ATTACHMENT 1

Comments on Draft Environmental Impact Report for the Water Quality Certification of Pacific Gas and Electric Company's Upper North Fork Feather River Hydroelectric Project (FERC Project No. 2105):

Section 6.5 Water Quality: Analysis and Comments,

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Overview

This is a review of section 6.5, Water Quality, of the Draft Environmental Impact Report prepared by the State Water Resources Control Board in response to Pacific Gas and Electric Company's application for a water quality certification for operation of its Upper North Fork Feather River Hydroelectric Project (UNFFR Project) under a new license. The proposed project is composed of elements of PG&E's application to FERC along with modifications. Because of unresolved water quality issues, primarily the elevated water temperatures in the North Fork Feather River upstream of Lake Oroville, the State Water Board has included:

Alternative 1: thermal curtains at Prattville Intake and Caribou Intakes and the release of 250 cubic feet per second (cfs) to Seneca Reach between June 15 and September 15.

Alternative 2: thermal curtains at Prattville Intake and Caribou Intakes.

Question: Why were the following topics omitted from discussion when they will affect or be affected by the project?

Water Visibility

The proposed UNFFR Project and the alternatives will result in warming of Lake Almanor. This could promote the growth of algae, particularly blue-green species. This would reduce visibility of the water. Our data shows that large populations of algae are produced when the lake is warm and nutrients are available in the fall (Johnston and McReynolds, 2015).

Global Climate Change

While the proposed UNFFR Project and alternatives may not affect the trends in water temperatures of Lake Almanor, climate change will certainly have an impact on the success of any project that depends on the existence of a coldwater resource and the transport of that cold water downstream. Climate change in California will result in higher temperatures, decreasing precipitation, a shift to precipitation falling as rain rather than snow and a decrease in Sierra Nevada snowpack by as much as 70 to 90% (California Climate Change Center, 2006; CA EPA, 2013). It is highly likely that climate change will result in even higher water temperatures throughout the Feather River system than exist today. The EIR did not address whether climate change is even partially responsible for higher temperatures in the NFFR downstream of Lake Almanor. However, data show that it is having an effect throughout the west. The impact of climate change on the seasonal cycles in streams in the Pacific Northwest has caused less snow in the winter snowpack, decreased water flow in summer, changes in the temperature of flowing water and warmer air temperatures above the streams (Oregon Climate Change Research Institute, 2013).

Climate change is also increasing the rate of cultural eutrophication (Havens, 2015). Higher water temperatures favor algal growth, especially toxic blue-green algae (USEPA, 2015; Kovner, 2013). Our data for Lake Almanor show that summer algal populations have been increasing and large populations of blue-green algae in August and September are already a concern (Johnston and McMurtry, 2014; Johnston and McReynolds, 2015).

Nutrients

The proposed UNFFR Project, as well as Alternatives 1 and 2, may cause a detrimental change in the overall concentrations of nutrients due to mixing in the hypolimnion and lower metalimnion induced by the withdrawal of hypolimnetic water from Lake Almanor. Modeling of the thermocline elevation during a critically dry year predicts that the thermocline could be deepened by as much as 3-7 feet over the course of the summer (Appendix E-1, Table 8). This could cause mixing of the nutrient-rich hypolimnetic water with the epilimnetic water above, where algae are photosynthesizing, resulting in algal blooms. Our data show that in late August and early September the thermocline in Lake Almanor is only about 2 meters (6.6 feet) in extent (Johnston and McMurtry, 2009; Johnston and McReynolds, 2015). The mixing in the hypolimnion due to withdrawal may increase the amount of nutrients available to algae at a time when sunlight and warmer water temperatures are ideal for growth. Since algal growth is limited by the availability of nutrients at this time of year, increased nutrients will increase algal growth.

Nutrients will also be sent into Butt Valley Reservoir and Seneca Reach. The effects of these nutrients released from Lake Almanor in the hypolimnetic water has not been addressed.

6.5.1 Environmental Setting and Water Quality Conditions of Concern

Question: Is coldwater habitat in Lake Almanor impaired and would this project or alternatives increase impairment?

While Lake Almanor generally meets water quality objectives, the decrease in coldwater habitat during warm critically dry years is significant and increasing in temporal and spatial extent. Analyses of surface temperatures in other California lakes have shown warming (Schneider et al, 2009; California EPA, 2009; Kovner, 2013) and this is mostly likely happening at Lake Almanor, as well. Surface temperatures at Station LA-01, near Canyon Dam, were warmer in July 2014 than they were in 2009 (Johnston and McMurtry, 2009, 2014). Also noted was an increase of 2°C in the temperature of NFFR water at Chester, CA from 2009 to 2014. The changes in overall climate, the subsequent change in snow -water content, and shifts in precipitation from snow to rain that are predicted for California (Scripps, 2013) will further decrease the limited coldwater resource at Lake Almanor. PGE's data for 2008 and our data for 2014 (both critically dry years) showed that thermal stratification was established sooner, epilimnion temperatures were warmer, and the stratification persisted until the end of October. Our data also showed that algal production was very high, but oxygen concentration dropped rapidly to zero in the thermocline. The result was essentially no coldwater habitat in August and September. Unfortunately, anthropogenic warming is increasing the probability of co-occurring warm-dry conditions that have created the current drought (Diffenbaugh et al, 2015).

It is imperative that the depletion of oxygen in the deepest areas of the lake and the resulting lack of suitable coldwater habitat be considered as an indication of water quality impairment. The calculation of habitat reduction was made in the Stetson Report (2009). Those calculations were based on data from 1984-2002, which is not representative of actual conditions and trends evident over the past 10 years and operating in the Lake today. Key water quality conditions at Lake Almanor have worsened. Appendix E1, Table 12, shows there is no suitable habitat for the month of August under both current and proposed UNFFR Project conditions. Our data indicate that lack of habitat now extends well into September (Johnston and McReynolds, 2015). On September 10, 2014 the epilimnion extended down to 10 meters (33 feet) and was at 21°C. Oxygen was at 6 mg/L. At 12 meters the temperature had dropped to 16°C, but the oxygen had dropped to zero and was zero throughout the hypolimnion. A continuous temperature data logger at LA-01 near Canyon Dam showed that thermal stratification persisted until the end of October (Johnston and McReynolds, 2015).

In a normal water year there would still be a considerable reduction (-3,490 AF) of suitable habitat volume (Appendix E1-Table 9) in August with implementation of the proposed UNFFR Project, but nearly three times the impact with Alternative 1 (-10,420 AF) or Alternative 2 (-9,370 AF). Our data for 2011 (the closest year to a normal water year since our monitoring began)) shows that in September the reservoir was still stratified with no oxygen in the hypolimnion. The epilimnion was at 22°C and extended down to 10 meters. At 12 meters oxygen was at 3mg/L and dropped to zero below that depth (Johnston and McMurtry, 2012).

Our data show that the coldwater habitat is currently impaired in the summer and this project or alternatives will increase that impairment by removal of cold water. The proposed UNFFR Project should have a mitigation measure that addresses the impairment and improves coldwater habitat

Question: would water withdrawn from the hypolimnion of Lake Almanor affect the quality of water downstream or in Butt Valley Reservoir?

If water is withdrawn from the hypolimnion as described for the Proposed UNFFR Project, as well as Alternative 1, a "cocktail" of trace metals, along with nitrogen and phosphorus compounds will be sent downstream. The amount will depend on the duration of the flow as well as the rate. Water samples from the hypolimnion at LA-01 near Canyon Dam were collected on four dates in 2014. In September, after a few months of thermal stratification and the resulting anoxic conditions, elevated levels of aluminum, arsenic, copper, iron, manganese, mercury and zinc were detected. Also present were nitrogen-containing compounds (ammonia, nitrite, nitrate, etc.) and phosphorus-containing compounds (Johnston and McReynolds, 2015). With greater withdrawal and discharge to the Seneca Reach, some of these compounds would be adsorbed onto sediments of the Seneca Reach, but not all. Some would be transported and could affect water quality in the water bodies downstream. Many studies of trace metal transport show that the mobility depends on several factors including abundance, reactivity and hydrology (Nordstrom, 2011). Higher flows in the Seneca Reach will result in increased transport of metals, as well as sediment, downstream. Nitrogen compounds are very soluble, so they would not be adsorbed onto sediments. Phosphorus compounds would also be present as dissolved and particulate components and transported (Ruttenberg, 2003). Hydrogen sulfide, a common ingredient in the hypolimnetic water, would be at higher levels with increased discharge through the lower gates of Canyon Dam.

If Alternative 1 or 2 is implemented, Butt Valley Reservoir will receive hypolimnetic water from Lake Almanor. As stated above, this water will be devoid of oxygen and will have elevated levels of several trace metals, along with nitrogen and phosphorus compounds. Because of its lower temperature it will sink to the bottom of the reservoir. Simulations of the impact of Alternatives 1 and 2 on the suitable habitat (temperature $\leq 20°c$, oxygen $\geq 5mg/L$) during a critically dry year shows that no such habitat exists from mid-July until mixing occurs in September (Appendix E-1, Table 20). The metals and nutrients will be transported downstream and could have an impact in those water bodies.

It should further be stressed that withdrawal of cold water by alternative 1 or 2 will be sufficient to result in a warmer Lake Almanor. Mixing of the hypolimnetic water with the metalimnion or epilimnion will generally warm the upper hypolimnion. This may result in a warmer water column at turnover. Warmer temperatures generally encourage the growth of algae (Konopkai and Brock, 1978; Donath, 2013;Valentine, 2015), particularly blue-green species. Overturn is the time of greatest algal growth at Lake Almanor and warmer temperatures in conjunction with increased nutrient availability will increase that growth (Johnston and McReynolds, 2015). Increased algal growth will interfere with water contact recreation, another beneficial use.

6.5.2 Environmental Impacts and Mitigation Measures

Question: will the proposed UNFFR Project or the alternatives result in substantial water quality changes that would adversely affect beneficial uses?

WQ – 1: Implementation of the UNFFR Project could affect water temperature in Lake Almanor

Proposed UNFFR Project

The DEIR states that increased releases from Canyon Dam could affect distribution of water temperatures during the period of summer thermal stratification. The magnitude of the effects is based on the results of the Level 3 Report by Stetson Engineers (2009). This analysis used data from 1984-2002, which may not adequately represent thermal conditions today. Plumas County Flood Control and Water Conservation District, through the efforts of an advisory group, has conducted basic limnological studies from 2009-2014. (Copies of the reports for 2011-2015 have been sent to Peter Barnes, SWRCB, in a packet from Lake Almanor Watershed Group.) These studies show that the onset of thermal stratification is occurring earlier and persisting longer than in 2002. Data from a continuous temperature data logger located near Canyon Dam show that thermal stratification lasted until the end of October 2014. The assumption that the reduction in suitable habitat due to hypolimnetic withdrawal is limited to August (thus, short-lived) is incorrect.

The DEIR states that in a critically dry water year, Lake Almanor is already devoid of suitable coldwater habitat by August (page 6.5-17). The only way that impact assessment could be conducted was to raise the water temperature criterion to 21°C. Table 13 (Appendix E-1) shows that this takes the marginal coldwater habitat from 4% to 3% of the total reservoir storage, or a change of 25%. In a critically dry year such as 2014, there may be another two months before thermal stratification disappears, so this is neither a small change nor is it of short duration.

The DEIR concludes that under all water year types, the proposed UNFFR Project could increase the suitable habitat volume in September and early October. Our data show that this would not occur because the lake would still be strongly stratified until at least mid-September and cold-water withdrawal will continue until mid-September. The only way that habitat could be increased is if the thermal stratification were to be disturbed by hypolimnetic withdrawal, resulting in destruction of the coldwater pool.

The DEIR states that on a lakewide basis the proposed UNFFR Project could result in a reduction of less than one percent of suitable habitat volume. Therefore the impact on water temperature would be less than significant. However, the report states that in a normal water year, the reduction would about 7.9 % and in a critically dry water year, there is no suitable habitat available, at all. The report conclusion is not supported by the analysis presented. The obvious conclusion is that the proposed UNFFR Project would further decrease an already compromised coldwater habitat. Even in a normal water year the coldwater habitat would be 5% of the total lake volume in mid-August. Therefore, the report conclusion should be that implementation of the proposed UNFFR Project will result in substantial water quality changes that would adversely affect beneficial uses. The proposed UNFFR Project should also include a mitigation measure that addresses the reduction in coldwater fish habitat and seeks to improve or increase habitat.

Alternative 1

The operation of a thermal curtain at the Prattville intake could induce mixing at the interface of the hypolimnion and thermocline, as well as in the hypolimnion, itself. Our sampling program for 2012 included a sampling station (LA-07) in the vicinity of the proposed thermal curtain. In early September 2012, the epilimnion extended to more than 10 meters (33 feet). The deepest point was at 16 meters (53 feet) and was at 10.3°C, but the water at the thermocline, 12 meters depth, was considerably warmer at 17.5°C. The entire metalimnion was only 4 meters in extent and the hypolimnion was only 2 meters in extent (Johnston and McMurtry, 2013). In order to maximize the operation of the thermal curtain, water must be drawn from as deep as possible, which will increase the likelihood of mixing in the hypolimnion and the introduction of nutrients and trace metals into the thermocline and possibly the epilimnion. This could result in algal blooms since nutrients would be made available to algae. It is well known that algae will respond to inputs of nutrients (Hecky and Kilham, 1988).

As was previously discussed, the withdrawal of hypolimnetic water from Canyon Dam would have the same effect on mixing at the metalimnion-hypolimnion interface and in the hypolimnion, as well. This would introduce nutrients and metals into the upper metalimnion (thermocline), stimulating algal growth. During the six years of our study (2009-2014), the greatest algal abundance has been at overturn when the nutrients from the hypolimnion are mixed into the entire water column. Typically, algal populations are low during the summer because nutrients are trapped in the hypolimnion. Any disturbance of the thermal stratification could increase nutrient supply and algal growth.

Operation of the thermal curtain at Prattville and withdrawal of hypolimnetic water at Canyon Dam will result in a further decrease of suitable coldwater habitat beyond the proposed UNFFR Project discussed above. In a normal water year suitable habitat volume would be reduced by about 10,420 AF, compared to current conditions. The report concludes that this is a small change in volume and that it would be of short duration. This would reduce the total suitable habitat from 5% to 4% of the lake's total volume. This is not a reduction of 1%, as the report states, but actually greater than 20% reduction. It would also not be of short duration, but would last as long as the end of September.

In a critically dry water year there would be no suitable habitat from mid-July until the end of September. There would a reduction of even marginally suitable habitat by 50% (from 4% of the total lake volume to 2%). The report concludes that the impact would be significant without mitigation.

Because Butt Valley Reservoir would receive hypolimnetic water withdrawn from Lake Almanor, the water would be devoid of oxygen and would contain particulate and dissolved trace metals, as well as nitrogen and phosphorus compounds. Since this reservoir is shallow and poorly stratified, mixing could occur as this water leaves the Butt Valley powerhouse and deliver additional nutrients to the algae downstream. Metals could become incorporated into the food chain and concentrate in the fish.

Alternative 2

A thermal curtain at the Prattville Intake without increased releases through Canyon Dam would have similar effects on suitable coldwater habitat volume. During a normal water year, the decrease in habitat would be from 5% (baseline or present day value) to 4% with alternative 2. It must be stressed that this is not a decrease of 1%, but rather a decrease of 20%, and a habitat volume of only 4% of the total lake volume is extremely small and fragile.

In critically dry years, no suitable habitat exists, and marginal habitat is 10% or less of total lake volume from mid-July until mid-September, according to our data (Johnston and McReynolds, 2015). The DEIR concludes that the effects would be significant without mitigation.

No data are presented to estimate the impacts on suitable habitat in Butt Valley, except that generally the coldwater habitat would be increased. However, the water quality would be decreased by the nutrients and metals carried from the hypolimnion of Lake Almanor.

Our data indicate that the proposed UNFFR Project or the alternatives will result in substantial water quality changes that will adversely affect beneficial uses.

Mitigation Measure WQ-1

Question: Considering that the proposed project and alternatives will have significant effects, is the proposed mitigation measure appropriate? How would the mitigation measure reduce impact to a less than significant level?

The DEIR concludes that the proposed UNFFR Project, as well as Alternative 1 and 2, will have a significant impact on the volume of suitable coldwater habitat during mid-July through August of critically dry years unless mitigation reduces that impact. This is because suitable habitat is not even present in the lake. The proposed mitigation of temperature monitoring and augmented stocking of coldwater fish following critically dry water years would just increase competition for a limited resource. No evidence is presented that restocking will improve the ability of the coldwater fishery to recover. No evidence is presented to explain how this would reduce the project impact on the coldwater habitat.

A more appropriate mitigation for the proposed UNFFR Project would actually increase coldwater habitat, reduce thermal stress and reduce overcrowding of coldwater species. The installation of a Speece Cone, such as has been installed at Comanche Reservoir, would oxygenate the hypolimnion without disturbing the thermal stratification. This would allow coldwater fish to utilize this portion of the lake during the summer months and it would prevent release of nutrients and hydrogen sulfide from the sediments. Such a mitigation measure should be required for the UNFFR Project, as proposed in the State Water Board Staff Recommendation.

Comanche Reservoir, where a Speece Cone has been operating for more than 20 years, is less than half of the volume of Lake Almanor and 135 feet maximum depth. Prior to installation it was plagued with an anoxic hypolimnion, fish kills and hydrogen sulfide generation in the sediments. Hypolimnetic oxygenation was selected as the best alternative to balance the coldwater fishery with water supply needs. The oxygen plume from the Speece Cone extends out as much as 3 miles into the reservoir and maintains oxygen concentration at 6 mg/L (Mello, 2014; Beutel and Horne, 1999).

Although installation of a Speece Cone will increase habitat for coldwater fish species in Lake Almanor, the lake will still be warmer, since cold water will be withdrawn from June –September at an increased rate.

Our data indicate that because there is no suitable coldwater habitat in Lake Almanor during summer of critically dry years, restocking the lake will not reduce the impact of the project to a less than significant level.

Impact WQ-2: Implementation of the UNFFR Project could affect water temperature in Butt Valley Reservoir

Question: Are there other measures that could achieve reduced water temperatures in Butt Valley Reservoir besides a thermal curtain and have they been considered?

Since the proposed UNFFR Project would result in increased flows through Canyon Dam and decreased flows though the Prattville Intake, the temperature in Butt Valley Reservoir would be increased in the summer. In a critically dry water year, this increase could be significant, since the temperature of the epilimnion of Lake Almanor would also be increased. Preferential use of Caribou No.1 powerhouse, as well as insulation and shading of the penstocks into the Butt Valley powerhouse and those into the Belden forebay, would help preserve the cooler water temperature. Also, reduction of the Butt Valley powerhouse discharge to about 500 cfs can cause selective withdrawal of hypolimnion cold water at the Prattville Intake, as was demonstrated during a 2006 special test (Stetson Engineers and PG&E, 2007a).

Alternatives 1 and 2

Both alternatives 1 and 2 would decrease water temperatures in Butt Valley Reservoir, since they would withdraw hypolimnion water from Lake Almanor. However, as discussed above, decreased water temperatures in Butt Valley Reservoir can be achieved in other ways that would be less disruptive to Lake Almanor.

Impact WQ-3: Implementation of the UNFFR Project could affect water temperatures in the North Fork Feather below Canyon Dam and Belden Dam.

Question: Will the proposed UNFFR Project achieve the desired water temperature in the downstream reaches? Will the installation of thermal curtains achieve the desired water temperature in the downstream reaches? Are there other approaches that would decrease temperature as much but have less impact on Lake Almanor?

The DEIR concludes that the proposed UNFFR Project will still result in water temperatures that exceed the optimal temperatures for rainbow trout in summer months in the Belden and Rock Creek reaches.

Alternative 1

With the combination of thermal curtains and increased Canyon Dam discharges, MWATs would continue to exceed 20°C along portions of the Rock Creek and Cresta reaches in critically dry water years. More than half of the Poe reach would remain above 20°C during summer months. Much of the increase in water temperature is due to the warmer East Branch of the North Fork Feather River, which enters above the Belden powerhouse. Obviously, revegetation or shading to reduce temperature in the East Branch should be implemented prior to construction of thermal curtains.

Alternative 1, while placing the coldwater habitat of lake Almanor in serious jeopardy, "would not be sufficient to eliminate the occurrence of exceedances of 25°C diel fluctuations for the Poe reach during warm summer months of dry and critically dry years..." (DEIR, page 6.5-22).

Alternative 2 could result in diel fluctuations of water temperature that reach or exceed lethal levels for coldwater species in the Poe reach.

The conclusion is that alternatives 1 and 2 will be very disruptive to the Lake Almanor ecosystem, but they may not achieve the objective of sufficient cooling in the lower reaches. If warming of the system due to climate change is considered, this casts further doubt on achieving this objective.

Impact WQ-4 Implementation of the UNFFR Project could affect DO concentration in water discharged from Canyon Dam and Butt Valley powerhouse.

Since these discharges would be hypolimnetic water from Lake Almanor, they would be devoid of oxygen for most of the summer months. The Use of a Speece Cone at Canyon Dam would result in oxygenated water releases into the Seneca Reach.

It is possible that a Speece Cone at Canyon Dam would have effects as far as the Prattville Intake. A combination of a Speece Cone at Canyon Dam and reduced flow at Prattville Intake could achieve improved water quality at Lake Almanor and Butt Valley Reservoir, as well as decreased temperatures downstream.

Impact WQ-5 Implementation of the UNFFR Project could cause water released from Canyon Dam to have an undesirable taste or odor.

Impact WQ- 6 Implementation of the UNFFR Project could cause a change in the character or quantity of dissolved metal concentrations or other contaminants in Lake Almanor or the North Fork Feather River.

Question: Has the transport and biological impact of trace metals, nutrients and sediment on downstream reaches and Oroville Reservoir been seriously considered?

As discussed in the DEIR (page 6.5-26), increased withdrawal from the outlet gate would result in considerable mixing and possible dilution of the sulfide-containing hypolimnetic water. Mixing could also increase transport across the sediment-water interface. Nutrients and trace metals would be distributed throughout the hypolimnion, not just at the sediment-water interface. Therefore, withdrawal will result in transport of hydrogen sulfide, trace metals and nutrients to the Seneca Reach. Our data (Johnston and McReynolds, 2015) have shown that nutrients and trace metals are relatively high in Hamilton Branch below Mountain Meadows Reservoir. Nutrients, as well as iron and other trace metals accumulate in the hypolimnion at LA-01, near Canyon Dam.

Installation of a Speece Cone would have the benefit of preventing the release of hydrogen sulfide and nutrients from the sediments. That coupled with increased flows as needed from Canyon Dam should be considered instead of thermal curtains.

The DEIR does not consider the impact of transport of trace metals, nutrients and sediment on downstream reaches or Lake Oroville. Further study is needed to determine if these components will have an impact on water quality or the fish populations.

Summary

The DEIR and our data document that suitable coldwater habitat in Lake Almanor and Butt Valley Reservoir is already impaired. The proposed UNFFR project will further jeopardize that resource and Alternatives 1 and 2 will only increase that impact. The only proposed mitigation measure of increased temperature monitoring and increased stocking of coldwater species will do nothing to alleviate the impact.

The DEIR predicts that the proposed UNFFR project will not achieve the necessary decrease in water temperature in the Belden and Rock Creek reaches and water temperatures would still exceed the 20°C threshold in summer months.

In the summer months of dry and critically dry water years, alternatives 1 and 2 would still not produce water temperatures of 20°C or less in more than half of the Poe reach.

Mixing due to removal of cold water from the hypolimnion of Lake Almanor could result in increased nutrients in the thermocline or epilimnion and increased algal growth, further deteriorating water quality. Transport of trace metals, sediment and nutrients to downstream reaches could impact their water quality.

Measures such as increased flow through Canyon Dam, insulation and shading of penstocks throughout the UNFFR system, reduced flow through Prattville Intake to encourage hypolimnetic withdrawal, preferential use of Caribou #1 intake and revegetation and shading of streams should all be implemented prior to consideration of thermal curtain construction. A mitigation measure, such as installation of a Speece Cone, should be implemented for the proposed UNFFR Project to improve coldwater habitat. This measure would still not be sufficient to mitigate the impacts on the coldwater habitat of alternative 1 and 2 because the high rates of withdrawal they would require.

Questions Concerning State Water Board Staff Recommendation

Although the State Water Board staff has developed a preliminary recommendation that will allow the implementation of the proposed UNFFR project with increased releases from June 15 to September 15, their own DEIR has concluded that this project will not achieve sufficient water temperature decreases.

1. What will constitute the monitoring program? Who will design it?
   A monitoring program should include temperature, dissolved oxygen, trace metals and nutrients at multiple locations in the two reservoirs and in inflowing streams and the NFFR and at multiple times during the year. Any monitoring program should be designed with input from Plumas County, Department of Water Resources and Department of Fish and Wildlife.
2. At what point will sufficient monitoring be completed to show that elevated water temperatures are still occurring in the NFFR?
   The State Water Board will reserve the right to require installation of thermal curtains based on monitoring results. However, the DEIR already predicts that thermal curtains will be necessary to achieve temperature reductions in the Belden and Poe reaches. No other means of temperature reduction have been considered in the DEIR. Although no details are given for how much monitoring will be necessary, the data showing increased water temperatures in the North Fork Feather River already exist, so installation could be required at any time.
3. What will constitute "adaptive management", as suggested by the Staff alternative, and who will be involved in planning and implementation?

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CURRICULUM VITAE: Updated March 2015

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Employment History

1. January, 1971-August, 1977 - Assistant Professor, Department of Geology and Physical Sciences, California State University, Chico. Tenured-August,1976.
2. September, 1977-August, 1982 - Associate Professor, Department of Geology and Physical Sciences, CSU, Chico.
3. 1982-2009 - Professor, Department of Geology and Physical Sciences, CSU, Chico (now Geological and Environmental Sciences Dept.).
4. June, 1981-Aug 1987 - Chair, Department of Geology and Physical Sciences, CSU, Chico.
5. June, 1990- August, 1993 - Director, Institute for Liberal and Interdisciplinary Studies, CSU, Chico.
6. August, 1995 - August, 1998: Chair, Department of Geosciences, CSU, Chico.
7. August 2001- August 2004: Director of Liberal Studies Program, CSU, Chico
8. August 2004- August 2006: Professor, Dept. of Geological and Environmental Sciences
9. August 2006- May 2009: Chair, Dept. of Geological and Environmental Sciences
10. Retired, Professor Emerita, 2009

Publications and Presentations

1. 1970 - K. R. (Gina) Maslin. Effects of the Cross-Florida Barge Canal on Water Quality In the Oklawaha Regional Ecosystem, In Environmental Impact of the Cross-Florida Barge Canal, pg. 73-79. Florida Defenders of the Environment.
2. 1970 - K.R. (Gina) Maslin. Interactions of littoral zooplankton and their fish predators (portion of Ph.D. dissertation), In Eutrophication Factors in North Central Florida Lakes. Univ. of Fla. Ind. Eng. Exp. Sta. Bull. Ser. 134.
3. 1976 - K.R. (Gina) Huntsinger and Paul E. Maslin. Contribution of phytoplankton, periphyton, and macrophytes to primary production in Eagle Lake, California. Calif. Fish and Game 62(3):187-194.
4. 1976 - K.R. (Gina) Huntsinger and Paul E. Maslin. A limnological comparison of the three basins of Eagle Lake, California. Calif. Fish and Game 62(4):232-245.

5. 1983 - K.R. (Gina) Rothe. Defining the relationship between turbidity and precipitation in two northern California water supply reservoirs.Verh. Internat. Verein. Limnol. 22: 1456. (abstract only).
6. 1984. K.R. (Gina) Rothe. Variation in trophic state indicators in two northern California reservoirs. Calif. Fish and Game 70(2): 68-77.
7. August, 1983 - presented a paper "An Investigation of Turbidity in Two Northern California Water Supply Reservoirs" at Societas Internationalis Limnologiae, Lyon, France.
8. December, 1984 - presented "Turbidity Investigations and Watershed Management" at Environmental Protection Agency, Corvallis, OR.
9. November, 1996 - presented paper at North American Lake Management Society Symposium in Minneapolis: Effect of Varying Precipitation on Trophic State Indicators in a Northern California Water Supply Reservoir.
10. November, 1998 – presented a paper at North American Lake Management Society Symposium in Banff, Canada: Changes in Phytoplankton, Zooplankton, and Nutrients In a Water Supply Reservoir as a Result of Drawdown.
11. November, 2008 – presented a paper at the North American Lake Management Society Symposium in Lake Louise, Canada: Long-term Effects of Varying Precipitation on Trophic State Indicators in a Northern California Water Supply Reservoir". Co-author: John McMurtry.

Recent Awards and Contracts:

1. November, 1989 - awarded $4,945 CSU Research Award for project, "Investigation of the Bioaccumulation of Lead from Ammunition in Horseshoe Lake".
2. August, 1990 - $17,691 from National Science Foundation for purchase of gas chromatograph. Matching funds provided by CSU, Chico.
3. March, 1991 - awarded $4,911 from College of Natural Sciences to buy flame ionization detector, supplies and chemicals for preliminary studies with gas chromatograph.
4. May, 1991 - awarded $3,500 Summer Fellowship for research on pesticides in ground water of Butte and Glenn counties.
5. August, 1992 - awarded $4799 from Auxiliary Revenue Distribution Funds to support graduate student/faculty environmental research.
6. May, 1994 - awarded $9652 from Auxiliary Revenue Distribution Funds to purchase environmental science equipment
7. June, 1996 - awarded $46,633 from NSF to purchase equipment for Environmental Lab. $54,000 matching funds provided by CSU, Chico.
8. December, 1997 - awarded $5959 contract from Nature Conservancy to conduct water quality monitoring at Vina Plains Preserve (with Dave Brown).
9. May, 1998 - awarded $7708 contract from Paradise Irrigation District to conduct water quality monitoring at Paradise and Magalia Reservoirs.
10. April – May 2000: awarded a contract ($1275) from Shasta Vineyards Homeowners Association in Redding, CA to perform a water quality evaluation of their lakes. A report was submitted in May 2000.
11. May - August 2000: awarded a contract from Paradise Irrigation District ($7708), for limnological investigation of their water supply reservoirs.

12. April-June 2002: awarded contract from Paradise Irrigation District ($7735), for limnological investigation of their water supply reservoirs.
13. April 2005: awarded contract from Paradise Irrigation District ($10, 532) for limnological investigation of water supply reservoirs.
14. March 2008: awarded contract from Paradise Irrigation District ($14,498) for limnological investigation of water supply reservoirs. Co-PI: John McMurtry.
15. March 2009: awarded contract from Almanor Basin Watershed Advisory Committee ($16,126) for limnological investigation of water quality in Lake Almanor. Co-PI: John McMurtry

15. March 2010: awarded contract from Almanor Basin Watershed Advisory Committee ($13,000) for limnological investigation of water quality in Lake Almanor. Co-PI: John McMurtry
16. March 2011: awarded contract from Almanor Basin Watershed Advisory Committee ($11,500) for limnological investigation of water quality in Lake Almanor. Co-PI: John McMurtry
17. April 2012: awarded contract from Almanor Basin Watershed Advisory Committee ($13,316) for limnological investigation of water quality in Lake Almanor. Co-PI: John McMurtry
18. April 2013: awarded contract from Almanor Basin Watershed Advisory Committee ($14,000) for limnological investigation of water quality in Lake Almanor. Co-PI: John McMurtry
19. April 2014: awarded contract in conjunction with Scott McReynolds, DWR, from LAWG for limnological investigation of water quality in Lake Almanor.

Other Professional Activities

1. Consultant to Paradise Irrigation District, 1974-2008.
2. Consultant to community group, P.O.W. (Protect Our Watershed), 1991-1997
3. Judge, Butte County - Chico Science Fair (every year since 1974)
4. May, 1997 - attended NSF Chautauqua Workshop on Interdisciplinary Science Education.
5. December, 1997-attended two workshops: Advanced Algal Identification and Rapid Bioassessment Protocols
6. March 1999 –attended a 3-day worshop in Milwaukee, WI, sponsored by Lachat Instruments. I became familiar with the operation of the Lachat ion analyzer and have assisted several students in water analysis projects
7. April – May, 1999 - served as a peer reviewer for the California Regional Water Quality Control Board-Lahonton Region Draft Basin Plan for Indian Creek Reservoir.
8. Member, Certification Board of North American Lake Management Society, 1989-2010.
9. Certified Lake Manager award from North American Lake Management Society: Fall, 1993 and renewed in 2001. This required review of professional record.
10. Chapter reviews for Environmental Science texts: at least one per year, 1996-2006
11. Consultant to Almanor Basin Watershed Advisory Committee since 2000.

ATTACHMENT 2

A.A. RICH AND ASSOCIATES

Alice A. Rich, Ph.D.
Principal

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March 25, 2015

Randy Wilson
Planning Director/Co-Manager of
Flood Control and Conservation District
Plumas County Planning and Building Services
555 Main Street
Quincy, CA 95971

RE: Upper North Fork Feather River Hydroelectric Project Draft Environmental Impact/Comments on Fisheries

Dear Randy:

Attached are my comments, regarding the Upper North Fork Feather River Hydroelectric Project Draft Impact Report SCH No. 2005082t2.

Thank you.

Sincerely,

Alice A. Rich, Ph.D.

Attachment

March 25, 2015

Randy Wilson
Planning Director/Co-Manager of
Flood Control and Conservation District
Plumas County Planning and Building Services
555 Main Street
Quincy, CA 95971

RE: Upper North Fork Feather River Hydroelectric Project Draft Environmental Impact/Comments on Fisheries

I. BACKGROUND

The State Water Resources Control Board (SWRCB) prepared a Draft Environmental Impact Report (DEIR) in response to Pacific Gas and Electric Company's (PG&E's) application for a water quality certification for operation of its Upper North Fork Feather River Hydroelectric Project (UNFFR Project) under a new license from the Federal Energy Regulatory Commission (FERC). The proposed project is composed of:

- Three dams that form Lake Almanor, Butt Valley reservoir, and Belden forebay, respectively;
- Five powerhouses (Butt Valley, Caribou No. 1, Caribou No. 2, Oak Flat, and Belden);
- Tunnels and penstocks connecting the reservoirs to the powerhouses; and,
- Transmission, recreation, operations and maintenance, and access facilities.

Lake Almanor is the upstream-most reservoir on the Upper North Fork Feather River (NFFR) within the proposed UNFFR Project. Butt Valley Reservoir is south of Lake Almanor on Butt Creek, a tributary to the NFFR. Belden forebay is on the NFFR downstream of Lake Almanor and below Butt Valley reservoir.

The proposed UNFFR Project is composed of the elements of PG&E's application to FERC, as well as modifications made in accordance with the 2004 Settlement Agreement (Appendix A of DEIR), mandatory conditions, and the FERC staff alternative. The SWRCB developed an array of measures that could reduce water temperatures in the NFFR below Canyon Dam. Three of the measures (thermal curtains at the Prattville intake, thermal curtains at the Caribou intakes, and increased Canyon Dam flow) were carried forward for analysis in the DEIR:

(1) Alternative 1: Installation of thermal curtains at the Prattville and Caribou Intakes and the release of up to 250 cfs to the Seneca Reach between June 15 and September 15; and,

(2) Alternative 2: Installation of thermal curtains at Prattville and Caribou Intakes.

II. OVERVIEW

This is a review of the SWRCB's DEIR, with regard to the potential impacts of PG&E's Proposed UNFFR Hydroelectric Project and Alternatives 1 and 2 on fishery resources and recreational fishing in Lake Almanor, Butt Valley Reservoir, and the NFFR, downstream of Lake Almanor. PG&E's Proposed UNFFR Project and Alternatives 1 and 2 could result in significant impacts on water quality, water temperature, and suitable (defined in the DEIR as $\leq$20°C and $\geq$5 mg/L) coldwater habitat. Those impacts, in turn, could result in significant negative effects on the fishes (rainbow and brown trout, special status fish species, and other fishes) and recreational fishing opportunities (e.g., trophy trout) in Lake Almanor, Butt Valley Reservoir, and the NFFR downstream of Lake Almanor. My comments focus on the potential effects of Alternatives 1 and 2 on the fishery resources and recreational fishing in the two reservoirs and the NFFR.

The DEIR states (page 6.5-13) that, "Impacts on fisheries would be significant if the Proposed UNFFR Project, Alternative 1, or Alternative 2 would:

- Substantially affect, either by take or through habitat degradation (e.g., adverse changes in flow or deterioration of water quality), a special-status fish species;
- Substantially interfere with the movement of any resident or migratory fish species;
- Cause a fish population to drop below self-sustaining levels; or
- Substantially affect native or introduced fish species, resulting in a reduction in the quality of the recreational fishery provided by Lake Almanor, Butt Valley reservoir, and the North Fork Feather River."

There is a good possibility that all of the above could be significant with implementation of Alternatives 1and 2.

The following are summarized in my comments:

(1) The DEIR failed to analyze and disclose factors that could have significant impacts on fishery resources habitat and populations;

(2) The DEIR's critical water temperature criteria may not be protective of rainbow trout in the NFFR, Lake Almanor and Butt Valley Reservoir;

(3) Existing coldwater conditions and Alternatives 1 and 2 would result in a larger decrease of suitable coldwater habitat that would last longer in Lake Almanor than was stated in the DEIR;

(4) Alternatives 1 and 2 could introduce nutrients and heavy metals into Lake Almanor and Butt Valley reservoir that, in turn, could have significant negative effects on the fishes and recreational fishing in the reservoirs, and the NFFR;

(5) The Maximum Weekly Average Temperature (MWAT) Methodology is an unvalidated hypothesis that is of questionable biological reliability and value, without site-specific data for this project;

(6) To determine the potential impacts of the Proposed UNFFR Project and Alternatives 1 and 2, additional studies and monitoring are needed;

(7) There is no evidence that the mitigation measures would result in less than significant impacts to fishery resources and recreational fishing in Lake Almanor, Butt Valley Reservoir, and the NFFR; and,

(8) An alternative to the mitigation of re-planting trout that is offered in the DEIR is provided: the use of a Speece Cone, or some other oxygenation infrastructure.

II. COMMENTS

A. The DEIR omitted topics that could have significant impacts on fishery resources habitat and populations and recreational fishing opportunities

The DEIR omitted the following factors from discussion, any of which could negatively affect the fishery resources in Lake Almanor, Butt Valley Reservoir, and the NFFR:

(1) Increased water temperatures in the NFFR as a result of global climate change;
(2) Increased eutrophication in Lake Almanor as a result of global climate change;
(3) Potential detrimental change in the overall concentration of nutrients, due to mixing in the hypolimnion and lower metalimnion induced by the withdrawal of hypolimnetic water from Lake Almanor; and,
(4) Studies that would identify the factors that limit populations of fish in Lake Almanor, Butt Valley Reservoir, and the NFFR.

The omission of the above-listed topics from discussion in the DEIR could affect the DEIR's impact analyses, and conclusions of the significance of potential impacts of the Proposed UNFFR Project and Alternatives 1 and 2 on fishery resources, including the rainbow trout, and two fish species of special concern, the hardhead and the Sacramento perch. In addition, such omissions could result in a reduction in recreational fishing opportunities.

1. **Increased water temperatures, as a result of climate change, could have a significant negative impact on the rainbow trout in the NFFR**

A discussion of global warming was omitted from the DEIR. Global warming could increase water temperatures in the Feather River system, regardless of the Proposed UNFFR Project and its Alternatives (Dr. Gina Johnston's Comments). The DEIR did not discuss whether or not climate change was even partially responsible for higher temperatures in the NFFR downstream of Lake Almanor. Higher water temperatures in the NFFR, as a result of global warming could have a significant negative impact on the rainbow trout in the NFFR, irrespective of the Proposed UNFFR Project and Alternatives. That information needs to be analyzed to differentiate the results of higher water temperatures in the NFFR that would be due to global warming versus those due to the Proposed UNFFR Project and it Alternatives.

Furthermore, given the long-term time horizon (e.g., 30-50 years) of the proposed FERC license and 401 certification, climate change and its potential to warm baseline temperatures and reduce the availability of suitable coldwater habitat in summer/fall months to critical levels needs to be addressed. To accurately analyze and disclose all of the potential effects of Alternatives 1 and 2 over the life of the project, the DEIR must assess the impacts of the Alternatives removing coldwater habitat in the context of warmer, climate-change affected Lake Almanor.

2. **Increased eutrophication, as a result of increased temperatures due to climate change, could result in significant negative impacts on Lake Almanor**

Global warming could lead to eutrophication, including increased algal growth in Lake Almanor. Data collected from 2010-2014 demonstrated that algal populations have been increasing in Lake Almanor (Johnston and McMurtry, 2012-2015, 2010). Large populations of blue-green algae in August and September are already a concern (Comments of Dr. Gina Johnston, Plumas County Comments).

Increased eutrophication could result in the following impacts on the trout (and other fish species) in Lake Almanor:

- Blue-green algae (cyanobacteria) can be toxic to fishes, similar to its effects on humans; and,
- Decreased dissolved oxygen (DO) concentrations could negatively affect, or even kill, the trout and other fishes.

The toxins produced by the blue-green algae include neurotoxins and hepatoxins (Codd et al., 1989; Carmichael, 1992). Chronic exposure of fish (including salmonids) to toxic cyanobacterial blooms resulted in death, ionic imbalance and reduced growth, gill function inhibition, and digestive organ disorders (Huynh-Delerme et al., 2005; Bury et al., 1995; Gaete et al., 1994; Beveridge et al., 1993; Rabergh et al., 1991; Sugaya et al., 1990).

When algae die, they decompose and the nutrients contained in that organic matter are converted into inorganic form by microorganisms. This decomposition process consumes oxygen that, in turn, reduces the concentration of DO. The depleted DO levels might lead to fish kills (www.cdph.ca.gov), sublethal chronic effects on fishes, and a range of other effects, including reducing biodiversity.

Fish kills, as a result of blue-green algae blooms, often occur in California and are listed on the California Department of Public Health's web site (www.cdph.ca.gov), as algae is a health hazard to humans and other animals. To accurately analyze and disclose all the potential effects of Alternatives 1 and 2 over the life of the project, the DEIR must assess the impacts of the Alternatives in removing available coldwater habitat in the context of a warmer, climate-change-affected Lake Almanor.

3. Nutrient changes could result in negative effects on fishes in Lake Almanor

The proposed UNFFR Project may cause a detrimental change in the overall concentrations of nutrients, due to mixing in the hypolimnetic and lower metalimnion, induced by the withdrawal of hypolimnetic water from Lake Almanor (Dr. Gina Johnston's Comments). The mixing in the hypolimnion could increase the amount of nutrients available to algae at a time when sunlight and warmer water temperatures would be ideal for growth. Increased nutrients would increase algae growth. The potential negative effects of the increased algae on trout (and other fish species) in Lake Almanor are discussed in the previous section above.

4. Studies that would identify the factors that limit populations of fish in Lake Almanor, Butt Valley Reservoir, and the NFFR

To quantify potential impacts of the Proposed UNFFR Project and its Alternatives on the fish in Lake Almanor, Butt Valley Reservoir, and the NFFR, studies are needed to identify factors that are currently limiting populations of the fish in those waterbodies.

Food Availability

The importance of food availability in determining protective water temperatures in Lake Almanor, Butt Valley Reservoir, and the NFFR cannot be overemphasized. In both the laboratory and in the wild, trout growth varies as a joint function of ration and water temperature (Bjornn, 1971;Filbert and Hawkins, 1995). In general, the effect of food quantity on growth is greatest at optimum temperatures. And, the effect of varying temperature is small, under conditions of low food supply. The effect of varying temperature increases, as the amount of food available to individual fish increases.

Food limitations commonly cause reductions in summer growth in rainbow trout (Cada et al., 1987; Preall and Ringler, 1989). If food becomes limited in the field, the maximum temperature at which growth is positive declines and the optimum growth zone shifts to lower temperatures to compensate for the elevated respiration/growth ratios (Elliott, 1981). The amount of food available to the trout in Lake Almanor, Butt Valley Reservoir, and the NFFR is unknown. To determine whether or not the Proposed UNFFR Project and its Alternatives would affect the trout's ability to feed and assimilate that food under the varying thermal conditions, studies of food availability/ingestion/assimilation, as a function of water temperature, need to be conducted.

Affect of current trout stocking practices on the trout fishery

The effectiveness of the current stocking of trout in Lake Almanor is unknown. Although California Department of Fish and Wildlife plants thousands of trout each year, and the Fisherman's Association raises trout in pens and releases them into the lake each year, there are no current data that demonstrate how effective these stocking practices are. As reported in Table 6.6-2 in the DEIR (page 6.6-7), from 2001-2011, there have been varying quantities and sizes (ages) of trout and Chinook salmon planted in Lake Almanor. No recent angler creek surveys have been conducted, nor has anyone determined the relative success of each year of planting. To determine the relative success of the current stocking program in Lake Almanor, ongoing angler creel census monitoring is warranted. Without such data, it is not possible to determine whether or not the mitigation measure to plant trout would be effective and result in reducing the impacts of the proposed UNFFR Project and Alternatives to less than significant.

Affect of the thermal refugia areas on survival of rainbow trout in Lake Almanor

Persons knowledegable about the fishery resources (including fishing guides in the area) that I spoke with, told me that the springs around Lake Almanor offer a thermal refuge for the trout during the summer months (Maumoynier, 2015; Jemenez, 2015; Kossow, 2015). The trout appear to leave Lake Almanor to avoid the unsuitable habitat conditions (increased water temperatures and decreased DO concentrations) and move to the springs. The trout leaving the lake for cooler waters in the spring often have parasitic copepods in their gills, the presence of which is a typical stress reaction as a result of thermal or other stress. In addition, Lake Almanor has large underwater springs. The DEIR (page 6.6-5) states that:

> *"Lake Almanor's large underwater springs have also been anecdotally reported to be localities where trout and salmon may congregate during the summer, when coldwater is limited. However, it is not known what portion of the lake's coldwater fish population may use these spring areas as a thermal refuge."*

Information about such thermal refugia areas is critical to the management of the impacts of the Proposed UNFFR Project and Alternatives and could provide the SWRCB with additional mitigation opportunities.

B. The DEIR's critical temperature criteria may not be protective of the rainbow trout in the NFFR, Lake Almanor, or Butt Valley Reservoir

Of all environmental factors that affect fish, water temperature is considered to be the ecological master factor (Brett, 1971). Thus, it is of paramount importance to determine thermal criteria that would protect the rainbow trout in the NFFR, Lake Almanor, and Butt Valley Reservoir.

To determine protective water temperatures for rainbow trout under the conditions of the Proposed UNFFR Project and its Alternatives is no small task. Water temperature requirements for rainbow trout are dependent on a variety of factors, including, but not limited to: (1) previous temperatures that the fish have been exposed to; (2) food availability; (3) environmental stressors (e.g., diseases, pollution; (4) fish size and age; and, (5) photoperiod (McCauley et al., 1977; Filbert and Hawkins, 1995; Dockray et al., 1996; Kwain and McCauley, 1978; Evans et al., 1962). Thus, one cannot determine water temperature requirements and, from there, impacts from the Proposed UNFFR Project and its Alternatives, on rainbow trout, without carefully analyzing the existing information on thermal requirements of rainbow trout and identifying any data gaps that exist. Such an analysis would aid in determining the water temperatures that would be protective of the rainbow trout under the conditions of the Proposed UNFFR Project and Alternatives 1 and 2.

Similar to all specific areas of scientific inquiry, fish thermal physiology has its own nomenclature that can be confusing when there are different meanings for "optimal", "lethal", "preferred", "tolerance", "threshold", and "stressful" temperatures. Such a lack of standardization is problematical when one is attempting to determine the temperatures that would be protective for rainbow trout under the conditions of the Proposed UNFFR and Alternatives. It is extremely important that the information contained in existing scientific literature not be misinterpreted. It is also of utmost importance that, when trying to find scientific support for thermal protection for rainbow trout, information not be "cherry picked" out of specific publications, as that would present an incomplete picture of both thermal requirements and potential impacts on the rainbow trout.

A variety of thermal studies has been undertaken on the various life stages of rainbow trout over the decades. When one examines the results of the thermal studies, the following general conclusions can be made about fish in general and rainbow trout, specifically:

- The physiological and behavioral responses of water temperature to fish, including trout, are site-specific;
- Water temperature requirements are directly dependent upon the availability of food;
- Fish do not feed maximally in the wild. Thus, one cannot directly apply the results of laboratory data when fish are fed maximal rations, to a field environment;

- Rarely, and only under very controlled conditions, can one use data from a laboratory study and apply those data to a field situation with any level of confidence;

- Water temperatures that are considered optimal for fish in a laboratory environment, where the fish are fed all they can eat, will always be higher than those for fish in a creek or river or lake. If site-specific data are not available, and one is relying on existing scientific studies, in an attempt to determine protective water temperatures, the laboratory results need to be adjusted downward to account for the influences of reduced food availability, competition, predation, and other environmental variables. Growth rates have been observed in the field that are less than those predicted in the laboratory under maximum feeding (Preall and Ringler 1989; Cada et al., 1987);

- To determine the optimal water temperatures for any species of fish, one needs to know how efficient the food eaten is being converted to "fish flesh" at each temperature studied. This process is called "food conversion efficiency". It is not enough to measure growth rate alone in a laboratory environment and directly apply those results to fish in the wild because, as water temperatures increase, it takes more and more food for the fish to grow. And, in a laboratory environment, one can keep feeding the fish. But, in the natural environment, if the fish does not obtain adequate food at the higher temperatures then it will not grow; and,

- Due to the variation that exists in the results of thermal studies for rainbow trout, one should always err on the side of caution and provide a margin of safety.

Different results occur for different types of studies. Laboratory studies allow manipulation of factors that control and limit a fish's response to water temperature. Cause-and-effect relationships can be derived from such manipulations. In the natural environment, it is much more difficult to determine protective water temperatures for rainbow trout and other fishes, due to the myriad of factors that can affect the outcome. Thus, in the absence of field studies, to determine protective water temperatures, the information from the laboratory studies must be interpreted correctly, whether it be information that is physiological (e.g., growth, food conversion efficiency), behavioral (e.g, preference) or lethal.

The DEIR states that,

> "*Key temperature thresholds above which some level of physiological impairment can occur are generally found to occur over a temperature range of from 18°C to 21°C for rainbow trout for chronic exposures, typically measured as the daily temperature over a time frame of one week or more (Hokanson et al 1977, Wurtsbaugh and Davis 1977, Bell 1990, McCullough 1999, Myrick and Cech 2000, Sullivan et al 2000, McCullough et al. 2001).*" (DEIR page 6.6-2)

It is not clear to me how the DEIR reached its conclusion that, "Key temperature thresholds above which some level of physiological impairment can occur.... (is) from 18° C to 21° C for rainbow trout.....". The studies cited in the DEIR do not support the DEIR's conclusion and there are no site-specific studies to support this conclusion. Please indicate where in the DEIR this conclusion is supported.

Regarding the citations above that, purportedly, provide scientific foundation for the DEIR's "Key temperature thresholds..." , the following is a list that summarizes each of the researcher's conclusions in those studies, which demonstrate that these studies do not support the DEIR's "Key temperature thresholds...":

- Hokanson et al. (1977), in a laboratory study with juvenile rainbow trout fed maximal rations all day, did not study conversion efficiency of the food consumed. Therefore, the optimal water temperature (s) could not be ascertained from that study.

- Wurtsbaugh and Davis (1977) studied juvenile anadromous steelhead, instead of the resident rainbow trout. Steelhead are known to have much lower thermal requirements than resident rainbow trout. As there are no steelhead anymore in the NFFR, it is not clear how that study supported the DEIR's conclusion, regarding thermal range at which there will be no physiological impairment to the rainbow trout.

- After summarizing many of the studies that have been conducted on rainbow trout, McCullough et al. (2001) concluded that, because thermal criteria must protect both adult and juvenile forms of rainbow trout, an optimal regime appeared to most consistently occur in the range of 13-15 °C. This range is considerably lower than the one reported in the DEIR and yet this publication was cited in support of the DEIR's thermal thresholds.

- Myrick and Cech (2000)[1], who used fish fed to satiation and measured food conversion efficiency, concluded that 14-19 °C was the optimal growth temperature for both the strains ("Eagle Lake" and "Mt. Shasta") of rainbow trout. This is a wider, but lower upper protective temperature, thermal range than the DEIR's 18-21°C.

- Bell (1990) used data from previous studies and depicted them on a figure labeled "E Sportfish-Optimum Range". On that figure, the range under rainbow trout was 12.2-18.9 C. Again, the lower part of this range is considerably lower than the range in the DEIR purported to be protective of rainbow trout.

- In the Sullivan et al. (2000) report, water temperature studies that had been conducted on salmonids were summarized, but the only information on rainbow trout related to lethal temperatures. In that report the studies focused on lethal temperatures, effects of growth on temperatures, and bioenergetics modeling, but the focus, except for the lethal temperatures, did not include rainbow trout. Instead, the effects of temperatures on steelhead were discussed. Steelhead are known to have much lower thermal requirements than rainbow trout (Rich, 1987). Thus, the Sullivan et al. (2000) report does not appear to be relevant for determining protective water temperatures for rainbow trout for the UNFFR Project and its Alternatives.

In addition, a laboratory study (Myrick and Cech, 2000) was cited in Appendix F of the DEIR, presumably, as scientific support for the DEIR's 18-21° C range. The study focused on two California strains of rainbow trout ("Eagle Lake" and "Mt. Shasta"), as discussed in the previous paragraph. And, the optimal thermal range for growth for the rainbow trout reported in that study was 14-19 °C, which is not a scientifically-based reason to choose the 18-21°C "protective" range reported in the DEIR.

In the discussion of the field study (Matthews et al., 1994) in Appendix F of the DEIR, the authors stated that "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 19 °C (the warmest available) than at cooler temperatures (available down to 14.5 °C) in a stratified pool."

[1] Myreck and Cech (2000) were not listed in Chapter 9. References. However, I assume it is the same reference cited in Appendix F

Appendix F to the DEIR cited (page 8) this reference in support of the upper end of the "protective" 18-21° C range. The actual story behind the Matthews et al. (1994) study is more complicated than reported in Appendix F:

- The rainbow trout were found in a wide range of water temperature, 12.8-19.1 °C , whereas the range of water temperatures in the pool was 6.1-19.4 °C, depending upon whether the thermal data were collected at the bottom or surface of the pool, or the inlet to the pool. Thus, the trout were not found below 12.8 °C or above 19.1°C;

- No food availability studies were conducted, so there were no data to determine why the fish inhabited the various parts of the pool;

- The authors stated that rainbow trout might have occupied the warmer areas of the pool when they did because the cool water area was too small to accommodate all of the fish; and,

- Of the six rainbow trout that occupied the pool in the study, two were deleted from the analysis, so their results were based on only four fish, hardly a robust population sample upon which to make conclusions.

Thus, as with all of the laboratory and field studies on the effects of water temperature on rainbow trout, the actual details of, and conclusions made, in the studies were much more complicated and revealing that reported in the DEIR or Appendix F to the DEIR.

Furthermore, there have been no site-specific food availability or thermal bioenergetics studies that would demonstrate that there is enough food to sustain the different life stages of the rainbow trout in Lake Almanor, Butt Valley Reservoir, and the NFFR at temperatures between 18-21 °C. Finally, although the subject of sublethal thermal stress was discussed in Appendix F of the DEIR, a number of studies have demonstrated that temperatures within the 18-21°C range and below could result in thermal stress in rainbow trout (Taylor and Barton, 1992; McCauley and Pond, 1971; Dickson and Kramer, 1971; Kwain and McCauley, 1978; Piper et al., 1982; Sadler et al., 1986; Ferguson, 1958) and temperatures above 18 °C could inhibit long-term growth. Established indicators of thermal stress on fish include, but are not limited to (Elliott, 1981):

- reduced growth;
- reduced food conversion efficiency;
- avoidance;
- disease outbreaks;
- loss of appetite;
- hyperactivity; and,

- secretion of stress hormones such as adrenalin and cortisol.

All of these stress indicators have been directly and indirectly linked with the survival of natural populations of salmonids, including trout (Elliott, 1981). In addition, the stress impacts of chronic sublethal water temperatures on trout and other salmonids are positively correlated to the duration and severity of exposure. And, similar to humans, stress is cumulative in trout and other fishes (Barton et al. 1986; Mesa, 1994). Thus, if there are other stressors that are affecting the rainbow trout (e.g., pollution, low DO concentrations, etc.), in addition to the thermal stress, the physiological results are cumulative (i.e., the "whole is greater than the sum of the parts") and the fish can ultimately die, as a result of continued multiple stressors. And, the longer the rainbow trout is exposed to thermal stress and other stressors, the less likely it is to survive long-term. Any action, including the Proposed UNFFR Project and Alternatives. that promote stressful thermal conditions would reduce the chances for survival of the rainbow trout in Lake Almanor, Butt Valley Reservoir, and in the NFFR.

Water temperature affects all life stages of the rainbow trout and identifying protective ranges for each of the life stages of this species is complicated. "Cherry picking" specific facts out of studies, while ignoring other relevant facts and information requirements, is not a correct method for determining the temperatures that would be protective of rainbow trout under the Proposed UNFFR Project and its Alternatives. Thus, as there are no site-specific temperature studies (including food availability studies) that identify protective water temperatures for rainbow trout in Lake Almanor, Butt Valley Reservoir, and the NFFR, such studies are warranted before the SWRCB can determine the potential impacts on rainbow trout, and accurately present them in the DEIR.

C. Existing coldwater conditions and coldwater impacts under the Proposed UNFFR Project on the fishery resources in Lake Almanor are greater than stated in the DEIR

Existing coldwater conditions and conditions under the Proposed UNFFR in Lake Almanor are worse than stated in the DEIR (Dr. Gina Johnston, Plumas County Comments). As such, the DEIR's analysis needs to be corrected to disclose and account for the worse conditions, as the Proposed UNFFR Project would have a greater impact on the fish in Lake Almanor

D. Impacts of Alternatives 1 and 2 on the fishery resources in Lake Almanor, Butt Reservoir, and the NFFR

1. Alternatives 1 and 2 would result in a larger decrease of suitable coldwater habitat that would last longer in Lake Almanor than was stated in the DEIR

The DEIR's conclusion that the reduction of coldwater habitat would be small and of short duration in a normal water year, as a result of operation of the thermal curtains at Lake Almanor (Alternative 1), was incorrect (Dr. Gina Johnston Comments). In fact, in a normal water year there would be more than a 20% reduction in suitable habitat and it would last through September.

This DEIR's analysis needs to be corrected to disclose and account for this substantially larger impact and its longer duration. Lengthening the period of time during which fish in the lake are exposed to unsuitable conditions with limited refugia would obviously have a greater impact on the rainbow trout in Lake Almanor than was reported in the DEIR.

2. Alternatives 1 and 2 could introduce nutrients and heavy metals into Lake Almanor and Butt Valley Reservoir that, in turn, could have negative effects on the fishes in these reservoirs, and the NFFR

This topic was not discussed in the DEIR but should have been, as it could affect water quality and the fishes in Lake Almanor. In order to maximize the operation of the thermal curtains (Alternative 1), water must be drawn from as deep as possible. The result of this is to increase the likelihood of mixing the hypolimnion and the introduction of nutrients and trace metals into the thermocline and possibly the epilimnion. This could result in algal blooms, since nutrients would be available to the algae (Dr. Gina Johnston's Comments). In addition, the water that is discarged to the NFFR will be devoid of oxygen, and contain heavy metals, and nitrogen and phosphorous compounds. As Butt Valley Reservoir will receive hypolimnetic water from Lake Almanor, this water would also be devoid of oxygen and have elevated levels of several trace metals, along with nitrogen and phosphorous compounds. Since the reservoir is shallow and poorly stratified, mixing could occur as the water leaves the Butt Valley powerhouse and deliver additional nutrients to the algae downstream. The potential impacts of algae blooms was discussed earlier in these comments.

Although the DEIR stated (page 6.5-6) that, except for the cadmium (Lake Almanor and Butt Valley Reservoir) and iron (Lake Almanor), trace metal concentrations for Lake Almanor and Butt Valley Reservoir fell within applicable criteria, that conclusion was based on data collected from 2000-2003. The results of more recent data (Johnston and McReynolds, 2015) than those that are analyzed in the DEIR demonstrated elevated concentrations of aluminum, arsenic, copper, iron, manganese, mercury and zinc in the hypolimnion near Canyon Dam.

All of the above-listed heavy metals can be toxic, either lethal or sublethal, to fishes, including rainbow trout and other fishes that inhabit Lake Almanor and Butt Valley Reservoir (Rammoorthy and Baddaloo 1995; Taylor, 1996; Sorenson, 2000). To determine whether or not any of the heavy metals, as a result of Alternatives 1 and 2, would negatively impact the trout in the Lake Almanor, NFFR or Butt Valley Reservoir, further study/analysis is warranted. Future water quality monitoring should include heavy metal analysis for sampling sites in Lake Almanor, Butt Valley Reservoir, and the NFFR.

E. The Maximum Weekly Average Temperature (MWAT) Methodology is an unvalidated hypothesis that is of questionable reliable value without site-specific data for this project

Contrary to the statement on page 10 of Appendix F, that the MWAT was an established methodology, in fact, it is not. It is an unvalidated hypothesis. And, for the rainbow trout in Lake Almanor, Butt Valley, and the NFFR, the use of the MWAT method, as it was applied in Appendix F, is suspect. The original objective of the MWAT was to provide thermal thresholds that were safe, as well as productive, for each life stage of a given fish species (Brungs and Jones, 1977). However, as it was applied in Appendix F, it does not achieve that objective.

The MWAT method, or hypothesis, has never been rigorously validated in the field. There are many examples that demonstrate how the use of the results of one study on the same species and life stage compared to those of another study can change the results of the MWAT significantly. One example concerns the optimal temperature range for rearing coho salmon. In the report that introduced the MWAT to other government agencies, Brungs and Jones (1977) used 5-17 °C as an optimal thermal range, depending upon the season, with 15 °C being optimal in laboratory fish fed maximal rations. The upper lethal temperatures that they used ranged from 23-25° C. If one uses those optimal and lethal thermal ranges in the MWAT equation, the MWAT ranges between 11-19.7 °C for coho salmon. The NMFS and USFWS (1997) Matrix uses an "optimum" temperature of 13.2 °C and a range of upper lethal temperatures of between 24-25.8 °C for late summer rearing coho salmon. If one uses these optimal and lethal ranges in the MWAT equation, the MWAT ranges between 16.8-17.4 °C. Thus, there were two entirely different MWAT outcomes, depending upon what studies the agencies had selected to use in the MWAT model.

And, to make things more complicated, when one applies the MWAT model to a real life situation, the model may not work at all. After the 1980 Mt. St. Helens eruption, juvenile coho salmon were collected in streams where water temperatures exceeded 20 °C during much of the summer months. Despite the apparently unfavorable environment, both growth and survival rates were higher during these months than during those times when water temperatures were considered to be unstressful (i.e., below 15.6 °C). And, the long-term (i.e., 3-6 years post-eruption) consequences of the elevated water temperatures demonstrated a high productivity at these (theoretically) stressfully high water temperatures (Bisson et al. 1985). Thus, if we were to use the MWAT equation, with the data reported in the Brungs and Jones (1977) report, for the Mt. St. Helens coho salmon, one would conclude that the temperatures that would enable juvenile coho salmon to thrive should never exceed 19.7 °C. And, we would be wrong. Again, this is proof of the need for site-specific data when one wants to determine protective or optimal or preferred water temperatures for any fish species, including rainbow trout.

The temperatures used in the MWAT analysis in Appendix F were "guesstimates", based on their selection of 18-19 °C as the "optimal growth temperature" for juvenile rainbow trout that yielded an MWAT of 20.6 °C. It was this calculation that led them to select 20 °C for the mean daily temperature criterion used in all of the water temperature modeling conducted for this project. The problems with their use of the MWAT are multiple.

For example, the "optimal growth temperature" of 18-19 °C did not reflect the results of the study they cited (Myrick and Cech, 2000). Those researchers concluded that the optimal growth temperature for juvenile rainbow trout, fed maximal rations in a laboratory setting, was from 14-19 °C. Had they used the results of that study, instead of the range of 18-19 °C, in the MWAT equation, it would have yielded an entirely different MWAT, or "protective" temperature.

Also, in Appendix F, they chose a "one size fits" all approach and, by doing so, assumed that the "optimal growth temperature" was the same for juvenile rainbow trout as it was for adults. And, they assumed it was the same for the NFFR as it was for Lake Almanor and Butt Valley Reservoir. Food conditions and requirements for the rainbow trout in the NFFR are different than those in Lake Almanor Lake and Butt Valley Reservoir (Moyle, 2002). Thus, the thermal requirements may be different for the rainbow trout in the reservoirs than they are in the NFFR.

For the MWAT evaluation, the information must be available for a specific life stage and place (Armour, 1991). There are many studies that demonstrated that as trout mature, including rainbow trout, their optimal and preferred water temperatures decrease. Thus, the 20 °C that was used as the "protective" MWAT in Appendix F (and for all of the thermal modelling analysis) would probably not apply to the adult rainbow trout in Lake Almanor, Butt Valley Reservoir and the NFFR. Furthermore, as discussed on pages 7-9, the studies that were cited in support of the 18-21 °C "key threshold", did not provide scientific evidence in support of those range of temperatures chosen in Appendix F.

Finally, there isn't a fish anywhere that depends upon one temperature all the time. To choose 20 °C as temperature upon which all the temperature modelling is based, as was done in Appendix F, is short-sighted, at best. As trout and other fish live their days, water temperatures and food supplies change. With those changes, as well as others, their optimal water temperature changes. And, thus, the temperatures that are protective of the species for a specific life stage will also change. Fish are no more static than human beings. To model them as if they were static is to create a model that does not reflect their reality.

In summary, if MWAT is to be used, and I do not recommend it, at the least site-specific thermal bioenergetics studies and thermal preference studies should be conducted that would provide useful data for determining protective temperatures to use in the analysis of impacts of the Proposed NFFR Project and Alternatives 1 and 2.

F. No evidence that the Mitigation Measures would result in the less than significant impacts to fishery and other aquatic resources in Lake Almanor, Butt Valley Reservoir, and the NFFR

It is not clear to me how Mitigation Measures FS-2 through FS-5 and WQ-1 identified in the DEIR (pages 6.6-13 to 6.6-26) would result in a less than significant level for the following reasons.

(1) There are no site-specific water temperature studies that identify protective water temperatures for rainbow trout in Lake Almanor, Butt Valley Reservoir, and the NFFR

As discussed previously, the studies cited in the DEIR do not support the DEIR's conclusion that:

> *"Key temperature thresholds above which some level of physiological impairment can occur are generally found to occur over a temperature range of from 18 °C to 21 °C for rainbow trout for chronic exposures (DEIR, pages 6.6-2 to 6.6-3)..."*

Thus, before determining thermal impacts, let alone mitigation measures, of the Proposed UNFFR Projects and Alternatives 1 and 2 on the rainbow trout in Lake Almanor, Butt Valley Reservoir, and the NFFR, site-specific studies are required. Examples of the types of studies that should be conducted include: (1) site-specific thermal bioenergetics and thermal preference studies; (2) food availability studies; and, (3) water temperature monitoring at selected sites (e.g., "thermal refugia") in the reservoirs and springs, and in the NFFR.

And, before mitigation measures can be selected to reduce the potential impacts of the Proposed UNFFR and its Alternatives on the rainbow trout in Lake Almanor, Butt Valley Reservoir, and the NFFR to less than significant levels, the results of the above-listed studies need to identify protective water temperatures for the rainbow trout that provides a trophy trout fishery in the proposed project area.

(2) The DEIR provides no evidence that reduction of entrainment of the wakasagi in the Prattville intake, as a result of the installation of a thermal curtain at the Prattville intake in Lake Almanor, would not impact the Butt Valley Reservoir fishery

Wakasagi (Japanese pond smelt) is an extremely important forage fish for trout in Lake Almanor, Butt Valley Reservoir, and the NFFR Wakasagi were introduced in the early 1970's to provide an important forage base for fish-eating (e.g., trout, bass) fish in Lake Almanor (DEIR, page 6.6-6). Wakasagi are reported to reproduce in the Butt Valley powerhouse tailrace and at the mouth of Butt Creek (DEIR, page 6.6-8). The trophy trout fishery that occurs in Butt Valley Reservoir is attributed to the prey based provided by the wakasagi that have been entrained from

Lake Almanor and discharged into Butt Valley reservoir at the Butt Valley powerhouse (DEIR, pages 6.6-6 to 6.6-8).

Installation of a thermal curtain at the Prattville intake in Lake Almanor could reduce the entrainment of wakasagi, thereby reducing it transport to and abundance in, Butt Valley Reservoir (DEIR, page 6.6-25). Large numbers of wakasagi currently become entrained at the Prattville intake and are conveyed by the Butt Valley tunnel to the Butt Valley powerhouse tailrace. A reduction in entrainment, as a result of installation of the thermal curtain, would reduce the prey base in Butt Valley Reservoir for trophy trout (DEIR, page 6.6-25).

The DEIR provides no evidence that that there would be a significant decrease in wakasagi entrainment at the Prattville intake, nor does it provide any evidence that such a decrease would not impact the Butt Valley Reservoir fishery. In fact, as stated in the DEIR (page 6.6-26):

"Documents reviewed as part of the relicensing report do not provide adequate evidence neither 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."

The DEIR does not provide a mitigation measure that would reduce the potential impact of the decrease in wakasagi on the trophy trout fishery in Butt Valley Reservoir to less than significant. Instead, the DEIR states (DEIR, page 6.6-26) that:

> *"It is probably that wakasagi have established self-sustaining populations in Butt Valley reservoir and any reduction in wakasagi entrainment at the Prattville intake as a result of the thermal curtain is not expected to have a significant effect on the presence of a suitable forage fish in the reservoir. This impact would therefore by less than significant."*

Without focused studies on the effects of the decreased entrainment of the wakasagi, as a result of the installation of the thermal curtain at the Prattville intake at Lake Almanor, there is no way to determine whether or not such a decrease in the wakasagi would result in a "less than significant" impact on the trophy trout fishery in Butt Valley Reservoir.

(3) There is no evidence contained in the DEIR that the fish mitigation measure of re-stocking trout (Mitigation Measure WQ-1, DEIR, page 6.6-20) would mitigate for the impacts resulting from the Proposed UNFFR Project and Alternatives

The idea that re-stocking trout would serve as a mitigation measure for the impacts of the Proposed UNFFR Project and Alternatives is ill-conceived for the following reasons. Due to the lack of ongoing monitoring (e.g., focused cause-and-effect monitoring, angler creel census), there is currently no evidence that planting trout in the reservoirs has been successful. Hence, there is no evidence that re-stocking trout would mitigate for the impacts resulting from the Proposed UNFFR Project and Alternatives.

Furthermore, if there were a trophy trout die-off, as a result of the Proposed UNFFR Project and Alternatives, there would be a long period where there would be no trophy trout in the reservoirs. Fishermen consider a trophy trout to be from 5 pounds or larger, which could be a trout from 3 to 7 years old (Maumoynier, 2015; Kossow, 2015). Thus, after such a die-off and re-planting, there would be many years (3-7) where there would be no trophy trout fishery because CDFW only plant "catchable-sized" (8-12", 1.5 years old) (Maumoynier, 2015) and fingerlings (young-of-the year) trout. Thus, the mitigation to re-plant trout could actually result in a very significant impact on recreational fishing for the fisherman who have fished for trophy trout in Lake Almanor for decades.

G. Use of a Speece Cone or some other similar infrastructure would provide new summer trout habitat in Lake Almanor

Part of the limitation in coldwater habitat in Lake Almanor stems, not only from the lack of cold water, but also from the fact that, at the deeper depths, the hypolimnion, the existing coldwater has limited or no DO concentration. The resulting habitat is not suitable as coldwater fish habitat. As a mitigation measure that could be far superior to re-planting trout, the installation of the Speece Cone (Dr. Gina Johnston's Comments) would provide new summer trout habitat. Thus, although water temperatures in the epilimnion would only get worse under the Proposed UNFFR and Alternatives 1 and 2, to improve habitat for trout so that they could inhabit the hypolimnion area of the reservoir, where water temperatures would be acceptable, oxygenating the water would offer a much better alternative than them DEIR's mitigation of re-stocking the reservoir.

Oxygenation of reservoirs, or portions of reservoirs, is a proven technology. East Bay Municipal Utility District is using two forms of oxygenation technology: The Speece Cone in Camanche Reservoir (San Joaquin County) and the diffuse oxygenation system in Upper San Leandro Reservoir (Alameda County). In Lake Camanche, fishing has improved as a result of the Speece Cone distributing oxygen in the lower lake waters at the dam. The raised oxygen level draws a lot of different fish species to the area, making the dam an excellent place to fish.

Installation of a Speece Cone, or similar infrastructure, near Canyon Dam would create new summer trout habitat. Installation near Prattville would expand existing habitat, and maintain habitat viable in deeper (and, therefore, colder) water in Critically Dry years.

III. SUMMARY

The DEIR states (p 6.5-13) that, "Impacts on fisheries would be significant if the Proposed UNFFR Project, Alternative 1, or Alternative 2 would:

- Substantially affect, either by take or through habitat degradation (e.g., adverse changes in flow or deterioration of water quality), a special-status fish species;
- Substantially interfere with the movement of any resident or migratory fish species;
- Cause a fish population to drop below self-sustaining levels; or,
- Substantially affect native or introduced fish species, resulting in a reduction in the quality of the recreational fishery provided by Lake Almanor, Butt Valley reservoir, and the North Fork Feather River."

From the previous comments, I conclude that, under the Proposed UNFFR Project and Alternatives discussed in the DEIR, all of the above-listed impacts could be significant. Without filling in the omitted data and studies, identifying better mitigation measures, and re-evaluating the Proposed UNFFR Project and Alternatives and analysis, there would be significant impacts on the rainbow trout, special-status (hardhead, Sacramento perch), and the recreational fishery that could not be mitigated to a level of less than significant.

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ALICE A. RICH, PH.D., PRINCIPAL

RÉSUMÉ

Dr. Rich, who founded ***AAR*** in 1983, has had over 30 years of technical and administrative project management experience in a wide range of fisheries-related projects. Dr. Rich's professional experience encompasses work as an expert witness on fisheries issues, fisheries consultant, fisheries biologist, fish physiologist, analytical chemist, and university lecturer. Dr. Rich has worked on projects involving federal, state, and local agencies, private companies, law firms, and environmental non-profit organizations throughout the western states, Maine, British Columbia, and the Bahamas. Dr. Rich has designed and supervised projects involving environmental disasters (human-induced and natural), mining (gravel, gold limestone and phosphate), pollution, hydropower (dams and diversions), lagoons, bridges, dredging and pile driving, road construction, timber harvest, and other types of human land use activities on sensitive fish species. She has supervised hundreds of fish impact studies and analyses, including threatened and endangered fish species surveys and analyses, ESA Section 7 Consultations with federal agencies, fishery resources technical reports for EIR's, EIS's, and other environmental documents, fish risk assessments (mining), instream flow analyses, fish habitat and populations surveys and analyses, fish mitigation and rehabilitation, fish collection/salvage/relocation, fish age determination, fish limiting factor analysis, expert witness testimony, water quality and water temperature monitoring and impact analyses, fish physiology studies, and macro-invertebrate sampling and analyses. In addition, Dr. Rich is an expert in fish physiology and toxicology and has been called upon as an expert witness on the stressful impacts of environmental disasters, pollution, water temperature, dams, diversions and hydroelectric power, salmonid migration barriers, timber harvest, catch-and-release fishing, transportation and handling on fishes, and other factors that can be detrimental to federal- and state-listed fish species.

REPRESENTATIVE EXPERIENCE

- Provided expert witness testimony on wide range of federal- and state-listed fish species on water quality, water temperature, environmental disasters, mining, fish migration, logging, land development, and other factors that affect sensitive fish species;
- Designed and supervised over 50 water temperature and water quality monitoring for studies that focused on salmon, steelhead, and other threatened- and endangered-listed fish species.
- Supervised hundreds of studies on threatened, endangered, and candidate fish species throughout California, Nevada, and Idaho, including the threatened Central California Coast steelhead, endangered Southern steelhead, threatened Northern California steelhead, endangered Central California Coast coho salmon, threatened Southern Oregon/Northern California coast coho salmon, threatened Central Valley spring-run Chinook salmon, endangered Sacramento River winter-run Chinook salmon, endangered razorback sucker, Owens pupfish, endangered Owens tui chub, threatened delta smelt, endangered tidewater goby, threatened South Central California Coast steelhead, North American green sturgeon, threatened North American green sturgeon, threatened Lahontan cutthroat trout, endangered Pahranagat roundtail chub, and other federal- and state-listed fish species.
- Designed and implemented multi-year studies that focused on the impacts of streamflows, water quality and water temperature from hydropower, dams and diversions, pile driving, mining, dredging, oil and other pollutants, pile driving, road construction, levee construction, boat docks, boat activities, and marinas involving Federal- and state-listed fish species.

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REPRESENTATIVE EXPERIENCE **(cont.)**

- Designed and supervised thermal physiology studies to determine the optimal growth temperature for juvenile Chinook salmon in the Central Valley, California.
- Expert witness testimony on the effects of discharge effluent from a scrap metal company on salmon and steelhead in the Feather River.
- Expert witness testimony on the thermal impacts of PG&E's De Sabla-Centerville project on spring-run Chinook salmon in the Butte Creek and west Branch Feather River systems.
- Assessment and expert witness testimony of fishery resources impacts of multi-year flow/water temperature studies on the American River, California.
- Designed and supervised studies (fish habitat and population surveys; heavy metal analysis; fish bioenergetics-growth studies; macro-invertebrate bioassessment) on the impacts of the expansion of a gold and phosphate mines in Idaho and Nevada.
- Designed and supervised studies (fish habitat and population surveys; heavy metal analysis; fish bioenergetics-growth studies; macro-invertebrate bioassessment) on the impacts of the expansion of a gold mine on spring-run Chinook salmon, steelhead trout, bull trout, and westslope cutthroat trout in the Salmon River Watershed, Idaho.
- Designed and supervised studies (water temperature and water quality) on the impacts of the expansion of a gold mine on fishes Humboldt River Watershed, Nevada.
- Biological Assessment and fish relocation and Section 7 Consultation assistance with NOAA Fisheries, U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers
- Assessment of potential fishery resources impacts of the replacement of the Lewiston Dam Power Plant in Trinity County, California.
- Assessment of potential impacts on salmonids, delta smelt, and Sacramento splittail of diverting 15,000 acre-feet per year of Sacramento Municipal Utility District's American River entitlement to Sacramento County, California.
- Assessment of thermal impacts of reduced flows on Chinook salmon and steelhead in the Yuba River, California;
- Determined on-site restoration measures to provide additional habitat for a variety of Threatened and Endangered fish species including steelhead, delta smelt, winter-run Chinook salmon, spring-run Chinook salmon, Central Valley fall and late-fall Chinook salmon, North American green sturgeon, longfin smelt, and Sacramento splittail, and razorback suckers.
- Designed and supervised hundreds of fish habitat (e.g.,habitat typing, Essential Fish Habitat, Shaded Riverine Aquatic Habitat, etc.) and population surveys throughout the Central Valley and other parts of California and the other western states.
- Supervised studies on the impacts of gravel mining on salmon and trout in the Mad and Eel Rivers Watershed in northern California.

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REPRESENTATIVE EXPERIENCE (cont.)

- Written over 100 Biological Assessments and fishery resources technical reports for EIR's, EIS's, and other environmental documents on the effects of a variety of land uses on threatened and endangered fish species throughout California.
- Worked extensively with federal, state, and local agencies and facilitated permitting and other agreements with applicants/clients throughout all phases of projects for over 30 years.
- Supervised fish habitat and population (electrofishing, beach seining, snorkeling, fyke nets) studies on over 100 projects involving salmon and trout and other Federal- and state-listed fish species.
- Designed watershed-based fish restoration projects for over 30 years.
- Trained field crews for over 30 years on minimizing handling and transportation stress on fishes in marine, estuarine, and freshwater ecosystems.
- Designed and supervised projects involving fish migration, including mapping (GIS) potential migration barriers and follow-up studies to determine whether or not barriers prevented fish (anadromous and resident) migration.
- Supervised fish rescue and relocation of dozens of construction-related projects, involving federal- and state-listed fish species.
- Analyzed methods used to determine behavioral impacts of dredging on fishes throughout the world.
- Supervised a study on the impacts of past, present, and future gravel mining on steelhead in the Upper Russian River Watershed.
- Dredge-related ESA Section 7 Consultations with NOAA Fisheries, U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers for the River Islands Development Project in Lathrop, California.
- Impacts of boat docks on salmonids in the Calaveras River Watershed in connection with the Brookside Estates Project, Stockton, California.
- Impacts of maintenance dredging by the Sacramento Yacht Club on the North American Green sturgeon in West Sacramento, California.
- Impacts of dredging activities on the behavior of federal- and state-listed fishes in San Francisco Bay.
- Impacts of suspended sediments resulting from dredging activities on federal- and state-listed fishes in San Francisco Bay.
- Supervised fish age studies (scales, otoliths, fin rays) in numerous freshwater and marine fishes.
- Trained in the Instream Flow Incremental Methodology (IFIM) and Habitat Evaluation Procedures (HEP).

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EXPERT WITNESS TESTIMONY

- Impacts of effluent from a scrap metal facility on federal- and state-listed fish species (*Cannata, Ching & O'Toole, LLP, San Francisco, California*)
- Analysis of City of Napa's Mitigated Negative Declaration for the Napa Creek Apartments Project, Napa (Dan Muller, Attorney,
- Thermal Impacts from Diversions from the Delta Wetlands Project on Chinook Salmon and other Fishes of the Sacramento-San Joaquin River System (*Central Delta Water District, Stockton, California*)
- Thermal Impacts of Yuba County Water Agency's Proposal to Reduce Flows in the Lower Yuba River on Chinook Salmon and Steelhead Trout in the Yuba River (*California Department of Fish and Game, Sacramento, California)*
- Impacts of Reduced Flows on the Fishery Resource Habitat of the Lower American River (*County of Sacramento, California*
- Thermal Impacts of Altered Stream Flows on the Fishery Resources of the Lower American River (*County of Sacramento, California*)
- Thermal Impacts from Diversions from the Delta Wetlands Project on Chinook Salmon and other Fishes of the Sacramento-San Joaquin River System (*California Department of Fish and Game, Sacramento, California*)
- Impacts of Proposed Board of Forestry's Amendment to the Board of Forestry Rules on Salmon and Trout (*California Forestry Association, Sacramento, California*)
- Impacts of Sediment Associated with Timber Harvesting on Salmonids (*California Forestry Association, Sacramento, California*)
- Impacts of Sediment Associated with Vineyard Development on Salmonids (*Morrison and Foerster, Attorneys, San Francisco, California*)
- Impacts of Streamflow Alterations on Emigrating Salmonids *(North Marin County Water District, Novato, California)*
- Impacts of Streamflow Alterations on Emigrating and Resident Salmonids (*Casa de Fruta, Hollister, California)*
- Impacts of Summer Dams on Aquatic Species (*North Marin Water District, Novato, California)*
- Impacts of Handling and Transportation on Fresh Salmon (Alaska Airlines, Seattle, Washington)
- Stressful Impacts of Handling and Transportation on Salmonids (*Bangor Hydro-Electric Company, Bangor, Maine)*
- Impacts of Timber Harvest Practices on Salmonids *(East Bay Municipal Water District, Oakland, California)*
- Impacts of Timber Harvest Practices on Salmonids (*Barnum Timber Company, Eureka, California*)
- Impacts of Roads, Bridge, and Vineyard on Salmonids (*Friends of West Union Creek, Woodside, California)*

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EXPERT WITNESS TESTIMONY (cont.)

- Impacts of Construction of an Oil Rig Platform on the Fishery Resources (primarily herring) of Northern Puget Sound (*Kiewit Construction Company, Bellingham, Washington)*
- Impacts of Dropping Crates of Fresh Salmon on the Marketability of the Salmon as Food (*Alaska Airlines, Seattle, Washington)*

EDUCATION

- Ph.D., 1983. Fisheries, University of Washington, Seattle
- M.S., 1979. Fisheries, University of Washington, Seattle
- B.S., 1973. Zoology, University of California, Davis

PROFESSIONAL HISTORY

- A. A. Rich and Associates/Principal (1983-present)
- University of Washington, School of Fisheries/Lecturer (1982-1983)
- University of Washington, School of Fisheries/Teaching Assistant (1976-1983)
- University of Washington, School of Fisheries, Laboratory of Radiation Ecology/Analytical Chemist (1977-1980)
- U.S. Forest Service, Seattle/Fisheries Consultant (1980)
- U.S. Bureau of Reclamation, Sacramento, California/Fisheries Biologist (1975)
- California Department of Fish and Game, Sacramento/Fisheries Biologist (1973-1975)

CERTIFICATIONS

- IFG 200-Designing and Conducting Studies Using IFIM. Instream Flow Group, U. S. Fish and Wildlife Service, West Virginia, 1984.
- IFG 205-Field Techniques for Instream Analysis. U. S. Fish and Wildlife Service, West Virginia, 1984.
- IFG-210-PHABSIM-Using the Computer-Based Physical Habitat Simulation System. U. S. Fish and Wildlife Service, Colorado, 1984.
- Habitat Evaluation Procedures (HEP), Colorado, 1985.
- Fish Bioenergetics Growth Models, Toronto, Canada, 1988.
- SCUBA, N.A.U.I.

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PROFESSIONAL AFFILIATIONS

- American Association for the Advancement of Science
- American Fisheries Society
- American Association of University Women
- Professional Environmental Marketing Association
- Western Dredging Association

REPRESENTATIVE PUBLICATIONS AND PAPERS PRESENTED

Dr. Rich has published and presented papers on a number of fishery resources topics including: water temperature and water quality impacts of flow alterations on delta smelt, salmon, steelhead, and other Federal- and state-listed fish species throughout the Central Valley; gravel, gold, and phosphate mining on salmonids; water quality requirements for fishes; dredging impacts on fishes; impacts of catch-and-release fishing on salmonids; smoltification of salmonids; enhancement strategies of salmonids in urban and rural areas; impacts of logging on salmon and trout habitat and populations; impacts of rotenone on lake fishery resources; domestication of salmonids; preferred herring spawning substrates; and, exercise physiology of trout. Following is a list of representative publications and papers presented.

Rich, A. A. 2014. Middle Green Valley Specific Plan Project-DEIR/Potential Significant Impacts on the Threatened Central California Coast Steelhead (*Oncorhynchus mykiss*); California Red-Legged Frog (*Rana draytonii*); and, Western Pond Turtle (*Actinemy marmorata*), in Green Valley Creek. Expert Testimony Prepared for the Solano County Board of Supervisors, Fairfield, California on behalf of the Upper Green Valley Homeowners. November 25, 2014. 10 pages + Attachment and Exhibit.

Rich, A. A. 2014. Replacement of the Oak Ridge Drive Bridge, Roseville, Placer County. Fishery Resources Biological Assessment. Prepared for RBF Consulting, Sacramento, California. October 8, 2014. 36 pages +Appendices.

Rich, A. A. 2014. Study Elements required to Determine Salmonid Habitat and whether or not there are Factors that would Limit Salmonid Production in Permanente Creek Upstream of the Diversion Channel, Santa Clara County, California. Prepared for CSW/Stuber-Stroeh Engineers. March 3, 2014. 24 pages.

Rich, A. A. 2014. Knights Landing River Access Boat Launching Facility Renovation, Yolo County-Biological Assessment. Prepared for Yolo County, Woodland. February 19, 2014. 60 pages + Appendices.

ALICE A. RICH, PH.D., PRINCIPAL

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REPRESENTATIVE PUBLICATIONS AND PAPERS PRESENTED (cont.)

Rich, A. A. 2014. Expert Witness Testimony-City of Napa's Revised Initial Study/Mitigated Negative Declaration for Napa Creek Apartments Project. Prepared for Daniel Muller, Attorney, Walnut Creek. June 18, 2013. 5 pages.

Rich, A. A. 2013. Expert Witness Testimony: Declaration of Alice A. Rich, Ph.D. in the matter of the People of the State of California, Petitioner, vs George W. Scott, Sr. Respondent. Prepared for Cannata, Ching & O'Toole LLP, Attorneys, San Francisco, California. May 9, 2013.

Rich, A. A. 2013. Anadromous Salmonid Culvert Analysis I-80 Express Lanes Project. Prepared for the Solano Transportation Authority and CalTrans. October 30, 2013. 13 pages + Appendices.

Rich, A. A. 2013. Bank Stabilization Project at 21 Banchero Way, Fairfax, California. Fish Collection and Relocation Plan. Prepared for Village West, Fairfax, California. August 13, 2013.

Rich, A. A. 2013. Bank Stabilization Project at 48 Broadmoor Avenue, San Anselmo, California. Fish Collection and Relocation Plan. Prepared for the Williamsons, San Anselmo, California. August 12, 2013.

Rich, A. A. 2013. Green Gulch Zen Center Landslide Stabilization Project. Muir Beach, California. Biological Assessment. Prepared for the San Francisco Zen Center, June 20, 2013.

Rich, A. A. 2013. Bank Stabilization Project at 48 Broadmoor Avenue, San Anselmo, California. JARPA and Biological Assessment. Prepared for Brian and Melisa Williamson, San Anselmo, California. June 10, 2013.

Rich, A. A. 2013. Charro Way Pipe Replacement Project, Fairfax, California. JARPA and Biological Assessment. Prepared for Village West Homeowners, Fairfax, California. June 6, 2013.

Rich, A. A. 2013. Bank Stabilization Project at 21 Banchero Way, Fairfax, California. JARPA and Biological Assessment. Prepared for Village West Homeowners, Fairfax, California. May 30, 2013.

Rich, A. A. 2012. Interpreting water temperature impacts from streamflow alterations from hydroelectric power, mining, and other land use activities on coldwater fishes, such as salmon and trout. Prepared for Technical Advisory Services for Attorneys (TASA), December, 2012. Submitted for the TASA January, 2013 Newsletter.

Rich, A. A. 2012. Southern California Edison's Kaweah River Hydroelectric Power Intake 2 Modification Project, Tulare County, California - Fish Rescue and Relocation. Prepared for Southern California Edison. October 19, 2012. 10 pages + Appendices

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REPRESENTATIVE PUBLICATIONS AND PAPERS PRESENTED (cont.)

Rich, A. A. 2012. Brannan Street Wharf Pile Driving Project, San Francisco, California - Fishery Resources Monitoring Final Report. Prepared for the Port of San Francisco. December 27, 2012. 7 pages + Appendices.

Rich, A. A. 2012. The La Goma Project, 5-19 La Goma Avenue, Mill Valley - Potential Impacts of Contaminants on the Steelhead in Arroyo Corte Madera del Presidio Creek. Prepared for the City of Mill Valley. March 26, 2012. 21 pages +Appendices.

Rich, A. A. 2012. Biological Assessment for Bank Stabilization Project at 700-779 Center Boulevard (FairAnselm), Fairfax, CA. Prepared for Ballard & Watkins, San Anselmo, California. March 7, 2012. 21 pages + Appendices.

Rich, A. A. 2012. PG&E Line 109 External Corrosion Direct Assessments - Fishery Resources Assessment for Two Sites. Prepared for SWCA, Santa Clara County. March 3, 2012. 16 pages+ Appendices.

Rich, A. A. 2011. Heritage Ranch CSD-Gallery Wells Project, Paso Robles, California - Report of Fish Collection and Relocation. Prepared for SWCA, San Luis Obispo. October 14, 2011. 8 pages + Appendix.

Rich, A. A. 2011. Expert Witness on behalf of CalTrans regarding Contract No. 04-0A724 Potable Water Discharge, City of Woodside, California, Fish Kill in Bear Gulch Creek, Follow-Up Report. Prepared for CalTrans, June 24, 2011. 4 pp + Appendices

Rich, A. A. 2011. Sacramento Yacht Club Maintenance Dredging Project-Potential Impacts on the North American Green Sturgeon. April 2011. 23 pp + Appendices

Rich, A. A. 2011. USFWS Fishery Resources Evaluation for the Pahranagat National Wildlife Refuge. March 28, 2011. Prepared for Harris Environmental Group, Tucson, Arizona. 13 pages.

Rich, A. A. 2011. Lewiston Dam Powerplant Replacement Project, Trinity County-Fishery Resources Technical Report. Prepared for Sunrise Engineering, Utah. February 7, 2011. 47 pp + Appendices.

Rich, A. A. 2010. Potential Impacts of Re-Suspended Sediments Associated with Dredging and Dredged Material Placement on Fishes in San Francisco Bay, California -Literature Review and Identification of Data Gaps. Prepared for the U.S. Army Corps of Engineers, San Francisco. Draft Report. July 20, 2010. 75 pp + Appendices.

ALICE A. RICH, PH.D., PRINCIPAL

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REPRESENTATIVE PUBLICATIONS AND PAPERS PRESENTED (cont.)

Rich, A. A. 2010. Tools for Assessing and Monitoring Fish Behavior Caused by Dredging Activities. Prepared for the U.S. Army Corps of Engineers, San Francisco. Draft Report. June 23, 2010. 77 pp + Appendices.

Rich, A. A. 2010. Little Hastings Island Proposed Conservation Bank, Solano County, California. Fishery Resources Rehabilitation: An Analysis. Prepared for Wildlands, Inc., Rocklin, California. May 7, 2010. 89 pp + Appendices.

Rich, A. A. 2009. San Francisco Public Utilities Commission Calaveras Dam Replacement Project Public Draft EIR-Technical Comments on Fishery Resources Issues. Prepared for Weinberg, Roger & Rosenfeld, Alameda, California. December 21, 2009. 14 pp.

Rich, A. A. 2009. River Islands at Lathrop Project - Fishery Resources Technical Report. Prepared for Califia, Inc., Lathrop, California. November 11, 2009. 71 pp + Appendices.

Rich, A. A. 2009. River Islands at Lathrop Project - Potential Impacts of Water Temperature on Federal- and StateListed Fish Species. Prepared for Califia, Inc., Lathrop, California. November 11, 2009. 15 pp.

Rich, A. A. 2009. River Islands at Lathrop Project - Potential Impacts of Stormwater Runoff and Golf Course Discharge on Federal- and State-Listed Fish Species. Prepared for Califia, Inc., Lathrop, California. November 11, 2009. 46 pp.

Rich, A. A. 2008. Fishery Resources Conditions of the Alhambra Creek Watershed, Contra Costa County. Prepared for the Urban Creeks Council, Berkeley, California. July 25, 2008. 53 pages.

Rich, A. A. 2008. A Salmonid Monitoring Plan for Codornices Creek. Prepared for the Urban Creeks Council, Berkeley, California. May 23, 2008. 71 pages.

Rich, A. A. 2008. A Trout and Salmon Guide to the Urban Creeks and Rivers that Flow into San Francisco Bay. Prepared for the Urban Creeks Council, Berkeley, California. April 20, 2008. 47 pages.

Rich, A. A. 2008. Codornices Creek Restoration Project at Albina Avenue, Berkeley, California-Pre-Construction Relocation of Fishes. Prepared for the U. S. Fish and Wildlife Service, Santa Rosa, California. February 5, 2008. 12 pages.

Rich, A. A. 2008. Biological Resources Assessment for the Draper Project, 560 Inverness Road, Inverness, California. Prepared for the Drapers, Inverness, California. February 4, 2008. 14 pages + Appendices.

ALICE A. RICH, PH.D., PRINCIPAL

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REPRESENTATIVE PUBLICATIONS AND PAPERS PRESENTED (Cont.)

Rich, A. A. 2007. Impacts of Water Temperature on Fall-Run Chinook Salmon (*Oncorhynchus tshawytscha*) and Steelhead (*O. mykiss*) in the San Joaquin River System. Prepared for the California Department of Fish and Game, Fresno, California. September 24, 2007. 44 pages.

Rich, A. A. 2007. PG&E's DeSabla-Centerville Hydropower Project - Comments on the Thermal Effects of PG&E's DeSabla-Centerville Project on Spring-run Chinook Salmon (*Oncorhynchus tshawytscha*). Prepared for the California Sportfishing Protection Alliance, Berkeley, California. August 23, 2007. 25 pages plus Appendices.

Rich, A. A. 2007. Napa Creek Flood Wall Construction-Pre-Project Relocation of Fishes. Prepared for the U. S. Fish and Wildlife Service, Sacramento, California. August 7, 2007. 6 pages + Appendices.

Rich, A. A. 2007. Fishery Resources Technical Report for Napa County General Plan. Prepared for Napa County, Napa, California. January 2007. 110 pages plus Appendices.

Rich, A. A. 2006. Fishery Resources Assessment for the Town of Fairfax. Prepared for the Town of Fairfax, Department of Public Works. December 18, 2006. 77 pages plus Appendices.

Rich, A. A. 2006. The 505 Miller Avenue Project, Mill Valley. Biological Assessment. Prepared for Skyline/Miller/House, LLC. October 27, 2006. 33 pages + Appendices

Rich, A. A. 2006. Biological Assessment for the Bank Failure Project at 323/325 Bolinas Road, Fairfax. Prepared for the Wassermans. September 19, 2006. 31 pages.

Rich, A. A. 2006. Biological Assessment for Bank Failure Project at 39 Cascade Drive, Fairfax. Prepared for Steve Katz. September 10, 2006. 26 pages.

Rich, A. A. 2006. Biological Assessment for Bank Failure Project at 91 Mt. Tallac Court, San Rafael. Prepared for the Moreno Family. September 7, 2006. 35 pages.

Rich, A. A. 2006. Critique of NOAA Fisheries Report Entitled *Monitoring Sediment Delivery to Streams Following Vineyard Development from Forested Lands and the Effects on Steelhead Trout.* Submitted to the California Board of Forestry. Prepared for Morrison & Foerster, Attorneys, San Francisco. August 7, 2006. 33 pages.

Rich, A. A. 2006. Redwood Lodge, Mill Valley-Assessment of Fishery Resources Habitat Conditions in Arroyo Corte Madera del Presidio Creek. Prepared for Clearwater Hydrology, Berkeley. May 30, 2006. 19 pages.

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REPRESENTATIVE PUBLICATIONS AND PAPERS PRESENTED (Cont.)

Rich, A. A. 2006. Construction of 18-Unit Residential Building at 5-19 La Goma Avenue, Mill Valley. Biological Assessment. Prepared for CirclePoint, San Francisco. May 17, 2006. 31 pages + Appendices.

Rich, A. A. 2005. Fish Relocation Summary of Results for Town of Ross (Marin County) Annual Dredging. Prepared for NOAA Fisheries, November 8, 2005. 10 pages.

Rich, A. A. 2005. SFPP Pipeline Inspection and Repairs-Summary Results of Collection and Relocation of Fishes in Donner Creek, Nevada County, California. Prepared for U.S. Fish and Wildlife Service and California Department of Fish and Game. November 2, 2005. 10 pages.

Rich, A. A. 2005. Carmel River Lagoon Mechanical Breaching- Steelhead Issues. Prepared for the Carmel Point and Lagoon Preservation Association. August 7, 2005. 37 pp.

Rich, A. A. 2005. River Islands Project - Fishery Resources Technical Report. Prepared for River Islands at Lathrop, California. April 21, 2005. 85 pp + Appendices.

Rich, A. A. 2005. Replacement of Deck at #14 and #16 Creek Lane, Mill Valley. Biological Assessment. Prepared for Cascade Properties, Boulder, Colorado. February 2005. 34 pp + Appendices.

Rich, A. A. 2004. Bank Stabilization at 1 Sylvan Lane, Marin County, Relocation of Fishes. Prepared for the U.S. Corps of Engineers, San Francisco, CA. March 29, 2004. 8 pp + Appendices.

Rich, A. A. 2004. Fishery Resources Conditions at Emmerson, Blue Lake, Johnson, and Graham Bars. Prepared for Granite Construction Company, Eureka, Ukiah, California. March 8, 2004. 36 pp + Appendices.

Rich, A. A. 2003. Fishery Resources Conditions of Suscol Creek, Napa County, California. Prepared for Friends of the Napa River. April 21, 2003. 68 pp + Appendices.

Rich, A. A. 2003. Long-term Water quality and Temperature Monitoring for Boat Dock Construction at the Brookside Estates in Stockton, California. Summary of Results of 2002 Data. Prepared for Brookside Development Associates, Stockton. April 4, 2003. 25 pp + Appendices.

Rich, A. A. 2002. Results of Presence/Absence Fishery Resources Electro fishing Survey within the North Branch of the South Fork Littlejohns Creek, San Joaquin County. Prepared for Forward Inc., Manteca, California. June 25, 2002. 9 pp + Appendices.

ALICE A. RICH, PH.D., PRINCIPAL

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REPRESENTATIVE PUBLICATIONS AND PAPERS PRESENTED (Cont.)

Rich, A. A. 2002. On-Site Biological Monitoring for Boat Dock Installation and Construction at Brookside Estates in Stockton, California. Prepared for Brookside Development Associates, Stockton. April 19, 2002. 22 pp + Appendices.

Rich, A. A. 2002. Bahia Dredging and Lock Project Environmental Assessment for Fishery Resources. Prepared for Bahia Homeowners' Association, Novato, California. February 22, 2002. 62 pp + Appendices.

Rich, A. A. 2002. Environmental Assessment for the Chaplinsky Boat Ramp to Pier Conversion at 93 Shoreline Circle, Incline Village, Lake Tahoe, Nevada. Prepared for R. Chaplinsky. January 18, 2002. 36 pp + Appendices.

Rich, A. A. 2001. Noyo River Fish Monitoring 2000 Summary Report. Prepared for the City of Fort Bragg, Fort Bragg, California. April 25, 2001. 25 pp + Appendices.

Rich, A. A. 2001. Response to the California Department of Fish and Game's February 2, 2001 Testimony presented to the California Fish and Game Commission with regard to listing coho salmon (*Oncorhynchus kisutch*) as an endangered species. Testimony submitted to the California Fish and Game Commission. April 3, 2001. 26 pp.

Rich, A. A. 2001. Response to the Salmon and Steelhead Recovery Coalition Petition submitted to the California Fish and Game Commission to list coho salmon (*Oncorhynchus kisutch*) as an endangered species. Testimony submitted to the California Fish and Game Commission. January 31, 2001.

Rich, A. A. 2000. Fishery Resources Conditions of the Corte Madera Creek Watershed, Marin County, California. Prepared for Friends of Corte Madera Creek Watershed, Larkspur, California. November 10, 2000. 120 pp. + Appendices.

Rich, A. A. 2000. Aguas Frias Road Bridges-Impacts on Fishery Resources, Chico, Butte County, California. Prepared for Eco-Analysts, Chico, California. October 25, 2000. 29 pp.

Rich, A. A. 2000. Oral Testimony of Alice A. Rich Presented to the California State Water Resources Control Board in the Matter of the Delta Wetlands Project Regarding Water Right Applications 29062, 29066, 30268, and 30270 and Petitions to Change these Applications. September 15, 2000.

Rich, A. A. 2000. Brookside Dock Expansion Environmental Assessment for Fishery Resources-Addendum. Prepared for Brookside Development Associates, Stockton. September 4, 2000. 67 pp. + Appendices.

ALICE A. RICH, PH.D., PRINCIPAL

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REPRESENTATIVE PUBLICATIONS AND PAPERS PRESENTED (Cont.)

Rich, A. A. 2000. Brookside Dock Expansion Environmental Assessment for Fishery Resources. Prepared for Brookside Development Associates, Stockton. July 10, 2000. 6 pp. + Appendices.

Rich, A. A. 2000. Potential impacts of the proposed Congregation Beth El Synagogue and School on the fishery resources of the Codornices Creek Watershed, Alameda County, California. Prepared for the City of Berkeley. June 26, 2000. 50 pp. + Appendix.

Rich, A. A. 2000. Testimony of Alice A. Rich, Ph.D. Submitted to the State Water Resources Control Board by the California Department of Fish and Game Regarding the Yuba River Hearings. May 1, 2000.

Rich, A. A. 2000. The potential impacts of the emergency work performed at the Kendall Ranch on the fishery resources of the Garcia River, Mendocino County. Prepared for Rawles, Hinkle, Carter, Behnke & Oglesby, Attorneys, Ukiah. February 9, 2000.

Scientific Review Panel. 1999. Report of the Scientific Review Panel on California Forest Practice Rules and Salmonid Habitat. Prepared for The Resources Agency of California and the National Marine Fisheries Service, Sacramento, California, June, 1999. June 1999. 92 pp + Appendices.

Rich, A. A. 1999. FMC Phosphate Mine Expansion, Fishery Resources Technical Report. Prepared for FMC Phosphate Mine, Soda Springs, Idaho. February 5, 1999. 100 pages + Appendices.

Rich, A. A. 1999. Fishery Resources Conditions in Pine and Mill Creek Watersheds, Rovana, Inyo County, California. Prepared for Inyo County. January 11, 1999. 48 pp + Appendices.

Rich, A. A. 1999. Ventura River Fish Survey and Fish Relocation Results. Submitted to the National Marine Fisheries Service as part of Section 7 (ESA) Consultation. January 4, 1999.

Rich, A. A. 1999. Leeville Gold Mine Expansion Project, Carlin, Nevada. Fishery Resources Technical Report. Prepared for Newmont Gold Company, Carlin, Nevada. January 1999.

Rich, A. A. 1998. Fishery Resources Conditions of Adobe Creek, Petaluma, Sonoma County, California. Prepared for the Petaluma Planning Department, December 8, 1998. 46 pp.

Rich, A. A. 1998. Assessment Plan for the Talache Mine Mill Tailings Site, Atlanta, Idaho. Prepared for Monarch Greenback, Boise, Idaho, April 14, 1998. 36 pp + Appendix.

ALICE A. RICH, PH.D., PRINCIPAL

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REPRESENTATIVE PUBLICATIONS AND PAPERS PRESENTED (Cont.)

Rich, A. A. 1998. Talache Mine Tailings Project, Preliminary Review of Existing Information on Fishery Resources Conditions. Prepared for Monarch Greenback, Boise, Idaho. April 24, 1998. 71 pp + Appendices.

Rich, A. A. 1997. Noyo River Fish Monitoring 1997 Summary Report. Prepared for the City of Fort Bragg, Fort Bragg, Mendocino, California. December 30, 1997. 36 pp + Appendix.

Rich, A. A. 1997. Ord Ferry Road Bridge Seismic Retrofit Project, Impacts on Fishery Resources, Butte County, California. Prepared for Butte County. November 25, 1997. 27 pp + Appendix.

Rich, A. A. 1997. Testimony of Alice A. Rich, Ph.D., Submitted to the State Water Resources Control Board, Regarding Water Rights Applications for the Delta Wetlands Project. July 1997, on behalf of the California Department of Fish and Game, Exhibit 7, 88 pp + Appendix.

Rich, A. A. 1997. Novato Creek Flood Control Project, Marin County. Fishery Resources Conditions. Prepared for the County of Marin, California. June 19, 1997. 23 pp + Appendices.

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ATTACHMENT 3

CLIMATE CHANGE AND THE CHANGING WATER BALANCE FOR CALIFORNIA'S NORTH FORK FEATHER RIVER

Gary J. Freeman[1]

ABSTRACT

Climate change has likely had a large role the changing water balance on northern California's North Fork Feather River (NFFR) in recent years. In addition to changes in both snowpack quantity and timing of the spring snowmelt, some of its subbasins are also revealing a declining trend in water year (October 1 through September 30) runoff, while others do not. Pacific Gas & Electric Company (PG&E) divides the NFFR into multiple subbasins and subbasin reaches for purposes of effectively forecasting runoff and scheduling reservoir releases for hydroelectric operations. In order to effectively manage the hydroelectric resources on this river, at the watershed level as a collective whole, it is important to recognize loss in both data stationarity and trends that change both historical runoff timing and quantity of runoff. NFFR's complex terrain geometry includes a combination of both windward facing slopes and rain-shadowed leeward slopes that result in a mix of climatic gradients. The combined effect of having relatively low elevation and topographic barriers in the form of mountain ridges provide opportunity for both orographic cooling to take place on the windward slopes and compressional warming to take place on the leeward slopes as the airflow of frontal systems pass through the NFFR Basin. On the leeward, rain-shadowed slopes, air descends and warms quickly through compressional heating. Precipitation amounts quickly diminish as the descending air warms and increases its capacity to hold moisture. Both the Lake Almanor and East Branch of the North Fork Feather (EBNFFR) subbasins are two rain-shadowed subbasins that exhibit a declining trend in water year runoff. Trend declines that approach 308 hm^3 (250,000 AF)/year collectively from the two subbasins since the early 1960's were analyzed using a water balance approach to help understand the declining runoff trend in terms of changes taking place at the watershed level. Beginning in the 1970's, increased evapotranspiration is likely taking place in the mixed conifer forests due to rising air temperatures. Increased forest growth and warmer air temperatures are likely two of the contributing causes for the increased evapotranspiration that has taken place in recent years. The decrease in both the low elevation snowpack and the water year runoff has resulted in a decline in hydroelectric output and less outflow of the NFFR into Lake Oroville. (KEYWORDS: climate change, Feather River, orographic, water balance, rain shadow, northern California)

INTRODUCTION

California's Sierra Nevada Mountain Range ends the northern part of its approximately 644 km (400 mi) length in the Feather River Basin. Lake Almanor, a former meadow with several large springs, is located over the ending edge of the southern Cascades' porous volcanics, which in turn encounter the mostly impervious metamorphic rocks at the northern end of the Sierra. The northern Sierra and the Feather River Basin are relatively low elevation compared with the much higher southern Sierra that is often referred to as the 'High Sierra', which is often defined as starting its northern end in the headwaters above Yosemite Valley and extending southward along the Sierra crest. Uplift of the Sierra Nevada Mountains beginning in the early Pliocene Epoch approximately 5 million years ago has been most pronounced in the southern Sierra with lesser uplift and tilt taking place in the Yuba and Feather River Basins. Much of the ancestral Sierra rock remains exposed in the Feather, where the Western Metamorphic Belt widens in comparison with the central and southern Sierra. As a result of the lesser uplift, the Feather River cuts through the Sierra Crest. The west facing slopes are less sharply tilted into the Sacramento Valley, and as a result, much of the topographic complexity associated with the older Eocene-age drainage patterns remain. The Sierra south of the Feather River Basin is positioned such that winter storm fronts, which move eastward across the Central Valley encounter the relatively steep Sierra mostly at right angles to its west facing slopes causing orographic and adiabatic cooling through air mass expansion. As the air cools, it loses its capacity to hold moisture and the saturated air delivers precipitation, mostly in the form of snowfall to the higher slopes of the Sierra. The Feather River above Lake Oroville however has a somewhat complex topography characterized by a mixed arrangement of ridges and valleys, much more indicative of the older erosion surfaces,

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some which benefit immensely from orographic uplift and others that are sufficiently blocked by ridges to be considered as rain-shadowed subbasins. On the NFFR, air ascends upward and cross es the first westward facing ridges, losing much of its moisture, and quickly heats adiabatically as it compresses and descends into the various valleys such as at Lake Almanor (formally Big Meadows) and into the Indian and Genesee Valleys on the EBNFFR. As the flow of storm air crosses these valleys, the air mass warms sufficiently to hold much of its remaining moisture during its continued journey eastward. Consequently these valley areas, which are topographically blocked by ridges and various mountain peaks tend to be much warmer and drier than the Basin's other subbasin drainages. Snowpack accumulation for the west facing windward slopes and the canyon walls below Belden does not appear to have declined significantly (Freeman, 2010). The snow pack has shifted a portion of its melt regime from April into March, an effect of climate warming that seems to be increasingly becoming the norm for nearly all parts of the Sierra.

Both the 1,272 km^2 (491 mi^2) Lake Almanor subbasin and the 2,655 km^2 (1,025 mi^2) EBNFFR water year runoff started declining about 1960. Other subbasins such as Butt Valley, Bucks Creek, Grizzly, and the Feather River Canyon downstream of Canyon Dam and its confluence with the EBNFFR near Rich Bar are relatively high precipitation areas that have experienced relatively little change in both water year runoff and winter snowpack. These areas are characterized by windward facing slopes that cause the air to adiabatically rise, expand, and cool creating an increase in precipitation and snowfall due to loss in moisture holding capacity. While low elevation snowfall seems to be decreasing throughout northern California (Freeman, 2003, 2009), Freeman (2008, 2010) describes the Feather River as being relatively sensitive to the effects of climate change due to its relatively low elevation complex topography that includes some rain-shadowed subbasins. However, more recent study by Freeman, which is presented in this paper, indicates that rain-shadowed subbasins in northern CA are especially sensitive to climate change impacts characterized by changed hydrological pathways and water balances that include reduced aquifer outflow of springs, decreased runoff from snow melt, increased evapotranspiration, and for some topographically blocked subbasins, reduced water year runoff. With the conclusion that precipitation amounts have not significantly changed, and that a decline in aquifer outflow from springs has occurred, it seems likely that evapotranspiration has increased possibly as a result of both increased forest growth and increased fire suppression in recent years. Early 20th century pictures of the forest on the EBNFFR (Gruell, 2001) show a less dense forest than is currently observed. A less dense conifer distribution would have less evapotranspiration and

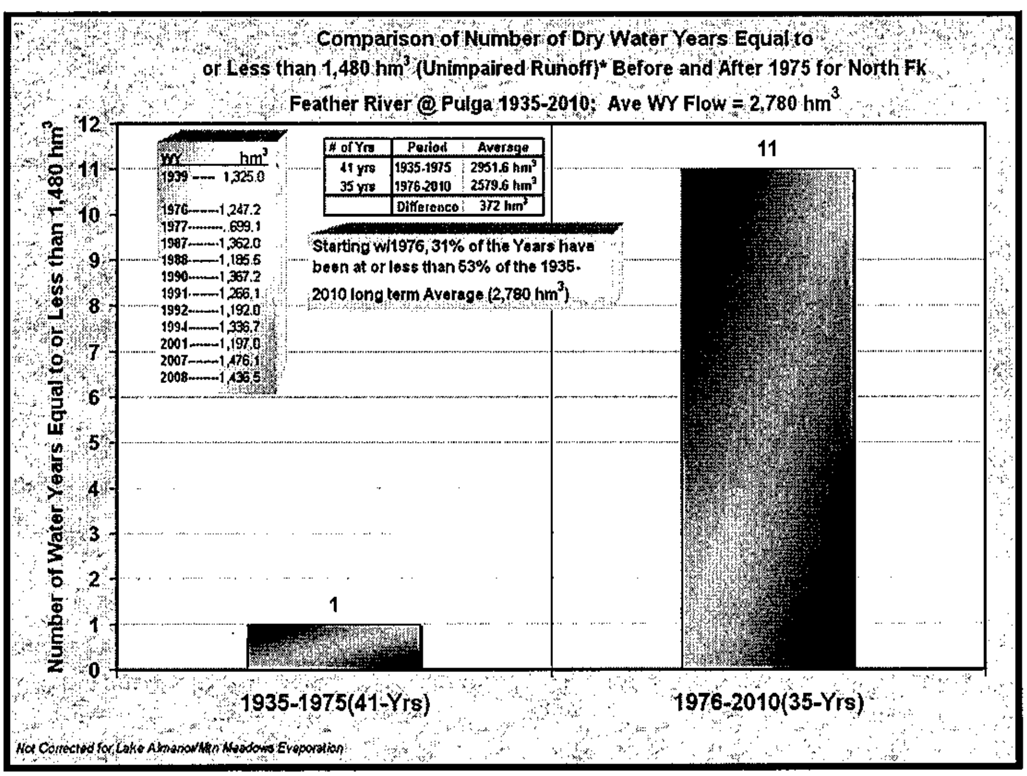

Figure 1. A comparison of the number of low flow water years for two different periods on the NFFR.

likely produce greater runoff compared with the current thicker conifer density. In recent years, runoff for a given amount of precipitation is most reduced in those years that are on the dry side. This observation appears to indicate that if soil moisture availability is limited, then runoff is further reduced as plant transpiration continues its demand on available soil moisture at and above the wilting point. Runoff is likely diminished in inverse proportion to increased evapotranspiration that is used in part to support leaf cooling and increased forest growth. Figure 1 illustrates that compared with prior years; starting in 1976 there is an increased frequency of low flow years for the NFFR @ Pulga. The NFFR @ Pulga collectively includes all upstream subbasins. In spite of the number of years for the more recent period being less following the 1935-1975 period, there are 11 times the number of years, which are less than 53% of the long term mean. This is consistent with the increased shift in the water balance from runoff to evapotranspiration. Groundwater for the Lake Almanor subbasin has continuously decreased in recent years. The springs for this subbasin consist primarily of relatively shallow porous volcanic basalts. Their depletion long term indicates susceptibility for drought imposed flow reduction. Prior to about 1970, aquifer outflow in the form of springs into and under the Lake accounted for more than 50% of the water year flow in average water years. Today that drought resistant reserve has become significantly reduced and accounts for less than 40% of the water year flow. Similar declines in outflow from springs have been found on the McKenzie River near Eugene, Oregon (Jefferson et al., 2008). Figures 2 and 3 illustrate the decline in aquifer outflow currently being observed for the Lake Almanor subbasin. An indexed approach, being used at PG&E, utilizes fall base flows to track and monitor aquifer outflow in a consistent manner. Once depleted to a low rate of outflow, it may take multiple years of wetness to restore the aquifers to their former storage levels. The springs under Lake Almanor are mostly the result of porous volcanic lava flows north and northeast of the Lake that encounter the harder, relatively impervious metasedimentary rocks of the Sierra block The loss of low elevation snowfall may have also decreased the rate of aquifer recharge opportunity from snowmelt. The relatively slow release of water from the snowpack typically creates an ideal opportunity for groundwater recharge. During wetter than normal precipitation years when soil moisture recharge is not limited from precipitation or snowpack amount, recharge opportunity is maximized and can satisfy all evapotranspiration demands as well as provide a directly proportional increase of runoff from each centimeter of precipitation added. Contributing factors to increased forest growth likely include warmer temperatures, increases in carbon dioxide, and fire suppression in recent years. If vegetation is not moisture stressed, then the increase in carbon dioxide that accompanies climate change may possibly be accelerating forest growth, utilizing increased amounts of water, which in prior years was available for surface

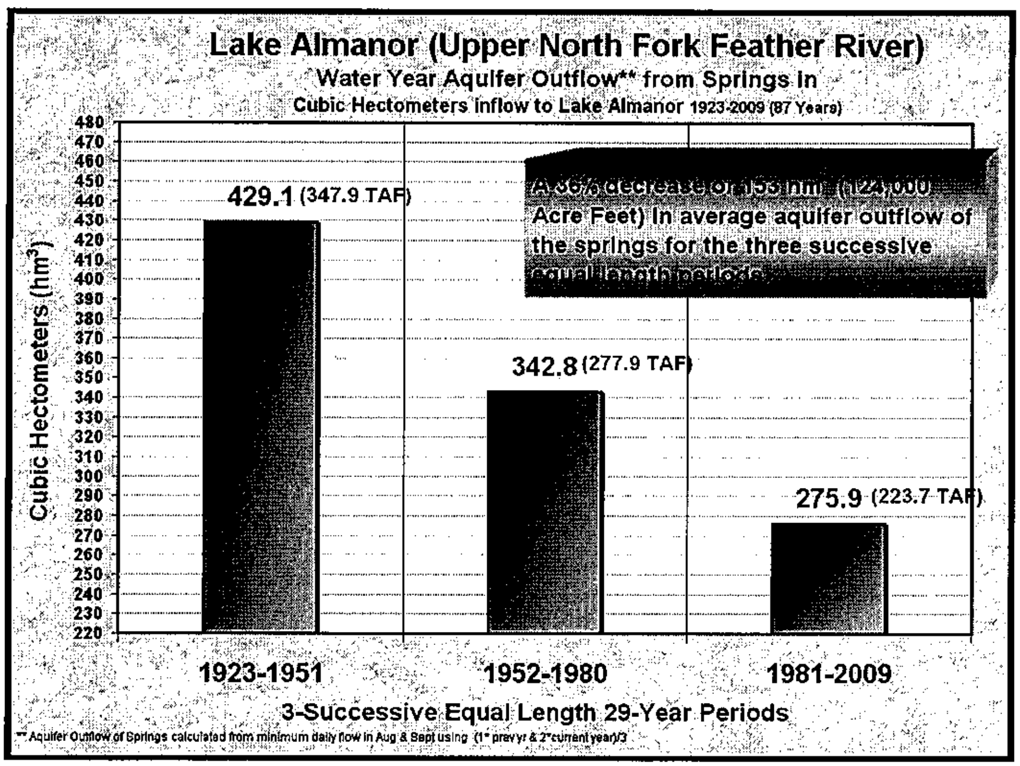

Figure 2. The long term decline in aquifer outflow of springs into Lake Almanor.

runoff. Today much of that water,w hich has in recent years become increasingly used to satisfy evapotranspiration is neither replenishing the aquifers nor running off as surface flow. The physiographic controls on how the Feather

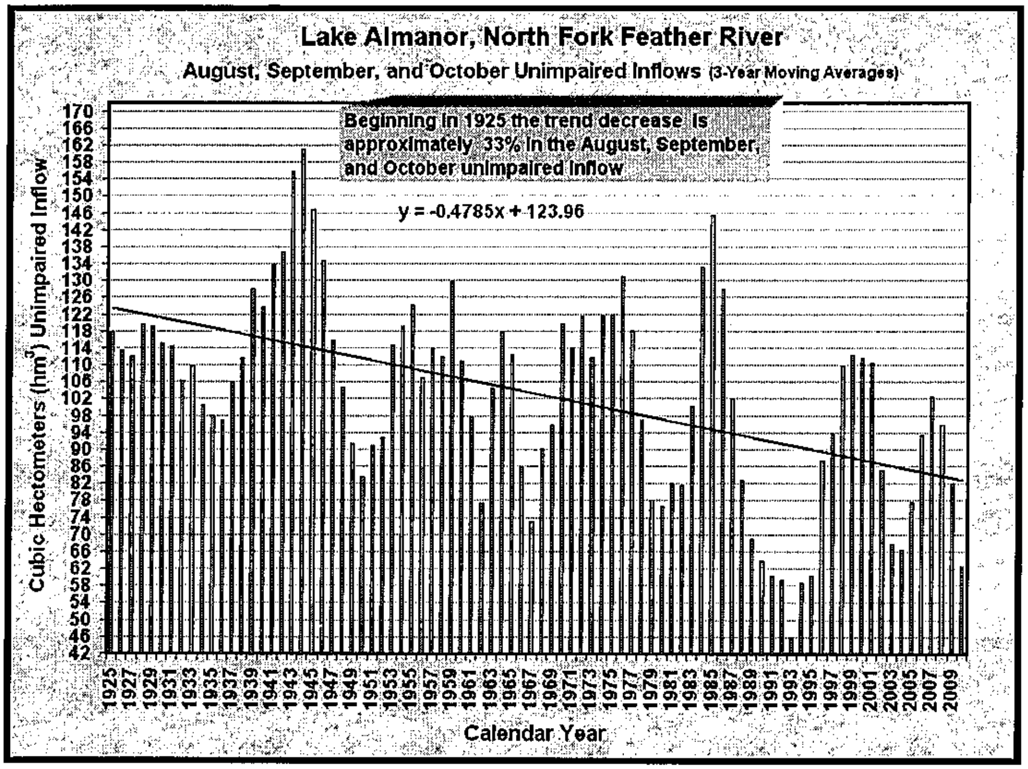

Figure 3. Summer and fall unimpaired inflows to Lake Almanor have declined approximately 33% (trended change) since 1925.

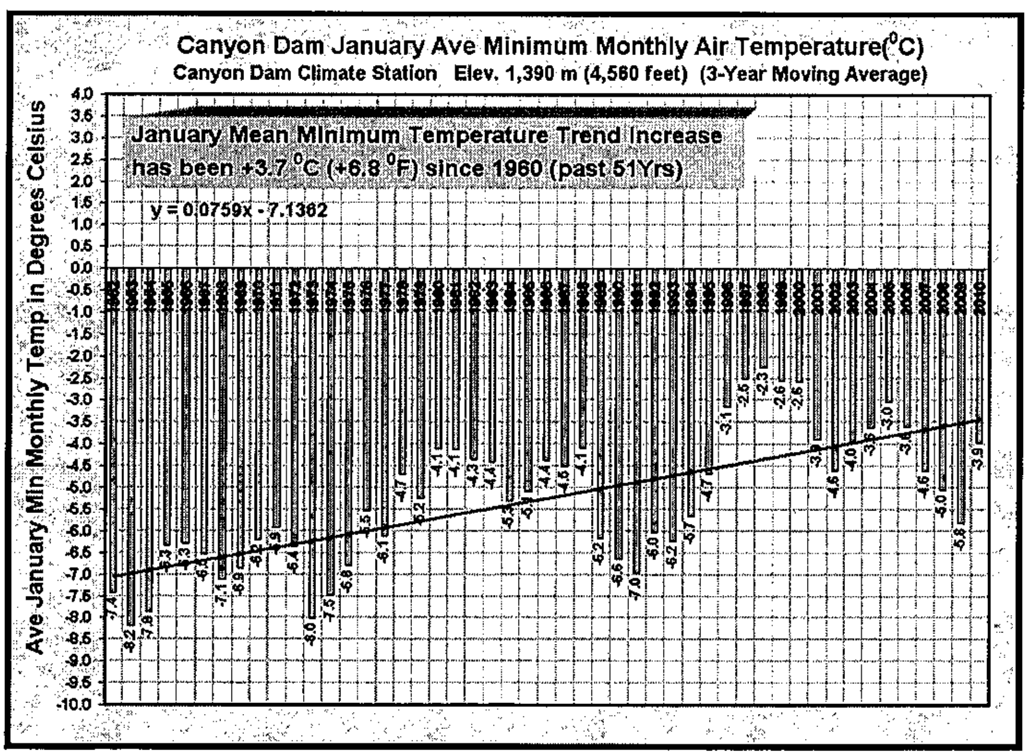

Figure 4. Increase in the mean minimum January temperature at Canyon Dam.

River's vegetation including the forests respond to change in energy and water flux mostly in the form of increased warming and soil moisture stress are not well understood. At this time there is a scarcity of ground based instrumentation with sufficient good quality record to fully understand what is taking place.

Minimum January temperatures were analyzed at existing climate stations on the Feather River. Minimum January trended temperatures were an average of 5.1^{0}C (9.2^{0}F) degrees warmer at Quincy on the EBNFFR, 3.8^{0}C (6.8^{0}F) degrees warmer for Canyon Dam, and 2.8^{0}C (5.0^{0}F) degrees warmer at Chester since the early 1960's. This is 2-4 times the increase observed for most mountain locations elsewhere in the Sierra to the south. Figure 4 is an example of data charted for the Canyon Dam climate station. The minimum temperature at the nearby Prattville climate station showed a similar increase. While there is only a limited number of climate stations in the area, the much warmer winter temperatures, loss of snowpack, and decrease in annual runoff appear supportive that the hydrology is changing for at least the two of the subbasins, EBNFFR and Lake Almanor on the upper NFFR.

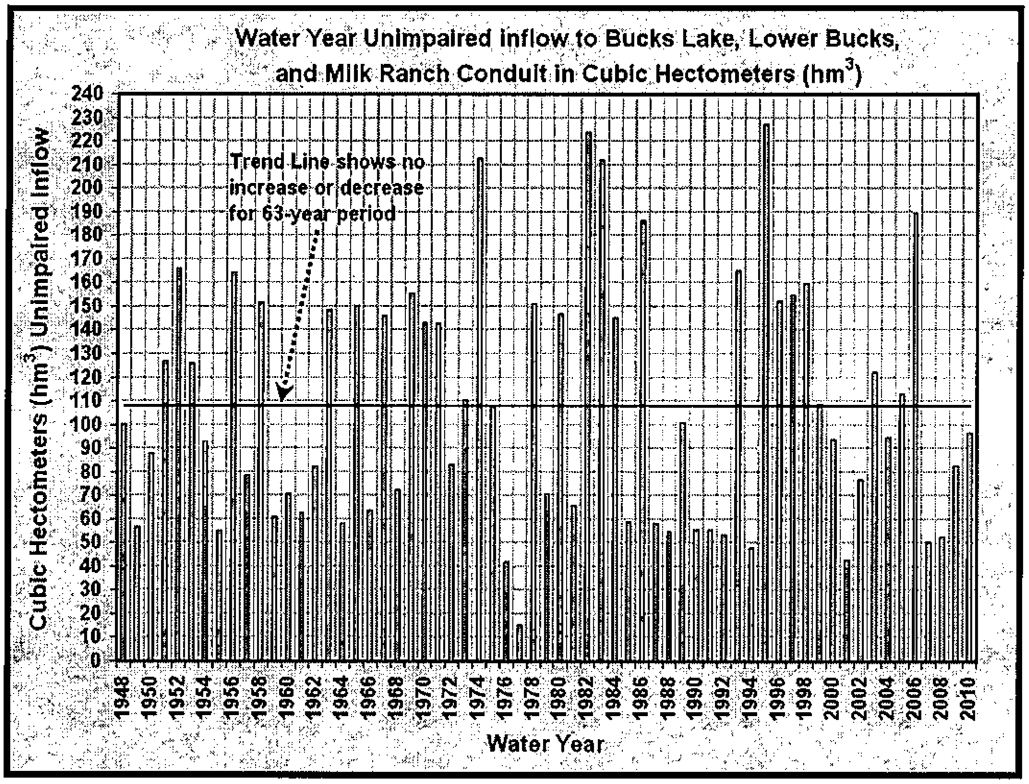

Figure 5. The Bucks Lake Subbasin is characterized by strong orographic cooling.

The Bucks Lake and Lower Bucks Diversion subbasin exhibits strong orographically caused precipitation increases during storm systems. The water year runoff shown in Figure 5 reveals very little change for water year runoff quantity from the warming climate. The Bucks Lake low elevation snowpack has mostly remained unchanged historically, but with warmer air having the capacity to hold more water, annual precipitation amount in the future could potentially increase for these types of windward facing subbasins that are orographically cooled (Freeman, 2010). The warming climate's impact on areas with very strong orographic cooling has the overall potential to increase precipitation and snowfall for isolated peaks such as at Mt. Shasta and Mt. Lassen (Freeman, 2010; Howat, et al., 2007) and also for the higher elevations in the southern Sierra (Howat and Tulaczyk, 2005).

WARMER STORMS IN RECENT YEARS

A comparison of average daily minimum storm temperatures from the Canyon Dam climate station as shown in Figure 6 for days with precipitation for two successive 34-year periods shows an average 1.4 ^{0}C (2.5^{0}F) increase for the more recent January through March period. This increase supports the decrease in low elevation snowpack being observed for snow courses on the Feather River such as for the Mt. Stover snow course at the 1,646 m

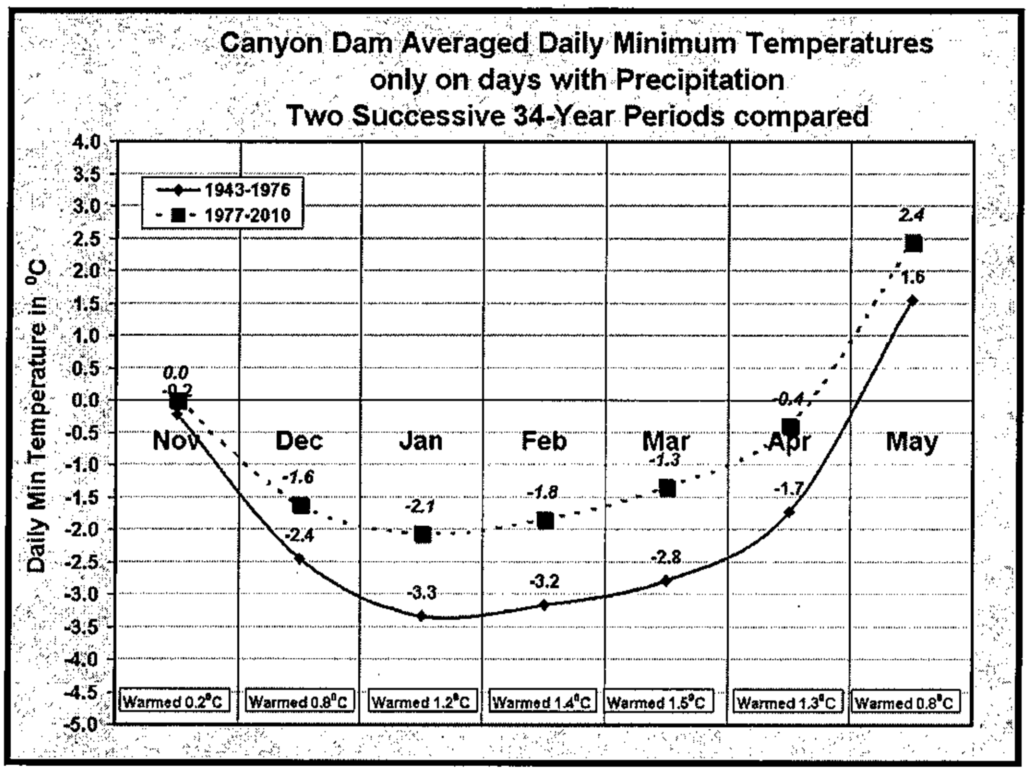

Figure 6. Canyon Dam averaged daily minimum temperatures only on days with precipitation for two successive 34-year periods.

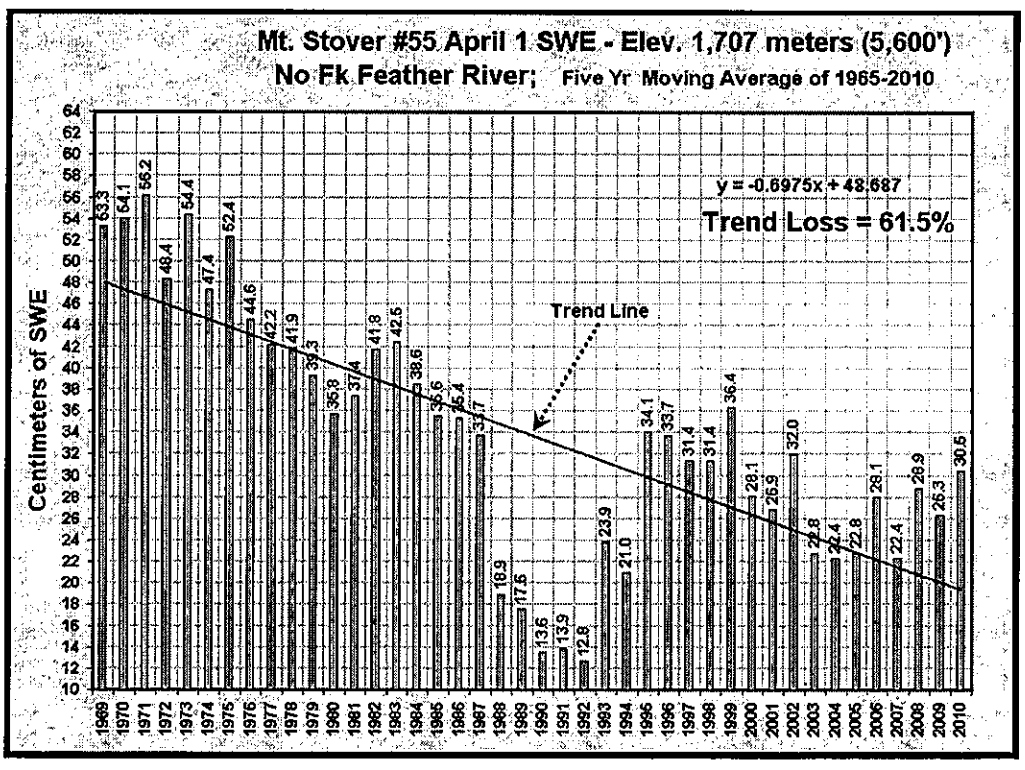

Figure 7. A 5-year moving average for the April 1 snow water equivalent at the Mt. Stover snow course on the Lake Almanor subbasin. The trend loss is almost 63%.

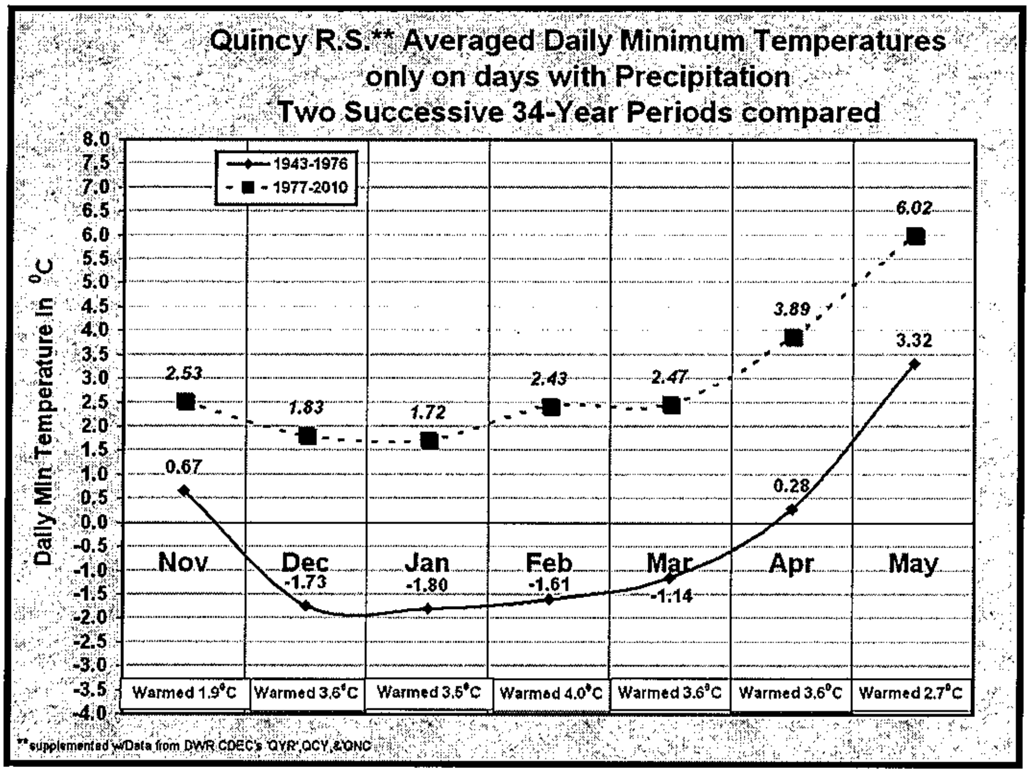

Figure 8. Quincy Ranger Station's averaged daily minimum temperatures only on days with precipitation for two successive 34-year periods.

(5,600 ft) elevation (Figure 7). The reduced April 1 snow water equivalent appears consistent with both less snowfall in recent years and an earlier snowmelt with increased runoff that now occurs in the month of March. Because such a large portion of the Lake Almanor subbasin is below the 1,646 m (5,600 ft) elevation, a large proportion of the watershed's snowpack no longer exists in most years. The loss of mountain snowpack observed for the NFFR is consistent with findings by others (Stewart, 2009, Pierce, et al., 2008). The loss of the low elevation snowpack may likely be limiting groundwater recharge. However, reduced aquifer outflow also seems to have partly been the result of increased evapotranspiration taking place on the subbasin. Regardless of the long term trend, it should be kept in mind that even with a strong trend, individual year variation can result in an occasional year having a large April 1 snowpack such as occurred in 2010 when the April 1 SWE at Mt. Stover was 49.0 cm (19.3 in) and 131% of the 1951-2000 50-yr average of 37.3 cm (14.7 in). Trends and moving averages are simply the smoothed over statistic of the individual years with their included variance. Figure 8 shows a similar, but more significant increase in minimum temperature accompanying storms in the more recent 34-year period at the Quincy R.S. climate station, which was used to represent the rain-shadowed EBNFFR. The implications of warmer winter minimum temperatures accompanied by increasing snow loss from the low elevation snow zone could result in earlier drying of soils. Rainfall typically diminishes after April. This and the loss of the low elevation snowpack that typically provides spring and early summer soil moisture recharge from snowmelt may lead to earlier soil moisture loss. Warmer temperatures in recent years would support increased forest growth and the depletion of remaining soil moisture. The increased soil moisture demand on soils may explain some of the loss of aquifer outflow from the springs. The early spring loss of the thinning snowpack is also likely to lead to increased surface heating from loss of albedo. This has potential to cause increased soil warming and evapotranspiration.

THE IMPORTANCE OF OROGRAPHIC COOLING WITH A WARMING CLIMATE

For most of the Sierra Nevada Mountains, the west side slope is conducive to orographic cooling almost up to the summit. The Feather River in the northern end of the Sierra, however, has not been tilted or pushed upward from Basin and Range crustal extension nearly as much compared with the southern Sierra, such as west of the Owens Valley, which has been lifted more than 2,438 m (8,000 ft) in elevation. Much of the original ancestral

Sierra's metamorphic complexity remains as it did during the mid-Tertiary period. During winter storm fronts, if incoming air is not sufficiently cooled, the snowline rises. If air temperatures during storms continue to rise, there may eventually be a point in time where less water year precipitation occurs for the rain-shadowed subbasins on the Feather Basin. A minor loss appears to have already occurred in the Quincy area, but the data quality is insufficient to scientifically support making that conclusion. The water year runoff averages for those subbasins on the NFFR Basin which are strongly orographic influenced during storm fronts have remained essentially unchanged since the mid-1960's.

THE CHANGING WATER BALANCE

In terms of a mass balance, water year surface runoff equals water remaining from precipitation after evapotranspiration and infiltration is augmented by water flowing from soils and aquifers all for the same 12 month period. The water balance is reviewed in this section for both the rain-shadowed EBNFFR and for Lake Almanor. The Lake Almanor subbasin has considerable aquifer outflow from precipitation of past years that occurs from springs even during very dry years. In addition to the decrease in April through June runoff, the water year runoff for both subbasins has also declined since about the mid 1970's. Figure 9 illustrates this decline in water year runoff for the EBNFFR along with an estimate of increased evapotranspiration based on using the 1950-1970 20-year period as the zero base period. Assuming that the ground water storage has declined, the reduction in aquifer

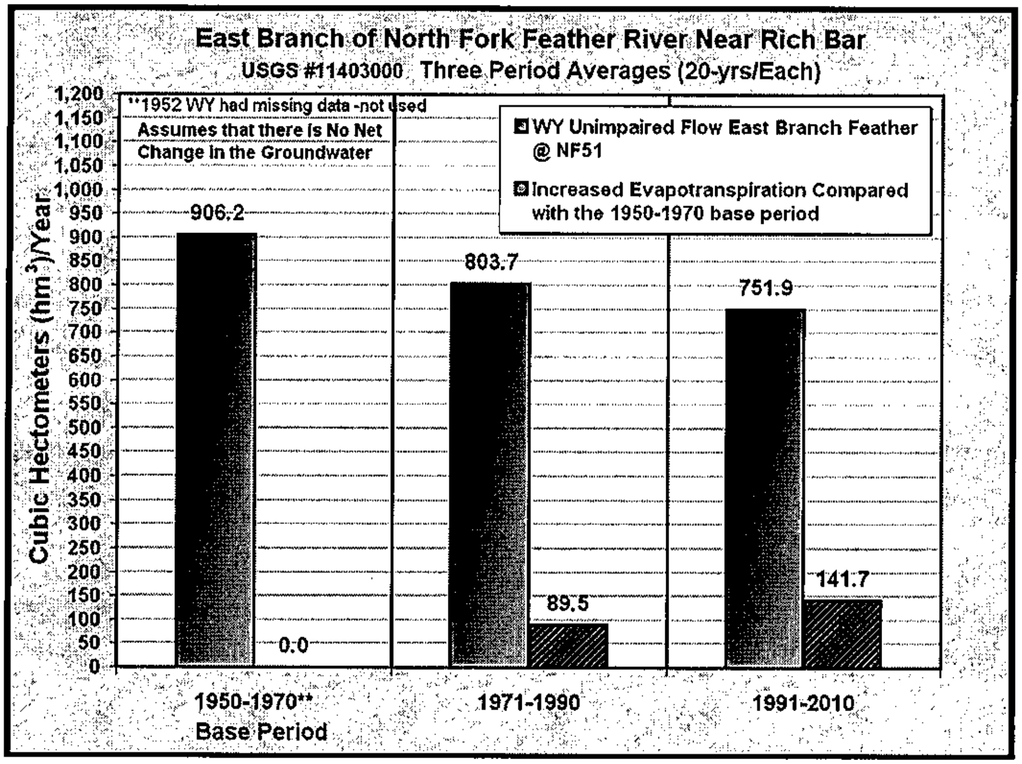

Figure 9. Three successive 20-year periods showing surface runoff decline for the EBNFFR near Rich Bar.

outflow may in part be due to lack of groundwater recharge opportunity. Snowmelt in the spring tends to occur at a sufficiently slow rate to provide maximum opportunity for infiltration and groundwater recharge. Since aquifer outflow has declined on the Lake Almanor subbasin, one needs to investigate the precipitation for the same period to verify that seasonal precipitation has not also declined. If the seasonal precipitation trend is stationary and the aquifer storage is declining as is indicated from aquifer outflow rates, then the evapotranspiration rate is likely increasing in direct proportion to the loss in runoff. The Quincy climate station has considerable missing precipitation record and for purpose of this analysis was considered poor quality. However, the Caribou Power House climate station, which is also partially rain-shadowed had reasonably good quality precipitation record and was utilized to compute the relative recovery factor decline for the three 20-year periods. This would also provide an indication of the period evapotranspiration increase for the two more recent periods. Figure 10 illustrates the three-period decline in runoff recovery factors that have taken place with the evapotranspiration increases in recent years. The Caribou PH climate station shows only a slight decrease in the successive period precipitation amounts

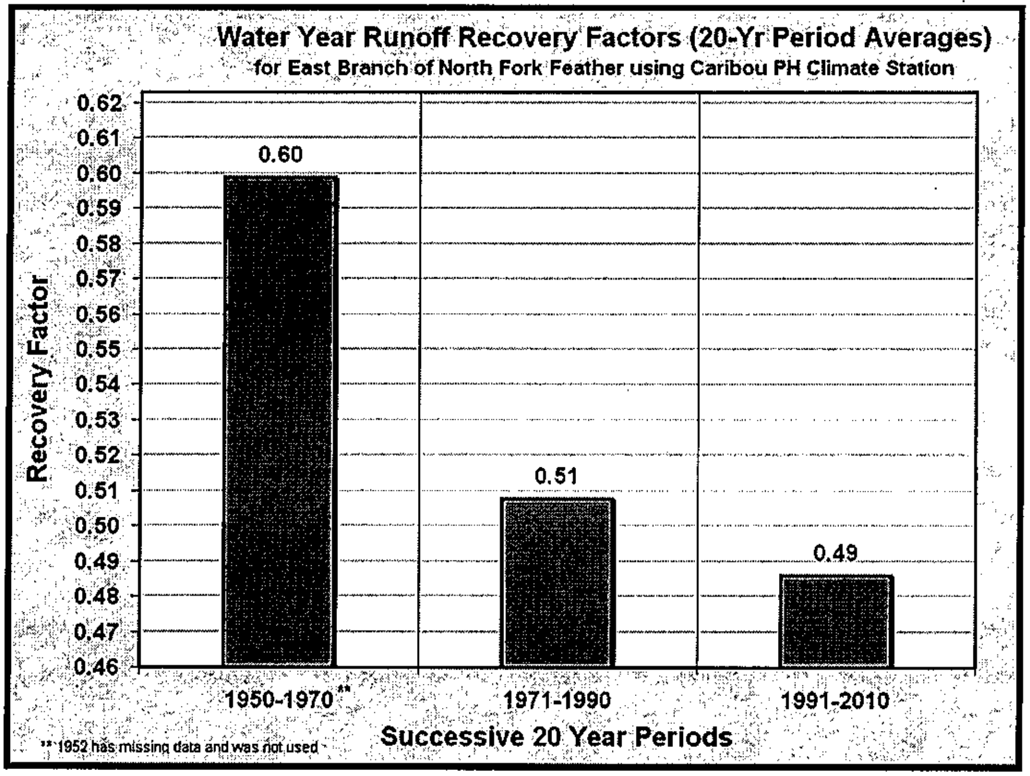

Figure 10. Runoff Recovery factors for the EBNFFR

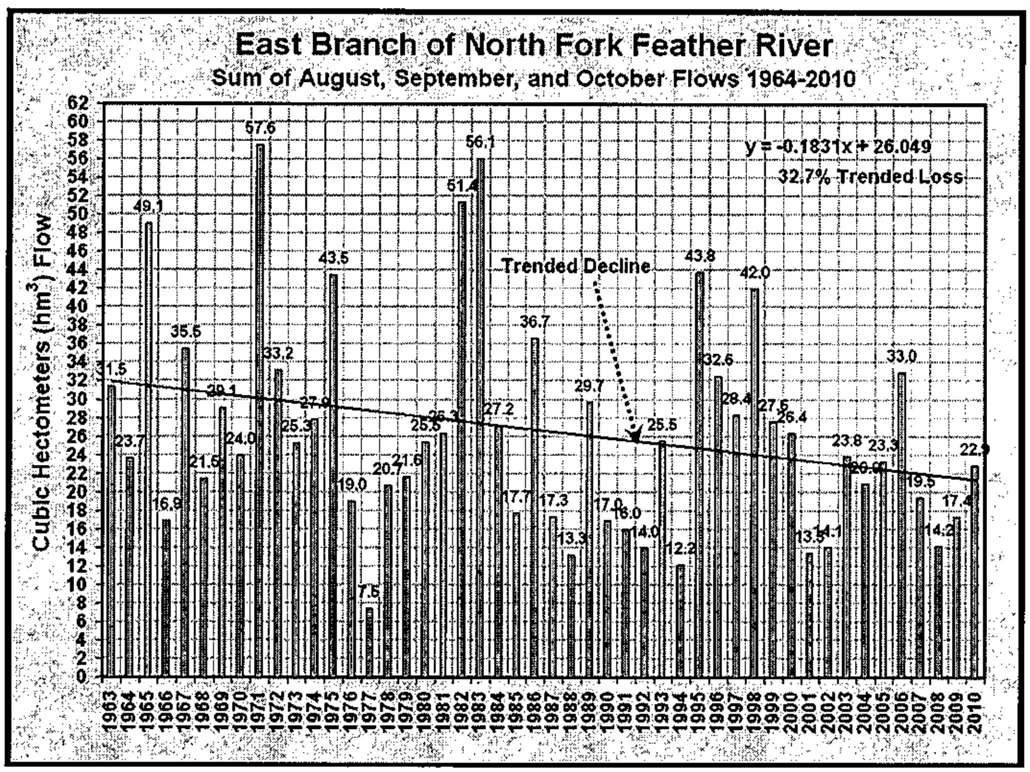

Figure 11. Decline in late summer and fall flows for the EBNFFR

Table 1. Recovery Factors for those water years on the EBNFFR that are 75% and 90% of normal (Caribou PH Climate Station).

Percent of 1950-2010 precipitation 61-Yr Average		90%	75%
Recovery Factor	1951-1980	0.40	0.35
Recovery Factor	1981-2010	0.33	0.30

during the three periods. Its decrease is essentially removed from the analysis by utilizing a single equation for computing the 3-period runoff recovery factor. Table 1 illustrates both a decrease in surface runoff recovery that takes place in the more recent period and also the decrease that occurs as precipitation decreases from 90% and less to 75% and less than normal. All of the recovery factors for below normal precipitation years are less than those for the most recent period of Figure 10. The general decrease in surface runoff recovery from water year precipitation likely results from the vegetation's moisture needs to support both its growth and increased need for evaporative cooling. Along with the reduced infiltration of water from the decline in low elevation snowmelt, the need for

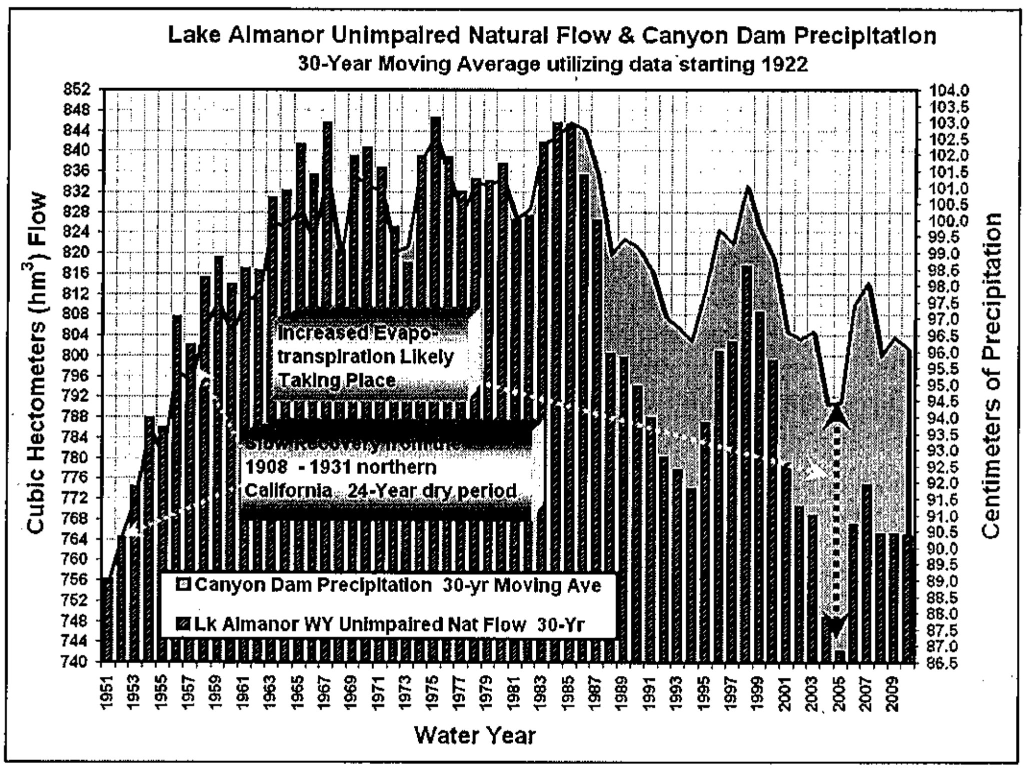

Figure 12. The Lake Almanor 30-year moving average of water year runoff plotted against the Canyon Dam 30-year moving average of water year precipitation.

vegetation to maintain a suitable Bowen Ratio by increased evapotranspiration also likely adds to the early summer soil moisture deficit and other losses that are taking place on the basin. While not volcanic like the headwaters above Lake Almanor, the soil moisture and ground water losses on the EBNFFR over the period of years since about the mid-1960's, can be seen in Figure 11. The decrease in the August through October late summer and fall flows is consistent with an overall decline in soil moisture and groundwater decline in the years since the mid-1960's. Utilizing long 30-year moving averages, Figure 12 utilizes data alignment through vertical axis scaling for the earlier years to illustrate this loss of surface runoff for equivalent quantities of precipitation that occurred in recent years. The long term averages utilized for Lake Almanor in Figure 12 also reveal the long term recovery that took place on northern California watersheds following the 1908 through 1931 'dry period' (Freeman, 2001).

USE OF TRENDED HISTORICAL DATA TO DETECT AND QUANTIFY CLIMATE CHANGE IMPACT AT THE SUBBASIN LEVEL

The decline in water year runoff, observed temperature increase, and significant low elevation snowpack decline in the observed data on rain-shadowed subbasins in northern California since the mid-1970's may not be consistent with the regional temperature increases that are currently being predicted by many of the most commonly used Global Climate Models (GCMs) and their associated scenarios. Actual data from the rain-shadowed subbasins on the NFFR and elsewhere in northern California indicate three and four times the warming that has occurred elsewhere in the Sierra on the larger regional basis. Utilizing the results of regional GCM models that may have not been corrected for topographic complexity and associated problems with high resolution spatial scaling may add large uncertainty, and may not be in alignment with the actual data currently being observed for these subbasins. Similar concerns with defining the effects of a warming climate on mountains with complex topography and its effect on orographic cooling and snowfall have been investigated in the Cascade Mountains near Mt. Rainier (Minder, 2010). The orographically influenced subbasins in the Feather River Canyon downstream of Belden and in the Bucks-Grizzly subbasin have a hydrological response to winter storms, which is more typical of much of the west facing tilted Sierra block to the south. They are characterized by strong orographic cooling during most winter storms, which appears to greatly moderate the effects of climate warming. Knowing that regardless of the hydrological modeling approach utilized to study and predict climate change, whether it be the lumped or the distributed hydrological response unit approach, if the temperature change assumptions are not sufficiently sensitive to relatively small topographic features that determine orographic cooling and compressional heating at the subbasin level of detail, then the hydrological extension and future assumptions may not be relevant. The Water Management Team at PG&E has sufficiently detailed unimpaired flows at the operational subbasin level of detail throughout the Sierra and southern Cascades to compare and identify trends now taking place at the relatively small subbasin level of detail. At PG&E isohyetal maps are utilized as an initial tool for quickly locating rain-shadowed subbasins that may have potential to be negatively impacted by water year flow decline from climate change. Analysis of monthly and seasonal historical data then follows to evaluate the extent of subbasin impact (Freeman, 2010). If the GCM modeling technology along with downscaling methodology eventually proves relevant, aligned with, and reflective of actual historical data for these rain-shadowed subbasins, then use of GCM output for predicting hydrological water balance changes at the subbasin level would have increased value for operational hydroelectric planning. At this time, utilizing simple extension of the observed data trends such as are being made for rain-shadowed subbasins on the NFFR may be the simplest and most meaningful approach to identifying short term future impacts of warming.

SUMMARY AND CONCLUSIONS

Two rain-shadowed subbasins on the NFFR, Lake Almanor and EBNFFR, were found to not only have less April through June Runoff in recent years, but they are also losing water year runoff as well. Minimum average temperatures have increased for both of these subbasins and the minimum temperatures for days with precipitation have also increased. Increased air temperatures accompanied by a significant decline in low elevation snowpack have likely led to less available soil moisture for surface runoff. Forest vegetation appears to be doing well and appears to have increased in biomass since the mid-1970's. Increased evapotranspiration appears to be the most likely reason for the decline in water year runoff. The Lake Almanor subbasin has also lost aquifer outflow as evidenced in a decline of late summer and fall base flows. The opportunity for soil moisture recharge appears to have declined with the loss of low elevation snowpack. As summer soil moisture has become increasingly limited since the mid-1970's, forest vegetation appears to be satisfying its soil moisture needs to meet potential evapotranspiration at the expense of declining streamflow. Warmer air temperatures during the active growing season have likely resulted in increased evapotranspiration needed to meet leaf cooling and maintain growth. Both the EBNFFR and the Lake Almanor subbasin have shown significant late summer and fall runoff declines since the mid 1970's. Recovery factors of water year runoff from precipitation have declined the most during years with below average precipitation. These are years when actual evapotranspiration may be less than potential evapotranspiration. Subbasins such as the combined Bucks Lake and Grizzly drainage area as well as the Feather River Canyon Area below the confluence of the EBNFFR with the NFFR near Belden Powerhouse are strongly orographic with frontal systems typically being cooled and receiving normal snowfall. These areas do not seem to show any decline in water year runoff, however the March runoff has increased since the mid-1970's, indicating the same earlier snowmelt as is observed for most mountain locations in the Sierra. For the NFFR as a whole, there is

11 times the number of water years with runoff below 1,480 hm^3 (1,200 TAF)/water year since the mid 1970's compared with the preceding period of equal length.

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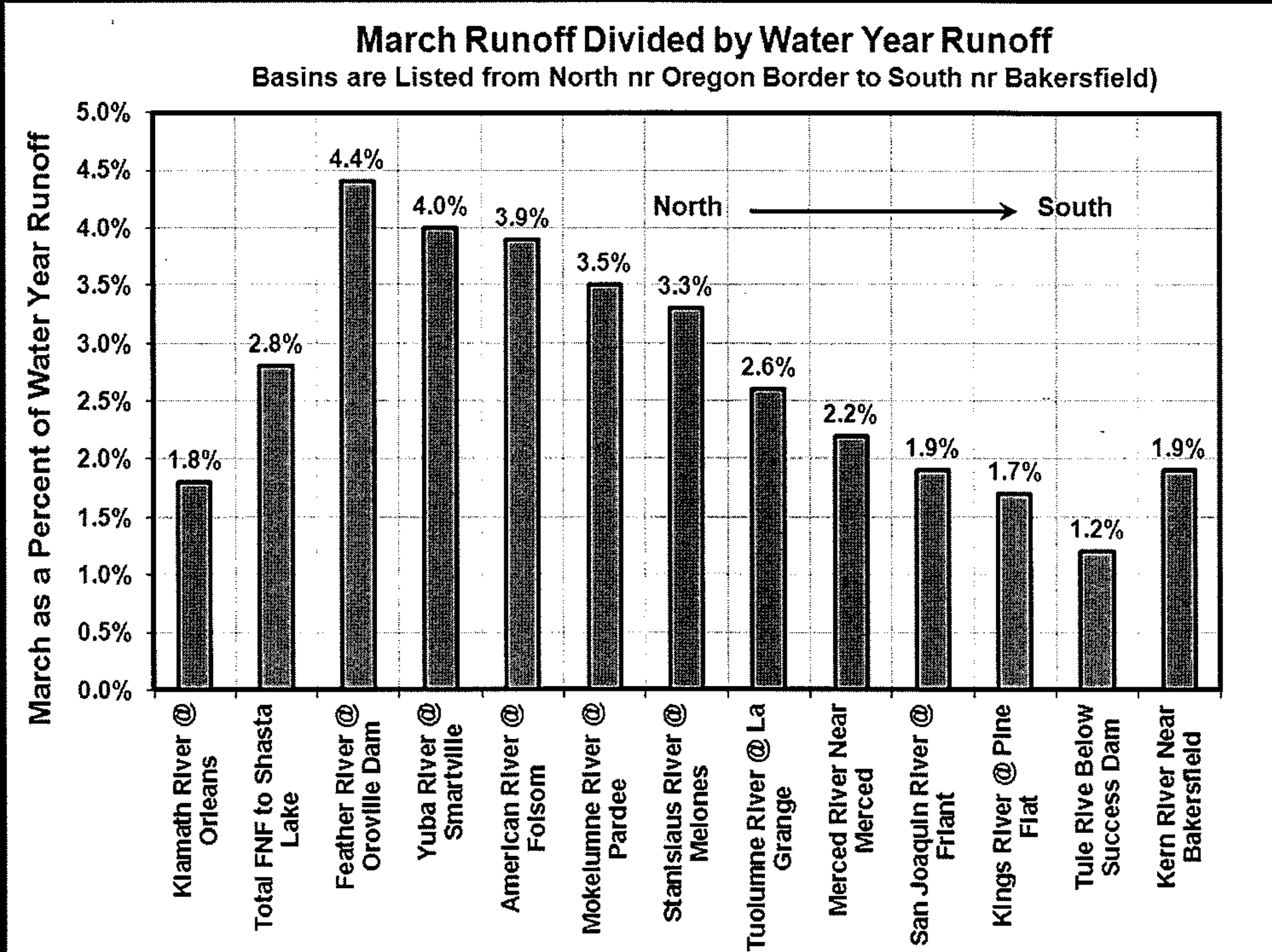
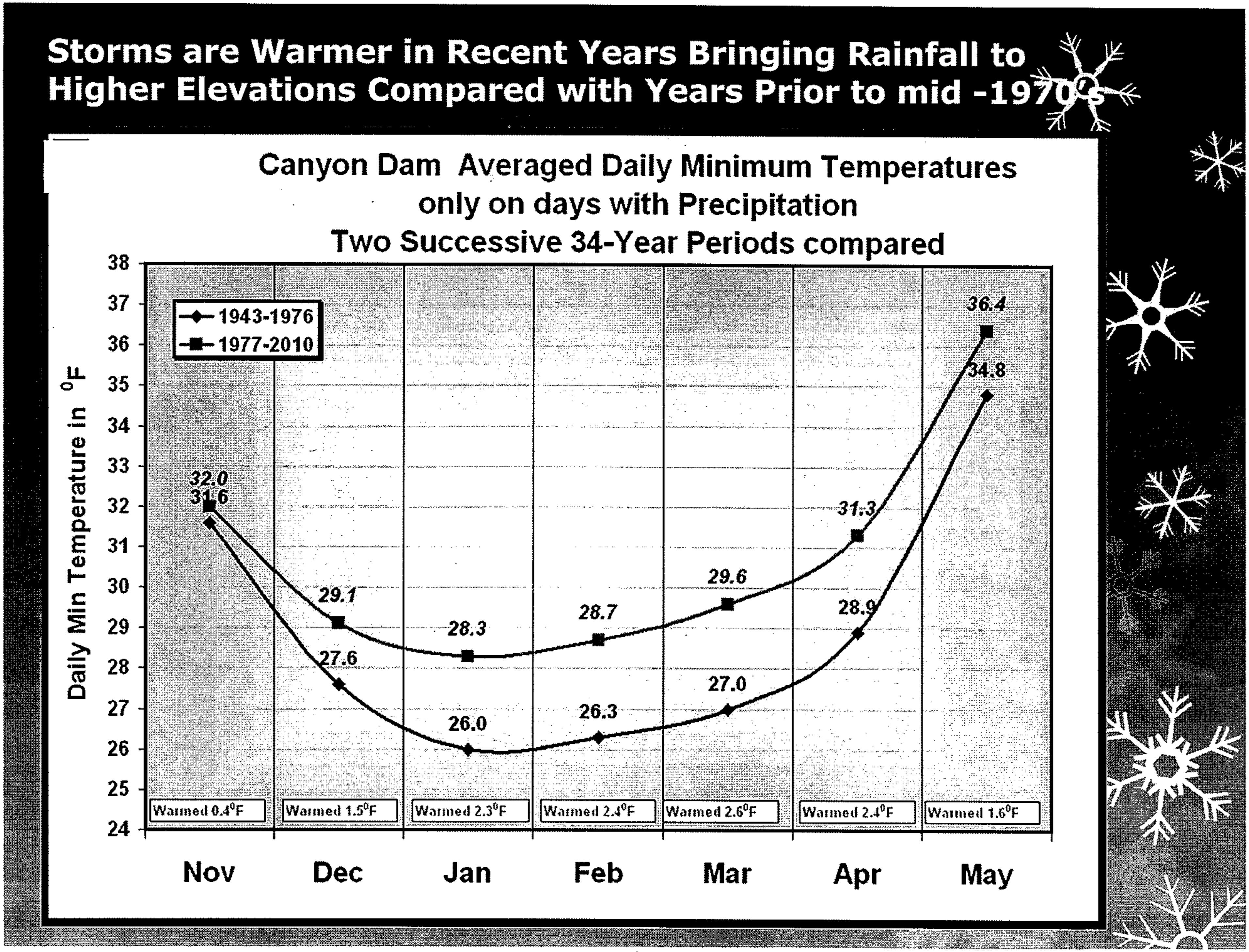
Some Hydrometeorological Effects of Climate Change for the North Fork Feather River Headwater Drainage with Focus on the Lake Almanor and the East Branch Subbasins

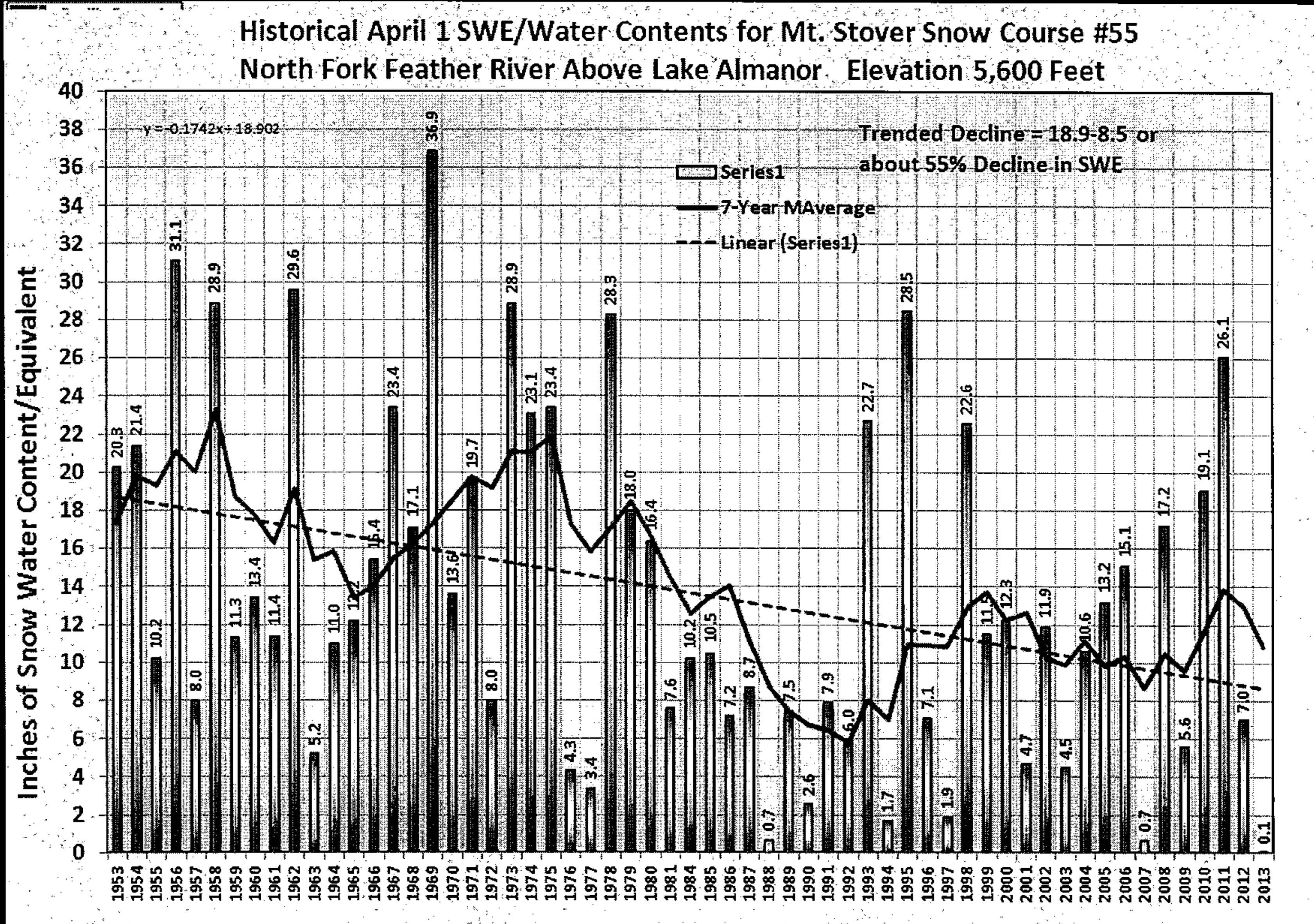
May 6, 2014

Compared Statewide an Analysis of Snowmelt Runoff Shows the Feather River to Have the Largest Shift towards an Earlier Snowmelt in March

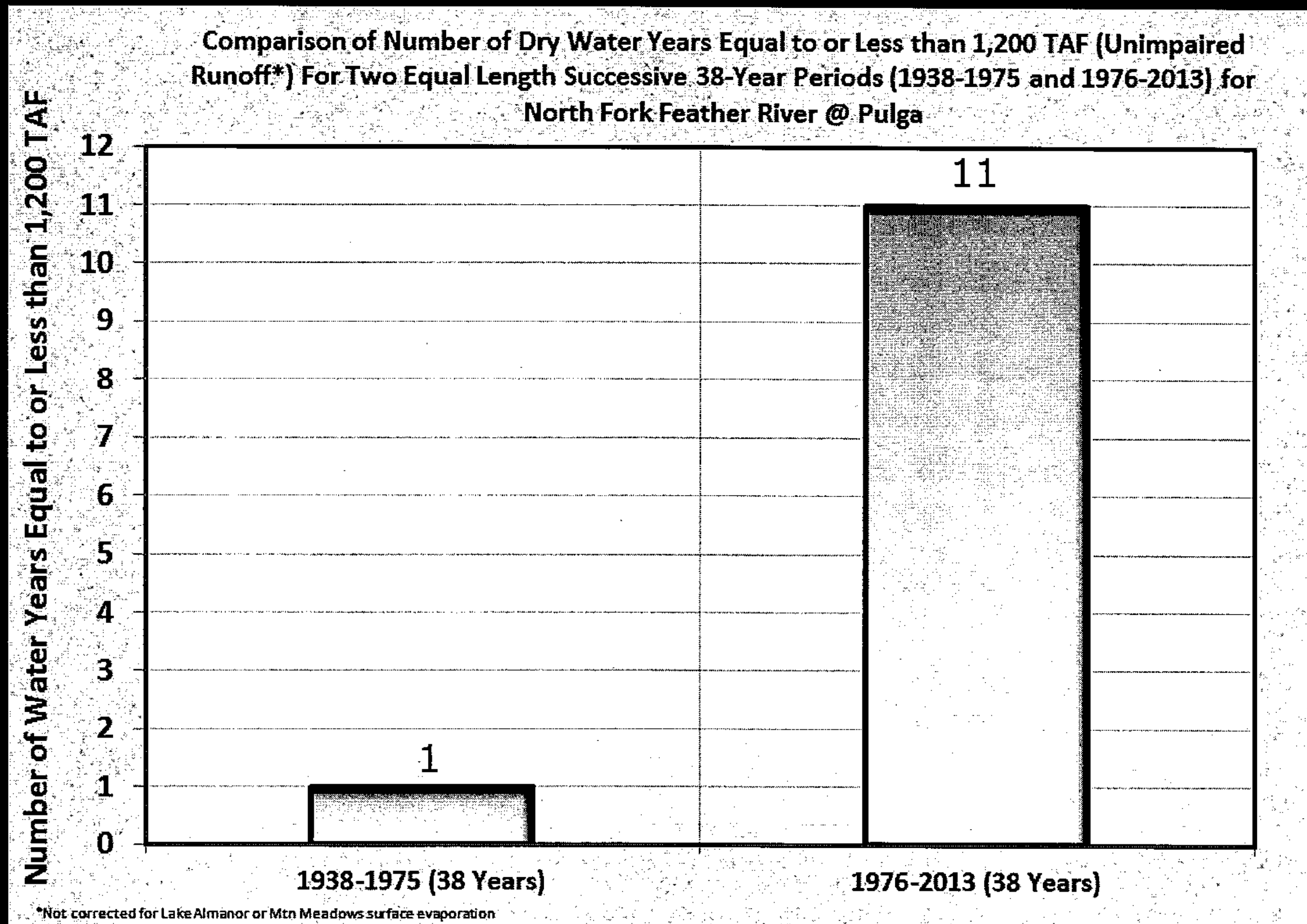


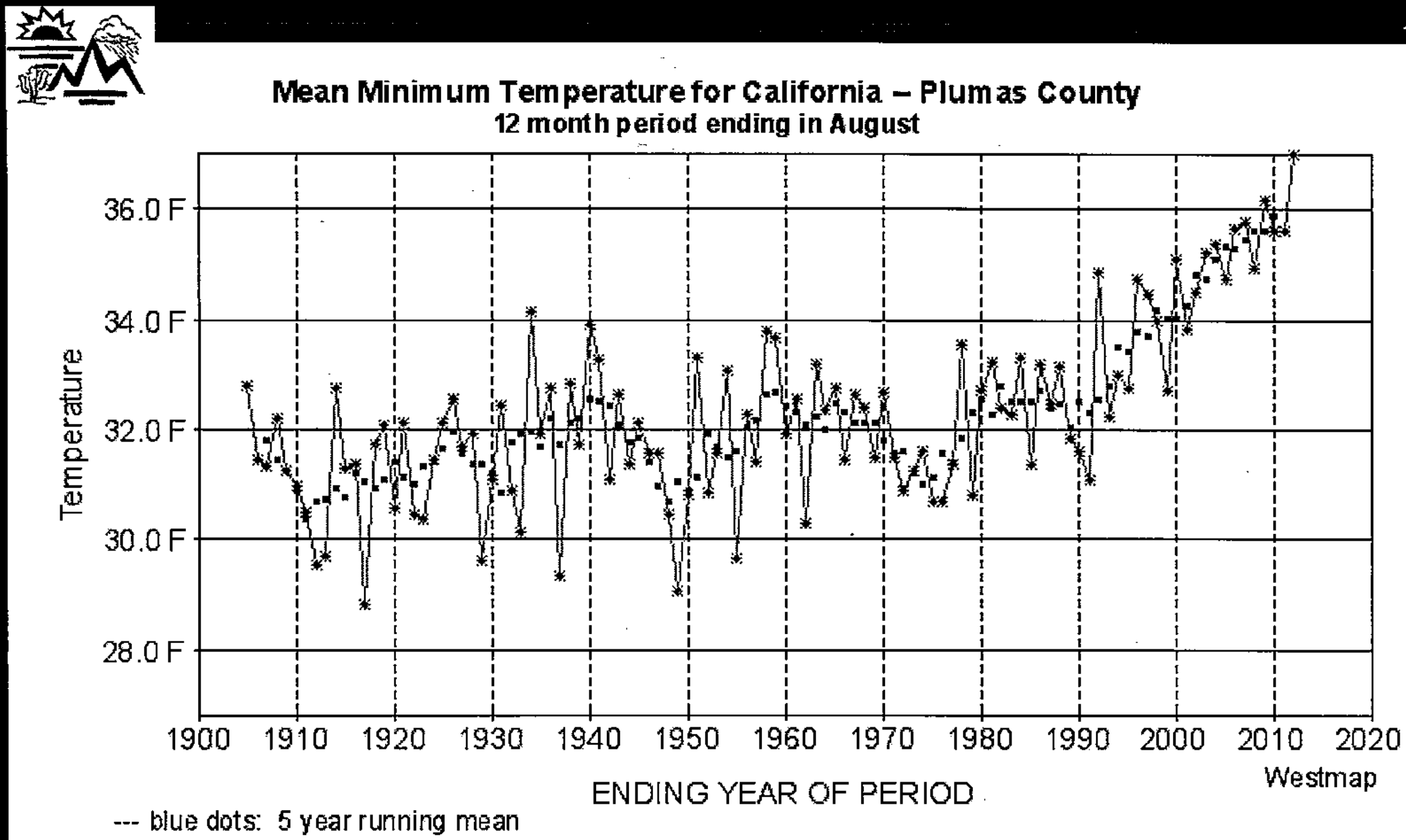

Storms are Warmer in Recent Years Bringing Rainfall to Higher Elevations Compared with Years Prior to mid -1970's
Canyon Dam Averaged Daily Minimum Temperatures
only on days with Precipitation
Two Successive 34-Year Periods compared
Daily Min Temperature in 0F
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
1943-1976
1977-2010
32.0
31.6
29.1
27.6
28.3
26.0
28.7
26.3
29.6
27.0
31.3
28.9
36.4
34.8
Warmed 0.4°F
Warmed 1.5°F
Warmed 2.3°F
Warmed 2.4°F
Warmed 2.6°F
Warmed 2.4°F
Warmed 1.6°F
Nov
Dec
Jan
Feb
Mar
Apr
May

An Example of a Trending Decline In Lake Almanor's Snowpack



Recent Years Reveal an Increase in Number of Dry Water Years for North Fork Feather River

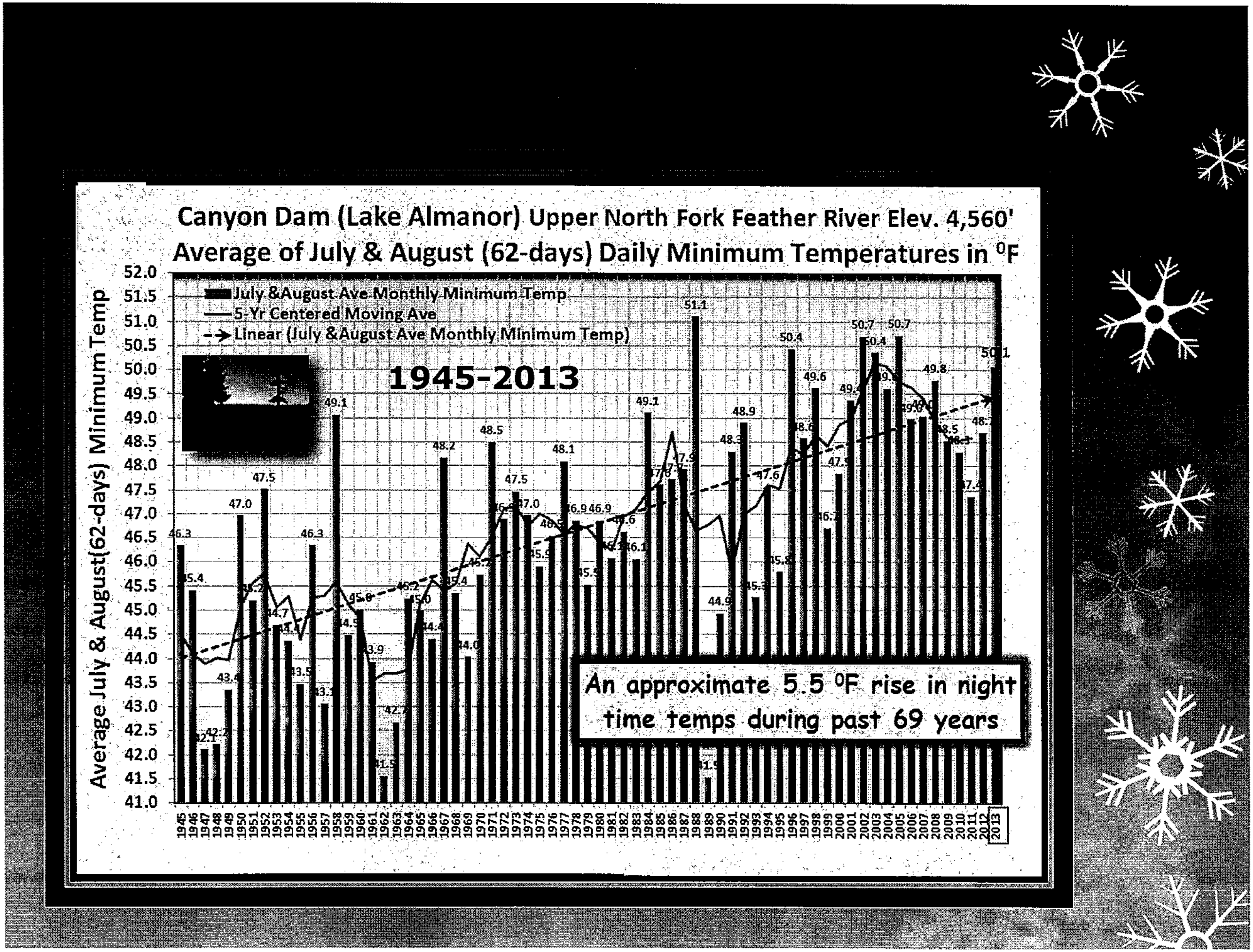




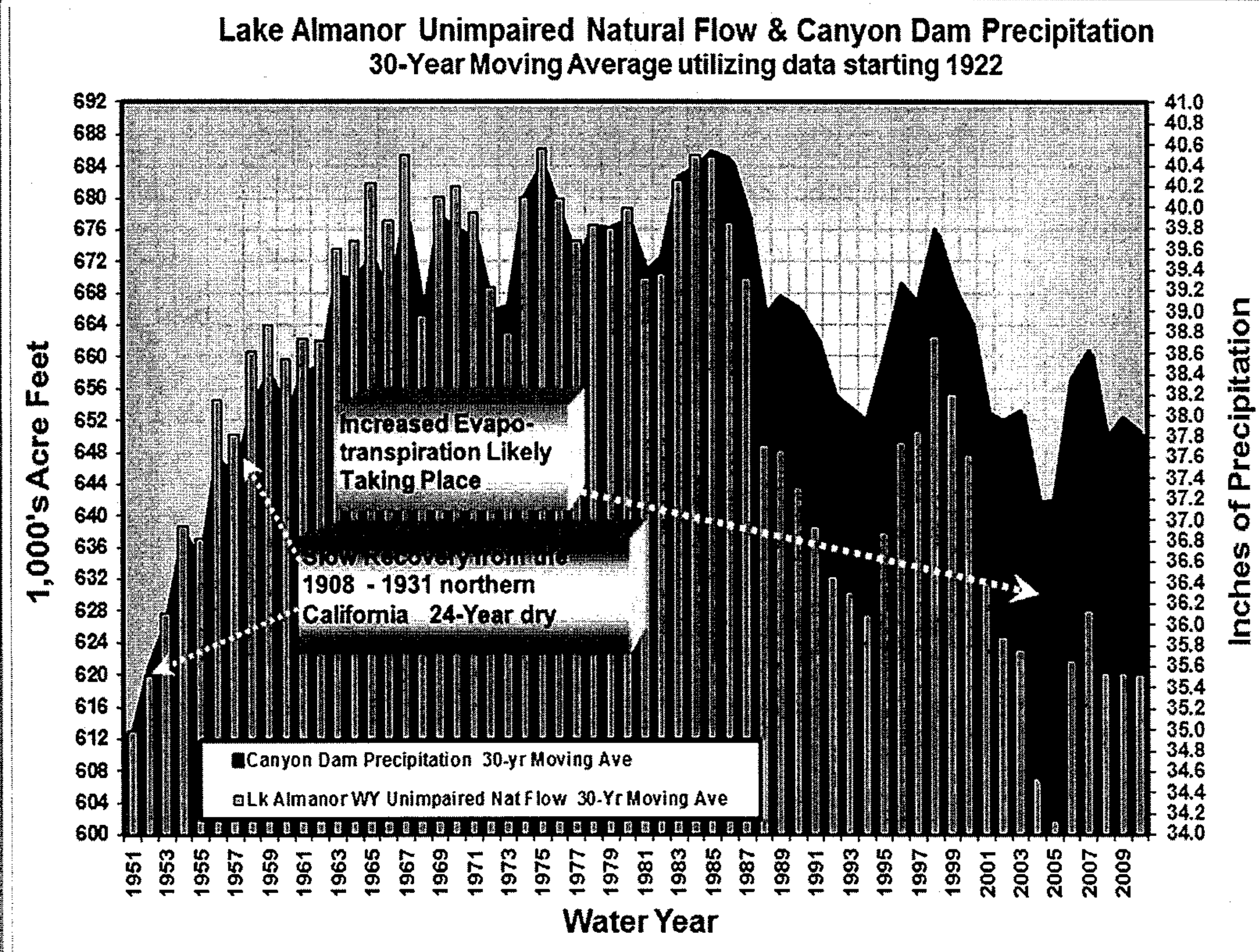
1990	31.6
1991	31.1
1992	34.9
1993	32.3
1994	33.0
1995	32.7
1996	34.7
1997	34.5
1998	34.0
1999	32.7
2000	35.1
2001	33.8
2002	34.5
2003	35.2
2004	35.4
2005	34.7
2006	35.7
2007	35.8
2008	34.9
2009	36.2
2010	35.6
2011	35.6
2012	37.0

Warming Trend of Nighttime Temperatures in Plumas County beginning about 1990 likely being caused by an increase in greenhouse gases *'trapping' daytime heating energy.*

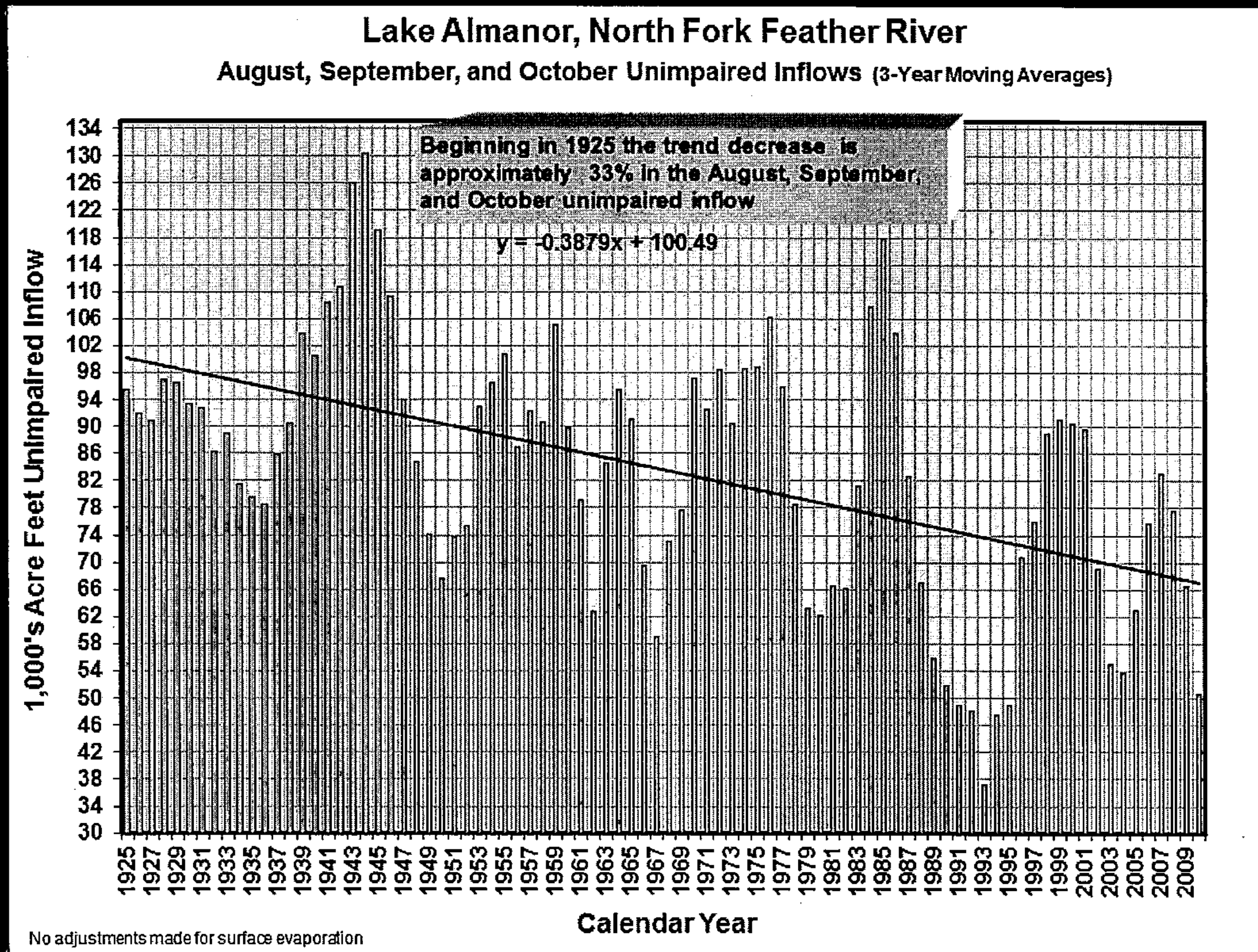
12-Month Period Ending in August
AVERAGE 32.303
MEDIAN 32.138
MINIMUM 28.817
MAXIMUM 37.050
SKEWNESS 0.562
COEFF OF VAR 0.049
SIGMA (RMS) 32.345
NUMBER OBS 108.000


Canyon Dam (Lake Almanor) Upper North Fork Feather River Elev. 4,560'
Average of July & August (62-days) Daily Minimum Temperatures in ⁰F
July &August Ave Monthly Minimum Temp
5-Yr Centered Moving Ave
Linear (July &August Ave Monthly Minimum Temp)
1945-2013
Average July & August(62-days) Minimum Temp
An approximate 5.5 ⁰F rise in night time temps during past 69 years

A Graphical Comparison of Canyon Dam Precipitation Compared With Runoff Utilized to Identify Increased Evapotranspiration which Started in the mid 1980's



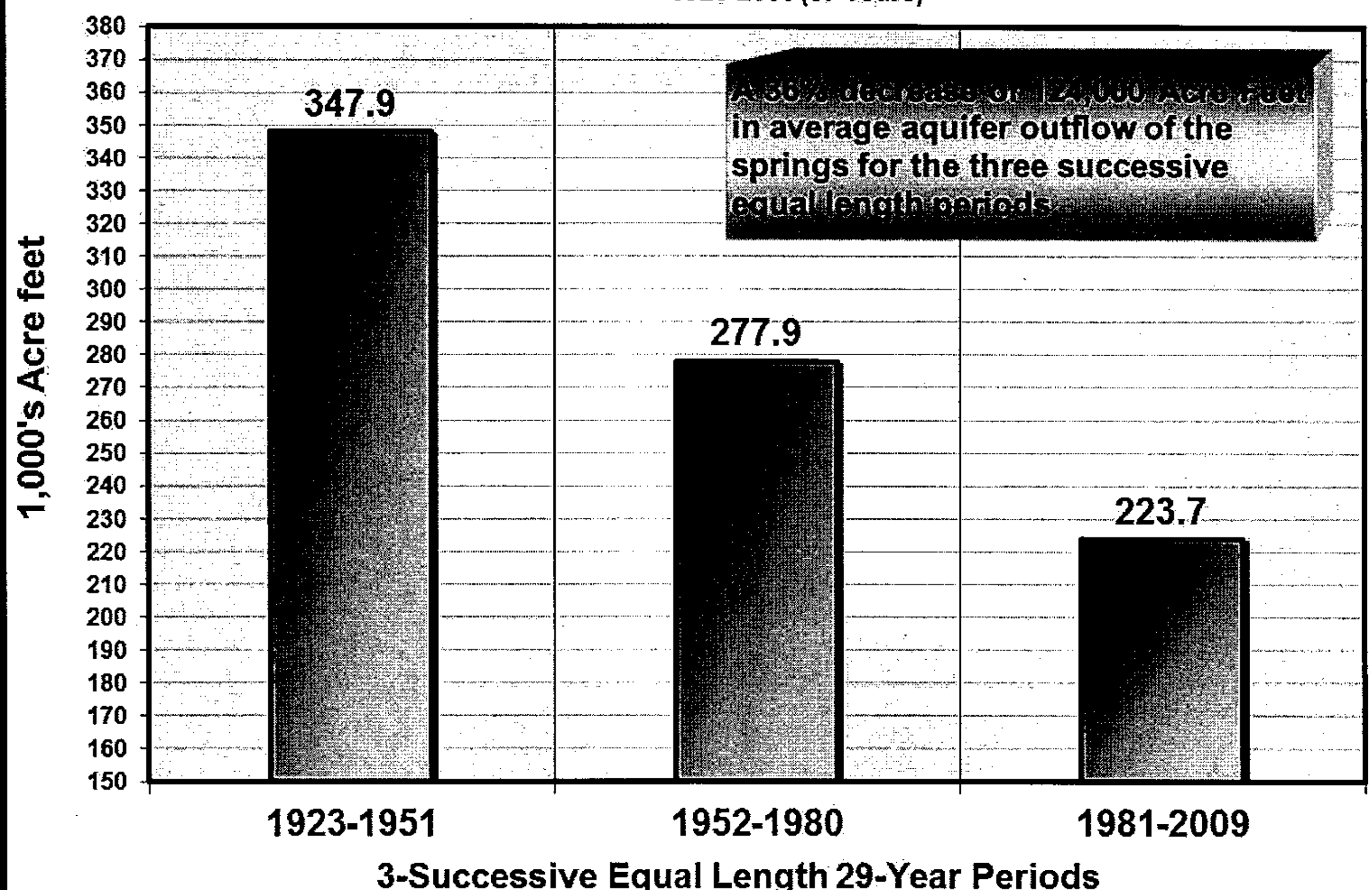
For the Upper North Fork Feather @ Lake Almanor Late Summer and Fall Base Flows (Aquifer Outflow) Show a Declining Trend in Recent Years



The Decline in Aquifer Outflow of the Springs Shown as Successive Equal Length 29-Year Periods

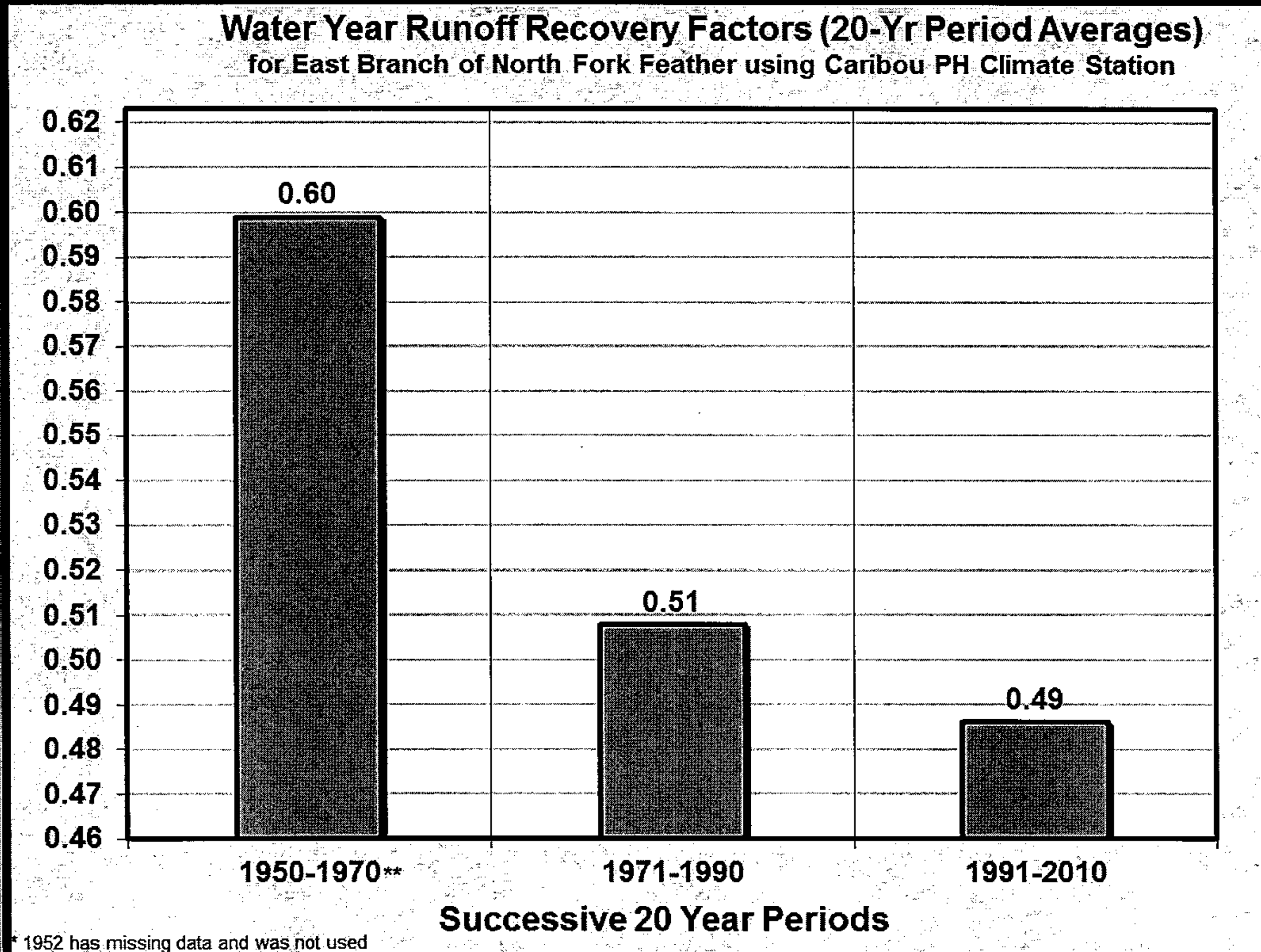
Lake Almanor (Upper North Fork Feather River)

Water Year Aquifer Outflow** from Springs in 1,000's Acre Feet inflow to Lk Almanor
1923-2009 (87 Years)

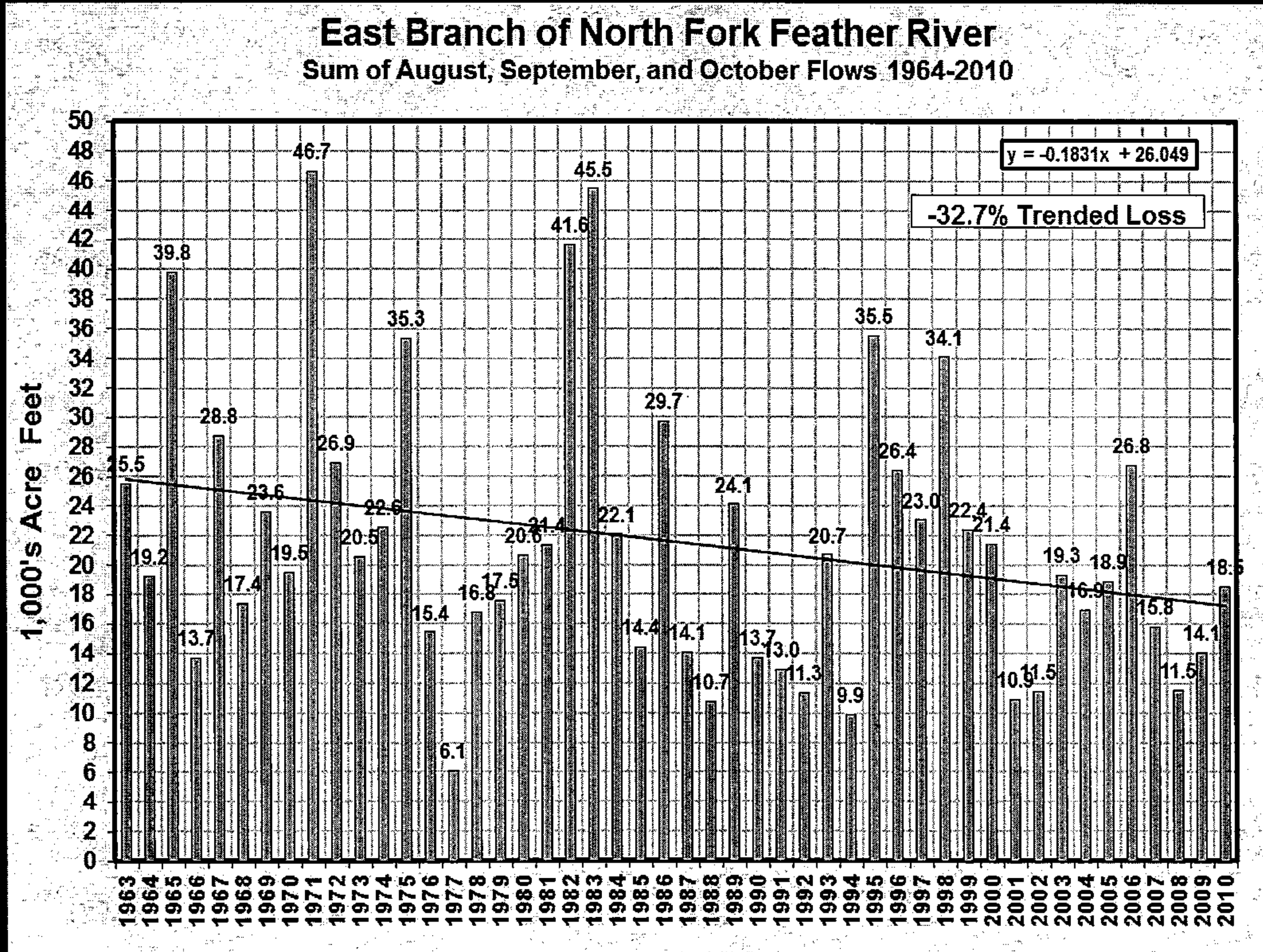


** Aquifer Outflow of Springs calculated from minimum daily flow in Aug & Sept using (1* prev yr & 2*current year)/3

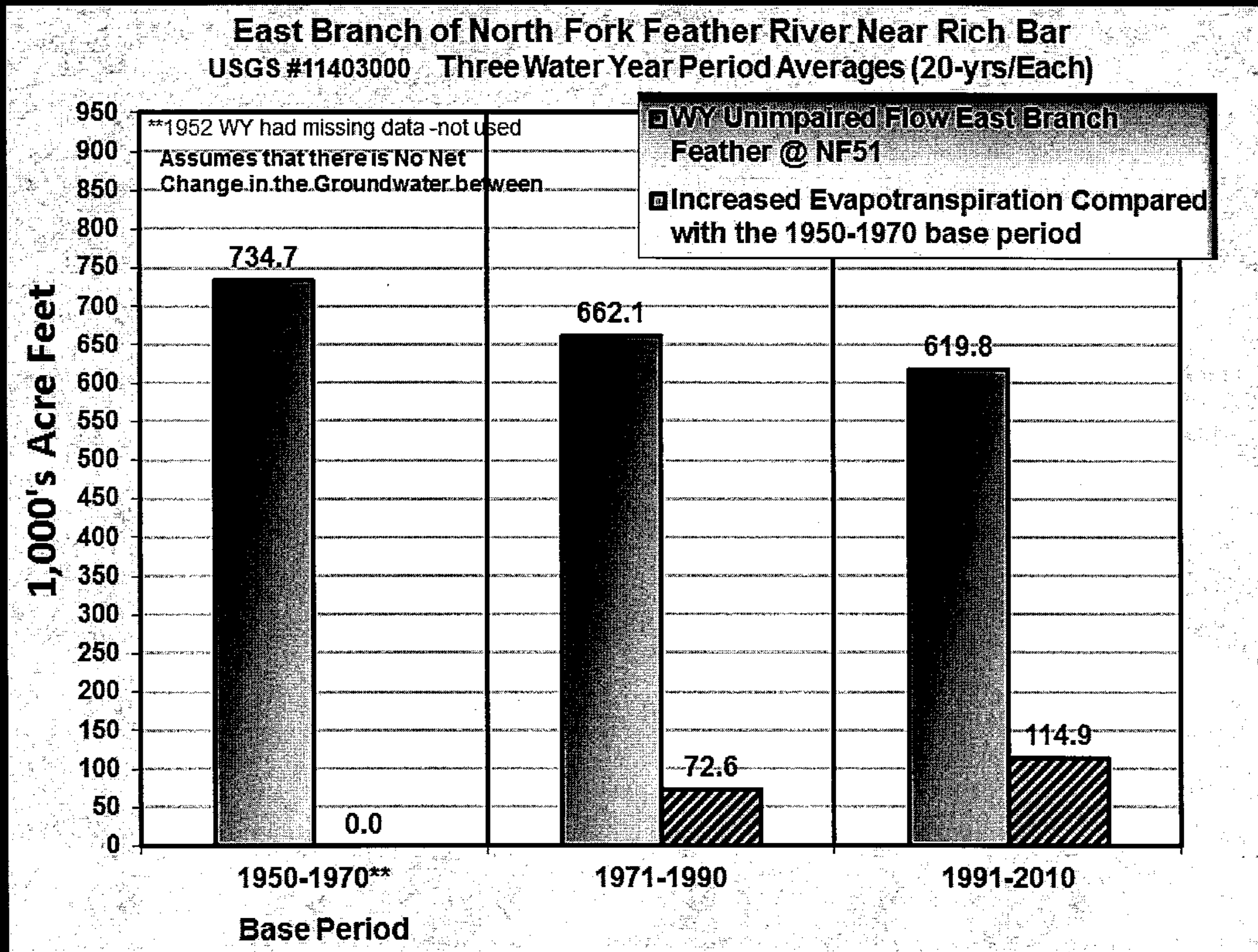
Revealing A Loss of Surface Runoff Starting in the 1970's Due Mostly to Increased Evapotranspiration



Decline in Late Summer and Fall Base Flows for East Branch of the North Fork Feather River



The Successive Decline in Water Year Runoff from The East Branch of the North Fk Feather River along w/Increase in Evapotranspiration



ANALYZING THE IMPACT OF CLIMATE CHANGE ON MONTHLY RIVER FLOWS IN CALIFORNIA'S SIERRA NEVADA AND SOUTHERN CASCADE MOUNTAIN RANGES

Gary J. Freeman[1]

ABSTRACT

The impact of climate change on monthly river flows in California's Sierra Nevada and southern Cascade Mountain Ranges and its potential to impact hydroelectric production was analyzed to determine changes that have taken place in two successive 35-year periods during the past 70 years. Unimpaired monthly flows from both California's Department of Water Resources' (CDWR) Data Exchange Center's (CDEC) files and from Pacific Gas and Electric Company's (PG&E) operational subbasin runoff forecasting files for the Feather River were analyzed for comparison of the two periods. A notable change was the shift of snowmelt runoff from the April through July period into the month of March. March flows were larger for the more recent 35-year period for all of the flow points analyzed in the Sierra and southern Cascades including two subbasins on the upper North Fork Feather River where rain shadowed climate change impact has significantly reduced both snowmelt and water year runoff in the more recent 35-year period. The increase in March runoff appears to be a combination of mostly earlier snowmelt due to warming temperatures and from an increase in proportion of March precipitation that now occurs as rainfall. In northern California both the shift of snowmelt into March and the reduction of snowpack overall has resulted in reduced late spring and summer flows during the months of April through June. Subbasins south of the Yuba River have for the most part increased overall snowmelt runoff for the March 1 through July 31 period, while subbasins from the Yuba River north have remained either equal or declined in snowmelt runoff in recent years. Both increased elevation and orographic cooling seem to be critical for delaying the impacts of climate change on affecting spring and early summer runoff. For a rain-shadowed subbasin such as Lake Almanor, the recent 35-year period shows a 22% decline in the April through July runoff caused primarily from a combination of: 1) earlier snowmelt, 2) increased proportion of precipitation occurring as rainfall in recent years with less snowfall overall, and 3) reduced aquifer outflow from springs. (KEYWORDS: climate change, subbasin, unimpaired flow, orographic, hydroelectric)

INTRODUCTION

The warming climate has changed the timing of spring runoff in the mountainous areas of California. Large watershed unimpaired flows were analyzed and compared throughout the Sierra and southern Cascades for two successive 35-year periods. Utilizing the same two periods for comparison, an analysis was also performed for several subbasins on the Feather River, a large river in northern California. In a comparison of the two periods, the more recent period shows a shift of snowmelt runoff into March. Also a greater percentage of the March precipitation now typically occurs as rainfall in recent years which results in an increase in rainfall-generated runoff during the month of March. This climate related change is supported by the findings of Knowles et al., (2006) and Mote et al., (2005). Shifting the spring freshet to earlier in the year typically results in less runoff being available for summer and fall flows. For PG&E, a large investor owned California gas and electric utility that manages its reservoirs to fill in late spring and early summer to meet its summer and fall hydroelectric needs for peaking power, the combination of a decline in the April 1 snowpack (Freeman, 2010), filling mountain reservoirs from snowmelt earlier in the year, and an increasing dependence on rainfall for filling is anticipated to eventually lead to increased likelihood for spill from PG&E's relatively small mountain reservoirs. The higher elevation subbasins in the southern Sierra are less influenced from climate change with regard to getting precipitation in the form of rainfall in March. However the March average for the 1977-2011 35-year period still shows an increase in runoff for the more recent of the two 35-year periods. This observed increase in March inflow seems to occur universally throughout the Sierra and southern Cascades. The earlier spring snowmelt runoff period may also be negatively impacting aquifer recharge on northern California's porous volcanic watersheds (Freeman, 2008, 2010, and 2011). This loss of recharge opportunity may be revealing itself in the observation that aquifer outflow of springs for the upper North Fork Feather River @ Lake Almanor has steadily declined during the past three decades. A similar effect has been shown for the McKenzie River in Oregon by Jefferson et al., (2008).

Paper presented Western Snow Conference 2012

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Snowmelt results in a slow somewhat steady infiltration downward into the soils, which eventually reaches the water table and helps recharge groundwater. Increased runoff into mountain reservoirs during the January through March period has some potential to reduce the historical snowmelt pulse that typically occurred in April through July on many watersheds. For hydroelectric operators such as PG&E, getting some runoff into reservoirs prior to April 1 provides reservoir operators with an opportunity to run the water through powerhouses rather than wait for the historical April through July runoff from snowmelt. Historically prior to 1977, a larger proportion of the January through March precipitation came as snowfall. Beginning in mid-to-late April in years prior to 1977, the runoff from snowmelt during years of average or greater wetness would take place beginning in early April , quickly filling the relatively small mountain reservoirs, with excess snowmelt runoff often spilling at diversion dams and bypassing powerhouses. The pricing for hydroelectric energy produced in February and March is often fairly good and is always valued higher than zero dollars, which is the consequent value of water spilling past powerhouse diversion dams. However the down side of a declining snowpack is that there is increasing risk from supply uncertainty when relying on an increasing proportion of precipitation occurring as rainfall. Snowpack is frozen water in storage and can be accounted for with reasonably high certainty; however the uncertainty of remaining weather and increasing dependence on future precipitation for filling reservoirs greatly increases operational risk for both spill and for not filling. Faced with the uncertainty of whether or not there will be sufficient precipitation in the spring for filling reservoirs, reservoir operators often find themselves holding onto or storing additional water in attempt to increase assurance for filling the seasonal reservoirs. If in late March, the reservoir operator has mostly full reservoirs, and March turns out to be wetter than normal with most precipitation occurring in the form of rainfall, the reservoirs can quickly fill and spill past the powerhouse's diversion dam with consequent hydroelectric generation loss. The water release planning period is decreased from the historically longer, mostly gradual snowmelt duration of 2-3 months, to a few days. Receiving short notice of a warm storm's arrival in the form of a weather forecast and the consequent filling of a small reservoir of 62 hm^3-148 hm^3 in size (50 TAF-120 TAF) is typically not more than a few days to a week. There is often inadequate time to increase powerhouse flows and utilize the water efficiently for hydroelectric production, especially for large rain producing storms. For PG&E during storm periods, the flumes and canals are typically operated with increased freeboard during storm periods to reduce the likelihood for storm related damage to the facilities such as sometimes occurs from falling trees and debris slides. If a water carrying conduit becomes damaged from storm related incidents, the consequent snowpack and winter mountain conditions may increase the time that it will take to complete a repair. In the meantime the canal downstream of a break or damaged area may not be able to carry water. In the high country, lack of sufficient water in an open conduit may result in the canal or flume filling with snow, or in some cases, the empty structure 'floating' or being buoyed upward due to lack of having sufficient weight for the water being displaced by the structure's base within the soil.

COMPARING TWO EQUAL LENGTH PERIODS OF RUNOFF DATA

In order to detect possible effects of climate change, two successive 35-year periods were selected and their means and standard deviations compared for differences. PG&E maintains unimpaired natural runoff for over 100 locations in the Sierra, southern Cascade, and the Coastal Mountain Ranges of California. Nearly all of these points are computed daily and kept current for the purpose of forecasting runoff and performing water studies in connection with the operation of PG&E's hydroelectric system. The two periods selected for comparison were 1942 through 1976 (35-years) and 1977 through 2011 (35-years). The 1976 and 1977 water years were selected as the dividing point for the two 35-year periods because both years were very dry with 1977 being a second consecutive year of drought and drier than 1976 in terms of both precipitation and surface runoff. Much of the change that has occurred in recent years appears to have begun in the mid-1970's. CDWR likewise computes unimpaired monthly natural flows for most of the major rivers that drain the Sierra and southern Cascades, but typically do so for the entire river to a point at or close to a large multipurpose reservoir near the floor of the Central Valley. These large multipurpose reservoirs are typically referred to as the 'rim' reservoirs as they are situated along the rim of California's Central Valley. While the study was mostly performed at the subbasin level of detail within the upper reaches of the large rivers, for the sake of simplicity many of the table and chart comparisons in this paper compare the monthly runoff for 13 of the large rivers which range from the Klamath River near the Oregon Border to the Kern River near Bakersfield. In many ways this relatively low resolution analysis summarizes the overall findings that were observed at the operational subbasin level of detail. Compared with the other large rivers, a primary difference was observed for the Feather River where rain shadowed operational subbasins lack the orographic cooling condition and the runoff is much more impacted from climate change than for the Feather River as a whole. For the Feather River Basin, some of the subbasins are analyzed for their somewhat unique climate change response. For these few rain shadowed cases, the winter minimum air temperatures have warmed significantly above the surrounding, more orographically influenced subbasins. The rain shadowed subbasins indicate a relatively large water year loss for the more recent of the two 35-year periods. In both cases this surface runoff loss appears to have resulted mostly from increased evapotranspiration.

THE WATER YEAR

Figure 1 indicates an overall linear trend in water year change in runoff for the more recent 35-year period compared with the earlier period that ranges from -10.6 percent for the Klamath River at Orleans near the Oregon border to +17.2% for the Kern River near Bakersfield. This increasing trend needed to be removed to evaluate the monthly flows. For the two time periods analyzed, the rivers show a gain in water year runoff for the more recent period from the American River southward. This increase may in part be related to increased elevation and relatively strong orographic cooling associated with the central and southern Sierra. While there is some tendency

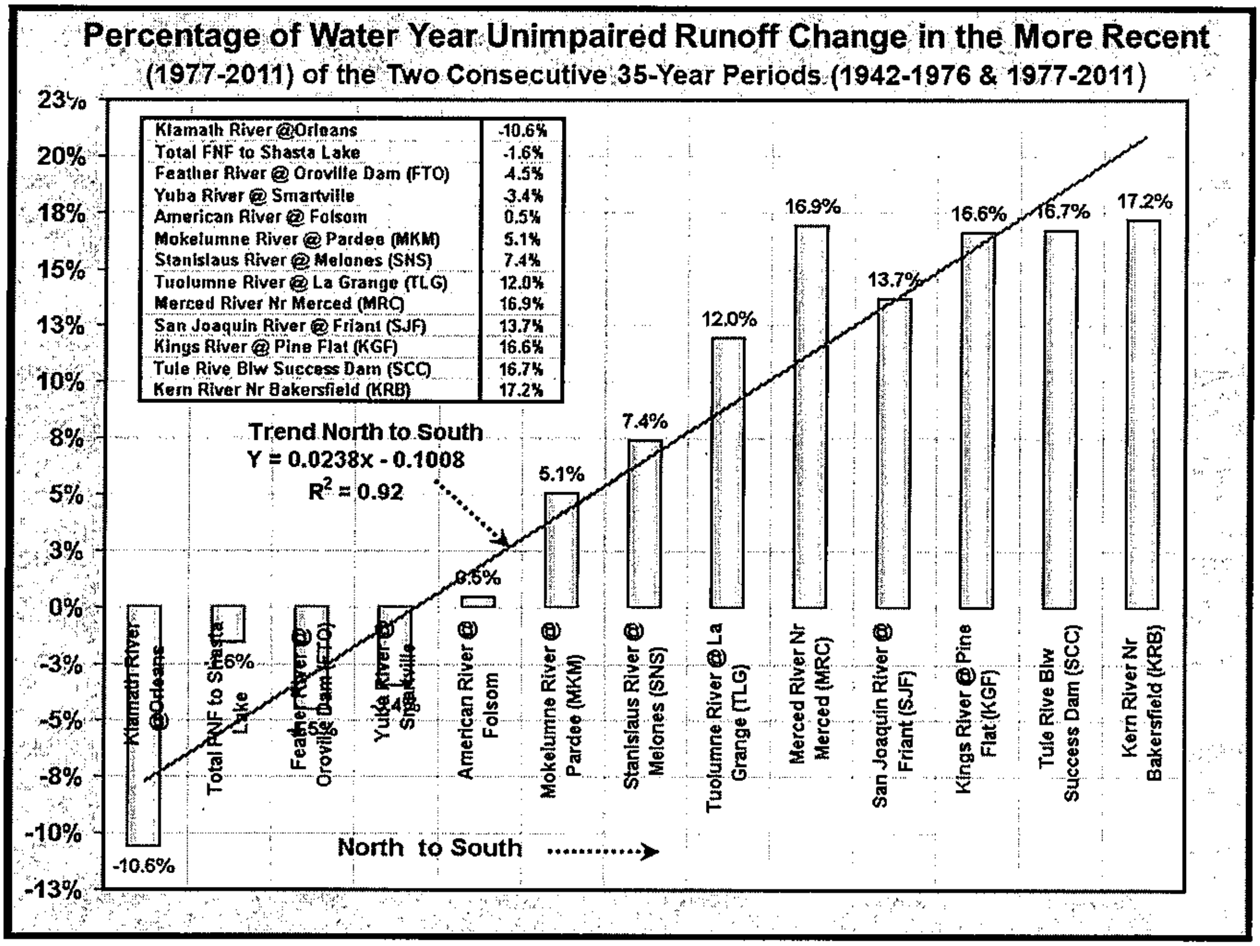

Figure 1. Water year runoff quantities for the American River southward generally increase in the more recent 1977-2011 period compared with the earlier 1942-1976 period.

for precipitation to increase in the north to south direction, the percent increase has a lot of variance. The northern Sierra is much lower in elevation overall, has several rain shadowed subbasins, and as such does not overall have the extent of orographic cooling effect. Orographic cooling is more common for subbasins along the west facing side of the Sierra Nevada, which encounter the eastward frontal flow from storms onto the relatively steep inclined windward slopes. For PG&E with its hydroelectric system distributed over the Sierra Nevada and southern Cascades, the overall impact from climate change has been somewhat of a "no net impact" at least during the past couple decades and this situation will likely continue to be the case for at least the near future. The increased runoff for the southern Sierra watersheds and the benefits of increased hydroelectric generation that results from an earlier snowmelt with increased rainfall overall leads to an earlier filling of the relatively small mountain reservoirs. Rather than waiting for snowmelt, which has historically started in April with high likelihood for spill in years with above average late spring snowmelt runoff, beginning in mid- January stored water is now increasingly released from the reservoirs with decreased risk for spill past the powerhouses. The downside risk for the operator is that with this earlier rainfall-caused inflow, reservoir planners are now becoming increasingly dependent on the uncertainty of remaining weather, often in the form of rainfall for filling reservoirs.

SUB-PERIODS WITHIN THE WATER YEAR

In order to remove the trending change in water year runoff for the 13 rivers analyzed in this study, the average monthly runoff for each of the subbasins and watersheds for the two comparative periods were divided by that period's water year total runoff. Converting the two successive 35-year periods into a monthly percentage of the water year totals produced a relatively trend-free set of monthly ratios to use in comparing the two periods irrespective of differing average water year totals. The watersheds were then compared from north to south along the Sierra and southern Cascades. The PG&E hydroelectric system is primarily divided into operational subbasins based on a combination of both diversion dams and the larger seasonal storage reservoirs. Runoff is forecasted and accounted for at each diversion dam. Some rivers such as the Feather River above Lake Oroville is forecasted with water release planning taking place at PG&E for approximately 20 operational subbasin diversion points. Each of these diversion points have sidewater unimpaired inflows associated with them, which allows for a fairly detailed elevation-based climate analysis that utilizes

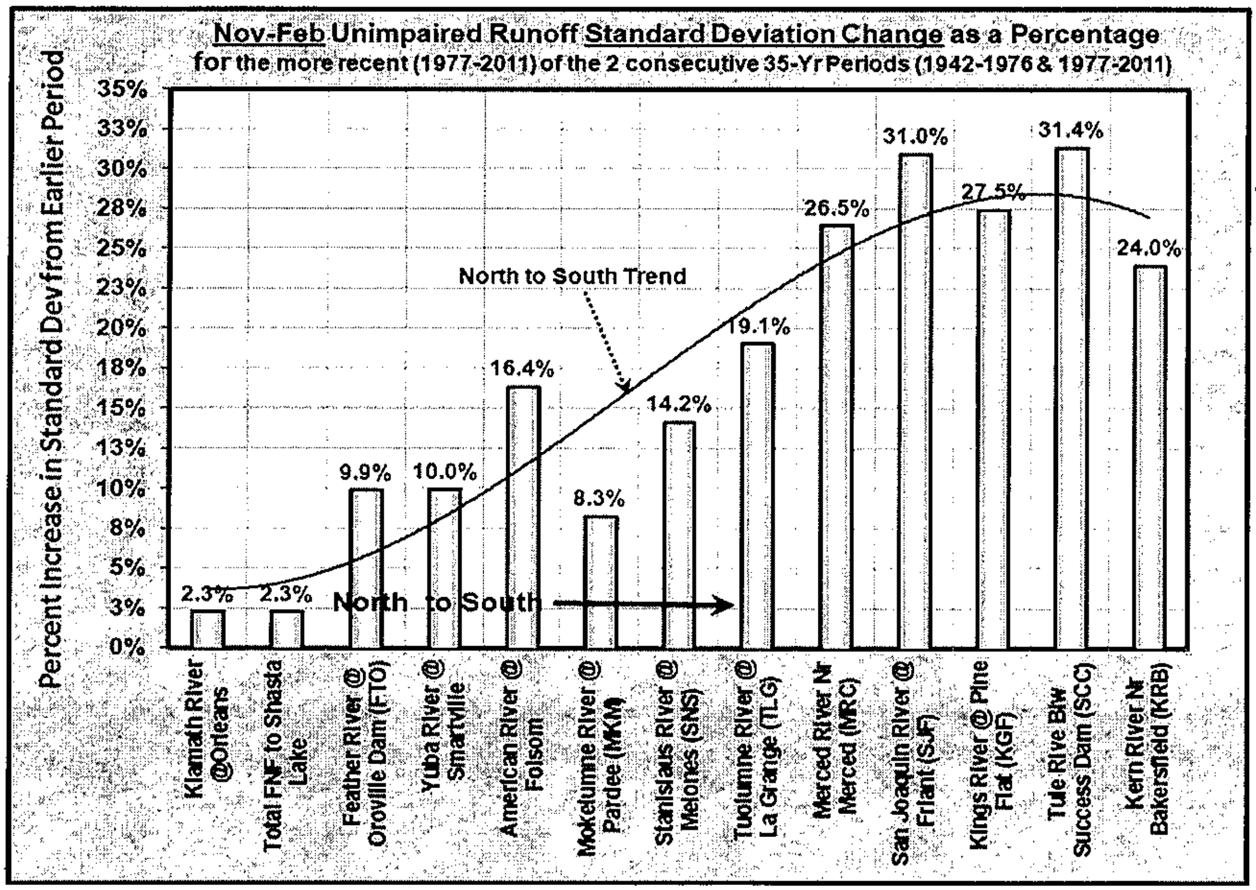

Figure 2. The percentage increase in standard deviation for the November through February runoff in the more recent (1977-2011) of the two 35-year periods.

calculated and daily compiled subbasin and river reach runoffs. An analysis of the Feather River subbasins was done to identify the runoff impact of climate change on orographic and rain shadowed subbasins.

Standard Deviation increase in the More Recent Period

The standard deviation for both the water year and the November through February 4-month sub-period increased in the more recent of the two 35-year periods. For the November through February 4-month sub-period, the trend in general increased from north to south, with somewhat of a leveling off for the Merced River southward. For the water year period, the standard deviation tended to decrease on both sides of the Merced River. It's fairly characteristic for the rivers that flow over the exposed granites, that they have historically had a large variance in flows in which either being very dry or very wet is almost the norm. What is observed is that with climate change the variance and related standard deviation increases in the more recent period with standard deviation increasing as much as much as 31 percent for the November through February period and up to 47 percent for the 12-month October 1 through September 30 water year period. Figure 2 and Figure 3 show the standard deviations for both the November through February and the water year periods for the thirteen major rivers.

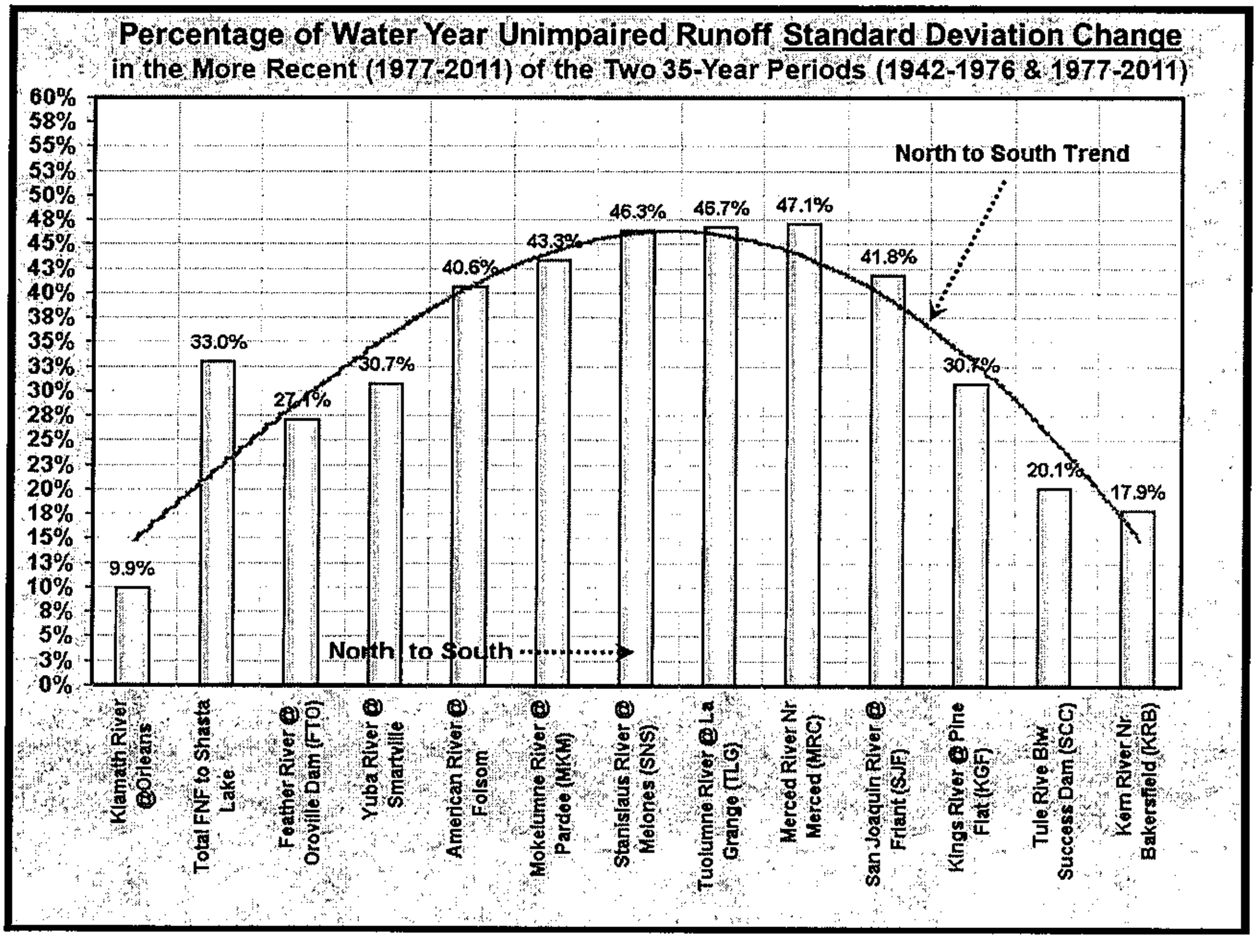

Figure 3. The percentage increase in standard deviation for the water year runoff in the more recent (1977-2011) of the two 35-year periods. The Merced River has the greatest increase in standard deviation.

Shift of the April through July into Earlier Months

Figure 4 illustrates the impact that climate change has on each of several large river basins that range in location from north to south from Northern California's Klamath River south to the Kern River near Bakersfield. A large portion of the April through July runoff has shifted into March and a lesser amount into February. The largest shift into March from the April through July period is 4.4% for the Feather River at Oroville Dam. Both north and south of the Feather River, the trend shifts downward. The Kern River, which is at the far right of the Figure 4 chart shows a slight increase of runoff shift into March. Due to the Kern River's upper basin, which drains distinctly southward behind the initial Sierra Crest, the Kern River as shown in Figure 5 does not have the same basin orographic orientation as the drainages to the north, but instead has a somewhat rain-shadowed configuration. In spite of the position of its downstream reach which empties into the San Joaquin Valley near Bakersfield; its headwater drainage has a somewhat blocked configuration giving it a more northern characteristic equivalent to that of the San Joaquin River in terms of the March ratio.

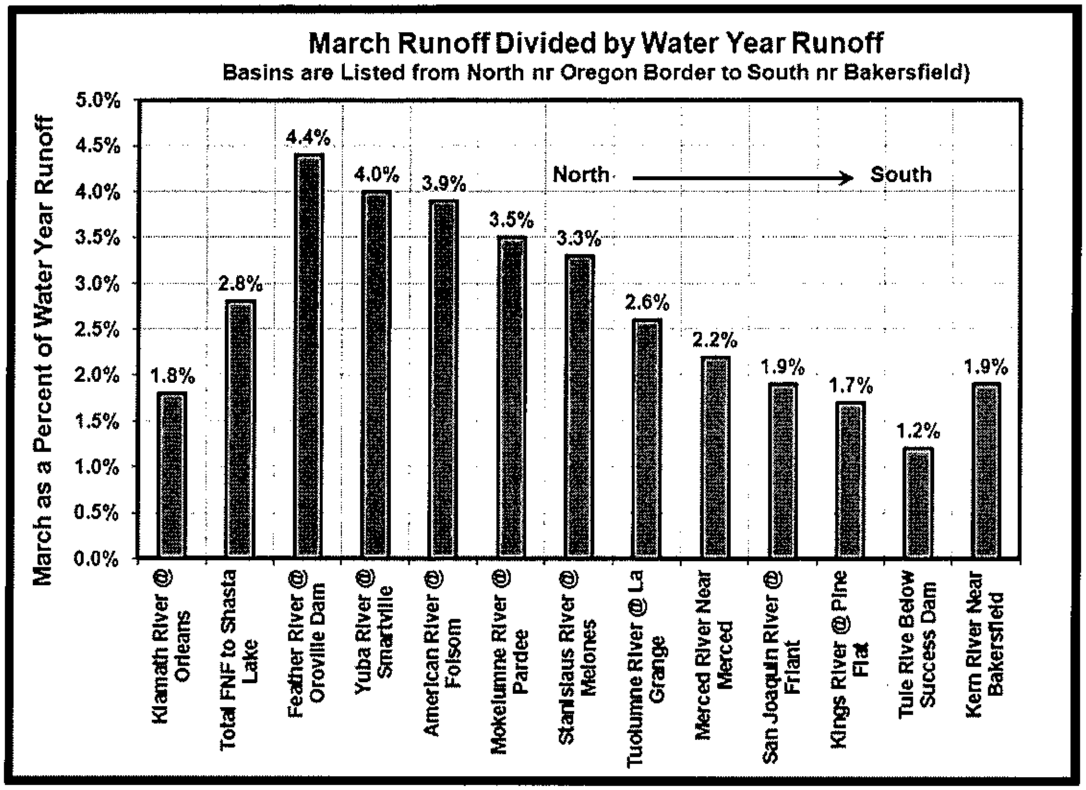

Figure 4. March runoff divided by water year runoff. Left to right order corresponds to north to south orientation.

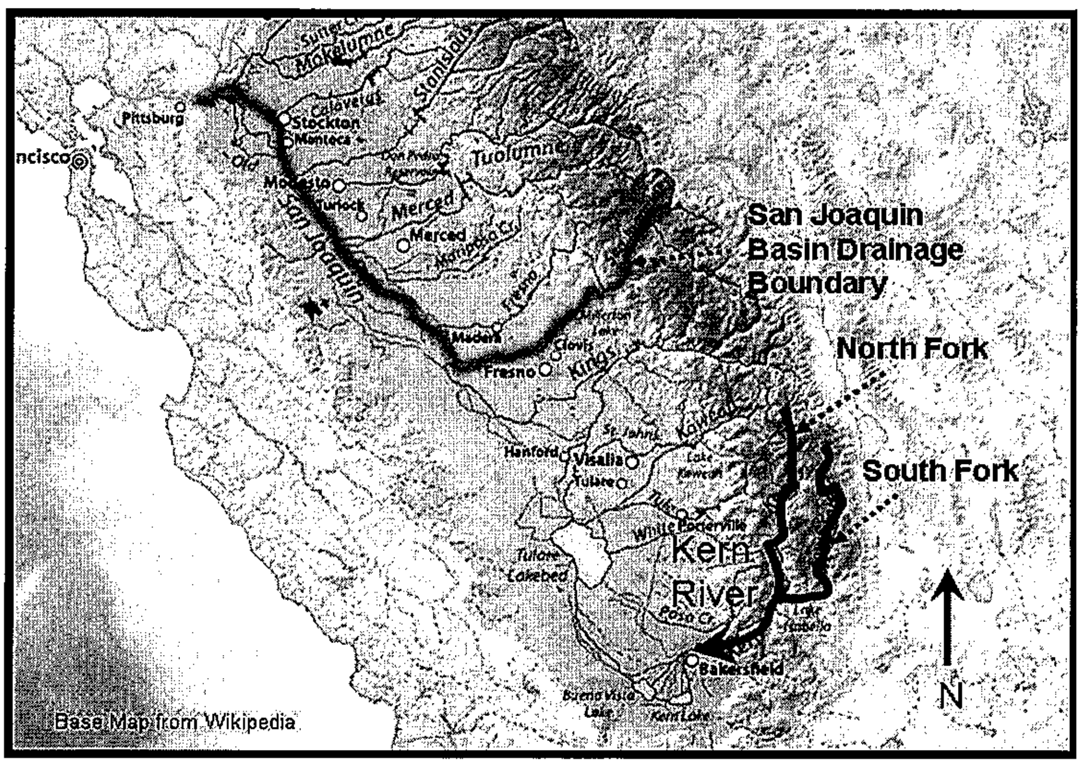

Figure 5. The Kern Headwaters differs from most Sierra Rivers by turning northward along the Sierra's southern block's Kern Canyon Fault behind the blocking influence of the Sierra Nevada's Great Western Divide sub range.

In terms of analyzing the effects of climate change on runoff, orographic effect seems to have major implications on how runoff in the Sierra and southern Cascades is impacted. Both the Klamath River and the combined Sacramento, McCloud, and Pit Rivers @ Shasta appear to likely have greater orographic cooling overall compared with the Feather River. Elevation overall appears to provide a benefit against the effects of climate change providing that the elevation has the windward benefits from steep upward cooling. In the case of the Kern River those windward benefits appear to have been slightly dampened by the Kern Basin's shape as it cuts behind and becomes somewhat blocked by a portion of the Sierra crest. The Kern River is the only major Sierra River to flow north to south. It runs nearly a straight line down the 87-mile long Kern Canyon Fault from the highest Sierra peaks including Mt. Whitney and south in two main forks that have carved dramatic canyons along their paths bordered to the west by the Great Western Divide, one of the largest and highest mountain sub ranges in the Sierra Nevada Mountains. The Kern River, the result of the Kern Fault is located on the southern block, which 60-20 million years ago emptied into the Colorado River to the East, but during the past 20 million years has shifted its outlet westward into the San Joaquin Basin, and within the past 12 million years shifted its outlet toward the city of Bakersfield (Hill, 2006; Nadin, 2007). Because of it not being a part the main Sierra block that tilted toward the west, the effect of orographic cooling from winter storm activity is likely slightly less than for much the more exposed west-facing, windward slopes of the Kings and Tule Rivers just north of Bakersfield. Freeman (2011) discusses the importance that subbasin and basin orientation has in minimizing and buffering the impacts from climate change.

MONTHLY CHANGES

Table 1 lists as a percent the monthly runoff divided by the water year runoff ratios for the more recent 35-year period for the 13 rivers studied. Table 2 lists the actual average monthly flows for October through September for the same 13 rivers. Unimpaired runoff data utilized for both Tables 1 and 2 was taken from the California Department of Water Resource's Data Exchange Center (CDEC). Creating monthly ratios such as was done for Table 1 helped remove the effect of some watersheds having had an increasing 35-year water year average and others a decreasing water year average for the more recent period. In addition to March having increased runoff in every basin and subbasin analyzed, February likewise gained runoff for several subbasins. A few cases showed a small January increase. Somewhat surprisingly October through December showed a general decrease in runoff percent of the water year for the more recent period. It was almost as if the months of February and March increased at the cost of the October through December period' increase and in some cases the fall runoff as well. Figure 6 shows the two 35-year periods with a monthly comparison of the month/water year flow ratios as percentages of the water year for the North Fork of the Feather River at Poe Diversion Dam. When the actual monthly flows were reviewed, the second 35-year period has a much changed water balance with significantly more water entering into evapotranspiration rather than surface runoff. The mean surface runoff for the 1977-2011 water

Table 1. Monthly water year ratios* for the two successive 35-year periods: 1942-1976 and 1977-2011. Thirteen large rivers are listed.

*Monthly Percentages = Monthly Runoff/Water Year Runoff					General Increase		General Decrease					
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Klamath River @Orleans	-0.3%	-0.7%	-0.2%	-1.4%	0.9%	1.8%	0.0%	0.3%	0.1%	0.3%	0.1%	-0.1%
Total FNF to Shasta Lake	-0.5%	-1.0%	-1.1%	-0.4%	1.0%	2.8%	1.2%	0.4%	0.2%	0.0%	-0.1%	0.0%
Feather River @ Oroville Dam (FTO)	-0.5%	-0.2%	-0.8%	-0.4%	1.5%	4.4%	1.4%	1.5%	0.6%	-0.2%	-0.2%	0.1%
Yuba River @ Smartville	-0.5%	-0.7%	-1.1%	-0.6%	1.6%	4.0%	0.4%	1.2%	0.9%	0.2%	-0.2%	-0.1%
American River @ Folsom	-0.2%	-0.7%	-1.2%	-0.4%	2.3%	3.9%	0.6%	1.9%	1.1%	0.0%	-0.1%	0.0%
Mokelumne River @ Pardee (MKM)	0.1%	-0.9%	-1.8%	0.7%	1.5%	3.5%	0.3%	2.6%	1.4%	1.1%	0.1%	0.2%
Stanislaus River @ Melones (SNS)	0.3%	-0.5%	-1.5%	1.4%	2.5%	3.3%	0.7%	3.5%	1.7%	0.2%	0.0%	0.2%
Tuolumne River @ La Grange (TLG)	0.3%	-0.8%	-1.7%	0.9%	1.1%	2.6%	0.5%	2.3%	1.6%	1.0%	0.6%	0.4%
Merced River Nr Merced (MRC)	0.3%	-0.9%	-2.0%	1.4%	1.5%	2.2%	0.5%	3.1%	1.3%	1.5%	0.6%	0.4%
San Joaquin River @ Friant (SJF)	0.2%	-0.4%	-1.2%	0.8%	0.7%	1.9%	0.2%	2.2%	1.1%	1.0%	0.3%	0.3%
Kings River @ Pine Flat (KGF)	0.3%	-0.2%	-1.1%	0.6%	0.7%	1.7%	0.0%	2.6%	1.2%	0.9%	0.3%	0.5%
Tule Rive Blw Success Dam (SCC)	0.3%	-0.4%	-2.6%	0.2%	2.1%	1.2%	1.3%	2.2%	0.9%	1.0%	0.5%	0.3%
Kern River Nr Bakersfield (KRB)	-0.1%	-0.3%	-1.5%	-0.1%	0.8%	1.9%	0.1%	0.9%	0.5%	0.3%	0.1%	0.1%

Table 2. Actual runoff listed for each of the 13 river basins. In general basins and their subbasin components for the American River southward showed an increase in their water year averages for the more recent 35-year period.

RIVER	All Water Values are in Cubic Hectometers (1 hm3 = 810.71 Acre Feet)												
Klamath River @Orleans (KLO)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY
1942-1976 (35-Yrs)	118.7	342.9	746.6	1,034.9	859.3	843.5	810.4	781.7	450.4	159.8	88.5	71.3	6,308.0
1977-2011 (35 Yrs)	91.4	264.6	658.7	845.9	818.9	853.4	722.9	682.4	399.1	160.1	82.7	60.0	5,640.1
													-10.6%
Total FNF to Shasta Lake (SHA)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1942-1976 (35-Yrs)	337.7	464.7	769.5	1,004.3	1,004.4	992.7	915.1	674.5	429.3	309.4	277.9	270.3	7,449.8
1977-2011 (35 Yrs)	293.3	383.1	673.5	960.5	1,060.2	1,181.4	812.5	692.8	438.8	306.3	266.9	264.3	7,333.4
													-1.6%
Feather River @ Oroville Dam (FTO)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1942-1976 (35-Yrs)	156.3	256.7	533.7	706.0	670.5	740.4	906.8	856.1	453.9	208.8	136.8	111.9	5,747.8
1977-2011 (35 Yrs)	120.8	233.4	467.4	649.6	722.1	945.6	789.6	743.4	397.7	187.0	120.6	110.5	5,487.8
													-4.5%
Yuba River @ Smartville (YRS)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1942-1976 (35-Yrs)	51.1	128.9	294.1	377.3	344.0	362.7	455.6	538.5	283.1	74.1	34.3	26.1	2,969.7
1977-2011 (35 Yrs)	35.7	104.6	251.7	347.7	378.1	465.6	427.5	484.4	247.4	76.2	26.3	22.4	2,867.7
													-3.4%
American River @ Folsom (FOL)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1942-1976 (35-Yrs)	38.2	126.8	300.0	417.4	361.2	423.9	551.1	655.4	358.2	90.9	24.4	14.7	3,362.4
1977-2011 (35 Yrs)	30.9	104.7	262.3	404.8	439.4	557.0	535.0	592.9	323.3	91.1	20.2	16.0	3,377.8
													0.5%
Mokelumne River @ Pardee (MKM)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1942-1976 (35-Yrs)	7.4	29.1	58.9	68.7	67.6	87.1	152.7	245.5	154.3	31.2	6.4	3.2	912.0
1977-2011 (35 Yrs)	8.6	22.3	44.3	78.6	86.1	124.8	157.7	232.7	148.6	43.4	7.4	4.8	958.3
													5.1%
Stanislaus River @ Melones (SNS)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1942-1976 (35-Yrs)	11.3	40.3	83.4	102.3	98.0	137.4	236.6	364.7	228.3	67.0	15.7	6.8	1,391.8
1977-2011 (35 Yrs)	16.0	35.3	66.7	130.1	142.4	197.6	244.1	339.4	219.3	75.7	17.5	10.8	1,494.7
													7.4%
Tuolumne River @ La Grange (TLG)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1942-1976 (35-Yrs)	18.3	71.3	136.1	153.4	154.0	200.8	327.3	556.2	441.6	143.5	26.9	10.9	2,240.4
1977-2011 (35 Yrs)	29.2	59.4	108.6	194.3	200.2	290.7	353.4	564.9	453.3	186.9	46.1	22.8	2,508.8
													12.0%
Merced River Nr Merced (MRC)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1942-1976 (35-Yrs)	7.8	30.1	65.8	77.6	82.1	107.2	171.7	297.9	209.8	61.1	13.0	5.2	1,129.1
1977-2011 (36 Yrs)	12.7	23.7	50.4	109.3	116.1	164.6	194.0	306.7	228.2	90.9	22.7	10.9	1,320.1
													16.9%
San Joaquin River @ Friant (SJF)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1942-1976 (35-Yrs)	22.2	46.6	88.9	100.3	110.6	152.8	279.9	533.7	459.8	197.7	61.5	27.3	2,081.4
1977-2011 (35 Yrs)	31.2	43.6	71.5	133.4	143.1	217.7	313.8	555.4	496.6	247.4	75.9	37.1	2,366.6
													13.7%
Kings River @ Pine Flat (KGF)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1942-1976 (35-Yrs)	21.1	39.6	75.4	83.1	86.1	121.2	248.6	529.7	455.4	186.5	55.7	23.7	1,926.2
1977-2011 (35 Yrs)	31.5	40.8	62.9	111.4	116.8	180.0	289.0	568.5	505.1	238.5	72.0	39.9	2,246.3
													16.6%
Tule Rive Blw Success Dam (SCC)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1942-1976 (35-Yrs)	1.5	5.9	14.8	19.4	19.1	28.1	28.9	27.1	12.6	3.8	1.4	0.9	163.5
1977-2011 (35 Yrs)	2.3	6.0	12.3	23.0	26.3	36.0	31.3	27.5	16.5	6.4	2.6	1.7	190.9
													16.7%
Kern River Nr Bakersfield (KRB)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
1942-1976 (35-Yrs)	20.4	26.1	44.1	46.9	47.0	67.0	111.1	183.6	168.6	81.1	36.5	21.2	843.7
1977-2011 (35 Yrs)	22.9	27.7	36.9	54.2	63.4	97.5	131.2	206.2	180.5	98.4	43.9	26.0	988.7
													17.2%

year period is 215.6 hm^3 (174.8 TAF) or approximately 7.5 percent less than the earlier period. The April through December months all declined while the February and March runoff increased. For the American River south as seen in Figure 1, water year flows increase in the more recent period and decrease for watersheds north of the American River. Freeman (2011) hypothesizes that this increase for the major River Basins that include the American River southward may be attributable to an increase of available moisture in frontal systems for the most recent 35-year period. The orientation and elevation of the Sierra south of the Yuba River may provide sufficient orographic cooling to capture the additional moisture as precipitation, which in turn appears to be resulting in increased surface runoff for the Sierra's central and southern Sierra watersheds south of the Yuba River, which is the case at least for the two periods analyzed.

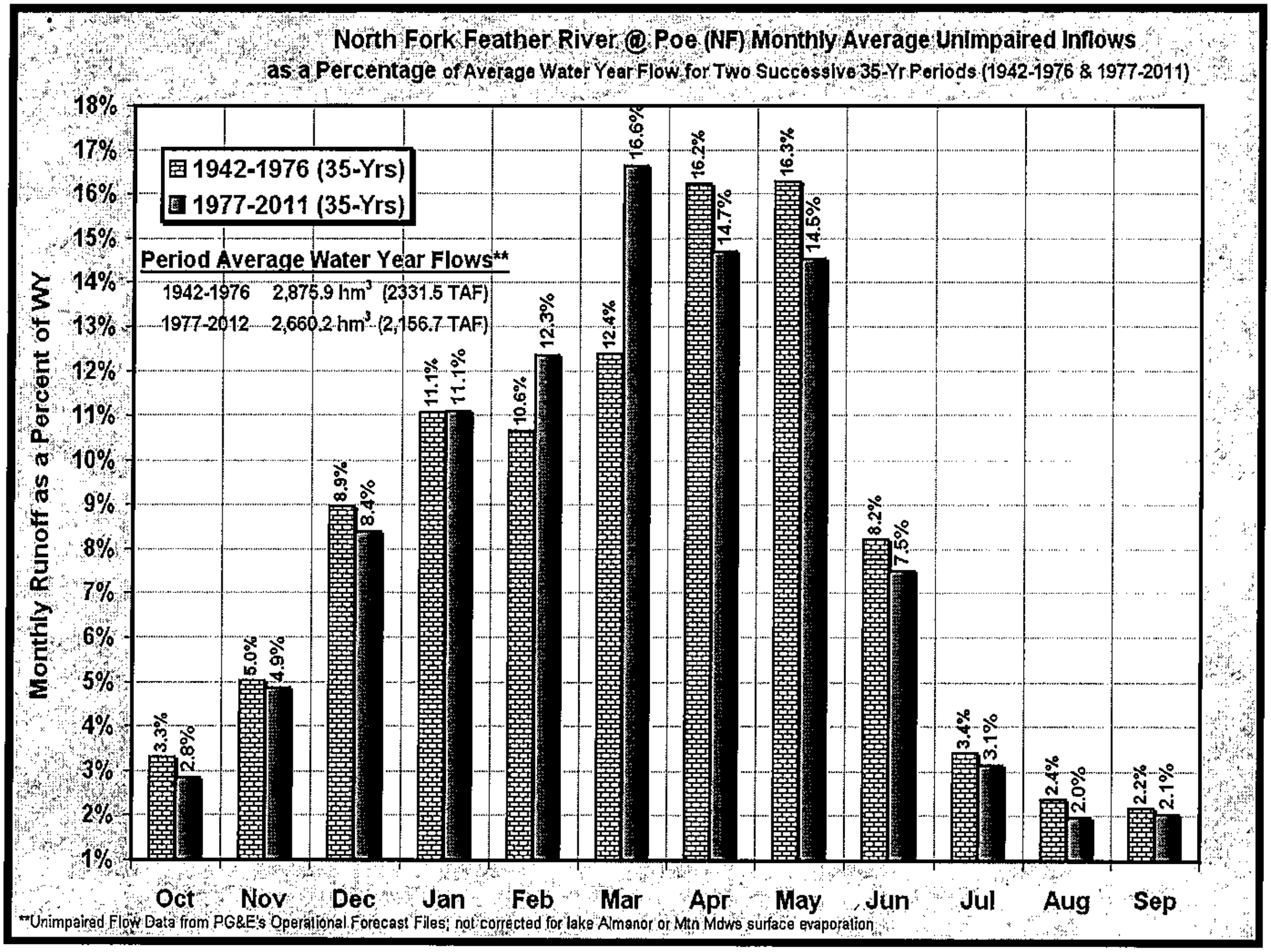

Figure 6. A comparison of the monthly/water year runoff ratios for the two consecutive 35-year periods for the North Fork of the Feather River @ Poe Diversion Dam.

In order to accurately forecast runoff for hydroelectric scheduling, PG&E utilizes a two pass regression approach in a system named PRM (Precip Recovery Method) developed at PG&E. The first pass contains a relatively long historical period of approximately 25-35 years to determine whether or not the forecast is for an average, wet, or dry period. Once the program has chosen the basic wetness type, the forecasting tool then performs a second pass regression on a much more limited set of years to improve its fit with the independent variables such as snow water equivalent, precipitation, and aquifer outflow of springs. In the face of changing seasonal runoff with climate change, PG&E's runoff forecasts handle the growing issue of runoff time series loss of stationarity, by utilizing relatively recent water years only with attention to the runoff changes such as shown in Table 2 for the larger river. Runoff for the April through July period has decreased for those watersheds north of the American River, and that decrease in spring runoff is anticipated to continue well into the mid-21st century as the climate continues to warm. Hydrologists can forecast the spring runoff with that fact in mind, which helps bias operating decisions toward less spring runoff than is being indicated by the long term historical data set. Likewise for the southern Sierra watersheds, a slight bias is given to expecting an increase in April through July and water year runoff. In all cases larger March runoff is anticipated than has historically occurred prior to 1977. In order to effectively deal with the changes being observed, PG&E is currently calibrating subbasins on the Feather River with the PRMS model (USGS Precipitation Runoff Modeling System), working in partnership with both the California Department of Water Resources and the US Geological Survey. PRMS, a distributed conceptual modeling tool that utilizes hydrological response units as described by Koczot et al., (2005) will help assist PG&E's forecasting hydrologists with an alternative physically based model that can more effectively handle temperature, evapotranspiration, soil moisture, and groundwater than the seasonal regression model by itself.

POTENTIAL IMPACT ON PG&E'S HYDROELECTRIC PRODUCTION

If the current trends in monthly and water year runoff continue, hydroelectric generation for PG&E's conventional hydroelectric system is anticipated to show little if any decline overall up through about 2025. Beyond 2025 the system overall may then likely begin a gradual net decline in hydropower production as the benefits of an earlier runoff into the mountain reservoirs likely begins to be outweighed by a number of other risk factors. Historically, the typical spring runoff quantity from snowmelt resulted in frequent spring spills as the runoff quantity exceeded both the available usable capacity of the seasonal reservoirs and the capacity of releasing snowmelt inflow through powerhouses. May and June spill at many of the mountain reservoirs occurred with a frequency of 1 in 2 to 1 in 3 years for many of PG&E's 98 reservoirs. Some of the smaller seasonal reservoirs spill every year even during very dry years. As the April through July snowmelt increasingly shifts into March and February as a result of both an increased frequency of earlier snowmelt and the change in physical form from snowfall to rainfall, the opportunity to move the inflow earlier has increased hydroelectric generation for some rivers especially for the Yuba River southward. The value for energy in February and March is typically less than for summer and fall, however it is still better than waiting for the snowmelt to start April 1 or later and then end up spilling much of the inflow from snowmelt in late May and early June after both the reservoir and powerhouse capacities have been exceeded. The energy value for water bypassing the powerhouses is often zero depending whether or not there are some downstream powerhouses that have sufficient capacity to utilize the water which is spilled past upstream lower capacity powerhouses. The overall benefit from earlier runoff in a large diverse system such as PG&E's is currently being balanced by hydroelectric losses such as are taking place on the Feather River that when balanced together appear to have at this time little or no net gains or losses in conventional hydroelectric generation. This net zero overall impact for the PG&E hydro system may possibly continue for another 12-15 years.

Balancing Energy Gains with Energy Losses Including Increased Risk for Spill

Figure 7 conceptually illustrates the impact that climate change is currently having on PG&E's hydroelectric production including increased risk for maintaining current levels of hydroelectric production being anticipated beyond 2025. Because PG&E's hydroelectric system has both Company and Partnership Projects that extend from the McCloud and Pit Rivers in northern California to the high elevation Kern River in the southern Sierra on approximately 16 major rivers in the Sierra, southern Cascade, and Coastal Mountain ranges, the operational subbasin response to current and anticipated climate change is highly diverse. In addition to subbasin diversity, historically approximately 38% of PG&E conventional hydroelectric generation comes from large springs in northern California (Freeman, 2007). This source of water is multidecadal in terms of quantitative water year supply and not necessarily dependent on a given year's precipitation, but instead depends on relatively long lag times that involve both long term increases and decreases in aquifer storage and the accumulated effect of the past 3-5 years of accumulated wetness including recharge opportunity. Some of the current identified losses include the impact of climate change for the upper North Fork Feather River rain shadowed subbasins where the water balance has increasingly resulted in increased evapotranspiration and declining outflows of the springs. For the North Fork Feather River, the runoff losses average about 308 hm^3 (250 TAF)/year. As the effects of warming continues and the snowpack continues to decline and that decline moves increasingly southward along the Sierra in extent, increasing planning uncertainty begins to increasingly take its toll on energy production. As the frozen snowpack continues to decline in an increasing number of years, the relatively small mountain reservoirs must be held higher and higher in the December through February period to help assure filling and to maximize their storage capacity for meeting summer recreation expectations and for meeting summer and fall hydroelectric peaking needs. The probabilistic opportunity cost for keeping reservoirs low beyond about mid-January is the rising uncertainty of depending increasingly on remaining weather for filling the reservoirs and less on the much easier forecast frozen snowpack for filling (Freeman, 2003). The inevitability of increasing spill in February and March comes with reduced assurance for 'filling reservoirs'. Historically the mountain reservoirs were reduced to minimum operating levels on or about Dec 31 and reservoir planners then relied on the building snowpack to fill and in many cases spill. But the historical balance had higher probability for spill than for not filling. With a declining snowpack, planners will have to begin holding additional water in storage in the reservoirs beyond mid-January or at least until a sufficient snowpack develops to help cope with the increased risk of increasingly having to rely on future weather rather than having both a snowpack and the expectation of remaining weather.

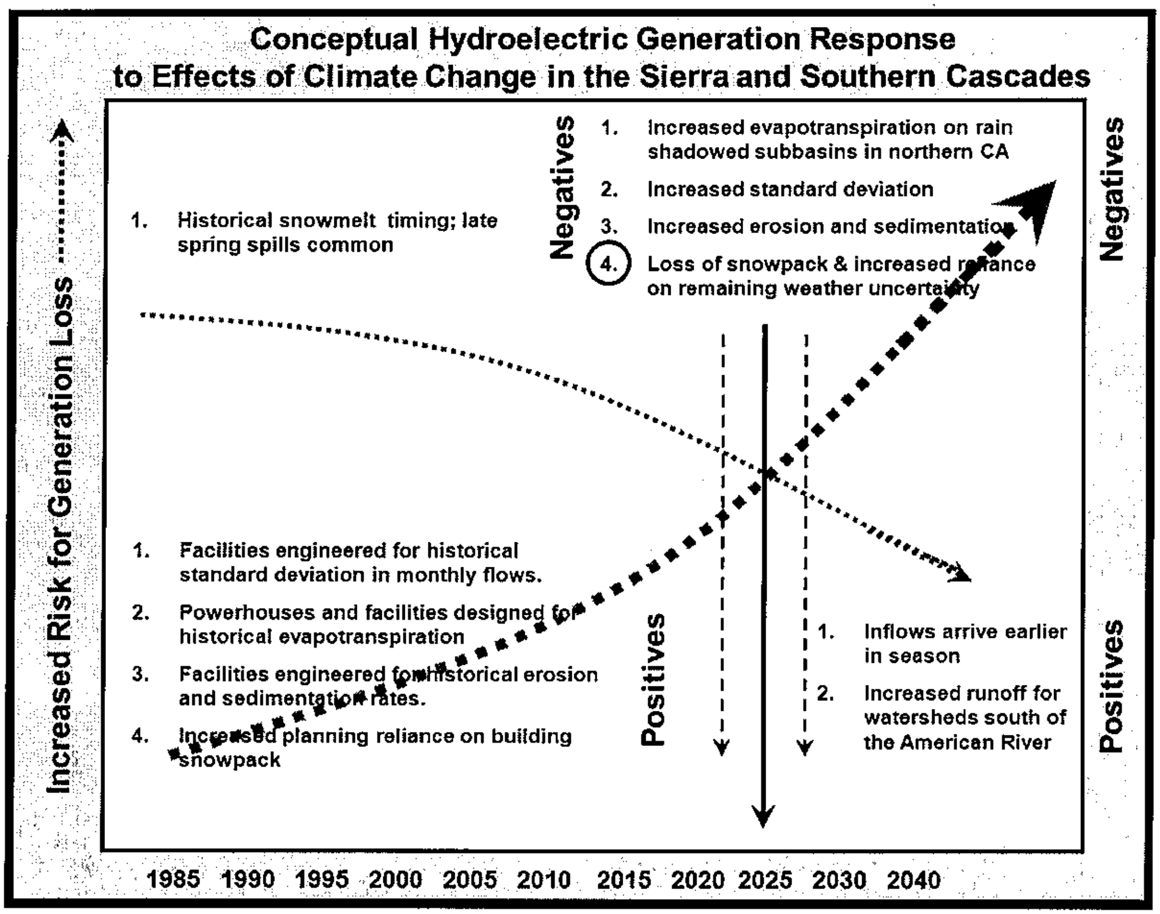

Figure 7. A likely generation response for mountain hydroelectric generation based on the two 35-year period analyzed.

CONCLUSIONS

When a number of large California rivers are compared for two successive 35-year periods, 1942-1976 and 1977-2011, it is apparent that changes indicative of climate change have occurred. In addition to an increasing standard deviation and overall variance in their water year and winter flows, there are trends that indicate a shift in spring flows into earlier months of the year, namely March and February. When grouped into two consecutive 35-year periods beginning in 1942, water year flows from the American River southward have increased since the mid-1970's. There are indications from earlier studies (Freeman, 2011) that warmer air may be capable of holding additional moisture, which when sufficiently cooled as it ascends the windward west facing side of the Sierra may be providing additional opportunity for precipitation increase, much of it in the form of snowfall. It should be noted that from the Yuba River north, the Sierra is lower elevation and less steep. Compared with the Sierra to its south, the Feather River on the northern end of the Sierra is more representative of the older ancestral Sierra. The Feather has maintained its more ancient cut though the Sierra crest eastward well into the Basin and Range Province near Honey Lake. The decline in April through July flow, with consequent increase in March and even February is likely the result of both an earlier snowmelt and an increase in the amount of precipitation which now occurs as rainfall during those two months. Freeman, (2010) showed that on the Feather River in rain shadowed subbasins, minimum winter temperature during storms have increased approximately 6-9 degrees Fahrenheit since 1976. For PG&E with its mountain hydroelectric system in the Sierra, southern Cascade, and Coastal Mountain ranges, its hydro system is sufficiently diverse across different topographic relief and geology that when comparing the two successive 35-year periods, PG&E is currently not seeing any overall change in its system's hydroelectric production that can be directly attributed to climate change. Water year losses in runoff that are occurring from rain shadowed subbasins in northern California, are currently being balanced by earlier inflows to the reservoirs along with an increase in water year runoff from the American River southward in the Sierra. The current "no net change" is anticipated to change in the near future with assumed continued warming. For the relatively small operational subbasin drainages above mountain reservoirs or between diversion dams, orographic cooling of winter and spring storm systems appear to have sufficient cooling effect to slow and somewhat buffer the warming impacts that are otherwise currently being observed on the northern Sierra rain shadowed subbasins such as Lake Almanor and East Branch of the North Fork Feather River.

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THE 2014 CALIFORNIA DROUGHT – DEALING WITH EXTREME DRYNESS FROM A HYDROELECTRIC PLANNING PERSPECTIVE

Gary J. Freeman[1]

ABSTRACT

The 2013 calendar year was the driest year on record for California. For San Francisco based Pacific Gas and Electric Company (PG&E), which operates the largest investor owned hydroelectric system in the United States, the water management planning challenges, which were encountered during the first three months of 2014 and the twelve unusually dry months preceding 2014 were unlike those of earlier droughts. The acceptance of both the concept of climate change impacts as well as new paleo-climatological research findings about California and the southwest were for the first time being given serious consideration in the Company's water release planning. The prospect that the persistent high pressure region blocking the storm track into California from the Eastern Pacific and Gulf of Alaska could possibly remain "parked in place" became a principal scenario needed for effective planning. In terms of snow water equivalent (SWE), the February 2014 statewide snow surveys were less than 15% of the historical February 1 average. The demands on downstream water release requirements for maintaining biological flows, whitewater rafting, and other recreational opportunities have continued to increase in the past 38-39 years from the 1976-1977 drought, which were two successive very severe dry years. Conditions leading into the 2014 drought included 15-years of generally declining wetness over much of California causing the northern California's porous volcanic aquifer storage to decline significantly from the aquifer's relatively high mid-1990's storage state. Also water year runoff from rain-shadowed areas of the northern California's Sierra and southern Cascades have been in a state of trending decline since the 1976-1977 drought, a condition likely attributable to impacts from climate change. Utilizing the latest research findings available in 2014 on climate change and drought, the approach to reservoir and power production planning at PG&E changed from that utilized with prior droughts. Rather than assuming median likelihood or some low level of exceedances probability for remaining seasonal precipitation, the planning would take place as if the high pressure system pattern would continue to persist with no additional runoff expected. (Key words: drought, climate change, reservoirs, Sierra, hydroelectric).

INTRODUCTION

On January 17, 2014, following California's twelve driest months on record, the governor of California Edmund G. Brown Jr. declared a statewide drought. This declaration would start the needed processes for drought planning and providing federal aid to impacted businesses, communities, and other affected entities. For Pacific Gas and Electric Company based in San Francisco with the largest investor owned hydroelectric system in the United States, water management operational planning for its mountain reservoirs would require giving consideration to two relatively new concepts, not given serious consideration during earlier 20th century droughts. The first concept that needed planning consideration was some of the new paleoclimatological findings that indicated droughts which had occurred in California prior to the start of climate records in the mid-19th century were both more severe and longer lasting than droughts that occurred during the existing record. The second concept for consideration was to consider that ongoing climate change may have begun to impact the severity and persistence of earlier prerecorded droughts. For effective hydroelectric planning, with a long history of relying on historical time series of unimpaired flows, precipitation, and snowpack data, the concepts of climate change and new climate data becoming available about droughts that occurred prior to the record period would change the water management approach to water release planning. California is located in an area that uniquely defines the Mediterranean climate, having a long dry summer and wet winter and early spring period. The summer dryness is dependent on an area of high pressure

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shifting northward just west of the California coast deflecting the storm track northward. In the winter with the return of arctic ice and cooling, the blocking high pressure ridge shifts southward and storms can once again enter California from the eastern Pacific. For California, atmospheric rivers (AR's), which typically are relatively warm and semitropical in origin, and therefore have relatively high moisture content and are typically are a major contributor to winter precipitation. The majority of precipitation for California typically comes from 5-6 of these large AR's. On occasion a very large, relatively long duration AR event takes place, an event which has historically been called the 'Pineapple Express'. Some of the notable Pineapple Expresses occurred in February and March 1986, and in the winter of 1998, a year with a strong El Nino. PG&E's reservoir operational planning team gave strong consideration that the high pressure ridge was revealing a strong persistent pattern of "parking", resistant to moving, and consequently not allowing the storm track to enter into California. Beginning in early January, the lack of snowpack and increasing awareness of the persistent high pressure blocking prompted reservoir operators to quickly reduce water releases from most mountain reservoirs. In addition to reducing water releases for hydroelectric production, variances were quickly requested to reduce instream flow releases for biological, recreational, and downstream water use. The process of getting a variance in downstream water releases requires a lengthy review, therefore in order to be effective the variance request process needed to be initiated quickly. Some early February AR's entered into California as the Pacific High shifted slightly southward, however, much of the storm track continued to remain to the far northern part of California and Oregon. By mid-February, the lack of precipitation led to a very shallow snowpack covering the higher elevations in the Sierra and southern Cascades. As with earlier droughts, both the regression and conceptual modeling procedures utilized to forecast seasonal runoff did not consistently provide reasonable results. For PG&E, in which nearly 40% of its historical conventional hydroelectric production comes from northern California's large springs, the continued long term decline in aquifer outflow was best defined by utilizing trending rather than actual modeled prediction. Following 13 months of unprecedented dryness, soil moisture accounting became an important factor for consideration during the first significant precipitation, which occurred in early February. The early February 2014 storms were mostly from relatively warm AR's that brought rainfall rather than snowfall into the medium to higher elevations of the Sierra and southern Cascades. For northern California with its relatively low elevation Feather, Pit, and McCloud Rivers and the Eel River located in the coastal mountain range, soil moisture accounting was an important first step in runoff forecasting and water release planning for reservoir management.

THE YEARS PRECEDING 2014

The years leading up to the late 1900's, especially for northern California's Pit and McCloud Rivers were somewhat similar to the years leading into the 1928-1934 seven year drought. A number of years of below average water year precipitation beginning about 1908 and ending with 1934 resulted in a long term decline in aquifer outflow into the Pit River. The low state in northern California's aquifer storage fully restored itself and again reached a high storage state in 1976. A long term trend downwards from the 1976 'high aquifer outflow state' started in 1977. During the years leading up to 2014, there were three other high aquifer outflow periods, but each less than the earlier aquifer water year outflow. Beginning in in the mid-1970's a relatively steep downward trend in aquifer outflow rate was accompanied by a long term decline in precipitation. In terms of water year precipitation, only the 2006 and 2011 water years were significantly above normal. Hat Creek, a tributary that flows into the Pit River readily shows this long term decline in Figure 1. The aquifer outflow index component is calculated utilizing the minimum daily flows during the fall months of August and September for both the current and prior year. Because the aquifer outflows contain precipitation that had fallen several decades prior to the current year, the natural lag created a moving average of its own with long term trends that appears sensitive to the wet and dry cycles of the Pacific Decadal Oscillation (PDO) which lasts 20-30 years, the El Nino Southern Oscillation (ENSO) which lasts 2-7 years , and other types of recurrent cycles. Once the overall trend starts, the decline or rise is often multi-decadal and the direction that it's headed can be forecasted utilizing trending until a change takes place. Because the trend direction for the aquifer outflows is relatively long lasting, some idea as to what may lay ahead in terms of flows may be inferred. The gradualness of the rises and falls in the outflow rate of the large springs are helpful in predicting approximate flow rate going forward. Approximately 89% of Hat Creek's surface runoff comes from large springs, which provide water that had entered the headwater recharge area several decades earlier in the form of snow- or rain-fall. Once the aquifers in the headwaters have become sufficiently depleted, it may take several years, and possibly decades for the aquifer storage to fully recover depending on future wetness and snowpack which would provide sufficient recharge opportunity. With climate change and the continuing loss of the northern California snowpack (Freeman, 2011, 2012), the recharge opportunity for the aquifers are continuing to decline. Adequate recharge requires both sufficient wetness and precipitation in the form of snow to be effective in terms of slow melt allowing the maximum potential for recharge consistent with infiltration capacity of the soils. One of the concerns with warmer storms containing high moisture is that while they may reach sufficient cooling for producing precipitation through the orographic process when encountering high mountain barriers, there are many areas in northern California that are relatively low elevation and are located behind mountain barriers creating effective rain shadows.

RECENT RESEARCH AND TOOLS FOR DROUGHT PLANNING

Recent research findings for climate change, paleoclimatology, and atmospheric rivers have influenced water management planning at PG&E. Research findings by Ingram, 2013 provide numerous examples of past droughts that were more severe than those experienced in the record period and also examples of those that lasted decades and even centuries in California. Prior to 2013, the period of available record has the 1976 and 1977 water years as being the most severe dry years and the 1928-1934 and 1988-1992 as the two longest periods of consecutive

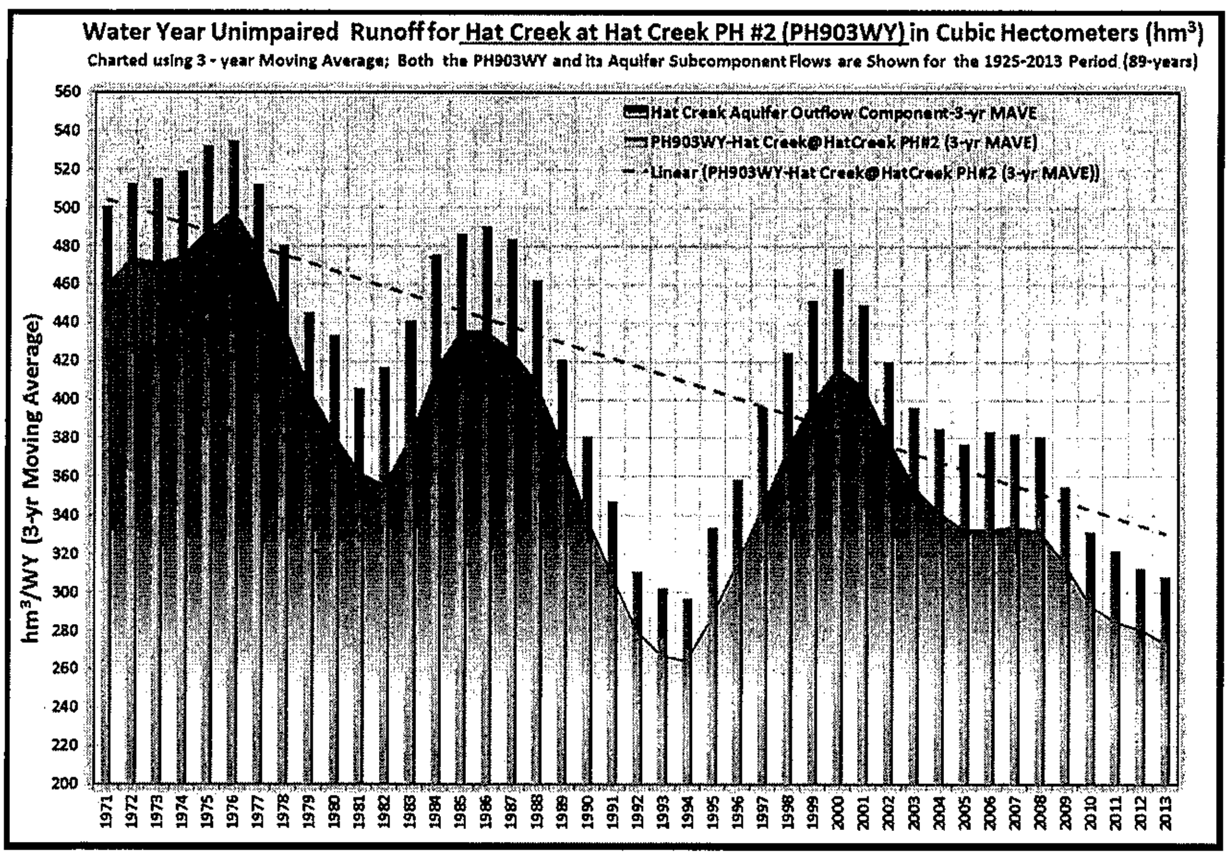

Figure 1. Hat Creek @ Hat Creek PH#2 (tributary to Northern California's Pit River) unimpaired flow including its aquifer outflow component for the period 1971 through 2013. All values are shown with a 3-year moving average.

drought. Knowing that long periods of severe drought were common in California's relatively recent past prepares us to plan for that possibility going forward. With regard to the persistent 'parking' of the Pacific High off of the California coast, the increasing loss of Arctic sea ice and warming of the Arctic may have influenced a slowing of the jet stream's zonal flow with greater amplitude of its waves leading to increased persistence of drought, floods, hot and cold spells (Francis, 2012). Increasing awareness that the persistent high may be caused from climate change led water management planning to become increasingly cautious in expecting a quick change in the pattern. Beginning in early January, water management's operational planning proceeded in a manner that assumed no additional runoff. If wetness returned than the 'little or no water release plan' would change accordingly. Recent research regarding atmospheric rivers increased overall awareness that should 4 or 5 atmospheric rivers occur, the drought could rapidly end and a possible return to normal could take place. However until such wetness happened, the plan would be to operate as if the high pressure ridging would continue to persist and that drought could possibly continue for several years. Moderate atmospheric rivers that occurred during the month of February were each watched closely for their forecasted positioning and whether or not they would be able to shift sufficiently far south to help the drought picture.

HYDROLOGICAL CONDITIONS FOR JANUARY, FBRUARY, AND MARCH 2014

The February snow surveys indicated a statewide snowpack snow water equivalent at only 24% of normal for that date. Even if normal snow accumulation was to occur between the first of February and April 1, the snowpack would only reach 65% of average. Precipitation overall statewide was likewise well below normal with the California Department of Water Resources (DWR) northern 8-station precipitation index indicating only 35% of normal for that time of year. With normal precipitation for the remainder of the season the index could be expected to reach 67% of average. The California Climate Tracker's statewide 12- month January 2013 through January 2014 precipitation shown in Figure 2 shows the past 12 months to be the driest such period on record for California. A growing awareness that this drought was in certain ways different from others experienced during the period of record quickly caught people's attention as requiring a higher level of planning and awareness than has previously been the case. In addition to being very dry, the average January temperatures for the Sierra Region where most of California's water comes from were also the warmest on record. The warm temperatures and general lack of soil moisture had also prompted a statewide fire alert. The expectation was becoming evident that if soil moisture was not restored, vegetation would likely be stressed the following summer with increased fire risk. For Lake Pillsbury, on the Eel River in California's coastal range, after several months with nearly no precipitation the first rains in 2014 required approximately 5.0 inches of soil moisture to be replenished before any significant inflow into Lake Pillsbury occurred. Likewise the first storms in 2014 gave a very limited runoff response in both the Sierra and southern Cascade streams. Figure 3 compares results from the State of California's DWR automated sensor system beginning on 12/31/2013 and displays results at approximate 15-day intervals. While PG&E's mountain lakes overall had almost near normal reservoir levels prior the spring snowmelt freshet, the lack of adequate snowpack for refilling them remained as a major concern. On March 1 most reservoirs did not have sufficient snowpack for filling the reservoirs. In 2014 most of the February and March storms were limited to far northern California and as such did not provide significant precipitation. The persistent high pressure ridge remained parked off the coast of central California, effectively deflecting the storm track into far northern California and into Oregon. Minimum temperatures accompanying storms as shown in Figure 4 have increased in recent years with the January and February minimum temperatures accompanying storms in 2014 being the highest on record for the Canyon Dam Weather Station on the North Fork Feather River.

CONCLUSIONS

The extreme dryness in California for the 2013 calendar year and record January and February high maximum temperatures were unprecedented. The 2014 California drought prompted PG&E's Water Management

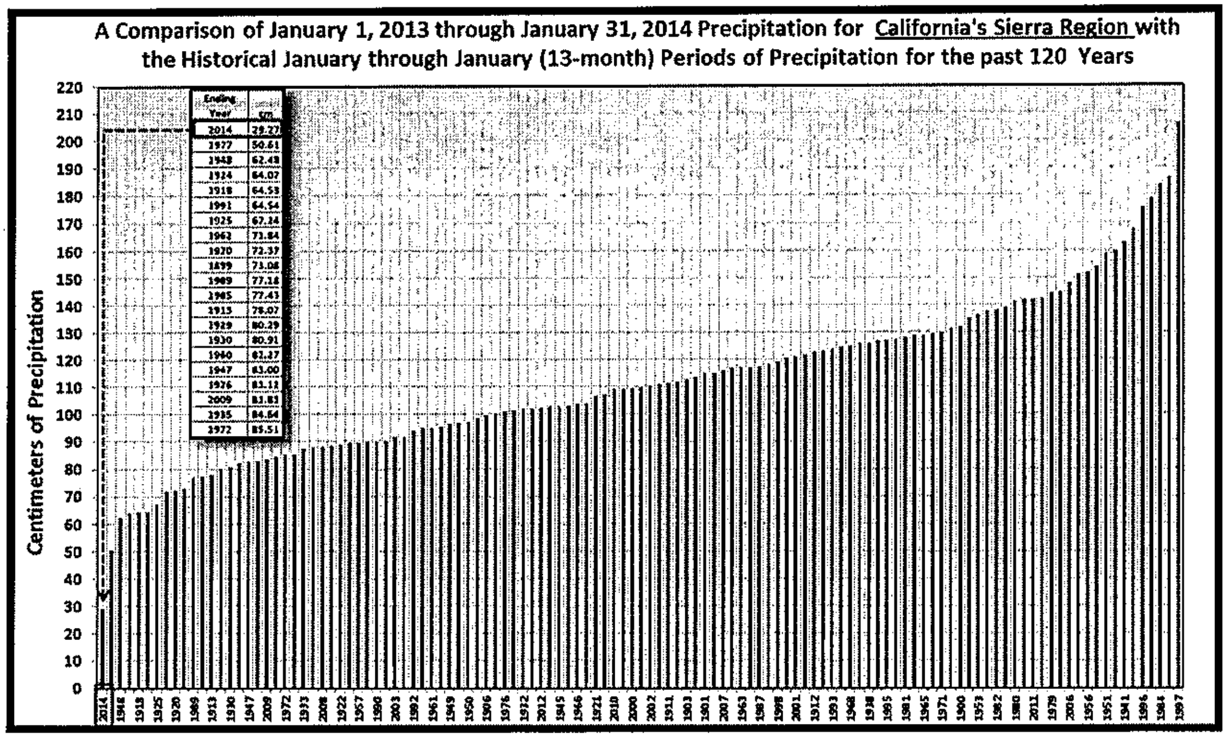

Figure 2. The January 1, 2013 through January 31, 2014 (13-month) period is shown in this chart from the California Climate Tracker as being the driest on record.

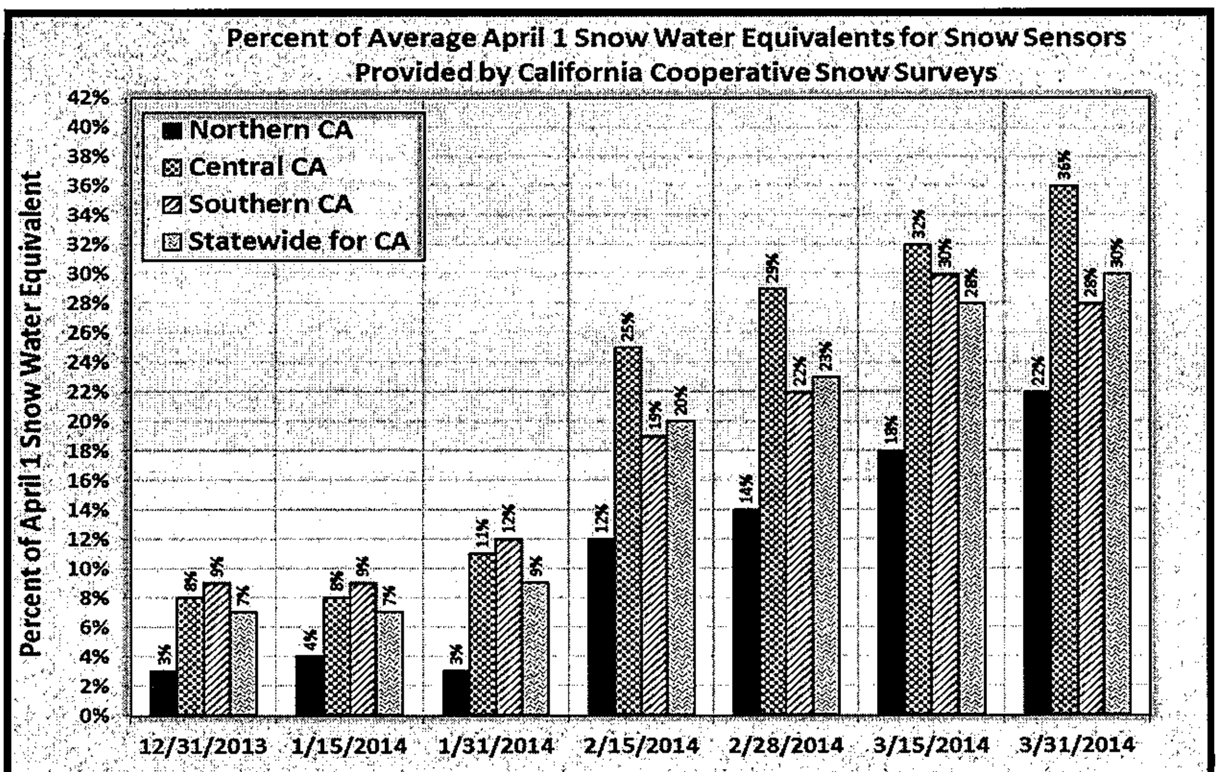

Figure 3. Percentage of average snowpack for the date shown. Data from all automated CDEC sensors statewide.

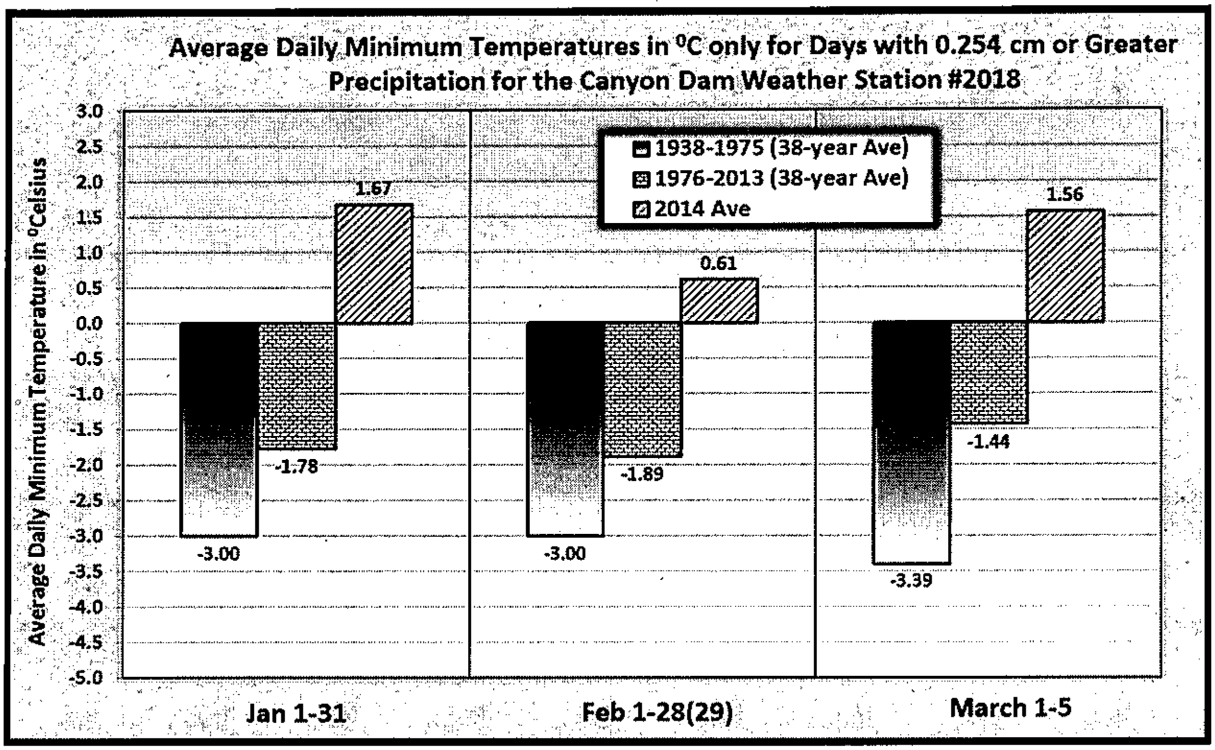

Figure 4. A comparison of two successive 38-year periods with the 2014 January, February and first 5-days in March for minimum temperature only on days with 0.254 cm or greater precipitation.

planning team to take into consideration a number of considerations with special consideration to: 1) recent paleoclimatological findings indicating that droughts lasting decades and centuries have been common and can be expected for California, 2) impacts of climate change may cause unexpected change outside of the recorded record, and 3) the Pacific Decadal Oscillation's current condition needed to be considered as likely having an influence on current drought conditions.

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ATTACHMENT 4

State Water Resources Control Board

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Alan C. Lloyd, Ph.D.
Agency Secretary

Arnold Schwarzenegger
Governor

January 12, 2006

To Individuals on Service List for P-2105:

TRANSMITTAL OF EIS COMMENT LETTER (FERC NO.2105-089)

This letter transmits the State Water Resources Control Board (State Water Board) comment letter, filed with the Federal Energy Regulatory Commission (FERC) on the final Environmental Impact Statement issued for relicensing of the Upper North Fork Feather River Project (FERC No. 2105). The comment letter along with an enclosure document has been posted to the FERC online e-library as submittal 20060111-5208. The filing may be accessed at FERC's website through the following link: http://elibrary.ferc.gov/idmws/search/fercgensearch.asp

In accordance with FERC Rules of Practice and Procedure, State Water Board staff serves this copy of the letter for your records. This mailing does not include the technical document that was enclosed with the comment letter. You may review and download the referenced document from the FERC posting, or you may obtain a hard copy upon request by contacting me at sstohrer@waterboards.ca.gov (please identify "Project 2105 - Willow Flycatcher" in the subject line).

Sincerely,

Sharon Stohrer

Sharon Stohrer
Environmental Scientist

with state and federal water quality standards by setting conditions of water quality certification as necessary to protect the beneficial uses along with requirements for monitoring and reporting to demonstrate adequate response to those protection measures.

With a focus toward Clean Water Act compliance, State Water Board staff offers the following comments on specified subjects with the hope that this will provide insight for the Commission and will aid that body in their decision-making.

Anadromous Fish Passage

The Commission invited comment on final EIS analyses and conclusions associated with the Modified Section 18 Fishway Prescriptions and Section 10(j) Terms and Conditions filed by NOAA Fisheries on March 14, 2005. State Water Board staff appreciates this opportunity, but recognizes the December 12, 2005 amendment to withdraw the fishway prescriptions and 10(j) recommendations at this time. NOAA Fisheries clearly reserves its right under section 18 of the Federal Power Act and requests an explicit license reopener on the issue of fish passage that may be exercised if certain events fail to materialize. State Water Board staff elects to make no comment on this matter today. However, if the Commission finds that a license reopener must be exercised and future section 18 prescriptions are filed on the Project No. 2105 license, State Water Board staff requests the legitimate option to provide comment on the terms and conditions filed by NOAA Fisheries at that time.

Water Temperature

The Basin Plan designates a beneficial use of cold freshwater habitat for both Lake Almanor and the NFFR, along with a coldwater spawning designation for the NFFR. The NFFR below Lake Almanor is currently proposed for temperature listing on the United States Environmental Protection Agency's (U.S. EPA) section 303(d) List of Water Quality Limited Segments in the State of California. Water temperature impairments are identified as the "pollutant" of concern, and must be addressed.

In its EIS, the Commission evaluates effects of continued project operation in accordance with a proposed "staff alternative." The staff's alternative (and subsequent *Recommended Alternative*) modifies the existing project with measures that are expected to improve some environmental and recreational resource conditions, but fails to include a future operational program with actions that will moderate water temperatures in the NFFR to effectively protect the cold freshwater habitat uses downstream of the Caribou Powerhouses. Although the Recommended Alternative (EIS, section 5.1.4) incorporates a proposed flow regime consistent with provisions of the partial Settlement Agreement[3] (S.A., Tables A-1 and A-2, Appendix A), this partial agreement clearly acknowledges the unresolved nature of water temperature issues (S.A. pages 6 and 19). A flow regime consistent with Table A-2 was not designed to moderate water temperatures in the Belden reach and will likely result in exacerbation of the thermal conditions of that diverted reach as summer flows are reduced by up to 46% from the existing condition (140 cfs) in Critically Dry and Dry water year types. State Water Board staff respectfully disagrees with analysis and conclusions described (EIS, pages 3-111 through 3-113) on water temperature response expected in the Belden diverted reach with implementation of minimum flows described above.

State Water Board staff supports the Commission's conclusions regarding potential thermal relief that may be recognized with increased releases from the Canyon Dam low-level outlet in July and August (EIS page 3-78). This measure in combination with other measures may have the potential to improve cold freshwater habitat downstream while maintaining habitat conditions in Lake Almanor. State Water Board staff suggests that other reasonable options for achieving seasonal water temperature relief in the Belden reach and downstream reaches of the NFFR have been dismissed without adequate analysis and justification. Potential measures for minimizing thermal impacts to the Belden reach and the NFFR watershed downstream will be developed and analyzed for effectiveness and incidental environmental impacts in the State's California Environmental Quality Act (CEQA) compliance efforts. The CEQA process parallels the National Environmental Protection Act (NEPA) process, and may introduce additional new mitigation alternatives that could resolve the water temperature impacts of Project No. 2105 on the NFFR watershed.

The State Water Board is currently in the process of developing an Environmental Impact Report (EIR) for compliance with CEQA. The EIR is expected to provide full disclosure of potential project-related impacts and the analyses to support issuance of the 401 water quality certification on the relicensing of Project No. 2105. On a nationwide conference call between Commission staff and various state certifying agencies for water quality (December 1, 2005), Commission staff promoted coordination between state and federal agencies in the development of CEQA and NEPA documents. State Water Board staff is encouraged by the Commission's cooperative approach and suggests that prior to filing with the U.S. EPA and adoption of the final EIS (40 C.F.R. §1506.3[a]), the Commission should consider the merits of information that may be presented in the State's EIR.

Willow Flycatcher Habitat

Discussions provided in the Upper North Fork Feather River Project Application for New License (Vol. II, page E-3.2-23 – 24) regarding Willow Flycatcher (*Empidonax traillii brewsteri*) report no records of this species in the immediate vicinity of Lake Almanor. The

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[3] PG&E. 2004. Project 2105 Relicensing Settlement Agreement; Upper North Fork Feather River Project, FERC Project No. 2105.

discussion suggests the existence of limited suitable habitat within the Project No. 2105 boundaries, and states these areas will not be impacted by continued operation of the project. This information fails to disclose known Willow Flycatcher breeding pairs and seasonally occupied habitat documented through surveys conducted by the Point Reyes Bird Observatory Conservation Science team (PRBO)[4,5]

Regarding Willow Flycatcher, the terrestrial resources section of the EIS (page 3-166) incorrectly states that suitable large stands of willow habitat are not found in the project area, making it unlikely that the species occurs here. Commission staff should consider the new and substantive information provided in the 2003 PRBO songbird monitoring report (Enclosure) and develop a Supplement to the EIS as necessary, pursuant to the requirements at 40 C.F.R. §1502.9[c][1].

During 2003 Willow Flycatcher surveys in wet meadows within the Project No. 2105 boundaries, PRBO biologists detected 13 breeding bird territories on the southwest shore of Lake Almanor and six on the northwest shore. These wetland locations are recognized as important strongholds for this State endangered species. Willow Flycatcher habitat along the shore of Lake Almanor is dependent on favorable water levels suitable to maintain the wet meadow conditions. State Water Board staff recommends that Commission staff analyze the effects of lake level on the sustainability of Willow Flycatcher habitat, including the direct influences of water surface elevation on local, unconfined aquifer water levels. A scientifically supported analysis of potential impacts (negative and beneficial) from the Recommended Alternative must be disclosed, and measures proposed as necessary to maintain or enhance Willow Flycatcher habitat qualities along the margins of Lake Almanor. A monitoring program and future adaptive management opportunities should be provided.

State Water Board staff recommends that the Commission's determination on completeness of the NEPA findings wait to consider data, analyses and conclusions that will be provided in the State's EIR. The draft EIR will identify feasible mitigation for any impacts to water quality that result from controllable factors resulting from project operation or proposed project alternatives. This environmental document may include innovative alternative proposals for mitigation of thermal effects of the project and it is expected that issues associated with Willow Flycatcher habitat will be introduced in the draft EIR.

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4 Humple, D.L. and R.D. Burnett. 2004. PRBO Songbird Monitoring in Meadow and Shrub Habitats within Lassen National Forest: Results from the 2003 Field Season; Progress Report to the U.S. Forest Service. (PRBO Conservation Science, Contribution Number 1173.)

5 Burnett, R.D., D.L. Humple, T. Gardali, and M Rogner. PRBO Avian Monitoring in Lassen National Forest: 2004 Annual Report. (PRBO Conservation Science, Contribution Number 1242.)