Journal of the Nevada Water Resources Association

Spring 2005

A publication of the Nevada Water Resources Association, providing hydrologic information to the people of Nevada and adjacent States

Lake Tahoe Edition

Volume 2, Number 1

A study of ancient trees rooted 36.5 m (120') below the surface level of Fallen Leaf Lake, California

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ABSTRACT

The author of this paper has discovered large trees rooted at a depth of 36.5 m (120') below the existing surface level of Fallen Leaf Lake. Fallen Leaf is one of the major watershed areas for Lake Tahoe. Some of these trees measure over 30 m (98') tall with a circumference of over 4.5 m (15'), which is an indication that they were over two hundred years in age when they died. The significance of this discovery is the fact that for these trees to be rooted below the surface of the lake, the lake must have been down at least 36.5 m for over two hundred years. This would indicate that a "mega drought" had occurred, since several of these trees have been carbon dated to have "drowned" in 1215 A.D. ± 40 years. This would indicate that the drought persisted during the medieval period 850-1150 A.D., and was followed by an extremely wet period that brought the lake level back up high enough to drown the trees. There are also signs on these trees that another severe drought occurred sometime later, but did not persist for as long as the first one.

The author obtained a small grant to help in the study of these submerged rooted trees. He has been operating a Remotely Operated Vehicle (ROV) that can obtain high resolution color video and retrieve small wood samples down to a depth of about 152 m (500') below the lake surface. The trees are invisible to sonar since they have become completely water logged from being underwater for approximately 800 years. Visual searching has been required to locate them.

This paper reports on the progress being made to study what may be the only known full size trees that grew during the Medieval drought period in the Sierras. The tree ring data from these trees are providing a valuable climate history of the Lake Tahoe Basin.

INTRODUCTION

Fallen Leaf Lake is a small lake located in the Tahoe Basin near South Lake Tahoe, California, Figure (1). The lake has a surface area of 5.2 km^2 (2 square miles) and drains into Lake Tahoe. The watershed for Fallen Leaf Lake covers an area of approximately 42 km^2 (16 square miles) and is within the Lahontan drainage basin. A sizable portion of the drainage basin is located within the Desolation Wilderness Area, and is drained by Glen Alpine Creek into the south end of Fallen Leaf Lake. The sole outflow of Fallen Leaf is through Taylor Creek (which flows from the north end of Fallen Leaf into Lake Tahoe) which makes Taylor Creek one of the major tributaries to Lake Tahoe.

There is a mix of private and U.S. Forest Service (USFS) cabins around Fallen Leaf Lake that in general appear to be similar to cabins that were once located around Lake Tahoe some 50 years ago. Also, the roads and general appearance look as if time had stopped there shortly after the end of World War II.

Figure 1. Fallen Leaf Lake with watershed boundary marked by red line

The dynamics of Fallen Leaf Lake's ecosystem are quite responsive due to the small size of the drainage, lake stream and basin systems. In fact the hydraulic residence time for water in Fallen Leaf Lake is only eight years, compared to Lake Tahoe's where it is approximately 700 years, (Reuter and others, 1996). Because of the proximity of Fallen Leaf Lake to Lake Tahoe, and also due to the similarities in the ecosystems, it is felt that Fallen Leaf Lake is a microcosm of Lake Tahoe and as such offers a multitude of research opportunities that are directly applicable to the overall Lake Tahoe Basin (Kleppe, 1997).

The Fallen Leaf Lake watershed (Hanes, 1981) is steep, somewhat narrow, and rises from 1945 m (6,380 ft) to 3039 m (9,970 ft) at Dicks Peak. Most of the Basin has undergone alpine glaciation. About 30% of the Basin is forested with soils of glacial or residual origin. The remaining portion supports thin residual soils or is composed of exposed granodiorite bedrock and talus slopes.

The climate can be described as typical Sierra montane. Summer temperatures are warm during the day and cool at night. Winter temperatures are cold, but extended daytime temperatures below -10°C (14°F) are uncommon. Precipitation is highly affected by topography and orographic effects are common. Mean annual precipitation is approximately 76 cm (30 in) near the dam and may exceed 1.5 m (60 in) at the top of the Basin. Approximately 80% of this precipitation falls as snow in the headwaters of the watershed. Mean April (end of snow year) snowpack water content at Lake Lucille, which is located in the Basin at an altitude of 2500 m (8,200 ft), is 1.4 m (54 in). Most precipitation is derived from frontal type events associated with Pacific weather systems. Major floods are usually associated with rain events that occur during November through January.

The rocky nature of the watershed does not provide for much soil water storage (Hanes, 1981). There is some surface detention storage provided by a number of small alpine lakes whose total surface area is approximately 1.3 km^2 (0.5 square miles). These lakes provide for some attenuation of small storm peak flows. In terms of the annual flow regime, the lack of soil water storage leaves Glen Alpine Creek, which feeds Fallen Leaf Lake, without a significant base flow component (Hanes, 1981).

Fallen Leaf Lake is of glacial origin, with the area near the outlet being an end moraine. The lake is quite deep, reaching a maximum depth of approximately 150 m (492 ft). For the most part the lake banks are steep and the change in storage with stage is small. Due to an elevation difference of only 45 m (148 ft) between Fallen Leaf Lake and Lake Tahoe, the local geology, and the presence of large meadows near the lake, seepage losses have been determined to be insignificant, (Hanes, 1981).

The ratio of watershed to lake surface area for Fallen Leaf Lake is (42:5) or over 8 times, which in part causes the level of water in Fallen Leaf Lake to rise quickly during wet periods. This is in contrast to Lake Tahoe that has a watershed to lake surface area of only approximately 1.6:1 or slightly over 1½ times. The importance of this fact is that the fast rising water of Fallen Leaf Lake is able to preserve shoreline trees, while in Lake Tahoe the slowly rising water would tend to rot and decay them (Kleppe and Norris, 1999).

PERIODS OF EXTREME DROUGHT AND WETNESS

Until recently, the most severe and persistent dry period in the Sierra's instrumentational records occurred between 1928 and 1934 (called the Dust Bowl period). During this period the Sierra runoff averaged approximately 70% of "normal". That interval was matched in severity during the six years 1987-1992, which seems to reinforce the notion that there is a maximum six to seven year dry spell cycle (Stine, 1994).

Evidence of Medieval “dry periods” that were of much greater severity and duration (over 100 years) should truly be considered as droughts. Evidence of these medieval droughts appears at many sites in and adjacent to the central Sierra, i.e., Mono Lake, Tenaya Lake, the West Walker River, Osgood Swamp (Stine, 1994), Fallen Leaf Lake (Kleppe and Norris, 1999; Kleppe, 2004), Lake Tahoe (Lindstrom, 1990), and Pyramid Lake (Benson and others, 2002).

These recent studies of selected tree stumps rooted in present day lakes, marshes and streams, suggest that California's Sierra Nevada experienced severe drought conditions for more than two centuries before 1112 A.D. and for more than 140 years before 1350 A.D. During these periods, runoff from the Sierra was significantly lower than during any of the persistent "dry spells" that have occurred in the region over the past 150 years.

DROWNED ANCIENT TREES ROOTED IN FALLEN LEAF LAKE

Using a remotely operated vehicle (ROV) (Figure 2), large trees were discovered that appear to have been rooted at a depth of 36.5 m (120’) below the existing surface level of Fallen Leaf Lake, (Kleppe and Norris, 1999; Kleppe, 2004). Some of these trees measure over 30 m (98’) tall with a circumference of over 4.5 m (15’) suggesting that they were over two hundred years of age when they died.

Figure 2. Remotely Operated Vehicle (ROV) with 152 m (500’) tether

The importance of this discovery is the fact that for these trees to be rooted 36.5 m (120’) below the surface of the lake, the lake must have been down at least 36.5 m (120’) for over two hundred years. This would indicate that a “mega drought” had occurred. Several of the trees have been carbon dated and found to have “drowned” in 1215 A.D. ± 40 years, which would imply that the mega drought persisted approximately during the Medieval period 850-1150 A.D., after which they were drowned by rising water during an extremely wet period following the drought.

There are also signs in the form of rotted tree tops on several of these trees that another drought occurred later that was severe enough to drop the lake level 7.6 m (25’), and, remaining there long enough for the tops to be rotted off at the same elevation. These observations may indicate that these mega droughts may be cyclic in nature with a period of more than several hundred years.

It was determined that these trees should be studied in more detail, and that a sample of the tree ring data should be gathered if possible and analyzed. The main purpose and first goal of this research work was to study methods whereby tree ring data could be recovered from one of these submerged trees. The second goal was to attempt to recover some initial tree ring data and send a sample for preliminary analysis by the University of Nevada, Reno tree ring expert, Dr. Franco Biondi, (Biondi, 2004).

After some basic investigation it was determined that the same coring methods used to sample trees in a forest could not be easily adapted for underwater use. The reasons for this were several and included the fact that normal trees are cored at a “chest high” level. This would mean that divers would have to drill and core the trees at a depth of over 37 m. This presented a real challenge because the altitude of Fallen Leaf Lake and the depth of the dive limit divers to work underwater for less than 20 minutes. Also, there were concerns over the trees being totally water logged and that it would be very difficult to drill a core, especially for a tree that may be over 4.5 m in circumference. Also of concern was the fact that even if the core could be obtained by drilling, it might fall apart underwater as it was extracted from the tree.

Another approach was investigated that involved cutting down one of the rooted upright trees and bringing it to the surface. The tree would then be raised off the lake bottom and taken to shallow water along the edge of the lake. There the bottom section, including the root section, could be sawed off and taken to UNR for analysis and study. This approach would require a lot of equipment, manpower, and expense, but would provide an entire "chest high" cross section of the tree, as well as the root structure. This approach was receiving serious consideration when Professor Kleppe discovered a tree that had already fallen over and was resting on the upslope of the lake bottom. This tree was 32.3 m (106') in length, had its base at 36.5 m (120') deep and was laying upslope on the lake bottom. The tree was carbon dated and found to have died simultaneously with the still standing, rooted ancient trees. This fallen tree was located on the east side of the lake, while all of the known and still rooted ancient trees so far have been located on the west side of the lake.

Since the already fallen tree died during the same period as the rooted trees, the fallen tree could be used to provide the required tree ring data. A company named Pacific Built was operating a large floating crane called the "Larc" on Fallen Leaf Lake and was available to raise the tree (Figures 3a and b).

Figure 3a. Pacific Built's floating crane the "Larc"

Figure 3b. Diver being lowered into the Lake by the "Larc"

A plan was then developed and executed wherein the fallen ancient tree was raised to the surface (Figure 4), moved to shallow water, and the bottom portion of the tree cut into sections. The root structure was saved. The major remaining part of the tree was returned to the lake, at a shallower depth, for storage and retrieval if more samples were needed in the future.

Figure 4. Top of the ancient tree being raised from the bottom of Fallen Leaf Lake

The tree sections were loaded on a truck (Figures 5a and b), and hauled to UNR for subsequent analysis and study. A tree surgeon was hired to cut several of the rounds into 10 cm (4”) thick disks (Figure 6), and several samples of the tree were turned over to Dr. Biondi for preliminary analysis and study.

Figure 5a. Sections of ancient tree loaded on a truck

Figure 5b. Close up of cross section of ancient tree showing quality of the water logged, preserved wood

Figure 6. Sample of dried out full diameter disk 10 cm (4") thick

Dr. Biondi used one of the disk sections at a height of 5 m (16.5') to produce three strips 10 cm wide and spanned a full diameter (Figure 7). The remarkable condition of the ancient tree can be seen in Figure 8, which shows how well preserved the tree is considering it died in 1215 A.D. ± 40 years. Microscope analysis clearly showed the presence of resin ducts, therefore it could not be a fir or a cedar (resin ducts are found in pines, spruces, and doug-firs). Based on the size, number, and distribution of the resin ducts, as well as the type of earlywood-latewood transition, the tree was determined to most likely be a pine, possibly a ponderosa. However, the final species identification (beyond what is allowed by the presence/absence of resin ducts) is difficult without additional microscopic analysis. This will be done at a later date.

Figure 7. Sample of cross section of ancient tree

Figure 8. Example of how well the rings of the ancient tree have been preserved

The carbon dating of the raised tree samples indicated that the tree died in A.D. 1215 ± 40 years. There were 220 rings, indicating the tree was over 200 years old at the time it died. The tree was totally "water logged" and still had sap coming out of the root section and other parts of the tree (Figure 9). Additional sampling will be done to confirm the date of death and to match tree ring samples with other trees determined to be from this same period of time.

Figure 9. Photo showing a sample of the sap that began to flow from the base of the tree after cutting.

A number of rooted trees have now been found. One of the rooted trees died in approximately the year 200 A.D. ± 40 years, which is approximately 1,000 years earlier than the others. This has presented a concern that the carbon dated time of death may be in error. Another sample of the tree should be taken and the carbon dating repeated. During the gathering of the sample, two more rooted trees were discovered and also sampled for carbon dating. The results have not as yet been received.

CONCLUSIONS

Evidence is growing that the Lake Tahoe Basin has experienced "mega droughts" over the past 2,000 years, including a multicentenniel drought that occurred between the years 1000-1250 A.D. These droughts may be cyclic in nature and may have a period of 400-500 years.

There is no doubt that perfectly preserved trees from mountain lakes can provide very valuable data for climate studies, fire history, and many other scientific studies. However, the raising of such trees is a labor and equipment intensive task costing a lot of money. Other trees have been discovered that date to 200 A.D. and 300 B.C. which also appear to have been perfectly preserved. One of these is at a depth of 100 m which would be very difficult and expensive to rise.

A ROV designed to locate and sample submerged trees at depths of up to 500 m in freshwater lakes could be used to recover additional information. The ROV should be mobile and easily carried into remote areas for deployment in mountain lakes. Such a vehicle would provide valuable data and help to better understand the cyclic nature of mega droughts.

The samples gathered from this project will continue to be analyzed and studied for fire damage. Also, it is planned (under a separate study) to take core samples from juniper trees that have grown on the moraines on the southwest side of Fallen Leaf Lake. Some of these trees appear to have been living for nearly 1,000 years. The tree rings from these junipers may assist in verifying the occurrence of the two mega droughts that may have occurred in the Tahoe Basin since Medieval times.

ACKNOWLEDGMENTS

The author would like to acknowledge the support provided by the USGS/DRI under Project ID# 2003NV39B, and also the support being provided by Dr. John Knezovich of the Lawrence Livermore National Laboratory for carbon dating of the samples.

The author would also like to acknowledge the assistance rendered by Grant and Glenn Adams for their continuing assistance; Chris Sauer, the Fire chief of Fallen Leaf Fire Department for use of the Fire Boat; the diver team, John and Andrea Shaw of Advanced Marine Services; John Ragan and the Pacific Built team for raising the tree; and finally, Martha Jones who donated the funds to purchase the ROV.

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