FALLEN LEAF LAKE: A MICROCOSM OF LAKE TAHOE

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ABSTRACT

This paper presents an overview of the reasons that Fallen Leaf Lake has been proposed as a microcosm of Lake Tahoe. It is postulated that the problems being faced in the Lake Tahoe Basin are social, political, economic and finally, scientific in nature. These problems are exactly the same as those being faced by Fallen Leaf Lake. Fallen Leaf Lake is shown to offer a unique opportunity to develop concepts, methods, instrumentation, monitoring approaches and complex models that will be essential to developing a long term management plan for the Lake Tahoe Basin. Air quality, water quality, aquatic systems, as well as a multitude of other complex issues can be readily studied on a smaller lake such as Fallen Leaf. The dynamics of Fallen Leaf's ecosystems are quite responsive due to its small size and offers a "real world" working model to develop answers for the problems found in the Lake Tahoe Basin. For purposes of this paper a focus is made on the hydrological aspects of the microcosm and the development of new sensor-technology that can be extrapolated to the entire Lake Tahoe Basin.

The "bottom line" conclusion is this - if problems cannot be solved on the scale of the smaller more manageable Fallen Leaf Lake, it is then highly unlikely they can be solved for the much larger Lake Tahoe.

INTRODUCTION

Lake Tahoe, Figure (1), located at an elevation of 1,898 m (6,226 ft) is the largest and most remarkable of mountain lakes in the Sierra Nevada range. It ranks fifth in mean depth, 313 m (1,027 ft) and tenth in maximum depth, 501 m (1,645 ft), of lakes of the world. Its surface area is 500 km^2 (193 square miles) and it is fed by a restricted drainage basin of only 1310 km^2 (506 square miles) which includes the area of the lake itself. Lake Tahoe is one of the clearest large lakes in the world, and easily one of the most unique lakes in North America.

Fallen Leaf Lake is a small lake located in the Tahoe Basin near South Lake Tahoe California, Figure (2). It 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 located 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.F.S. 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.

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, [1]. 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 [2].

RESEARCH OPPORTUNITIES ON FALLEN LEAF LAKE

Fallen Leaf Lake offers an excellent opportunity to study air and water quality, aquatic systems, and a full range of biological systems that make up the Tahoe Basin. It is also possible to gain valuable insight into the complex interactions of these ecosystems. There is a need to better understand and control the impact that human systems have on the Tahoe Basin. For example, Fallen Leaf Lake is the gateway to the Desolation Wilderness Area. Some 30,000 people travel into this wilderness area each year and hope to enjoy a wilderness type experience. This means that the Fallen Leaf area has to "come to grips" with the associated transportation and support service

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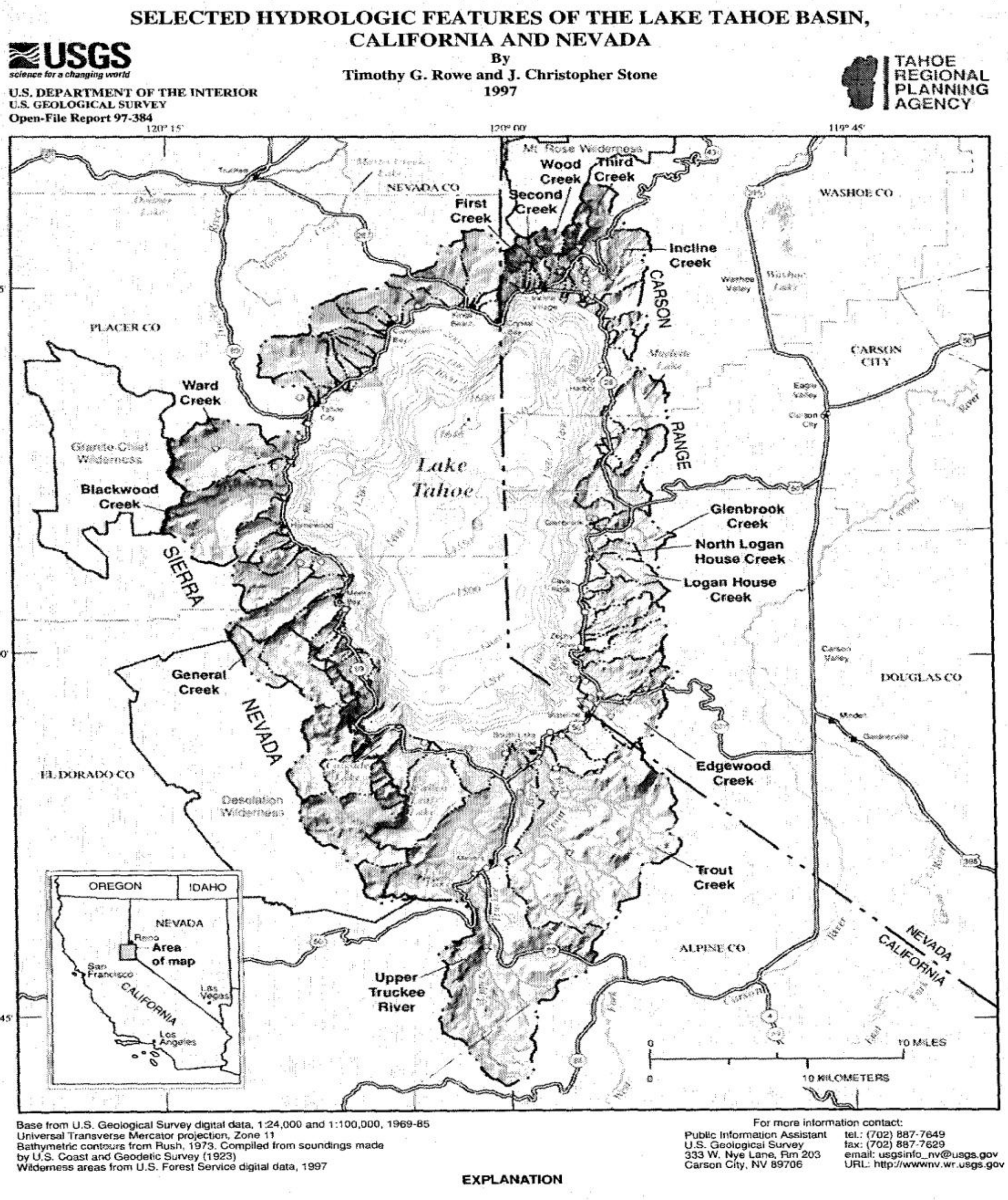


Figure (1) Lake Tahoe and Fallen Leaf Lake

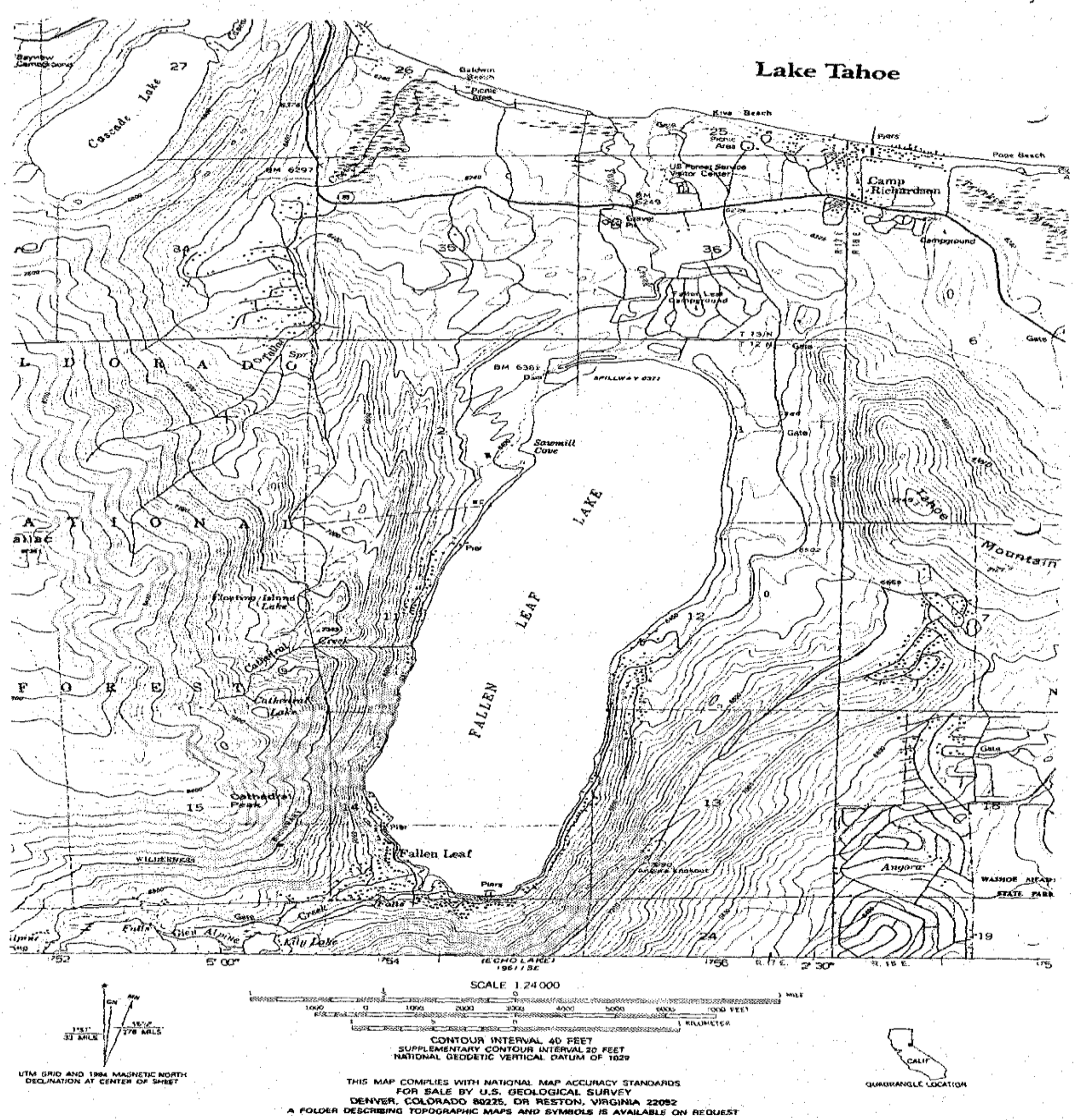


Figure (2) Fallen Leaf Lake

problems associated with such a public attraction. Chisholm and Kleppe, [3] at the Presidential Forum, suggested that advanced systems theory could be applied to the Lake Tahoe Basin. It was pointed out by Chisholm and Kleppe that complex systems that involve social, economic, and political elements and their interactions are not so easily understood and/or even well defined. Yet such systems are of increasing importance in modern society and certainly to understanding and defining the problems of the Lake Tahoe Basin.

One of the authors of this paper, Professor Kleppe, has been a Fallen Leaf resident for the past 19 years. During this time, he has been designing and carrying out numerous environmentally related research projects using his residence and shorezone facilities as a research platform. One of the major goals of this research effort has been the development of instrumentation, sensors, methods, techniques, teams of experts, and citizen "samplers" at Fallen Leaf Lake that can act as a role model for the establishment of a "real time" monitoring network for Lake Tahoe. The work being done at Fallen Leaf Lake provides a valuable service and supports the TRPA's Environmental Improvement Program (EIP).

HYDROLOGY OF THE FALLEN LEAF LAKE WATERSHED, [4],[5],[6],[7]

The Fallen Leaf Lake watershed 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. Mean April snowpack water content at Lake Lucille, which is located in the Basin at an elevation of 2500 m (8,200 ft), is 1.4 m (54 in). Most precipitation is caused by frontal type events associated with Pacific weather systems. Major floods are usually associated with rain events that occur during November through January. Convective type thunderstorm events may take place from July through September. However, they occur with neither the intensity or frequency that areas supported by a Gulf of Mexico summer maritime airflow experience.

The rocky nature of the watershed does not provide for much soil water storage. 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). The 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 that feeds Fallen Leaf Lake without a significant base flow component.

FALLEN LEAF LAKE AND TAYLOR CREEK

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 capacity with stage is insignificant. 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 are assumed to be insignificant.

Fallen Leaf Lake has a number of complex and sometimes conflicting uses of its lake waters. There are a number of private homes as well as public and private recreational facilities along the shore. These users derive some level of benefits from having certain "targeted" lake levels throughout the year. Figure (3) shows a sample comparison between the desired "target" levels and the actual level of Fallen Leaf Lake. There is only one outlet of Fallen Leaf Lake, that is Taylor Creek, which flows into Lake Tahoe. Taylor Creek is a major tributary to Lake Tahoe with the flow rate controlled by a small dam at the outlet of the lake. The operation of this dam is under the jurisdiction of the U.S. Forest Service (U.S.F.S.). There are a number of instream flow uses associated with Taylor Creek. These include maintenance of the Kokanee, Brown Trout and Rainbow Trout fisheries, a Bald Eagle habitat; operation of a U.S. Forest Service Stream Profile Chamber; aquatic ecosystems; and, recreational and aesthetic uses. There are considerable problems in providing for all of these numerous, diverse, and often conflicting requirements for the water. The development of the "targets" for the lake level of Fallen Leaf Lake and the ongoing management of the stream flow of Taylor Creek has helped to mitigate many of the conflicts that have arisen.

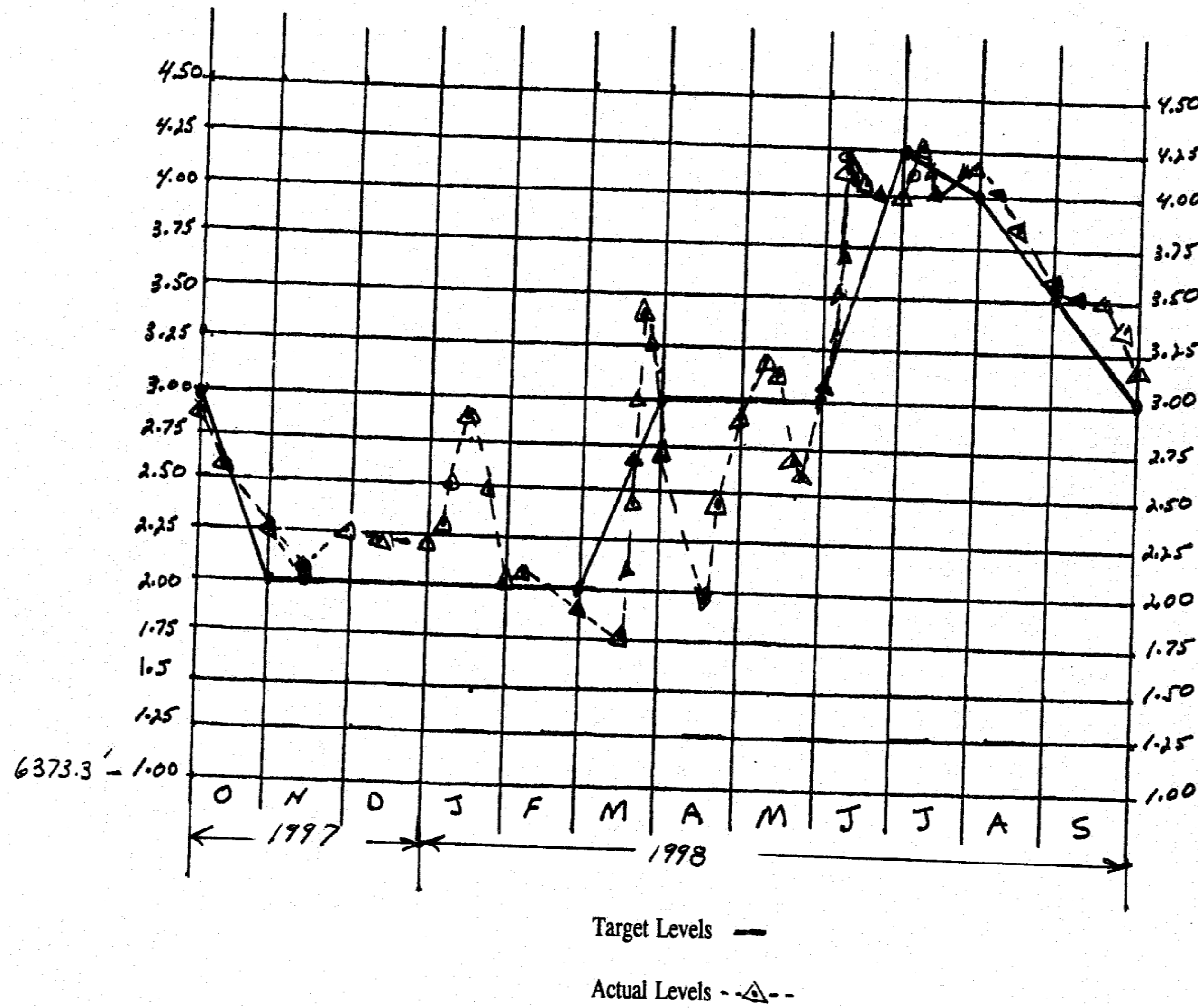


Figure (3) Sample of Actual Fallen Leaf Lake Level Compared to the Target Level

PERIODS OF EXTREME DROUGHT AND WETNESS

The level of Lake Tahoe undergoes extreme swings between dry and wet spells over the dynamic range between its natural rim and the high water level, Figure (4). The average value of the lake level exhibits a large standard deviation when calculated over the nearly 100 year period shown. This means that there is no real "normal" lake level.

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. These dry cycles, however, should not really be considered as "droughts".

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 [8], Fallen Leaf Lake [9], and Lake Tahoe [10].

A recent study of select tree stumps rooted in present day lakes, marshes and streams, suggests 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. [8]. 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 140 years.

One of the authors of this paper, Professor Kleppe, discovered what appears to be an ancient tree rooted in nearly 30 m (98 ft) of water in Fallen Leaf Lake, [9]. This tree, Figure (5), measures nearly 24 m (79 ft) high and some 7 m (23 ft) in circumference. This submerged tree appears to be well over 100 years in age. A sample of wood from this tree has been collected by diver and is being carbon dated. Because of the size of this tree, it is felt that it grew during one of two major droughts periods that occurred between A.D. 892 to A.D. 1112 or A.D. 1209 to A.D. 1350. It is noted that there was a time of wetness that lasted for nearly 100 years between these two dry periods, [8].

If indeed it is found that this tree dates to be approximately 1000 years old, and further that it is determined to be drowned rather than deposited by an earth slide, the resulting conclusion must be a "wake up" call for the entire region. What will happen to this area if there is another drought that lasts for 200 years or more in length? How could we survive? What could or should be done about it?

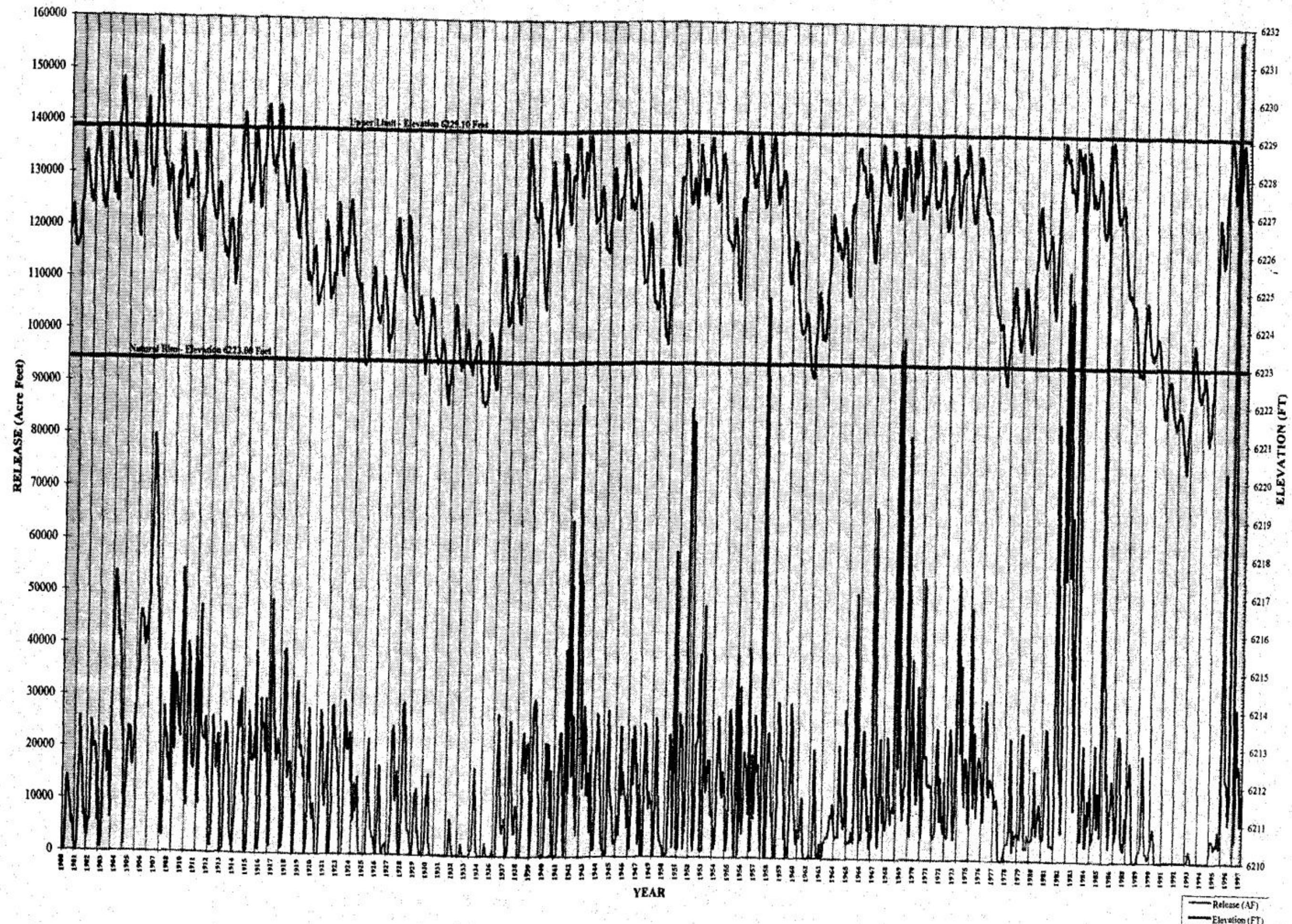
This wet/dry/wet cycle is also reflected in the hydrology of the Truckee River system. The Truckee River is the only exit flow from Lake Tahoe. There are several major tributaries to the Truckee River including two major uncontrolled water sheds, i.e., Squaw Valley and Dog Valley Creek.

The Truckee River has a long history of floods [11],[12]. Early accounts indicate that flooding or periods of high water occurred during December 1861, January and February 1862, December 1867, January 1886 and May 1890. Since about 1900, when records of streamflow were begun, serious floods occurred in March 1907, January 1909, March 1928, December 1937, November 1950, December 1955, February 1963, February 1986 and most recently January 1997. Snowmelt floods occurred in 1906, 1907, 1938 and 1952. Cloud burst flooding also occurs in the area, but it is of shorter duration and much less in areal extent than either rain or snowmelt floods. The most severe cloud burst flood, for example, in the Truckee Meadows area occurred in the Peavine Creek watershed on July 20, 1956. Here again we must ask the question, what could or should be done to control the flooding?

An optimum solution to the Truckee River System's varying extremes would be to provide adequate storage of excess water during wet spells for use later during dry spells. One must smooth out the wide swings being created by nature. The main question left to answer then is how to achieve the proper amount of storage in an optimum manner that would satisfy all of the varied interested and affected parties involved.

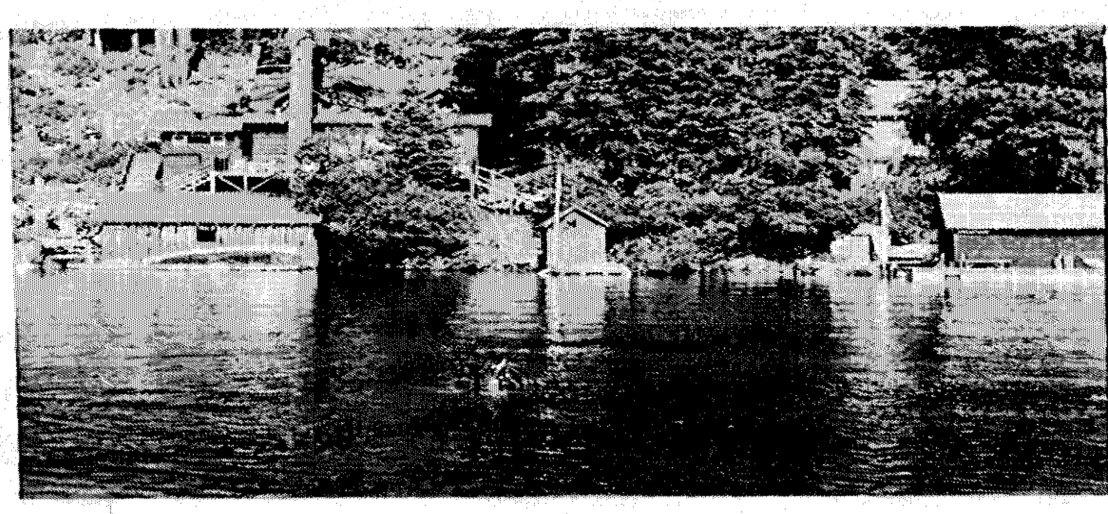
The major storage reservoir in the Sierra is in the snowpack itself. The problem with this is the fact that one cannot control the rate or timing of the snowpack melt to match the downstream needs of the system. Again one has to rely on nature's action to operate the control. There is at present no technology available or even imagined that could effect proper control of an entire snowpack over an entire mountain range. Techniques are however currently in use to enhance the snowpack using modern cloud seeding operations. With mountain top cloud seeding generators and special aircraft, Sierra storms have been seeded over the past thirty years, [13]. It is thought that such seeding efforts increase the snowpack by less than 10%. Maybe in the future a technology will evolve that will also allow for control of the snowpack melt. In the meantime the only known, proven method is through the use of dams and reservoirs.

Figure (4)

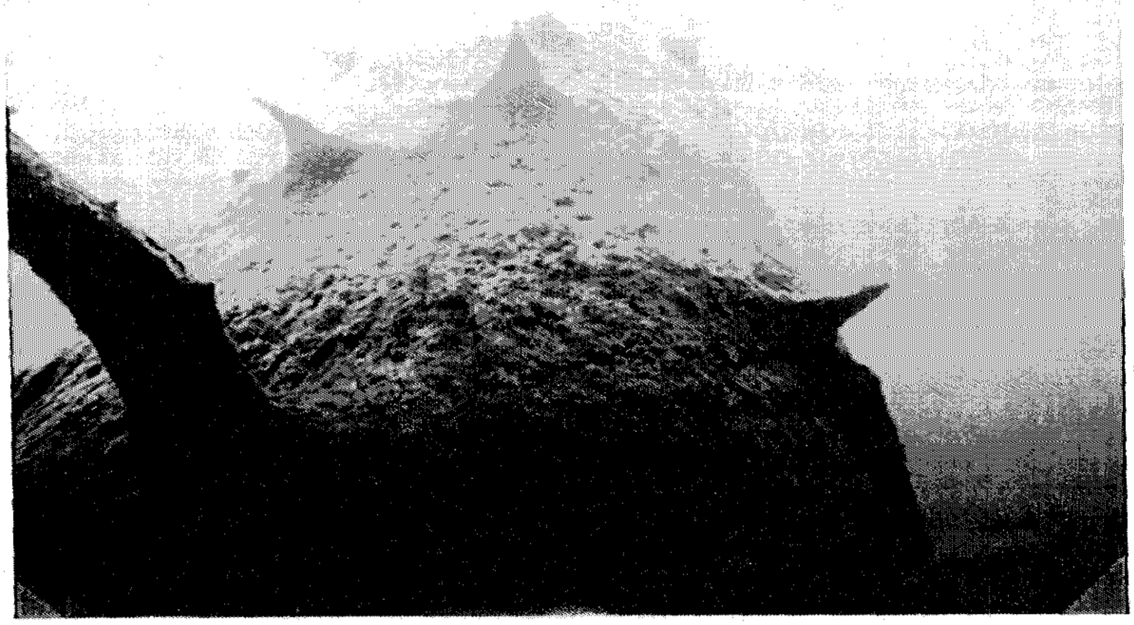


Lake Tahoe Historic Monthly Releases and End of Month Elevation

(1900 - 1997)



(a) Diver Showing Location of the Tree



(b) Photo of Submerged Tree - by Permission of Alpen Group

Figure (5) Rooted Tree Submerged in Fallen Leaf Lake

There is some existing storage capacity available in the Truckee River System, however it was taxed to the limit during the most recent "dry spell" of 1987-1992 and the flood of 1997. The main problem now is to determine a way by which one could increase storage and/or better use the existing storage. The following options merit further study [12]:

- Increase the heights of the existing dams on Stampede, Boca, Prosser, Martis and Independence Reservoirs. Accomplish these changes after careful study of the potential impacts on the areas surrounding each of these reservoirs. There appears to be minimum development in place at each of these at the present time.
- Widen and deepen the narrow outlet at the head of the Truckee River where it exits Lake Tahoe. That is, to simply widen and deepen (by 1 m) the narrow outlet and make the new operating range of the lake level vary between 1,898 m (6,228 ft) and 1,896 m (6,220 ft). The wider dam would allow water to be "dumped" out of Lake Tahoe more quickly during the events where the lake is used for flood control. The impact on Lake Tahoe itself would be minimal since currently the overall change in elevation is approximately 2 meters out of the average 1200 foot depth or a 1/2 of one percent change. Note that this compromise solution may satisfy many of the concerned parties because the lowering of the lake level would also help to minimize shorezone erosion and help to improve the clarity of the Lake, Figure (6).
- Form a Water Management District (WMD) that would be responsible for the design, construction and operation of the entire Truckee River System. The WMD would be responsible for the entire Truckee River System. This would include the planning, construction and operation of all of the data sensors, telemetry and computer modeling. Also included would be emergency operations during both dry and wet cycles. The WMD would have the ability to measure, telemeter and model the Truckee River System data in near "real time". Combining the data with National Weather Service information would also provide an early warning system in the event there is a flood danger. The WMD would be responsible for reservoir operations, tributary runoff, streamflow data, and all other relative matters during dry spells as well as flood periods.

HOW CAN A MICROCOSM HELP?

The problems of the Lake Tahoe Basin are social, political, economic and finally scientific in nature. Research at Fallen Leaf Lake can provide some fundamental help in the development of concepts, methods, instrumentation, monitoring approaches and models that will help to understand, quantify, and help to guide the entire Lake Tahoe Basin in its future growth patterns.

There is a great deal of knowledge to be gained from applying modern instrumentation to monitor the Fallen Leaf Lake watershed. An automated, integrated instrumentation and telemetry system would complement manual data collection efforts and provide real-time information of snowpack, lake level, and streamflow. The data collected would aid in developing a hydrological computer-model of the Fallen Leaf Lake watershed. A computer model would enhance the analysis, understanding, and management of the lake system. Better understanding of the lake system dynamics would aid the Forest Service in maintaining the functionality, ecology, and aesthetics of the lake. Homeowners would benefit from improved flood forecasting resulting in reduced flood risks. Real-time data combined with a working hydrological model would be an invaluable tool for managing and administering Fallen Leaf Lake. The Truckee River flooding of January 1997 dramatically demonstrated the consequences of inadequate instrumentation and the lack of a working computer model of area watersheds. There is a need for automated data collection and telemetry. The experience gained from instrumenting and telemetering the Fallen Leaf Lake System could be extended and applied to other watersheds around the country.

A major obstacle to deploying a data collection station in the Fallen Leaf Watershed is the prohibition by the Wilderness Act of manmade structures and equipment within a wilderness area. The restriction is enforced to preserve the natural character of the area. To conform to the Wilderness Act, an artificial pine tree is being developed at the University of Nevada, Reno. This "tree" camouflages the data collection and telemetry equipment, thus allowing it to be installed in sensitive areas. It also minimizes theft and/or vandalism at remotely located sites. There are a number of new innovations being incorporated into this "tree", Figure (7), including:

- a new gamma sensor that can measure snowpack water content [15],[16];
- novel, "invisible" antenna designs that allow use of standard SNOTEL and GOES type data collection telemetry systems;
- specially designed air cell (zinc/air) / lead acid battery pack to replace the solar panel;
- an ultrasonic snow depth sensor to measure snowpack depth and provide density measurements;
- an innovative "dumb waiter" system to provide wintertime access for maintenance.

Unlikely allies want lower Lake Tahoe

■ Property owners, environmentalists agree: High water degrades clarity.

INSIDE

■ Battle brewing: Environmentalists likely to fight lifting ban on new piers.
■ Below surface: Lake Tahoe hosts variety of fish.
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By Jeff DeLong
RENO GAZETTE-JOURNAL

Lake Tahoe is too full and its water level should be lowered to help reverse the loss of the lake's famous clarity, members of an advisory panel insist.

An unlikely coalition of environmentalists and property rights advocates will ask the Tahoe Regional Planning Agency to explore options to lower the lake's level. Among them: Reconstructing the Truckee River dam at Tahoe City.

Flowing from Lake Tahoe, the Truckee River is the primary water supply for Reno and Sparks and an important source for downstream farmers. Any move that might reduce that water supply would have profound consequences and spark major controversy.

Brimming with snow melt, the lake is now lapping at exposed earthen slopes in the Tahoe Basin. Resulting erosion washes dirt into the water, contributing to the algae growth that is causing Tahoe's clarity to drop more than a foot each year.

The situation is unacceptable, say some members of a group now meeting to iron out regulations affecting Tahoe's shoreline.

"It's an environmental disaster of monumental proportions, and TRPA is not addressing it," said Gregg Lien, an attorney representing private property interests for the Tahoe Shorezone Partnership Committee.

Lien plans to join with a frequent adversary — the environmentalist organization the League to Save Lake Tahoe — in approaching TRPA's governing board, possibly next week. Jan Brisco, representing lakefront homeowners, also supports lowering the lake level.

With government spending millions of dollars trying to control erosion into the lake, lowering the lake's water levels could be a beneficial step, said Jeff Cutler of the League to Save Lake Tahoe.

"That's what they really need to do — lower the lake," Cutler said. "The high lake level is doing water quality damage, and that's against the law."

Cutler said he believes the level should be lowered to within a couple of feet of the lake's natural rim at 6,223 feet. The dam at Tahoe City now raises water levels many feet above that. Heavy rains in January boosted lake levels beyond the maximum legal limit of 6,229.1 feet.

Federal Water Master Garry Stone declined to comment on the proposal other than to say such a change would require an amendment to the 1935 Truckee River Agreement. The pact dictates how Tahoe's water is managed, including a requirement that water storage at the lake be kept sufficiently high for downstream users. Hearings in federal court would likely be necessary. "There would certainly be some complications," Stone said.

Lowering Tahoe's water level would not necessarily diminish storage capacity for Reno and other downstream users, Lien said. The Tahoe City dam could be rebuilt so flows to the Truckee River could begin when water levels are below the lake's natural rim. The maximum lake level would be dropped by the same amount.

"The lake's now only managed for purposes of water supply," Lien said. "It's about time we start managing it for environmental reasons."

Figure (6) Article from Reno Gazette-Journal, April 16, 1997

(a) Natural Tree (Dead) on the Shore of Lake Tahoe

(b) Model of the Fake Tree Being Developed by the University of Nevada, Reno
Figure (7)

CONCLUSIONS

The Lake Tahoe Basin is a complex eco-business system that involves social, political, economic, as well as scientific elements and their interactions. The challenge at hand is to:

- develop the broadest models possible to help understand, define and manage the problems facing Lake Tahoe;
- formulate solutions to the problems that have been defined and quantified;
- create a regional economic base and the methods of funding needed to implement and manage the long term solutions.

Fallen Leaf Lake has been shown to be an important microcosm of Lake Tahoe. It is a "real world" working model of Lake Tahoe that can be effectively used to develop concepts, methods, instrumentation, monitoring approaches and complex models that are essential to understanding and solving problems throughout the Lake Tahoe Basin. An important part of this hypothesis is the role that hydrology plays in the overall system. It has been shown that research being conducted in the Fallen Leaf Lake watershed will be applicable to Lake Tahoe, including the development of new sensor technology.

It is also very important to develop a plan whereby local residents who have a "stake" in the Lake Tahoe Basin can serve as "citizen samplers". The "buy-in" by these residents provides them with a first hand knowledge of the problems and proposed solutions. This helps create the broad public support needed to successfully raise money and effect solutions. This plan is now being developed at Fallen Leaf Lake and will be extended to Lake Tahoe as it matures and the "bugs" are worked out.

The "bottom line" is the fact that if problems cannot be solved on the smaller scale of Fallen Leaf Lake, then it is doubtful they can be solved for the much larger Lake Tahoe.

ACKNOWLEDGEMENTS

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