422,840	990	-10,160	-14,190	2,660	60%	61%	59%	58%	61%
Aug 9	648,010	160,750	153,060	149,100	146,780	152,710	-7,690	-11,650	-13,970	-8,040	25%	24%	23%	23%	24%
Aug 17	642,460	282,590	254,640	103,720	124,360	142,530	-27,950	-178,870	-158,230	-140,060	44%	40%	16%	19%	22%
Sep 12	634,800	505,370	509,840	545,620	524,010	533,150	4,470	40,250	18,640	27,780	80%	80%	86%	83%	84%
Sep 28	625,800	543,700	545,630	575,920	558,700	565,360	1,930	32,220	15,000	21,660	87%	87%	92%	89%	90%
Oct 15	578,400	544,160	541,910	547,750	542,930	547,790	-2,250	3,590	-1,230	3,630	94%	94%	95%	94%	95%

Note: The bold dates represent observed profiles.

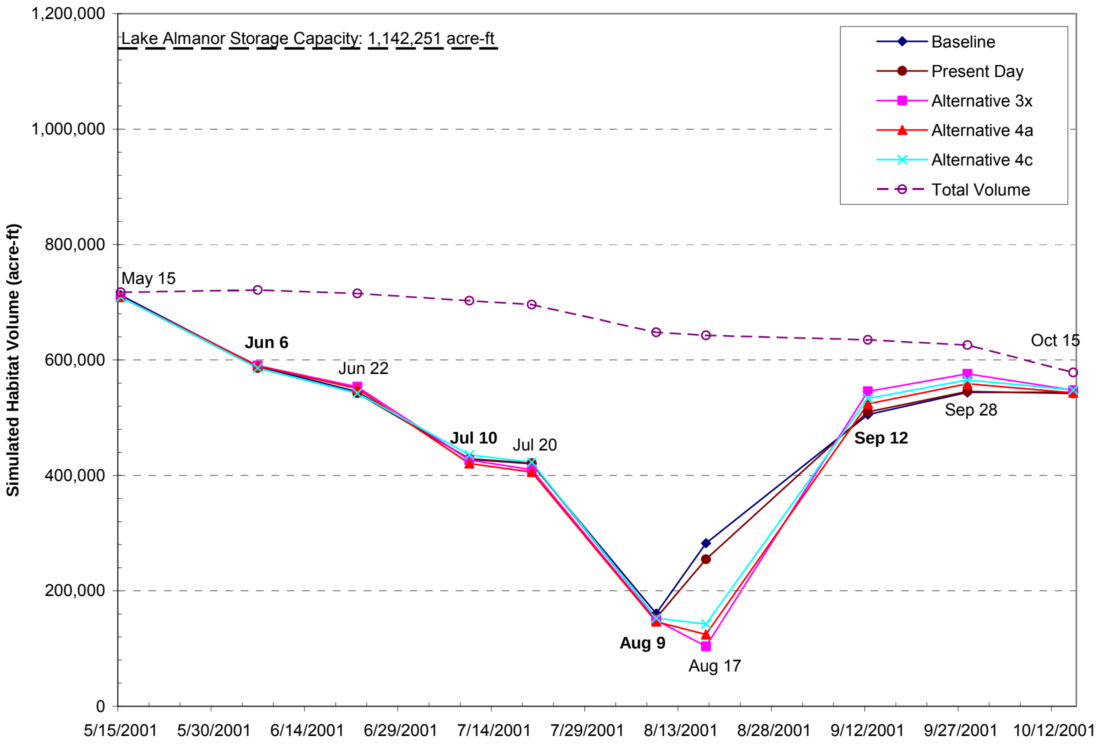


Figure 25. Comparison of simulated Lake Almanor habitat volume having water temperature ≤ 22°C and DO ≥ 5 mg/L for different alternatives (2001, critical dry year) (from Stetson Engineers 2009).

Table 21. Summary of simulated Lake Almanor metalimnion surface area (acres) for different alternatives and the change in metalimnion surface area (SA) relative to baseline condition with temperature at top of thermocline of 20–22°C (2000, normal year) (from Stetson Engineers 2009)

		Simulated Metalimnion SA (acre)					Change in Metalimnion SA Relative to Baseline Condition (acre)				% of Metalimnion SA to Total Lake SA				
Date	**Lake SA (acre)**	**Baseline**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**	**Base line**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**
May 15	25,280														
June 7	25,330	17,320	17,320	17,320	17,320	17,320	0	0	0	0	68%	68%	68%	68%	68%
Jun 22	25,260	19,370	19,370	19,370	19,370	19,370	0	0	0	0	77%	77%	77%	77%	77%
July 7	25,030	14,220	14,220	14,220	14,220	14,220	0	0	0	0	57%	57%	57%	57%	57%
Jul 20	24,240	15,080	15,080	14,220	14,220	14,220	0	-860	-860	-860	62%	62%	59%	59%	59%
Aug 7	23,890	15,080	15,080	14,220	14,220	15,080	0	-860	-860	0	63%	63%	60%	60%	63%
Aug 17	23,140	13,460	13,460	13,460	13,460	13,460	0	0	0	0	58%	58%	58%	58%	58%
Sep 7	22,830	11,560	11,560	9,210	10,410	10,410	0	-2,350	-1,150	-1,150	51%	51%	40%	46%	46%
Sep 28	22,020	11,560	11,560	9,210	9,210	10,410	0	-2,350	-2,350	-1,150	52%	52%	42%	42%	47%
Oct 15	21,790	7,900	6,540	5,070	6,540	6,540	-1,360	-2,830	-1,360	-1,360	36%	30%	23%	30%	30%

Note: The bold dates represent observed profiles.

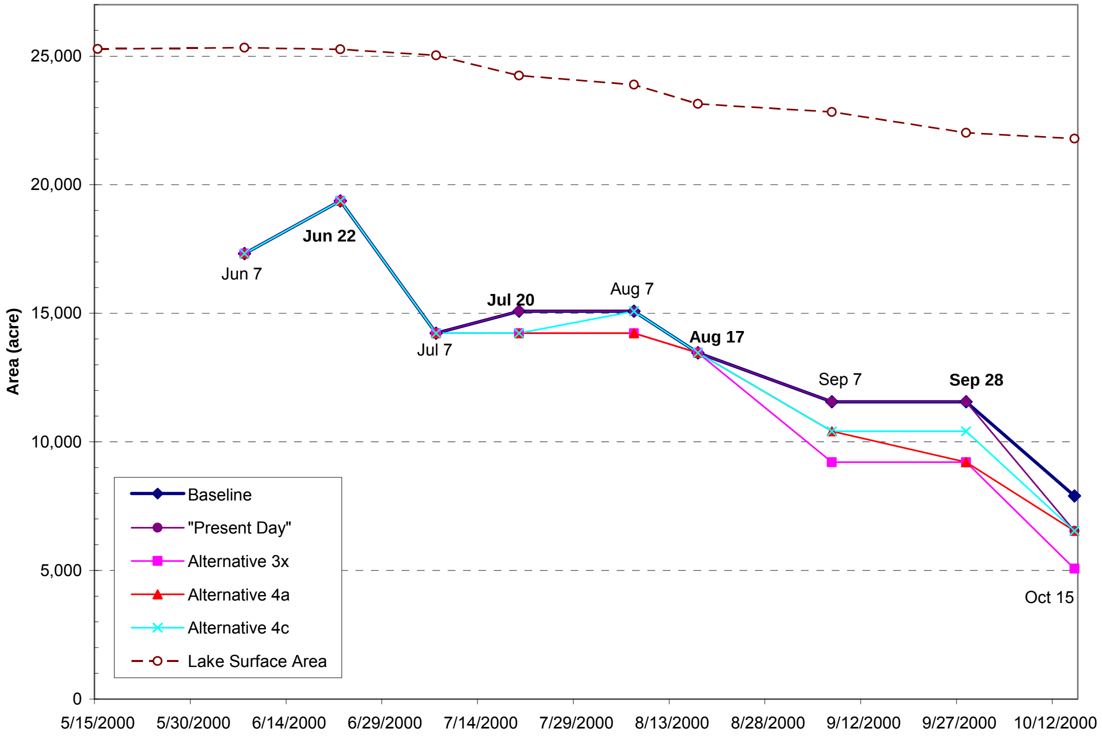


Figure 26. Comparison of simulated Lake Almanor metalimnion surface area for different alternatives (2000, normal year) (from Stetson Engineers 2009).

Table 22. Summary of simulated Lake Almanor metalimnion surface area (acres) for different alternatives and change in metalimnion surface area (SA) relative to baseline condition with temperature at top of thermocline of 20–22°C (2001, critical dry year) (from Stetson Engineers 2009)

		Simulated Metalimnion SA (acre)					Change in Metalimnion SA Relative to Baseline Condition (acre)				% of Metalimnion SA to Total Lake SA				
Date	**Lake SA (acre)**	**Baseline**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**	**Base line**	**Present Day**	**Alt 3x**	**Alt 4a**	**Alt 4c**
May 15	21,190	10,410	10,410	10,410	10,410	10,410	0	0	0	0	49%	49%	49%	49%	49%
June 6	21,240	15,080	15,080	15,080	15,080	15,080	0	0	0	0	71%	71%	71%	71%	71%
Jun 22	21,160	16,150	16,150	16,150	16,150	16,150	0	0	0	0	76%	76%	76%	76%	76%
July 10	20,980	12,610	12,610	11,560	11,560	11,560	0	-1,050	-1,050	-1,050	60%	60%	55%	55%	55%
Jul 20	20,890	14,220	14,220	14,220	13,460	14,220	0	0	-760	0	68%	68%	68%	64%	68%
Aug 9	20,220	12,610	12,610	12,610	12,610	12,610	0	0	0	0	62%	62%	62%	62%	62%
Aug 17	20,150	12,610	12,610	11,560	12,610	11,560	0	-1,050	0	-1,050	63%	63%	57%	63%	57%
Sep 12	20,040	7,900	7,900	6,540	7,900	6,540	0	-1,360	0	-1,360	39%	39%	33%	39%	33%
Sep 28	19,910	9,210	7,900	5,070	7,900	5,070	-1,310	-4,140	-1,310	-4,140	46%	40%	25%	40%	25%
Oct 15	19,230	510	420	360	420	360	-90	-150	-90	-150	3%	2%	2%	2%	2%

Note: The bold dates represent observed profiles.

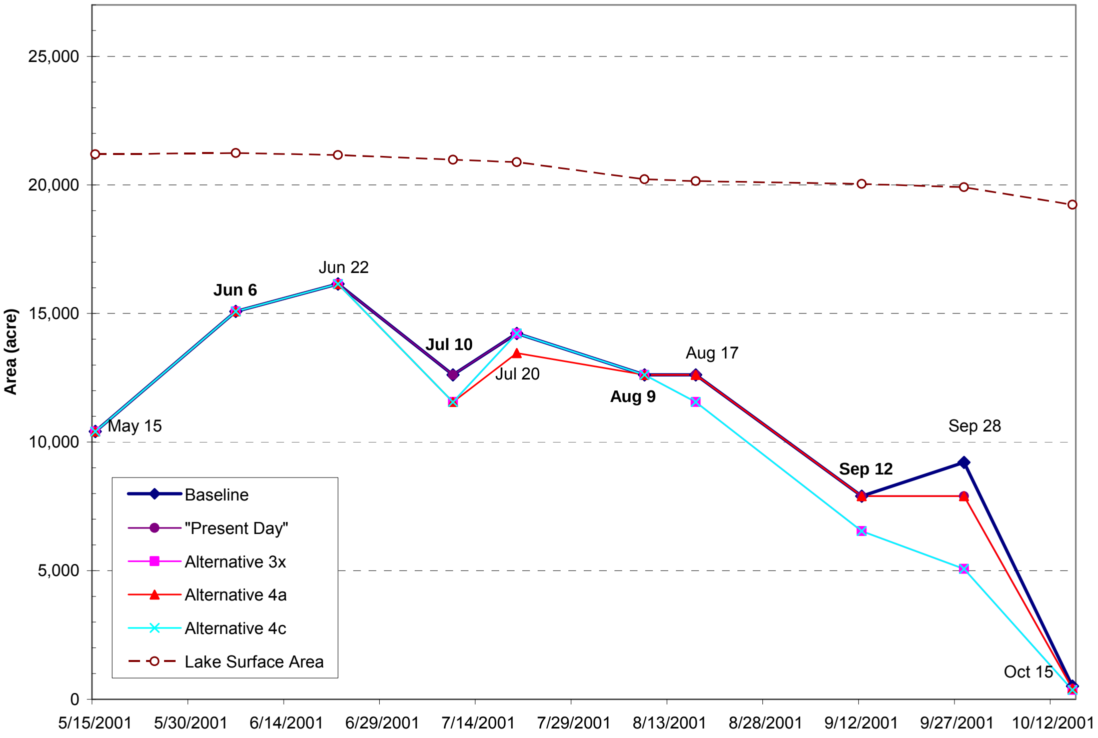


Figure 27. Comparison of simulated Lake Almanor metalimnion surface area for different alternatives (2001, critical dry year) (from Stetson Engineers 2009).

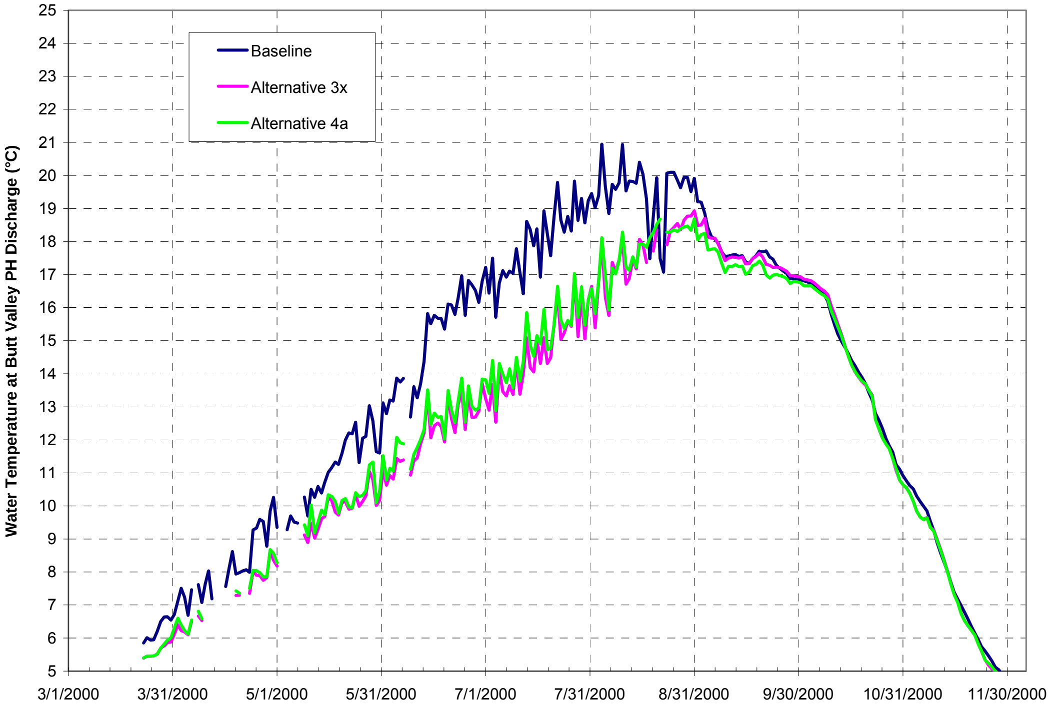


Figure 28. Simulated water temperatures at the Butt Valley Powerhouse (PH) discharge under different alternatives, 2000 (from Stetson Engineers 2009).

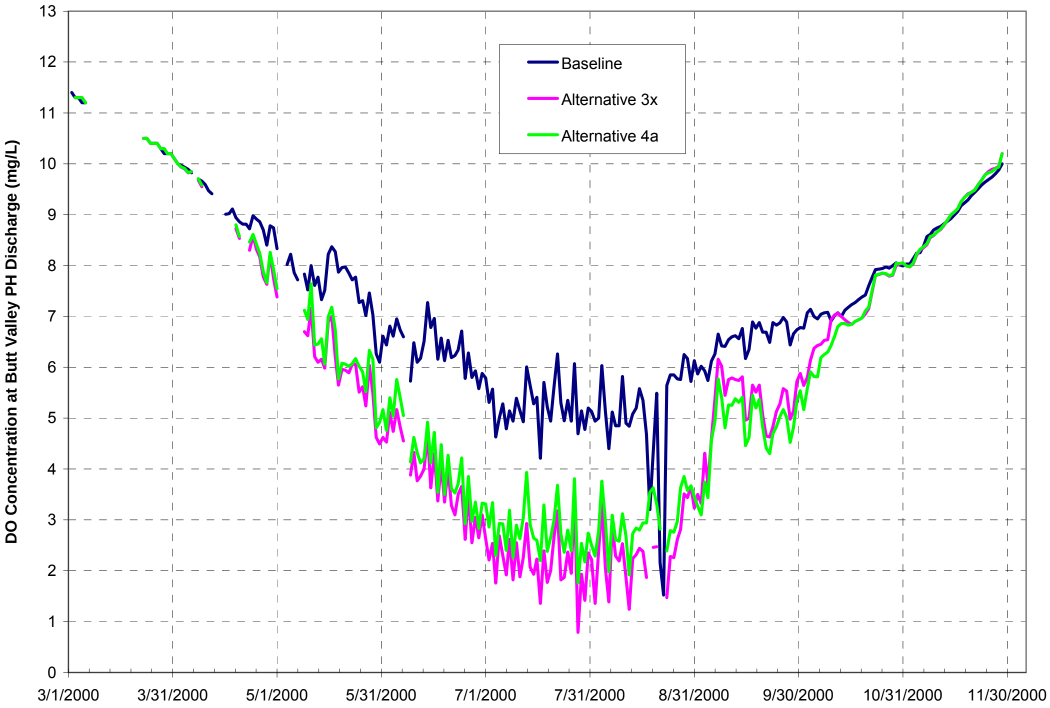


Figure 29. Simulated dissolved oxygen concentrations at the Butt Valley Powerhouse (PH) discharge under different alternatives, 2000 (from Stetson Engineers 2009).

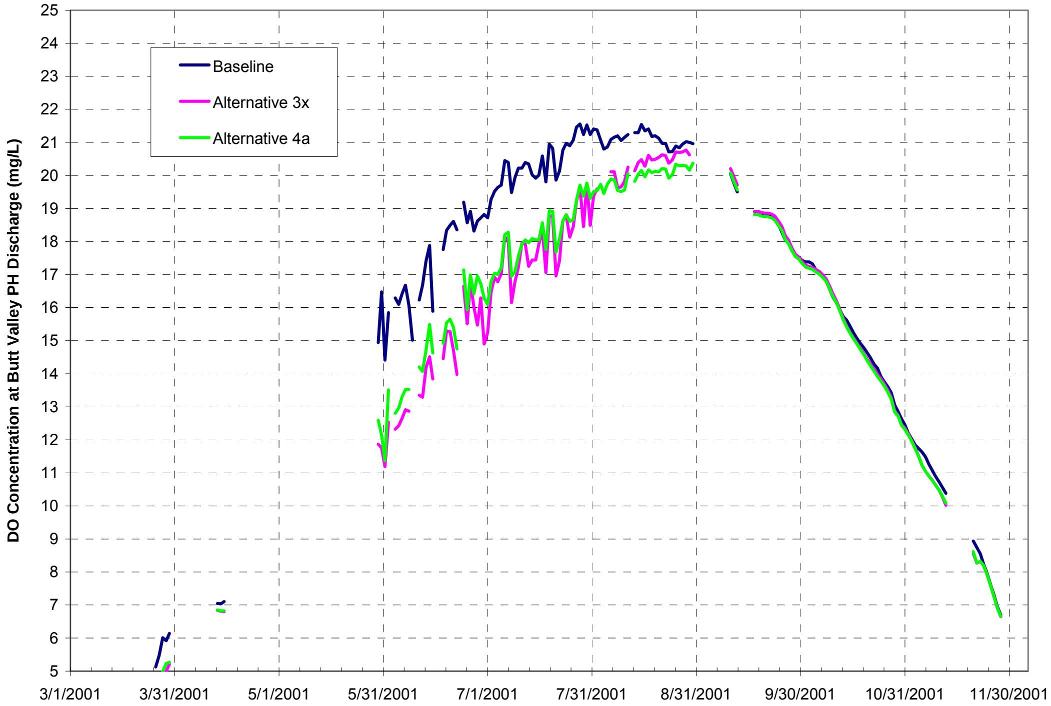


Figure 30. Simulated water temperatures at the Butt Valley Powerhouse (PH) discharge under different alternatives, 2001 (from Stetson Engineers 2009).

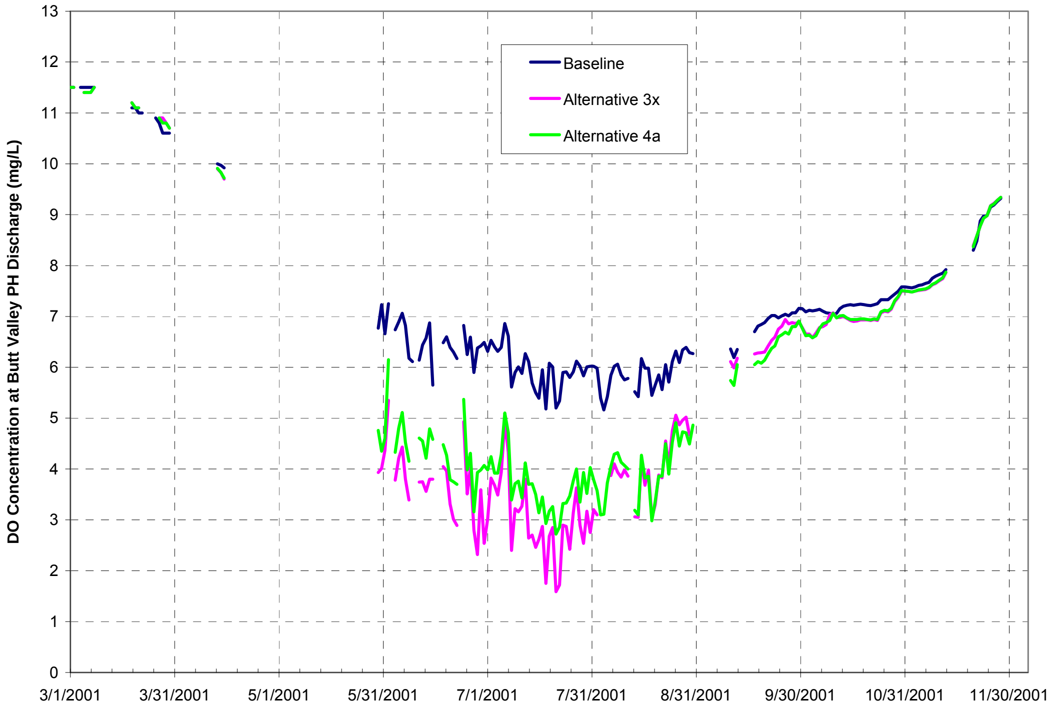


Figure 31. Simulated dissolved oxygen concentrations at the Butt Valley Powerhouse (PH) discharge under different alternatives, 2001 (from Stetson Engineers 2009).

Table 23. Summary of simulated Butt Valley reservoir habitat volume (acre-ft) having water temperature ≤ 20°C and DO ≥ 5 mg/L for Alternative 4a and the change in habitat volume relative to baseline condition (2000, normal year) (from Stetson Engineers 2009)

Date	Total Reservoir Storage (acre-ft)	Simulated Habitat Volume (acre-ft)		Change in Alt 4a Habitat Volume Relative to Baseline Condition (acre-ft)	% of Habitat Volume to Total Reservoir Storage	
		Baseline	Alt 4a		Baseline	Alt 4a
May 15	34,270	33,980	34,270	290	99%	100%
June 7	33,790	31,420	33,420	2,000	93%	99%
Jun 22	32,410	24,190	21,500	-2,690	75%	66%
July 7	36,790	33,510	26,460	-7,050	91%	72%
Jul 20	37,390	17,690	22,680	4,990	47%	61%
Aug 7	37,190	2,970	7,710	4,740	8%	21%
Aug 17	38,570	2,170	12,310	10,140	6%	32%
Sep 7	41,260	41,090	41,110	20	100%	100%
Sep 28	34,710	34,600	34,710	110	100%	100%

Note: The bold dates represent observed profiles.

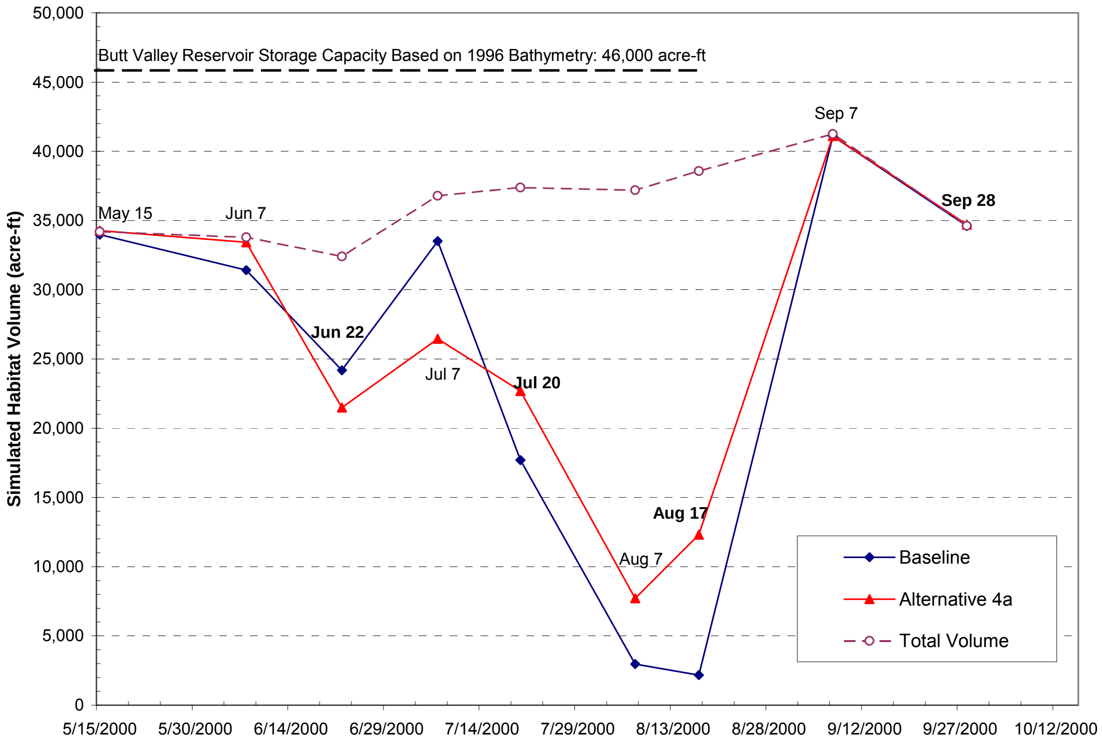


Figure 32. Comparison of simulated Butt Valley reservoir habitat volume having water temperature ≤ 20°C and DO ≥ 5 mg/L for Alternative 4a (2000, normal year) (from Stetson Engineers 2009).

Table 24. Summary of simulated Butt Valley reservoir habitat volume (acre-ft) having water temperature ≤ 21°C and DO ≥ 5 mg/L for Alternative 4a and the change in habitat volume relative to baseline condition (2000, normal year) (from Stetson Engineers 2009)

Date	Total Reservoir Storage (acre-ft)	Simulated Habitat Volume (acre-ft)		Change in Alt 4a Habitat Volume Relative to Baseline Condition (acre-ft)	% of Habitat Volume to Total Reservoir Storage	
		Baseline	Alt 4a		Baseline	Alt 4a
May 15	34,270	33,980	34,270	290	99%	100%
June 7	33,790	31,420	33,420	2,000	93%	99%
Jun 22	32,410	28,400	24,980	-3,420	88%	77%
July 7	36,790	34,380	27,080	-7,300	93%	74%
Jul 20	37,390	32,360	26,250	-6,110	87%	70%
Aug 7	37,190	16,340	16,010	-330	44%	43%
Aug 17	38,570	34,170	27,290	-6,880	89%	71%
Sep 7	41,260	41,090	41,110	20	100%	100%
Sep 28	34,710	34,600	34,710	110	100%	100%

Note: The bold dates represent observed profiles.

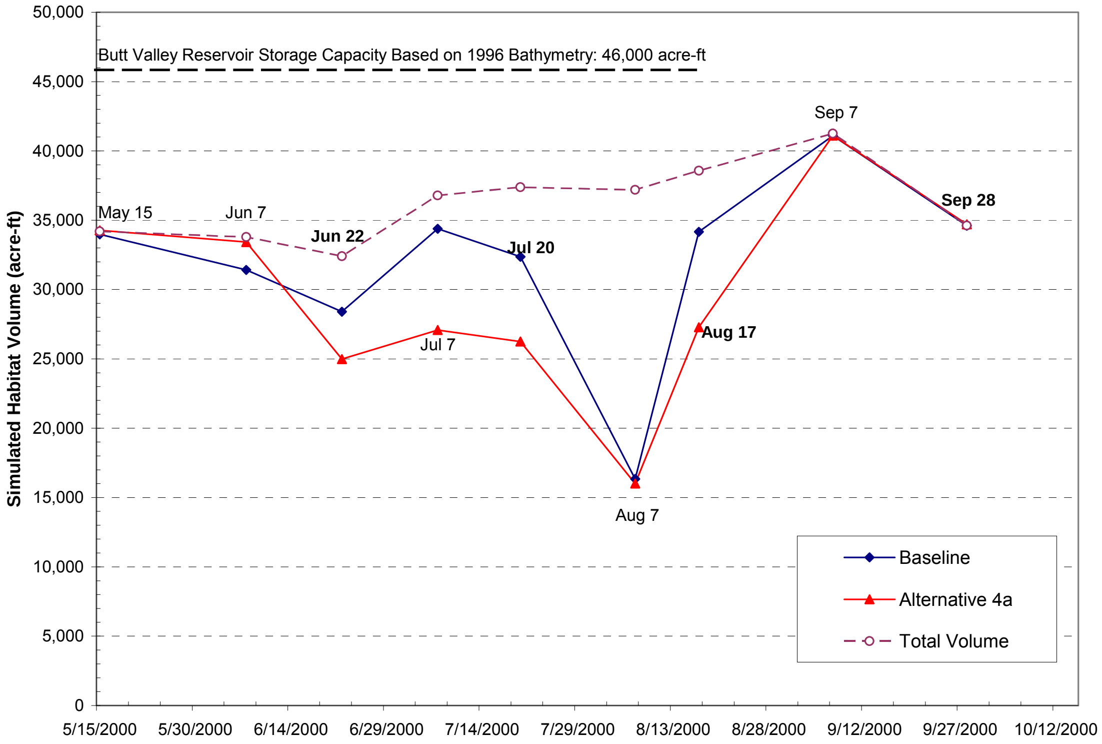


Figure 33. Comparison of simulated Butt Valley reservoir habitat volume having water temperature ≤ 21°C and DO ≥ 5 mg/L for Alternative 4a (2000, normal year) (from Stetson Engineers 2009).

Table 25. Summary of simulated Butt Valley reservoir habitat volume (acre-ft) having water temperature ≤ 22°C and DO ≥ 5 mg/L for Alternative 4a and the change in habitat volume relative to baseline condition (2000, normal year) (from Stetson Engineers 2009)

Date	Total Reservoir Storage (acre-ft)	Simulated Habitat Volume (acre-ft)		Change in Alt 4a Habitat Volume Relative to Baseline Condition (acre-ft)	% of Habitat Volume to Total Reservoir Storage	
		Baseline	Alt 4a		Baseline	Alt 4a
May 15	34,270	33,980	34,270	290	99%	100%
June 7	33,790	31,420	33,420	2,000	93%	99%
Jun 22	32,410	29,980	28,700	-1,280	93%	89%
July 7	36,790	34,380	27,080	-7,300	93%	74%
Jul 20	37,390	33,340	26,250	-7,090	89%	70%
Aug 7	37,190	32,420	26,740	-5,680	87%	72%
Aug 17	38,570	36,120	27,290	-8,830	94%	71%
Sep 7	41,260	41,090	41,110	20	100%	100%
Sep 28	34,710	34,600	34,710	110	100%	100%

Note: The bold dates represent observed profiles.

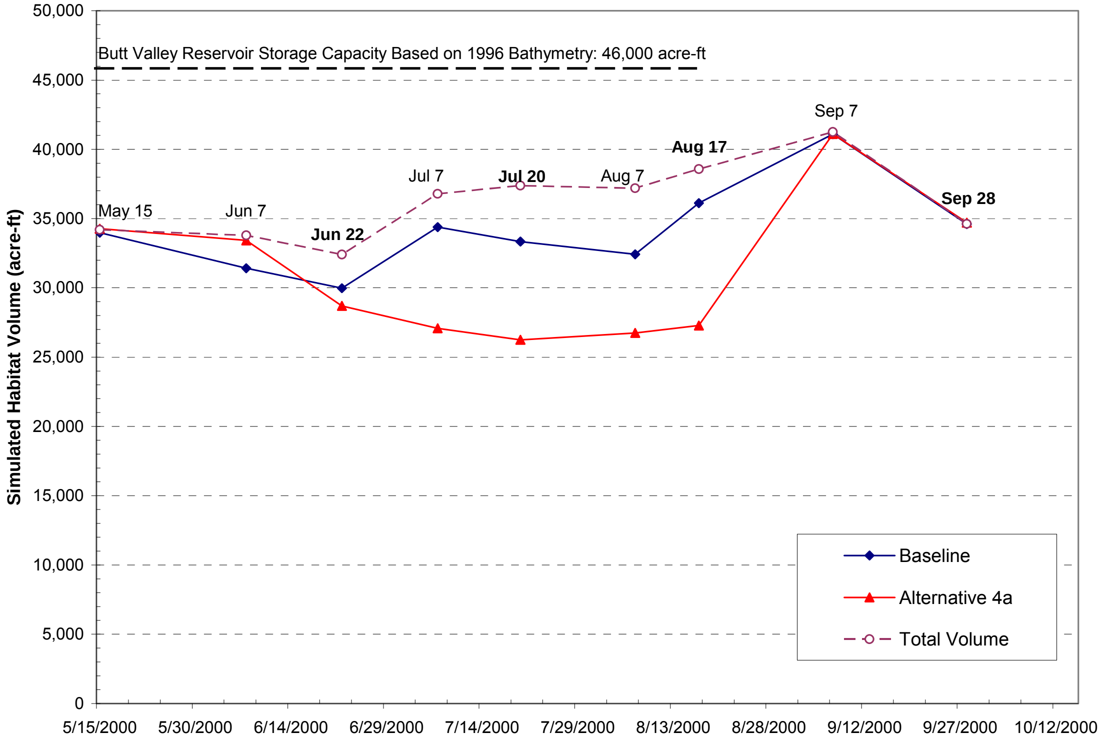
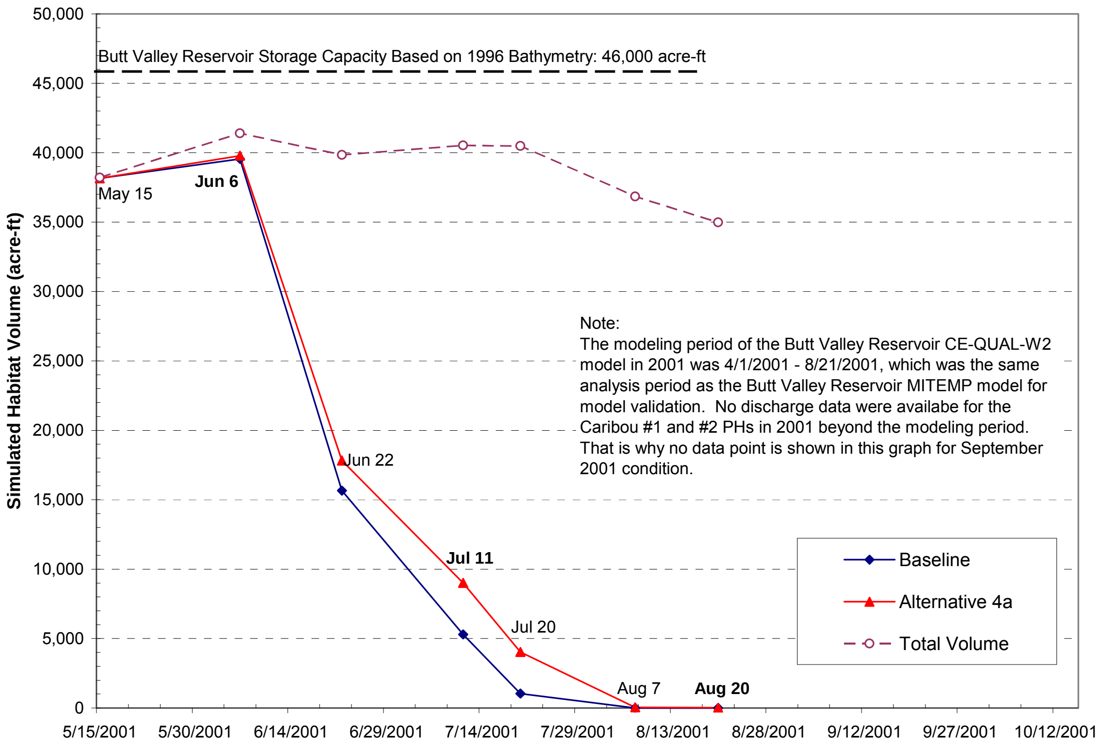


Figure 34. Comparison of simulated Butt Valley reservoir habitat volume having water temperature ≤ 22°C and DO ≥ 5 mg/L for Alternative 4A (2000, normal year) (from Stetson Engineers 2009).

Table 26. Summary of simulated Butt Valley reservoir habitat volume (acre-ft) having water temperature ≤ 20°C and DO ≥ 5 mg/L for Alternative 4a and change in habitat volume relative to baseline condition (2001, critical dry year) (from Stetson Engineers 2009)

Date	Total Reservoir Storage (acre-ft)	Simulated Habitat Volume (acre-ft)		Change in Alt 4a Habitat Volume Relative to Baseline Condition (acre-ft)	% of Habitat Volume to Total Reservoir Storage	
		Baseline	Alt 4a		Baseline	Alt 4a
May 15	38,210	38,160	38,150	-10	100%	100%
June 6	41,400	39,550	39,780	230	96%	96%
Jun 22	39,840	15,660	17,830	2,170	39%	45%
July 11	40,530	5,290	9,010	3,720	13%	22%
Jul 20	40,490	1,040	4,030	2,990	3%	10%
Aug 7	36,840	0	50	50	0%	0%
Aug 20	34,980	0	20	20	0%	0%

Note: The bold dates represent observed profiles.



Note:
The modeling period of the Butt Valley Reservoir CE-QUAL-W2 model in 2001 was 4/1/2001 - 8/21/2001, which was the same analysis period as the Butt Valley Reservoir MITEMP model for model validation. No discharge data were availabe for the Caribou #1 and #2 PHs in 2001 beyond the modeling period. That is why no data point is shown in this graph for September 2001 condition.

Figure 35. Comparison of simulated Butt Valley reservoir habitat volume having water temperature ≤ 20°C and DO ≥ 5 mg/L for Alternative 4a (2001, critical dry year) (from Stetson Engineers 2009).

Table 27. Summary of simulated Butt Valley reservoir habitat volume (acre-ft) having water temperature ≤ 21°C and DO ≥ 5 mg/L for Alternative 4a and change in habitat volume relative to baseline condition (2001, critical dry year) (from Stetson Engineers 2009)

Date	Total Reservoir Storage (acre-ft)	Simulated Habitat Volume (acre-ft)		Change in Alt 4a Habitat Volume Relative to Baseline Condition (acre-ft)	% of Habitat Volume to Total Reservoir Storage	
		Baseline	Alt 4a		Baseline	Alt 4a
May 15	38,210	38,160	38,150	-10	100%	100%
June 6	41,400	40,220	39,950	-270	97%	96%
Jun 22	39,840	24,890	24,690	-200	62%	62%
July 11	40,530	14,980	20,010	5,030	37%	49%
Jul 20	40,490	10,870	17,370	6,500	27%	43%
Aug 7	36,840	210	4,670	4,460	1%	13%
Aug 20	34,980	910	4,330	3,420	3%	12%

Note: The bold dates represent observed profiles.

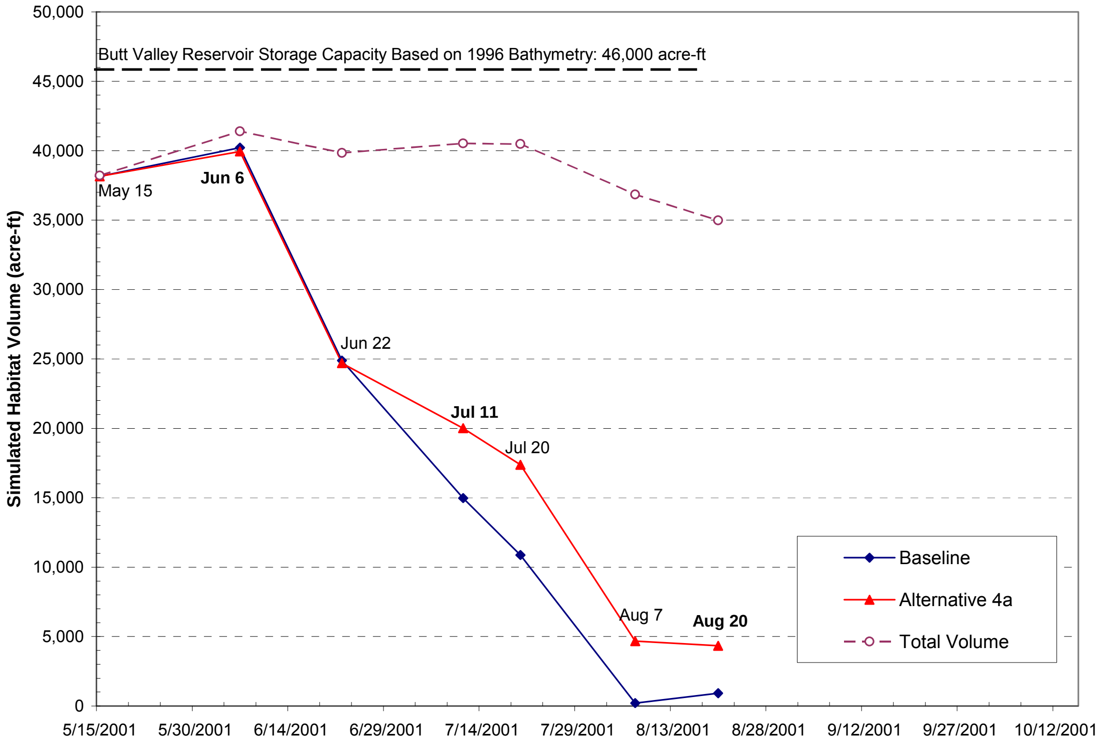


Figure 36. Comparison of simulated Butt Valley reservoir habitat volume having water temperature ≤ 21°C and DO ≥ 5 mg/L for Alternative 4a (2001, critical dry year) (from Stetson Engineers 2009).

Table 28. Summary of simulated Butt Valley reservoir habitat volume (acre-ft) having water temperature ≤ 22°C and DO ≥ 5 mg/L for Alternative 4a and change in habitat volume relative to baseline condition (2001, critical year) (from Stetson Engineers 2009)

Date	Total Reservoir Storage (acre-ft)	Simulated Habitat Volume (acre-ft)		Change in Alt 4a Habitat Volume Relative to Baseline Condition (acre-ft)	% of Habitat Volume to Total Reservoir Storage	
		Baseline	Alt 4a		Baseline	Alt 4a
May 15	38,210	38,160	38,150	-10	100%	100%
June 6	41,400	40,220	39,950	-270	97%	96%
Jun 22	39,840	35,140	35,020	-120	88%	88%
July 11	40,530	37,560	36,210	-1,350	93%	89%
Jul 20	40,490	35,920	35,680	-240	89%	88%
Aug 7	36,840	21,110	29,070	7,960	57%	79%
Aug 20	34,980	31,210	30,970	-240	89%	89%

Note: The bold dates represent observed profiles.

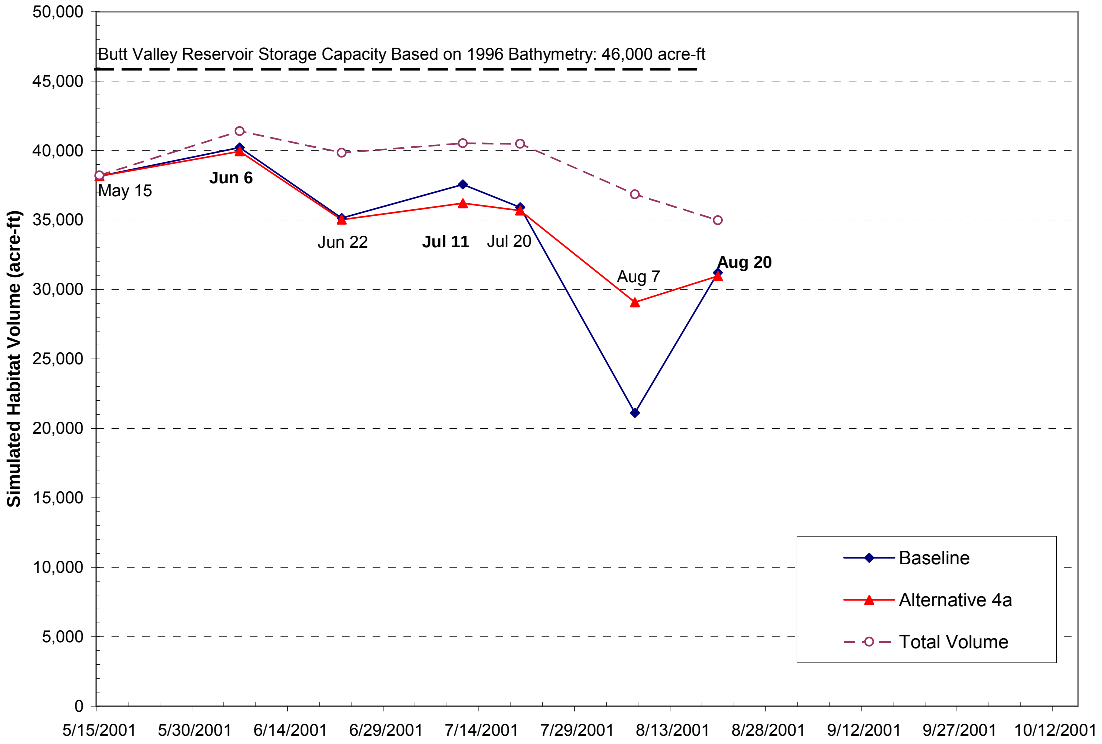


Figure 37. Comparison of simulated Butt Valley reservoir habitat volume having water temperature ≤ 22°C and DO ≥ 5 mg/L for Alternative 4a (2001, critical dry year) (from Stetson Engineers 2009).

Table 29. Summary of primary impacts to aquatic resources in Lake Almanor and recommended mitigation measures for alternative combinations of temperature control measures for the Upper North Fork Feather River Project (FERC Project No. 2105)

TEMPERATURE CONTROL ALTERNATIVE	IMPACT AND SIGNIFICANCE	RECOMMENDED MITIGATION
3 and 3x	1) Reduces coldwater (≤20ºC) refugia habitat volume by 27% from baseline in normal water year in August, resulting in only a 1% reduction in proportion of coldwater refugia to lakewide volume and a 3% reduction in proportion of coldwater refugia to lakewide surface area – Less than significant.	None
	2) Coldwater refugia ≤20ºC declines to zero in August of critical dry water years; reduces coldwater (≤21ºC) refugial habitat volume by 65% from baseline in critical dry water year in August, resulting in a 3% reduction in proportion of coldwater refugia to lakewide volume and an 8% reduction in proportion of coldwater refugia to lakewide surface area – Potentially significant.	Limnological monitoring program; annual stocking of limnologically-compatible trout strains, with high temperature tolerance; increased trout stocking rate after critical dry water years would reduce impact to less than significant.
	3) Reduction in entrainment and transport of forage fish to Butt Valley reservoir caused by operation of a thermal curtain at Prattville intake – Less than significant.	None
	4) In-water construction for installation of thermal curtain and supporting infrastructure at Prattville intake, dredging of submerged levees, installation of bulkhead-mounted slide gates on Canyon Dam outlet tower, and pumping or siphoning water to maintain instream flows during Canyon Dam gate and tunnel modification – Potentially significant.	These impacts would be reduced to less than significant with implementation of construction site stormwater best management practices (BMPs), hazardous materials management and containment BMPs, sediment fences and curtains to contain dredging spoils and use of geotextile fabric on lake bed to minimize sediment disturbance, and appropriate fish screens fitted to pumps and siphon inlets.
4a and 4b	1) Reduces coldwater (≤20ºC) refugia habitat volume by 21% from baseline in normal water year in August, resulting in only a 1% reduction in proportion of coldwater refugia to lakewide volume and a 3% reduction in proportion of coldwater refugia to lakewide surface area – Less than significant.	None
	2) Coldwater refugia ≤20ºC declines to zero in August of critical dry water years; reduces coldwater (≤21ºC) refugial habitat volume by 37% from baseline in critical dry water year in August, resulting in a 2% reduction in proportion of coldwater refugia to lakewide volume but no measureable reduction in proportion of coldwater refugia to lakewide surface area – Potentially significant.	Limnological monitoring program; annual stocking of limnologically-compatible trout strains, with high temperature tolerance; increased trout stocking rate after critical dry water years would reduce impact to less than significant.
	3) Reduction in entrainment and transport of forage fish to Butt Valley reservoir caused by operation of a thermal curtain at Prattville intake – Less than significant.	None

Table 29. Summary of primary impacts to aquatic resources in Lake Almanor and recommended mitigation measures for alternative combinations of temperature control measures for the Upper North Fork Feather River Project (FERC Project No. 2105)

TEMPERATURE CONTROL ALTERNATIVE	IMPACT AND SIGNIFICANCE	RECOMMENDED MITIGATION
	4) In-water construction for installation of thermal curtain and supporting infrastructure at Prattville intake, installation of bulkhead-mounted slide gates on Canyon Dam outlet tower, and pumping or siphoning water to maintain instream flows during Canyon Dam gate and tunnel modification –Potentially significant.	These impacts would be reduced to less than significant with implementation of construction site stormwater BMPs, hazardous materials management and containment BMPs, sediment fences and curtains to contain dredging spoils and use of geotextile fabric on lake bed to minimize sediment disturbance, and appropriate fish screens fitted to pumps and siphon inlets.
4c and 4d	1) Reduces coldwater (≤20ºC) refugia habitat volume by 14% from baseline in normal water year in August, resulting in only a 1% reduction in proportion of coldwater refugia to lakewide volume but no measureable reduction in proportion of coldwater refugia to lakewide surface area – Less than significant.	None
	2) Coldwater refugia ≤20ºC declines to zero in August of critical dry water years; reduces coldwater (≤21ºC) refugial habitat volume by 44% from baseline in critical dry water year in August, resulting in a 2% reduction in proportion of coldwater refugia to lakewide volume and an 8% reduction in proportion of coldwater refugia to lakewide surface area – Potentially significant.	Limnological monitoring program; annual stocking of limnologically-compatible trout strains, with high temperature tolerance; increased trout stocking rate after critical dry water years would reduce impact to less than significant.
	3) In-water construction for installation of bulkhead-mounted slide gates on Canyon Dam outlet tower, and pumping or siphoning water to maintain instream flows during Canyon Dam gate and tunnel modification – Potentially significant.	These impacts would be reduced to less than significant with implementation of construction site stormwater BMPs, hazardous materials management and containment BMPs, and appropriate fish screens fitted to pumps and siphon inlets.

Table 30. Summary of primary impacts to aquatic resources in Butt Valley reservoir and recommended mitigation measures for alternative temperature control combinations of measures for the Upper North Fork Feather River Project (FERC Project No. 2105)

TEMPERATURE CONTROL ALTERNATIVE	IMPACT AND SIGNIFICANCE	RECOMMENDED MITIGATION
3 and 3x	1) Reduces dissolved oxygen levels in the Butt Valley Powerhouse discharge to 2–3mg/L in July and August – Potentially significant.	Aeration or re-oxygenation of water diverted in Butt Valley pipeline or at powerhouse tailrace would reduce this impact to less than significant.
	2) Impact to coldwater refuge would be similar to or less than that analyzed for Alternative 4a – Less than significant.	None
	3) In-water construction for installation of thermal curtain and supporting infrastructure at Caribou intakes – Potentially significant.	These impacts would be reduced to less than significant with implementation of construction site stormwater best management practices (BMPs) hazardous materials management and containment BMPs, and sediment fences and curtains to contain dredging spoils and use of geotextile fabric on lake bed to minimize sediment disturbance.
4a and 4b	1) Reduces dissolved oxygen levels in the Butt Valley Powerhouse discharge to 2–3mg/L in July and August – Potentially significant.	Aeration or re-oxygenation of water diverted in Butt Valley pipeline or at powerhouse tailrace would reduce this impact to less than significant.
	2) Coldwater refugial volume ≤20ºC declines by 11 to 21% compared to baseline in late-June and early-July of normal water years, but is greater than baseline (no action) through rest of summer. Coldwater refuge volume is greater than baseline during critical dry water years – Less than significant.	None
	3) In-water construction for installation of thermal curtain and supporting infrastructure at Caribou intakes – Potentially significant.	These impacts would be reduced to less than significant with implementation of construction site stormwater BMPs, hazardous materials management and containment BMPs, and sediment fences and curtains to contain dredging spoils and use of geotextile fabric on lake bed to minimize sediment disturbance.

Table 30. Summary of primary impacts to aquatic resources in Butt Valley reservoir and recommended mitigation measures for alternative temperature control combinations of measures for the Upper North Fork Feather River Project (FERC Project No. 2105)

TEMPERATURE CONTROL ALTERNATIVE	IMPACT AND SIGNIFICANCE	RECOMMENDED MITIGATION
4c and 4d	1) No impact on dissolved oxygen levels at the Butt Valley Powerhouse discharge would be expected because no thermal curtain is used at Prattville intake.	None
	2) Although diversions from Lake Almanor would be reduced, withdrawal depths would not be changed, and no impact to coldwater refugia would be expected.	None
	3) In-water construction for installation of thermal curtain and supporting infrastructure at Caribou intakes – Potentially significant.	These impacts would be reduced to less than significant with implementation of construction site stormwater BMPs, hazardous materials management and containment BMPs, and sediment fences and curtains to contain dredging spoils and use of geotextile fabric on lake bed to minimize sediment disturbance,.