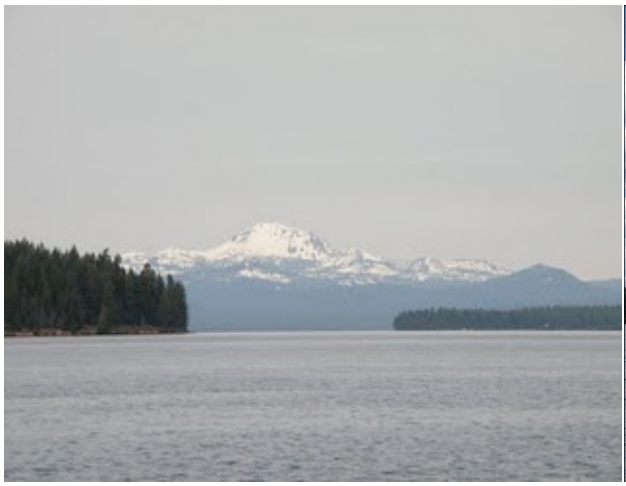
2011 Lake Almanor Review:

Survey of Water Quality, Trend Analysis, and Recommendations




Prepared by:

The Sierra Institute for Community and Environment

on behalf of

Almanor Basin Watershed Advisory Committee

Sierra Institute
for Community and Environment

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Introduction:

Importance of Lake Almanor and Building Relationships

At the head of the North Fork of the Feather River in Plumas County sits California's third largest reservoir, Lake Almanor. An idyllic mountain setting has made Almanor a major draw for both recreationists and second-home owners. With a surface area of nearly 32,000 acres, a capacity of 1.1 million acre-feet, and approximately 52 miles of shoreline, Lake Almanor is a playground for watersport enthusiasts and hosts one of California's top trophy trout fisheries.

Lake Almanor provides water to Southern California, hydropower for Pacific Gas & Electric, and is the basis of the region's economy. Ensuring proper protection of this headwaters lake is vital to both residents and downstream users. **Safeguarding this valuable asset will require a strong foundation of scientific knowledge**.

The ABWAC holds public meetings the 2nd Wednesday of every month.

The Sierra Institute for Community and Environment formally launched work in the Almanor watershed in 2003 after two years of seeking stakeholder interest. The Plumas County Board of Supervisors then worked with the Institute to create the Almanor Basin Watershed Basin Advisory Committee (ABWAC). Sierra Institute has staffed the ABWAC and coordinated its work since its inception.

The Sierra Institute watershed coordinator facilitates all ABWAC activities and develops and implements a yearly work plan to provide stewardship of the Lake Almanor basin. The watershed coordinator improves the institutional coordination of all projects by involving both citizens and agency representatives in stewardship activities, as **investment in the watershed is a shared responsibility**.

Section One:

Water Quality Monitoring: A History and A Strategy

Water quality monitoring at Lake Almanor dates back to the 1960s. With monitoring over this period of time, it might be expected that a clear picture would have emerged of the conditions of the lake. However, monitoring has been conducted by various groups and agencies (primarily California Department of Water Resources and Pacific Gas & Electric) with varied mandates over the years, resulting in a plethora of inconsistent and disjointed data.

Additionally, it is apparent that organizations could have more effectively coordinated efforts and data collection; as to date, there has not been a comprehensive dataset from which to source data for analysis of water quality in the lake. Achievement of the goals outlined in the 2009 Lake Almanor Watershed Management Plan will require a strong baseline database of water quality parameters and an understanding of observed trends in water quality.

The process of moving disparate data from years of collection to a unified database will aid future efforts to understand the watershed. The development of a useful water quality database was a multi-fold challenge. First, historical data had to be reconciled. Toward this end, the Sierra Institute has collected and organized data from various agencies that have monitored the lake over the years and created a comprehensive database which formed the basis for identifying and analyzing long-term trends. Once the results from past efforts were organized, plans for future monitoring actions had to be refined to build upon past efforts and create a consistent and comparable record.

From this work, the current health and any future changes in lake water quality can be identified with clarity and confidence. Consistently collected and properly catalogued, the data can now be used to inform the public and decision-makers. **As the region seeks to reconcile economic growth and protection of valuable natural resources to ensure preservation of the quality of life enjoyed, using knowledge of trends in lake health to inform management decisions regarding the lake and its basin is critically important.**

The future water quality monitoring strategy for Lake Almanor has been outlined as a program to identify long-term trends by tracking several key lake water quality parameters. By confirming a select group of parameters, future monitoring by the ABWAC will provide the necessary background data for drawing conclusions regarding changes in lake health by building on existing datasets. Based on a review of historical monitoring and input from experts, the following parameters were identified for continued monitoring at Almanor:

- Temperature
- Dissolved Oxygen
- Phosphorus
- Nitrogen
- Phytoplankton
- Secchi Depth

In addition to identifying these parameters for future monitoring, the committee has decided to continue monitoring at a consolidated number of sampling locations in order to enable better detection of seasonal variations in parameters and temporal trends. Monitoring will be conducted at two sampling locations, one located in each lobe of the lake, between April and November of each year. This was a strategic decision on behalf of the Water Quality subcommittee: acknowledging the most efficient way to pursue its goal of identifying trends in water quality with limited resources was to create a dataset which has a greater temporal (as opposed to spatial) extent.

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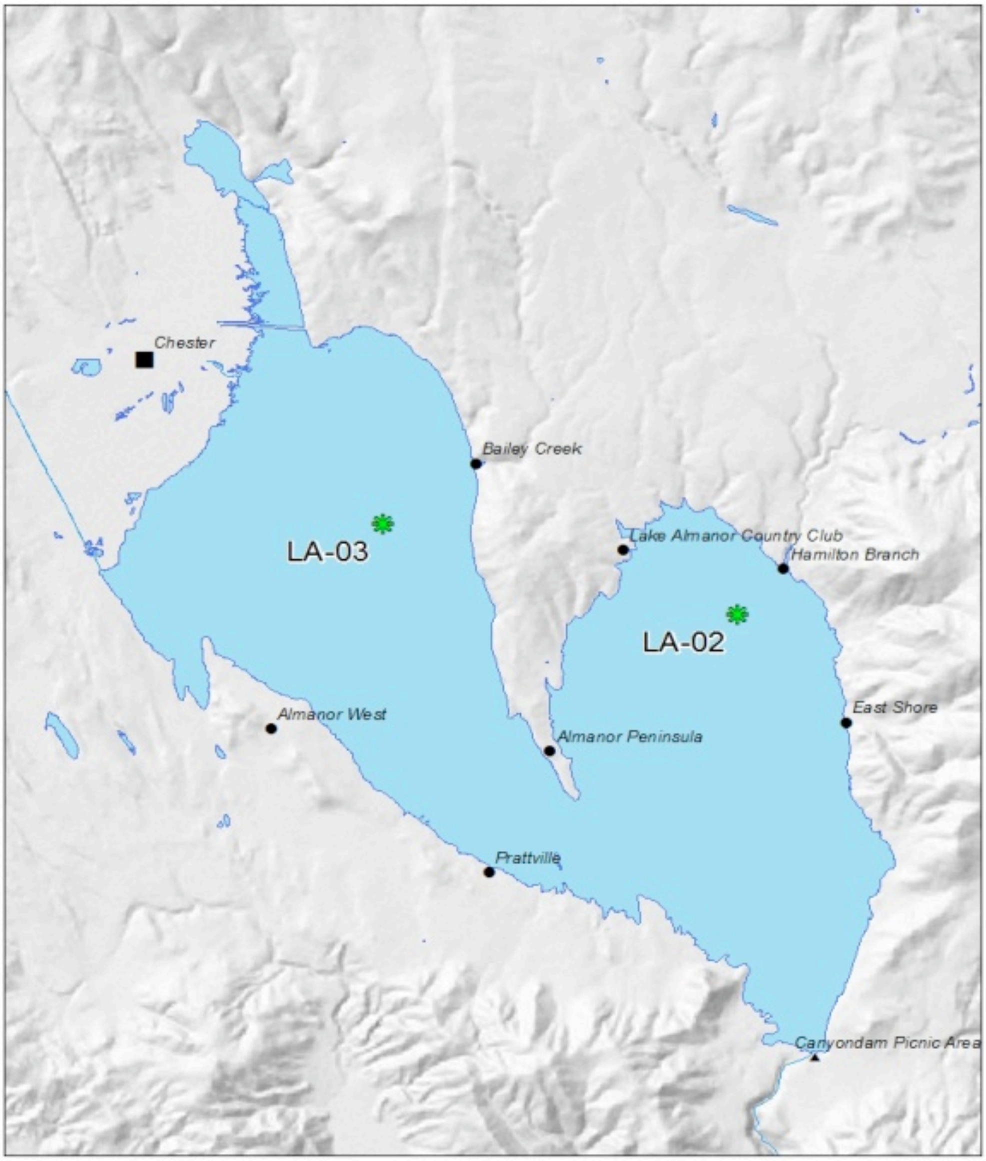


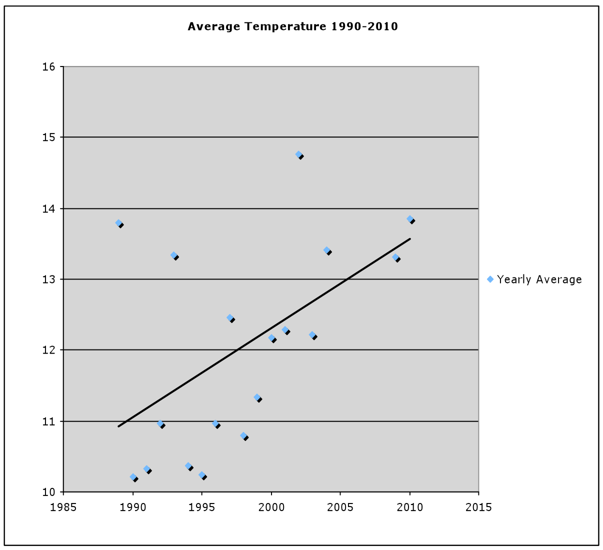
The diagram above illustrates the locations of future sampling sites labeled "LA-02" and "LA-03". Recognizing that variation in development levels and potential impacts may occur between the lobes because of the lake's shape, the decision to include one sampling location in each lobe will enable the water quality monitoring program to provide a representative picture of the lake as a whole, while focusing on identifying changes over time.

Section Two:

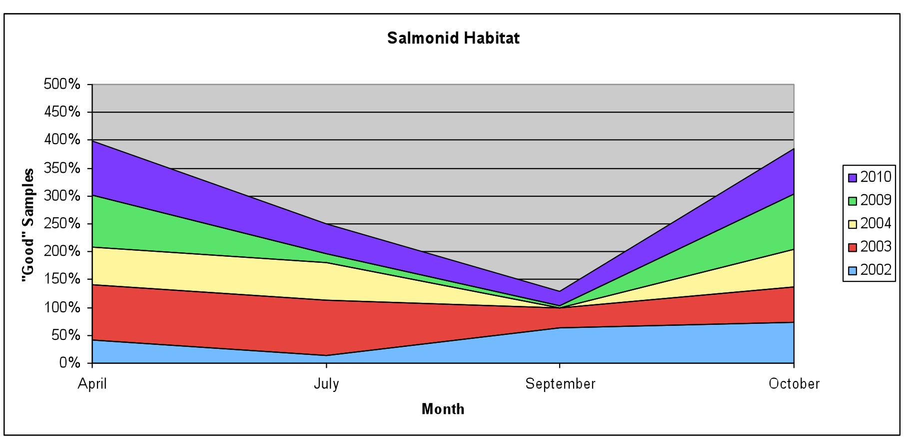
Current State and Trends in Water Quality

Temperature and Dissolved Oxygen

Temperature has been one of the most consistently monitored parameters at Lake Almanor, with comparable monitoring data available for the past 20 years. When the average yearly temperatures were calculated for the period from 1990-2010, an obvious upward trend appears.

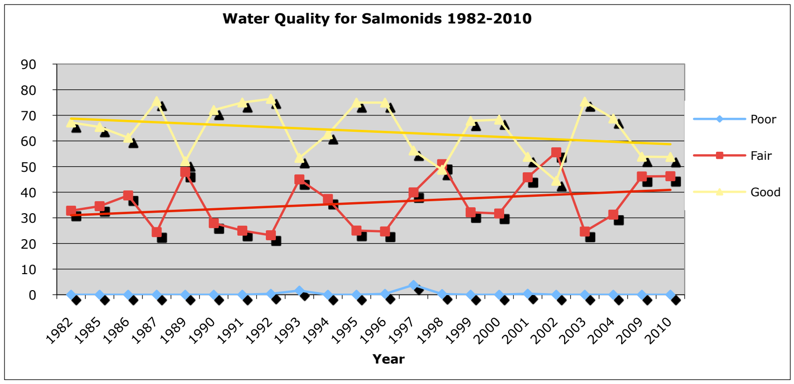


Average yearly temperature increased over this period from 50.38 °F in 1990 to 56.95 °F in 2010. Lake Almanor is by no means unique in this aspect, as other lakes in the California and Nevada region have also been shown to have increasing temperature trends in a 2009 NASA study using satellite observations to track surface temperatures at six lakes. However, the study also found that Lake Almanor is at the 'leading edge' of this trend – warming faster and more consistently than most of its counterparts. This review showed that the lake is not only warming at the surface nor only during the summer. Rather, the overall trend depicted in this graph holds true when the lake is examined from nearly any angle. **Increased temperatures have been accompanied by decreasing availability of dissolved oxygen in the water column, unwelcome news for a summer-stressed trout and salmon fishery in the lake.** This period of minimal habitat available for coldwater aquatic species is seen when good habitat is graphed over time, showing the annual changes which occur in the lake.

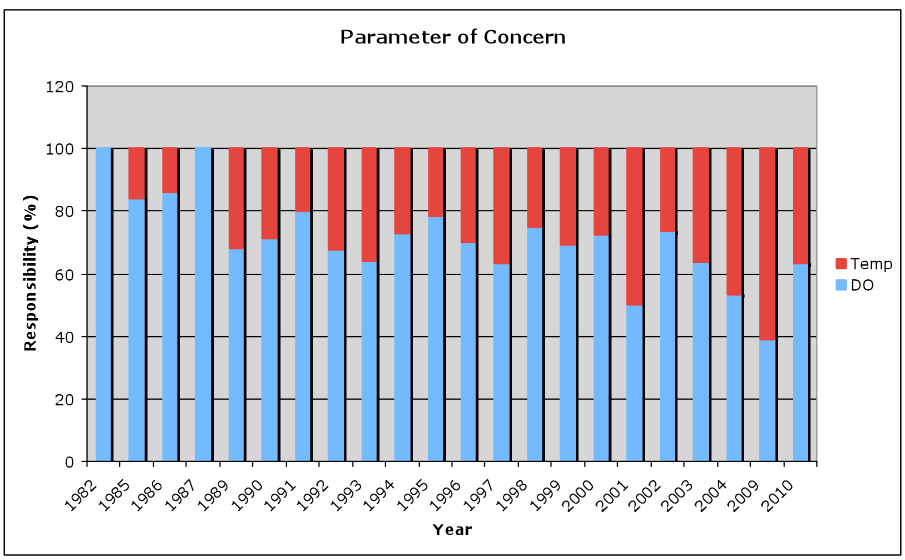


The graph at left depicts the seasonal changes in habitat availability for salmonids, an important fisheries component in Lake Almanor, showing the impact of the late summer constriction in terms of habitat reduction.

When temperature and dissolved oxygen are examined together, the results of these changes and their potential impacts on the lake's coldwater fishery become clearer. There has been a gradual decline in the amount of good habitat and an accompanying increase in the amount of fair habitat since the early 1980s (*see graph below*). To integrate these two parameters, "Good" salmonid waters were considered to be those with greater than 6.5 ppm dissolved oxygen and a temperature of less than 20 ° C. "Fair" conditions were waters in which only one of these conditions was unmet and waters which met neither condition were labeled "Poor."



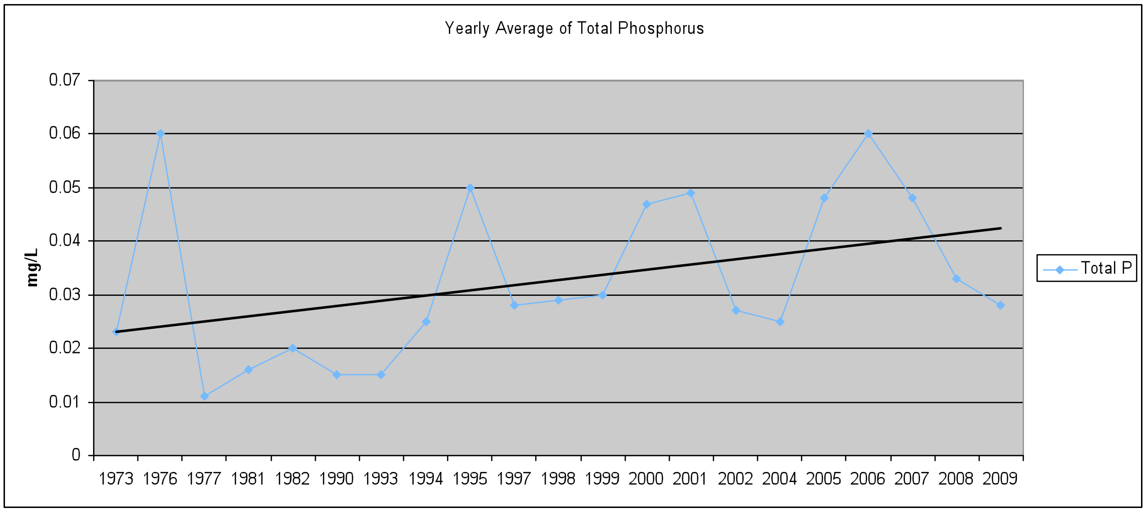
Beyond simply finding that there is less water that is both sufficiently cold and holds ample dissolved oxygen to meet the needs of trout and salmon in the lake, it was also found that high temperatures are increasingly the cause of this limitation.



The above graph illustrates the growing role warm temperatures are playing in the annual struggle for survival by Lake Almanor's trophy coldwater fishery. The expanding impact of temperature on the lake's ecology is represented by the increased proportion of the columns painted red.

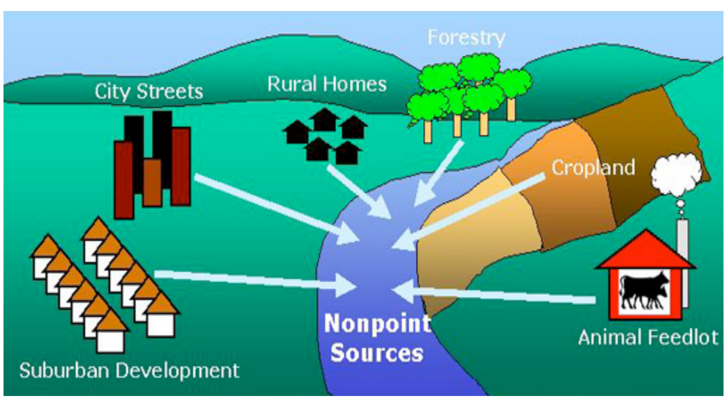
Nitrogen and Phosphorus

Nutrient data was reviewed and trends identified for total phosphorous and dissolved ammonia as these nutrient species had the most consistent records to work with. Total phosphorus has trended gradually upwards for roughly the past 30 years.



This graph demonstrates the increase in phosphorus found in the lake between 1973 and 2009. Phosphorus is a concern due to its potential role in fostering toxic cyanobacteria blooms.

Dunne and Leopold (1978) suggest that long-term eutrophication of water bodies should be avoided when total phosphorus remains below 0.5 mg/L – although the EPA water quality criteria state that total phosphorus should not exceed 0.025 mg/L in lakes and goes on to find that waters with total phosphorus of 0.03 mg/L or less are unlikely to support problematic algal blooms. In Lake Almanor, yearly total phosphorus averages have generally remained at or above the EPA proposed threshold since the mid-1990s.

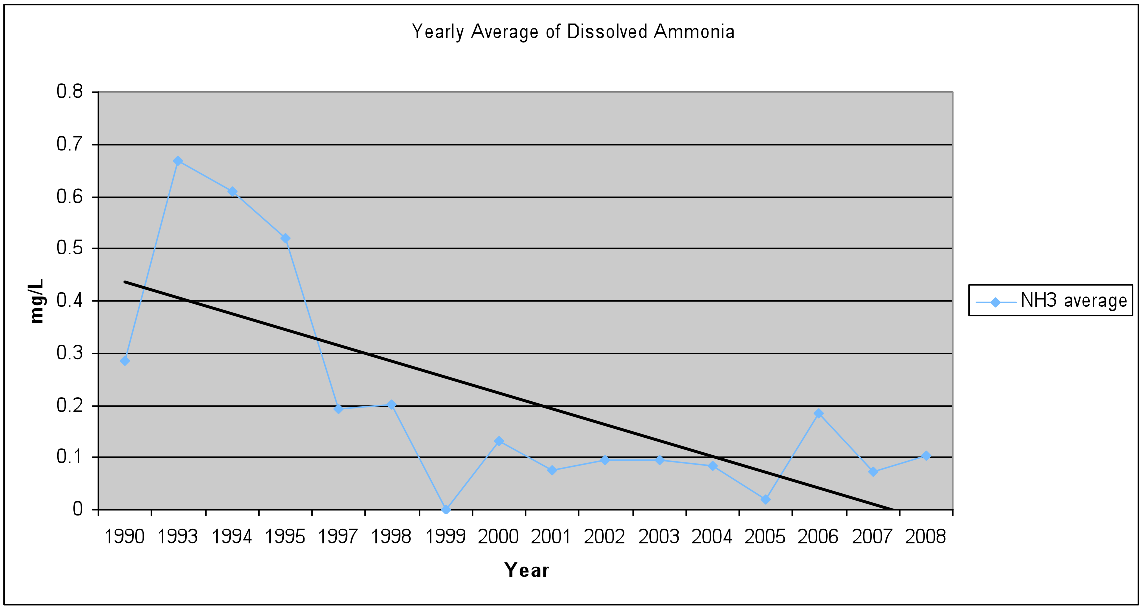


http://lakechamplainea.files.wordpress.com/2010/04/nonpointsources.jpg

As depicted above, nutrients may enter water bodies from a wealth of non-point as well as point sources, even in largely rural areas.

Phosphorus may enter the lake from a variety of sources. While the Almanor Basin remains in a state of a limited development and has retained much of its forest cover, **subtle changes in the landscape may release extra phosphorus to the lake**.

Interestingly, when the average yearly dissolved ammonia levels are calculated, the trend that appears is essentially the inverse of what is seen in total phosphorus over the same period. While dissolved ammonia levels were quite high during the 1990s, reaching a height of 0.67 mg/L (yearly average) in 1993, they have fallen to levels of around 0.1 mg/L since the beginning of the 2000s (*graphed below*).



While some trends in nutrient levels in Lake Almanor were identified, nutrients were one of the more irregularly monitored data points over the period of record compiled. Consistent monitoring of individual forms of both nitrogen and phosphorus should be undertaken in the future. In order to learn more about the lake's water quality, how it is changing, and what management actions should be taken in the future, it is imperative that additional knowledge be gained on the nutrients available in the lake. This will have important implications as the growing issue of global climate change begins to impact the region and for understanding the appearance of nuisance algal blooms.

Review of Minor Elements

A review of the concentrations of ten important minor elements in Lake Almanor was conducted using historical data (1986-1999, 2007). Overall, there was little or no cause for concern seen among any of the elements reviewed. Average concentrations for each element were calculated and found to be below identified water quality standards. Elements reviewed were: Arsenic, Cadmium, Chromium, Copper, Iron, Mercury, Manganese, Lead, Selenium, and Zinc. More detailed information can be found in Appendix A.

Summary of Current State

In general, lake health is good to excellent. Analysis of historic and recent lake monitoring data shows that Lake Almanor provides generally high water quality conditions for both recreational use and good habitat for biological organisms. Some concern over the lake's future is warranted however. Temperature and dissolved oxygen measurements indicate potential impacts to water quality in the future, particularly to cold water fisheries. Additionally, nutrient measurements suggest the lake is at risk for continued eutrophication if nutrient inputs are not properly managed.

Conclusion

An Uncertain Future: Preparing for Change

Lake Almanor is in good condition based on existing water quality data. However, this review also highlighted a number of ongoing changes in the lake's water quality. The lake has been a beneficiary of its own location in multiple respects. Protected from overwhelming mass tourism due to its relative remoteness, the arrival rate of exotic species is likely fairly low. Furthermore, the relatively cool climate, short growing season, and cold water temperature have limited growth of many aquatic species that do arrive.

At the same time, Lake Almanor is already seeing some changes which can only be expected to continue, with opportunity for additional impacts in the future. Current warming trends suggest that climate change is already impacting the lake and altered precipitation regimes in the coming years may produce effects whose outcomes haven't yet been observed. In conjunction with climatic changes, it is plausible that some exotics will become established in Lake Almanor as globalization continues to increase, or perhaps that some have already established, but have yet to be documented. There is also potential that major impacts on lake water quality could occur from human activities should the basin see an increase in development. Changes in the lake have the power to impact its aesthetic and recreational value.

It is important that we continue to monitor the lake's water quality and incorporate the knowledge that is obtained into decision-making processes in order to ensure that Lake Almanor is a great place for people to live and vacation in future generations, just as it is today.

Appendix A – Minor Elements Review

Period of Record: 1986-1999, 2007

Arsenic: The EPA standard for beneficial use impairment limit is .01 mg/L. The California Toxics rule established a standard of 0.150 mg/L (4-day average) for protection of aquatic life. Samples showed the average arsenic level to be approximately 0.002 mg/L and the range was <0.001 to 0.006 mg/L.

Cadmium: All samples for cadmium were below the detection limit at either <0.005 or <0.001 mg/L.

Chromium: Data ranges from 0.006 to <0.010 mg/L. Chronic exposure water quality limits are dependent on hardness but listed as 0.011 mg/L based on a hardness level of 100 mg/L.

Copper: Samples ranged from less than 0.005 to 0.02 mg/L. While the necessary parameters to calculate the BLM-based copper criterion for Lake Almanor are lacking, the levels are low, below the requirement to meet drinking water standards – 1.3 mg/L.

Iron: Total iron levels ranged from as low as 0.006 mg/L to as high as 5.2 mg/L with an average of 0.31 mg/L. The EPA guidelines for ambient water quality state that levels less than 1.0 mg/L should avoid negative effects of iron on aquatic life. This was exceeded 35 times out of nearly 480 samples taken from 1986 through 1999 and 1 time out of 36 samples in 2007.

Mercury: Range of 0.000002 mg/L to 0.00416 mg/L with an average concentration of 0.00013 mg/L. This is well below the standard of 0.77 mg/L for chronic exposure.

Manganese: Range from 0.005 to 2.10 mg/L with an average of 0.110 mg/L from 1986-1999. There is not an ambient water quality standard for this pollutant. The standard for human health protection for consuming organisms from waters is 1.0 mg/L. The highest concentration found during 2004 sampling was 0.65 mg/L.

Lead: Water samples during the period of record showed concentrations which range from <0.00004 to <0.005 mg/L. The chronic exposure standard for protection of aquatic life is 0.0025 mg/L for lead.

Selenium: Range from 0.001 to 0.005 mg/L with an average of 0.002 mg/L from 1986-1999. Both the average concentration and the range fall below the national recommended water quality criterion for selenium of 0.005 mg/L. Selenium concentrations did not exceed 0.0002 mg/L during 2004 testing.

Zinc: With an average concentration of 0.029 mg/L and a range of <0.005 mg/L to 0.11 mg/L. The majority of samples (all but 3) were 0.01 mg/L or less – well below the EPA water quality criterion of 0.120 mg/L.