United States
Environmental Protection
Agency

Environmental Monitoring Systems
Laboratory
Las Vegas NV 89114

Research and Development

EPA-600/S4-81-026 Apr. 1981

EPA

Project Summary

Meadowland Natural Treatment Processes in the Lake Tahoe Basin: A Field Investigation

F. A. Morris, M. K. Morris, T. S. Michaud, and L. R. Williams

An area planning agency for Lake Tahoe suggested that natural treatment processes in stream environment zones could be used to control nutrients and sediment flowing toward the lake. The purpose of the study was to measure the amount of constituents filtered from runoff water by natural processes; the study was a survey of existing conditions only, and no attempt was made to alter those conditions.

Samples were collected from seven tributary systems in the South Lake Tahoe area and analyzed to determine nutrient and sediment load before, during, and after storm episodes, and during seasonal weather changes.

All sheet-flow systems demonstrated filtration of pollutants and sediments to some extent; however, variables such as beaver dams and livestock grazing together with storm episodes yielded inconsistent results. It was concluded that sheet flow can be an effective way of treating runoff waters, and that ponding of runoff waters can also reduce chemical and sediment loads.

It was recommended that further study of the tributary systems be undertaken to determine impact of several untested variables, and that a test be initiated to determine the feasibility of diverting stream flow to sheet flow to enhance natural filtration processes.

This Project Summary was developed by EPA's Environmental Monitoring Systems Laboratory, Las Vegas, NV, to announce key findings of the research report that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The clear water of Lake Tahoe in Northern California is currently in danger of being clouded and muddied by surface water runoff from land development and construction activities in foothills surrounding the lake. Only two other lakes in the world have water as clear and clean as Lake Tahoe: Crater Lake in Oregon and Lake Baikal in the Soviet Union. Maintaining the clarity of Lake Tahoe for future generations of Americans to enjoy is currently a top priority of regional, state, and federal interests and the subject of continuing attention by the representatives of those interests. Regional planning agencies are charged with responsibility for making decisions about the future handling of surface waters entering the lake, as the nutrients and sediments they carry are the greatest current danger to the purity of the lake water.

Background of the study. The study was conducted at the request of the U.S. Environmental Protection Agency in San Francisco (Region IX). The results

are to be used by the responsible agencies to develop an Areawide Waste Treatment Management Program for Lake Tahoe. The management program was mandated by passage of the 1972 Federal Water Pollution Control Act, Section 208 (Public Law 92-500).

The Problem. The great volume of water in Lake Tahoe could effectively dilute large amounts of nutrients and sediment if the lake waters were totally mixed. However, increased algal growth in waters near the shore had been observed.

An area planning agency had suggested that natural treatment processes in stream environment zones (e.g., marshes, meadowlands, watercourses, drainageways, and floodplains) could be used to control nutrients and sediment flowing toward the lake. A field investigation was needed to evaluate changes in the quality of runoff waters as they passed through meadowlands.

Purpose of the study. The purpose of the study was to measure the amount of nutrients and sediments in water (1) entering and leaving natural meadowlands around Lake Tahoe, (2) at the outlet of streams draining into the lake, and (3) at sites along those streams. In addition, stream depth, width, and water velocity were measured, and air and water temperatures at each study site were recorded. Special studies were undertaken to obtain additional information from the area. The runoff from roads in the winter was studied to determine the nutrients being washed from roadways. Volcanic cinder, used as a road abrasive in winter, was studied for its nutrient contribution. In a special study for the U.S. Forest Service, the amount of pollutants in Tallac Lagoon and its main tributary were measured. Finally, a special study of a specific site on the Trout-Cold Creek stream system was undertaken in an attempt to pinpoint the source of severely elevated levels of nitrogen compounds discovered during the course of the study.

Description of the Study Area

The Tahoe Basin is located on the California-Nevada border. Two-thirds of the Basin is in California, and one-third is in Nevada.

The striking beauty of the Basin resulted from earthquake faulting activity which dropped the floor of the Basin and raised the surrounding mountains. The steep-sided depression formed by the earth movements filled with water, resulting in Lake Tahoe.

The surface area of Lake Tahoe is 122,000 acres; the surface area of the surrounding land is 202,000 acres. About one-half of the land surrounding the lake has a slope steeper than 20 percent. Most of the 45,000 acres of land with a slope of 10 percent or less is located at the south end of the lake.

The natural level of the outlet of the lake at Tahoe City is 6,223 feet above sea level. A low dam provides regulation of the lake level for water storage. The total amount of water in the lake subject to regulation is about 745,000 acre-feet.

Runoff from rainfall and snowmelt travels into Lake Tahoe through 64 separate watersheds of varying types. These tributary streams provide the link between land and soils, and the water quality of the lake. Stability of the soils over which the water courses vary, with very unstable granitic soils susceptible to erosion on the south and east, and more stable volcanic and metamorphic solid soils in the north and west. Because the soils surrounding the lake tend to be sterile, and the growing season short, vegetation is difficult to reestablish if it is disturbed by land development.

Theoretical Assumptions Underlying the Study

Studies of the effect of water flowing over meadowlands have shown that stream environment zones can provide a natural barrier to sediment. Other studies show that nearly all phosphorus and most nitrogen in surface runoff is attached to sediment. Therefore, by removing the sediment, most of the nutrients should also be removed.

Research Questions

Data were collected to provide answers to the following questions:

1. Does runoff water in Lake Tahoe Basin show decreased amounts of sediments and plant nutrients after crossing natural meadowlands?
2. How does change in loading and flow rate affect the natural treatment?
3. Does algal growth in nearshore waters reflect nutrient contributions from tributary streams?
4. Is runoff from roads a major source of nutrients for the Lake Tahoe tributary system, and does volcanic cinder contribute further to nutrient loading?
5. Does the quality of water change as it flows through Tallac Lagoon and its major tributary?
6. What is the source of elevated levels of nitrogen in Trout Creek?

Procedure

Sample sites and collection of data. Sites for collection of water samples were established as shown on the Figures 1 and 2. Key to the location symbols on the maps is as follows:

- Site A - Trout Creek
- Site B - Upper Truckee River (less than 1 year of data)
- Site C - Angora Creek and Sawmill Road Drainage
- Site D - Tallac Creek
- Site E & F - Blackwood Road Drainage and Chonokis-Glen Road
- Site G - Tallac Lagoon (less than 1 year of data)
- Sites LL1 and LL2 - Lake Tahoe Nearshore (unimpacted control area)
- Site DL1 - (Nearshore, Off Tallac Creek)
- Site BL1 - (Nearshore, Off Upper Truckee)
- Site EL1 - (Nearshore, Blackwood Drainage)

Sites for collection of water samples were established along seven stream tributary systems (A through G above), consisting of four streams and three meadowland drainage areas. Stakes were placed at the sampling sites to ensure that measurements were taken in the same location during the sampling period. Data collection sites were established in five locations along the shore of Lake Tahoe, three in impacted areas affected by tributary streams and two in unimpacted areas.

Samples were taken from September 1977 through August 1978; however, some sample sites were added after the study began and less than a full year of data were collected at those sites. Samples were taken at biweekly intervals during the winter and weekly intervals during the rest of the year. Winter lasts approximately 6 months in the Tahoe region.

Methods of analysis. Water samples were analyzed to determine levels of

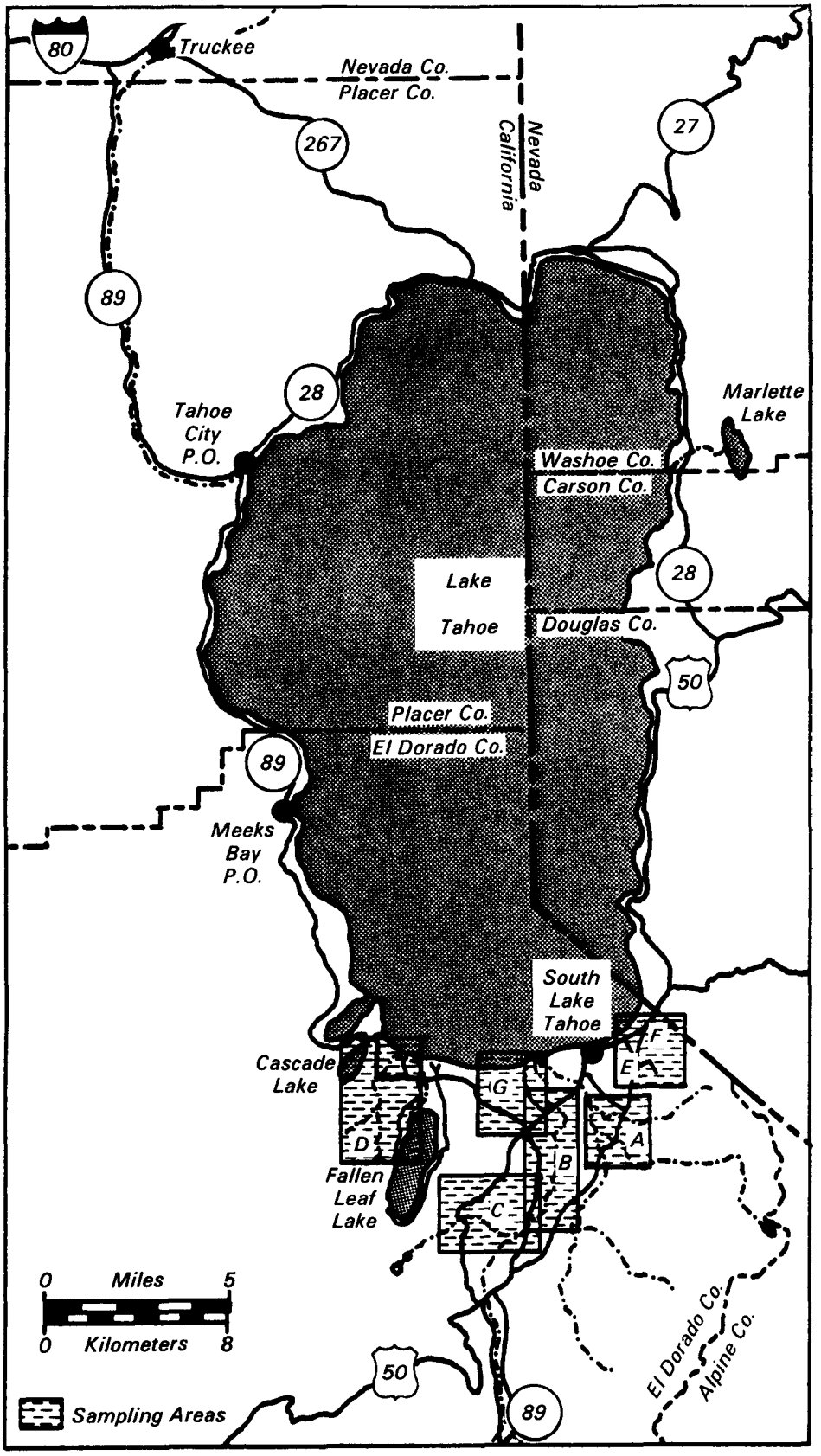

Figure 1. Lake Tahoe meadowland sampling system locations.

(1) nitrogen, phosphorus, and carbon nutrients; (2) chlorophyll *a* and fecal coliform; (3) pH, alkalinity, conductivity, residue, dissolved oxygen, and turbidity. The techniques used for analysis of water samples followed procedures from *Standard Methods for the Examination of Water and Waste Water* (APHA, 1975) and *Methods for Chemical Analysis of Water and Wastes* (EPA, 1974). Where comparison was desired, results were tested for significance using a standard one-way analysis of variance. Significance was determined at the .05 level of confidence. The data were entered in STORET, a computerized water quality data base.

Limitations of the study. Variables not tested include: (1) percent vegetation cover; (2) beaver dams; (3) ground frost; (4) snow cover; (5) sheet flow; (6) pollutant sources; (7) soil type; and (8) effect of livestock grazing. The study was delimited to marshlands or meadowlands in the South Lake Tahoe area through which water is impacted by a variety of land-use sources. The study was a survey of existing conditions, and no attempt was made to alter those conditions.

Results

All sheet-flow systems demonstrated filtration of pollutants and sediments to some extent; however, variables such as beaver dams and livestock grazing together with storm episodes yielded inconsistent results.

Site A - Trout Creek. Substantial reductions in concentrations of pollutants and sediment occurred in that portion of the stream and its tributary, Cold Creek, which entered sheet flow. The upper portion of both creeks is channelized. After the two streams converge, the flow toward the lake is impeded by beaver dams that cause about 50 percent of the water to leave the channel boundaries and flow across meadowland. Seasonal trends indicated fair to excellent reductions of all constituents except ammonia-nitrogen. The greatest reductions were noted during fall and winter when the beaver dams were intact. The percent of change in the levels of sediment and nutrients in Trout Creek during storms provides evidence of its capacity to absorb large, sudden loads of pollutants.

Site B - Upper Truckee River. This system contributes 23 percent of the annual runoff into the lake. This site was added to the study in June of 1978

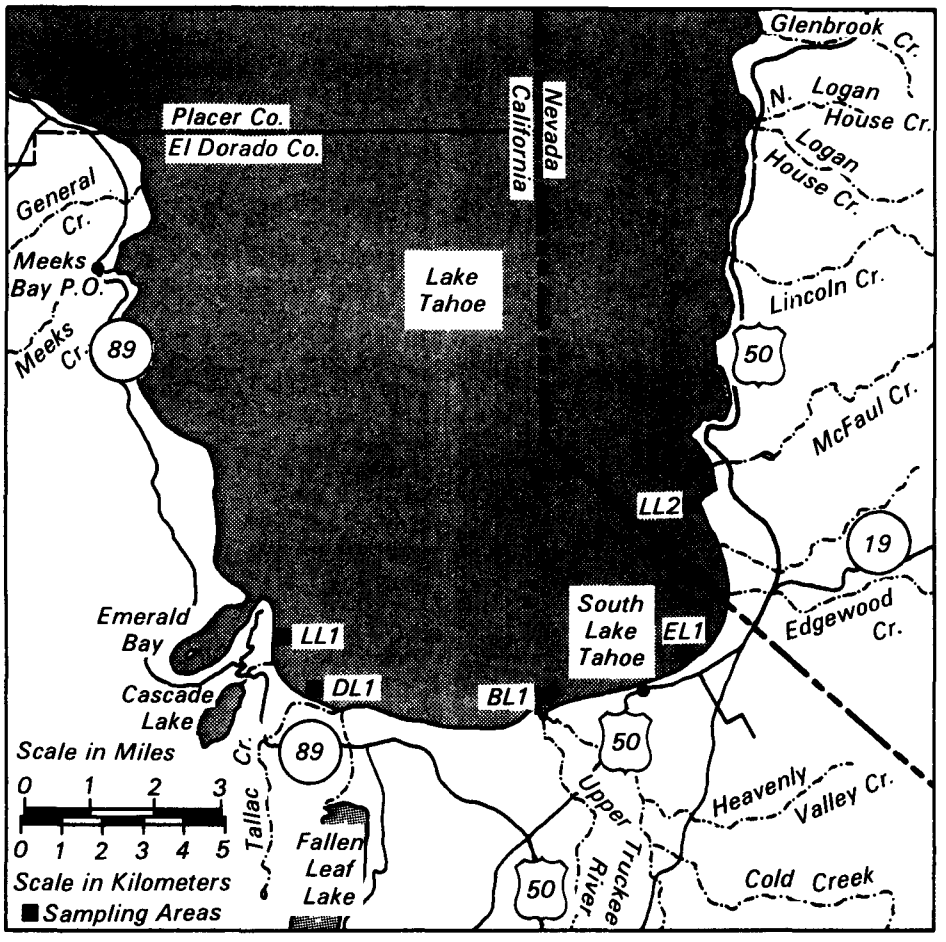

Figure 2. *Lake Tahoe nearshore sampling sites location map.*

to determine if the large meadow associated with it was responsible for any filtering action. The stream remained channelized through the data collection period A slight reduction in particulate organic carbon was noted. All other parameter values increased during all observations.

Site C - Angora Creek and Sawmill Road Drainage. Substantial contributions of surface water runoff entered Angora Creek meadowland system between the two sample sites, doubling the flow. Sediment and nutrient loading increased up to four times at the second downmeadow sample site. All constituents showed mean seasonal increases or no change in concentration between sample sites. The streams remained channelized except during storm episodes, when reductions in nutrients and sediment were observed.

The Sawmill Road Drainage is comprised entirely of snowmelt runoff from a small, isolated area, and flowed only from March 1978 to May 1978. Concentrations at the inlet to the meadowland system were usually below the detection limits of the analyses.

Site D - Tallac Creek. The upper reach of Tallac Creek flowed the entire year. Groundwater contributions from numerous springs increased the annual flow by 88 percent, which was not monitored. Filtering efficiency of the channelized portion of the stream was at least partially due to the result of this dilution by spring water. That portion of the Creek which traveled in sheet flow across a meadowland showed large net increases in nutrient and sediment concentrations. This meadowland is used for grazing during the snow-free period of the year and animals have caused extensive disruption of the ground surface and vegetation cover. However, this meadowland system consistently removed all nitrate and nitrite-nitrogen overloads during episodic flows.

Sites E and F - Blackwood Road Drainage and Chonokis-Glen Road Drainage. Blackwood Road Drainage system consistently showed substantial reductions of sediment and nutrients after passing as sheet flow over meadowlands. In all measurements, even during episodes of high runoff, this system consistently filtered between 70 and 97 percent of sediment alone from the water. In addition, all nutrients tested showed a considerable reduction in concentration after sheet flow.

The Chonokis-Glen Road Drainage system had limited flow during the study. Some pollutants were below the limits of analytic detection as water entered the sample site; however, organic carbon, suspended solids, and specific conductance were reduced within the meadowland.

Site G - Tallac Lagoon. Tallac Lagoon is located south of a residential development and was included late in the study to provide information to the U.S. Forest Service about the treatment capabilities of the lagoon. The lagoon is lined by vegetation and water ponds within its boundaries. Results from the limited sampling showed reductions of sediment, nutrients, and turbidity.

Sites LL1 and LL2 - Lake Tahoe Nearshore (unimpacted); and Sites DL1, BL1, and EL1 (impacted). Nearshore sampling yielded variable data within and between stations; however, there were no significant differences in the constituents in the water between impacted and unimpacted lake areas.

Street runoff. Results of the study of street runoff indicate that roadways contribute high levels of nitrogen, and volcanic cinder adds high levels of phosphorus to the runoff waters.

Air and water temperature, storm incidence, and stream flow. These results can be found in the study from which this summary was written.

Discussion

Of the systems that exhibited sheet flow, only Blackwood Road Drainage and, to a lesser extent, Trout Creek and the Chonokis-Glen Road Drainage system demonstrated reductions in sediments and pollutants after meadowland sheet flow. Tallac Lagoon demonstrated reductions primarily due to the ponding of water. Since nearly all phosphorus and most nitrogen in surface runoff is attached to sediments, the removal of suspended solids results in the removal of these constituents

from the water. Adsorption to clays and other substances can also contribute to organic carbon losses.

The reduction of the constituents in the water flowing across meadowlands in the Tahoe Basin can be credited both to sedimentation and to the interaction of the soil-water complex. The oxidized layer of submerged soils in the meadowland acts as a chemical trap for phosphorus, iron, and silicon. Other researchers note that the oxidized and reduced layers together cause a loss of nitrogen in its usable forms and suggest that in the case of orthophosphorus, the rate of sorption by the sediments decreases with decreasing concentration of overlying water; therefore, the efficiency of the meadowlands in constituent removal would be greatest when the concentrations of the constituents are highest.

All meadowlands with sheet flow that had measurable amounts of nitrate and nitrite-nitrogen exhibited significant reductions of this constituent; however, the filtering efficiency dropped off dramatically during the high flows accompanying rainstorms. Since nitrate and nitrite-nitrogen is a dissolved fraction and is not readily adsorbed to the soil surface a biological mechanism for reduction is suggested.

The nearshore lake sampling resulted in a limited data base. A one-way analysis of variance was not significant between stations when tested at the .05 level of confidence. The results suggest that nearshore lake stations are homogeneous with relation to most parameters. Goldman has stressed the importance of continuous monitoring of tributary and nearshore waters utilizing measures of primary productivity and heterotrophic activity. Data suggest that within the littoral zone of Lake Tahoe the impacts due to tributary inputs are dispersed over short periods of time and short distances to create a relatively homogeneous nearshore environment.

Conclusions

Because consistent reduction in nutrients and sediment was not demonstrated during all seasons, the results of the study are inconclusive. Instances of sheet flow enhancing the reduction of sediments and nutrients occurred, showing the probability that sheet flow can be an effective way of treating runoff waters. Ponding of runoff waters was also effective in reducing chemical and sediment loads.

Recommendations

It is recommended that further study of the tributary systems to Lake Tahoe be undertaken to determine the impact of the untested variables on the reduction of constituents in the water entering Lake Tahoe. In addition, the feasibility of converting channelized streams through meadowlands to sheet flow should be determined, and overload capacities and functional longevity of meadowland treatment systems should be tested. The nature of treatment processes within basin meadowlands should be studied.

For purposes of determining subtle differences in the littoral zones of Lake Tahoe nearshore waters, an extensive network of sampling stations consisting of several transect sites to address littoral drift patterns should be included in future studies.

F. A. Morris and M. K. Morris are with the Department of Biolgoical Sciences, University of Nevada, Las Vegas, NV 89154 and ***T. S. Michaud*** *and* ***L. R. Williams*** *are EPA authors with the Environmental Monitoring Systems Laboratory, Las Vegas, NV 89114.*

L. R. Williams *is the EPA Project Officer (see below).*

The complete report, entitled "Meadowland Natural Treatment Processes in the Lake Tahoe Basin: A Field Investigation," (Order No. PB 81-185 639; Cost: $15.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Environmental Monitoring Systems Laboratory
U.S. Environmental Protection Agency
P.O. Box 15027
Las Vegas, NV 89114

☆ U.S. GOVERNMENT PRINTING OFFICE: 1981-757-012/7089

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Postage and
Fees Paid
Environmental
Protection
Agency
EPA 335