pg 34 – Three basins – Three lakes

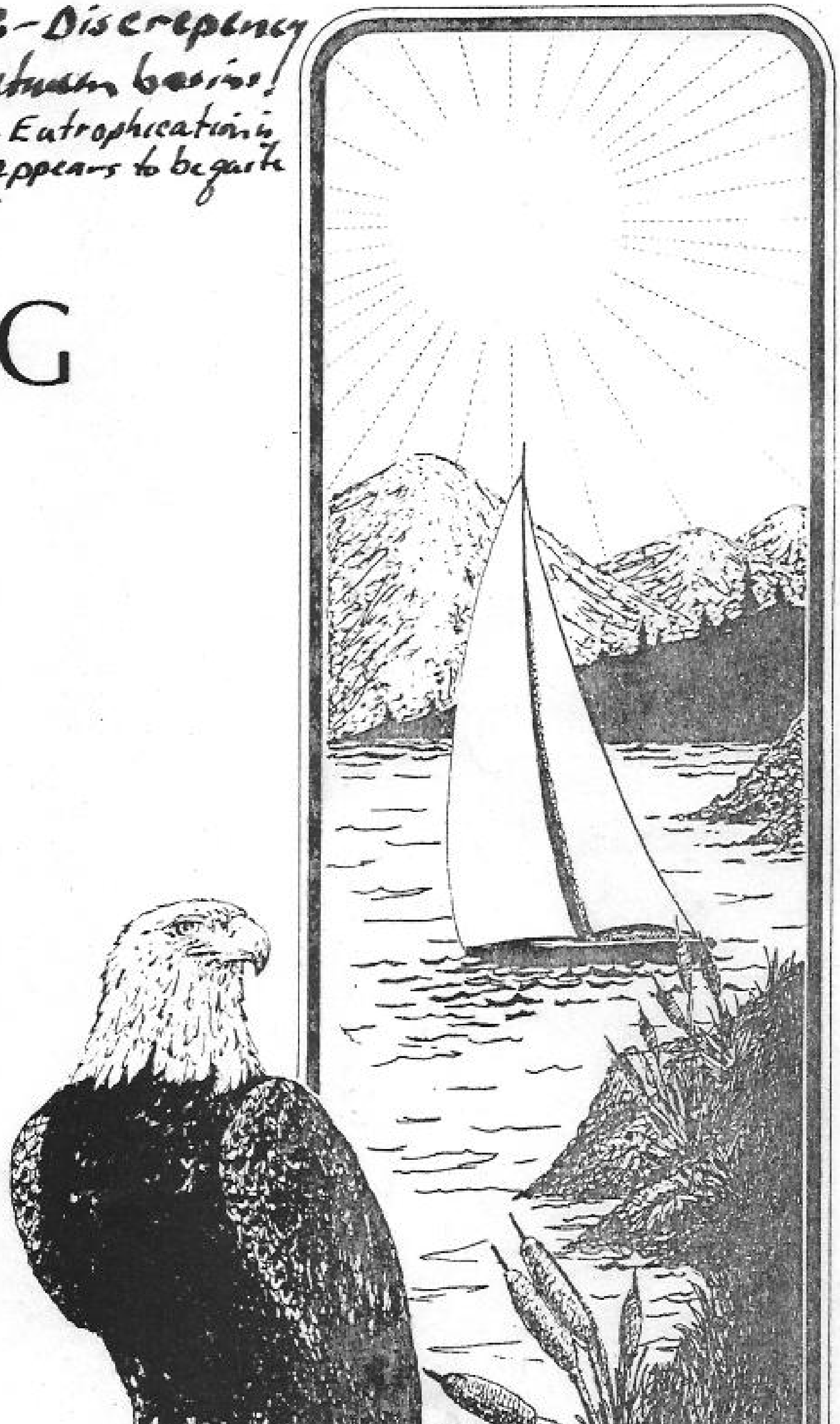
EAGLE LAKE BASIN PLANNING STUDY

pg 38 – Discrepency between basins!

pg 40 – Eutrophication is now appears to be quite slow –

volume 5

Eagle Lake Limnological Analysis



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RAYMOND VAIL AND ASSOCIATES

EAGLE LAKE BASIN PLANNING STUDY

VOLUME V

EAGLE LAKE

LIMNOLOGICAL ANALYSIS

Prepared By

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Sacramento, California

August 1979

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I. EAGLE LAKE OVERVIEW

Eagle Lake, located within the ancient, Pleistocene Lake Lahontan drainage system, is situation in a vaulted, volcanic basin. Originally, Eagle Lake was formed by tectonic shifting of the earth's crust; however, the present size and configuration of Eagle Lake is due to Holocene (recent) lava flows which blocked its drainage into the Willow Creek Valley (see Volume 2).

The lake has no natural outlet and fluctuates with variations in the hydrologic budget. The maximum water surface elevation recorded in 1916 was 5,125 feet (1,562 m) above mean sea level when it had a surface area of approximately 29,000 acres (11,900 hectares). The minimum elevation recorded in 1937 was 5,092 feet (1,552 m) when it covered only 16,000 acres (6,400 hectares). The lake varies in width from one-half mile (0.8 km) to 4 miles (6.5 km) and is presently approximately 13 miles (20.8 km) long. Two narrow channels separate the shallow central and north basins from the deeper south basin. Currently (at a surface elevation of 5,106 feet), the water depth in the north basin averages 13 feet (4 m), the central basin 17 feet (5 m), and the south basin 50 feet (15 m) with the deepest point approximately 98 feet (30 m). The figure on the next page shows the general shape and depths. More information on surface elevations may be found in the Hydrology section.

The surface elevation of Eagle Lake is determined by the amount of water recharging the lake minus that which is lost by evaporation, ground seepage, and leakage through the Bly Tunnel plug. Preliminary analyses of the Eagle Lake basin hydrologic budget indicate that during the period 1957 - 1969, ground water inflow accounted for 20 to 66 percent of the total budget.[1] Other studies indicate that during the period 1970 - 1973, ground water accounted for an average of 70 percent of the inflow and the remaining 30 percent was due to direct precipitation in the lake and surface runoff from the tributary watershed.[2] The total Eagle Lake Basin is approximately 438 square miles. The average annual pre-

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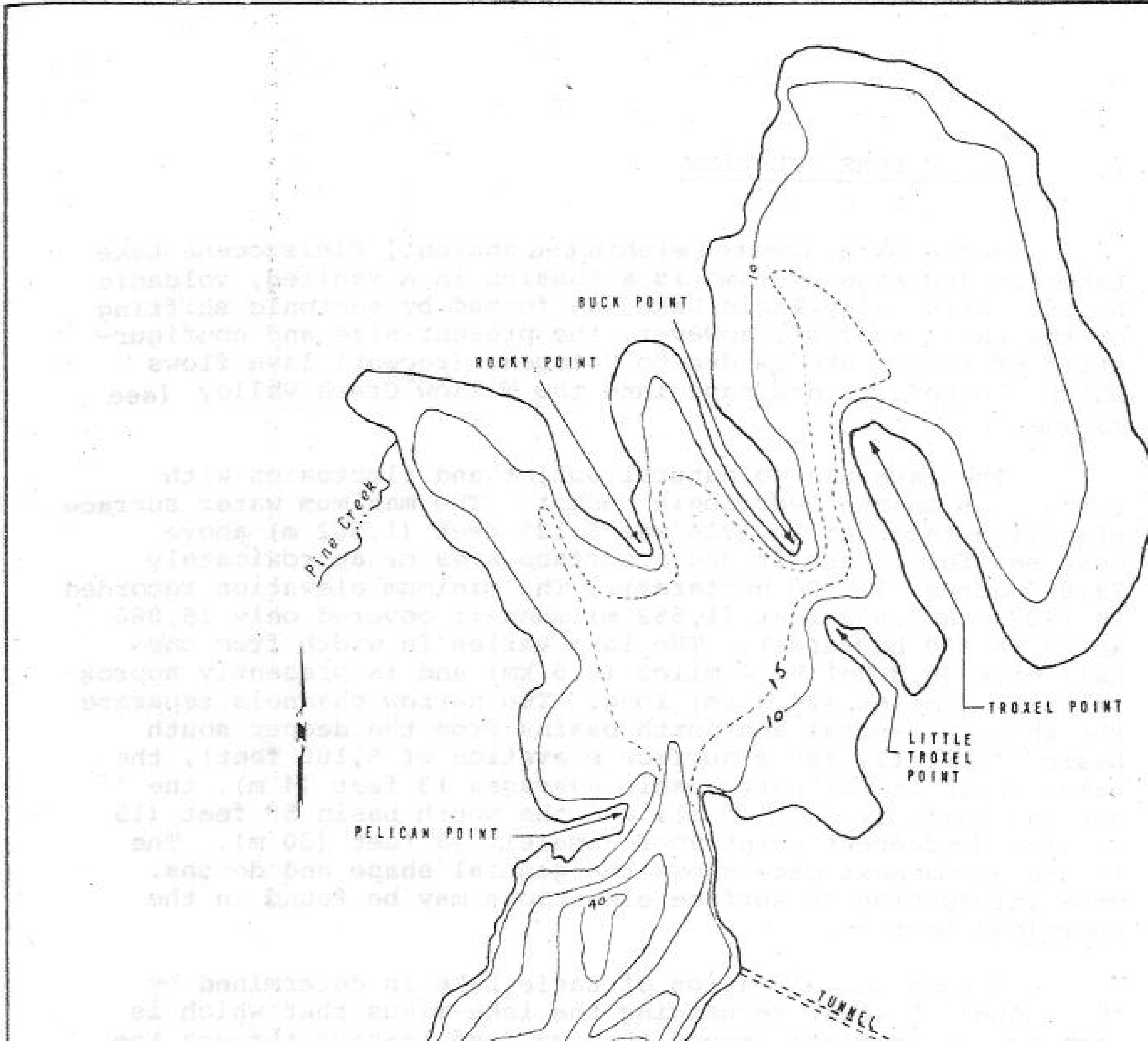
(1) Behnke, Jerold J., A Preliminary Hydrologic Analysis of Eagle Lake.

(2) Eagle Lake Limnological Data and Nutrient Study, California Department of Water Resources, December 1974.



Bathymetric Map of Eagle Lake

cipitation within the watershed ranges from 50 inches± at the west side to 16 inches± at the east side and an average of 18 inches± over the lake surface. The average annual gross evaporation has been estimated at 42 inches±. (1)

At the present time, Pine Creek is the major stream which is tributary to Eagle Lake with minor contributions from Papoose Creek and Merrill Creek. Pine Creek has its source in Stephens Meadow. The upper 7-mile section downstream to Highway 44 is a live, cold, mountain stream which flows year-round and averages approximately 8 feet wide and 1 foot in depth. The bottom composition is mostly pebbles and gravel with occasional silted areas. It has been reported that viable populations of eastern brook trout *(Salvelinus fontinalus)* and rainbow trout *(Salmo gairdnerii)* inhabit this section. The lower section of Pine Creek is an intermittent stream that normally flows into Eagle Lake for approximately three months during the spring. Pine Creek drains an area of approximately 225 square miles.

Prior to man's intrusion into the Pine Creek watershed, mature Eagle Lake trout would migrate 28 miles upstream to the headwaters and principal spawning grounds. However, natural spawning in Pine Creek has now been virtually eliminated. The watershed has been so severely altered by logging, grazing, agricultural water diversions, and associated activities that it is no longer a suitable spawning and nursery area for Eagle Lake trout. (2) The spawners can no longer successfully reach the spawning grounds in sufficient numbers to assure continued survival. Without the hatchery and planting efforts of the Department of Fish and Game, Eagle Lake trout probably would have become extinct by now.

It has been reported by several "old timers" that at one time, two other intermittent tributaries were used by spawners. One is now a dry ravine passing through Stone Ranch and enters the north basin; the other is Merrill Creek. Barriers to fish migration have been constructed at the mouths of Merrill and Papoose Creeks to prevent the stranding and loss of Eagle Lake trout where there is presently little or no chance for reproductive success due to the intermittent nature of the streams. Spawning trout are also blocked by a barrier and egg-taking station on Pine Creek just above the mouth of the stream. However, spawning runs of non-game species are allowed to pass the Pine Creek barrier, but their spawning success in Pine Creek is probably very low.

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(1) Eagle Lake - Alternative Plans for Controlling Lake Levels, California Department of Water Resources, November 1972.

(2) Habitat Management Plan - Forest Fisheries, U.S. Department of Agriculture, Forest Service, 1968.

II. ECOLOGICAL INTERRELATIONSHIPS

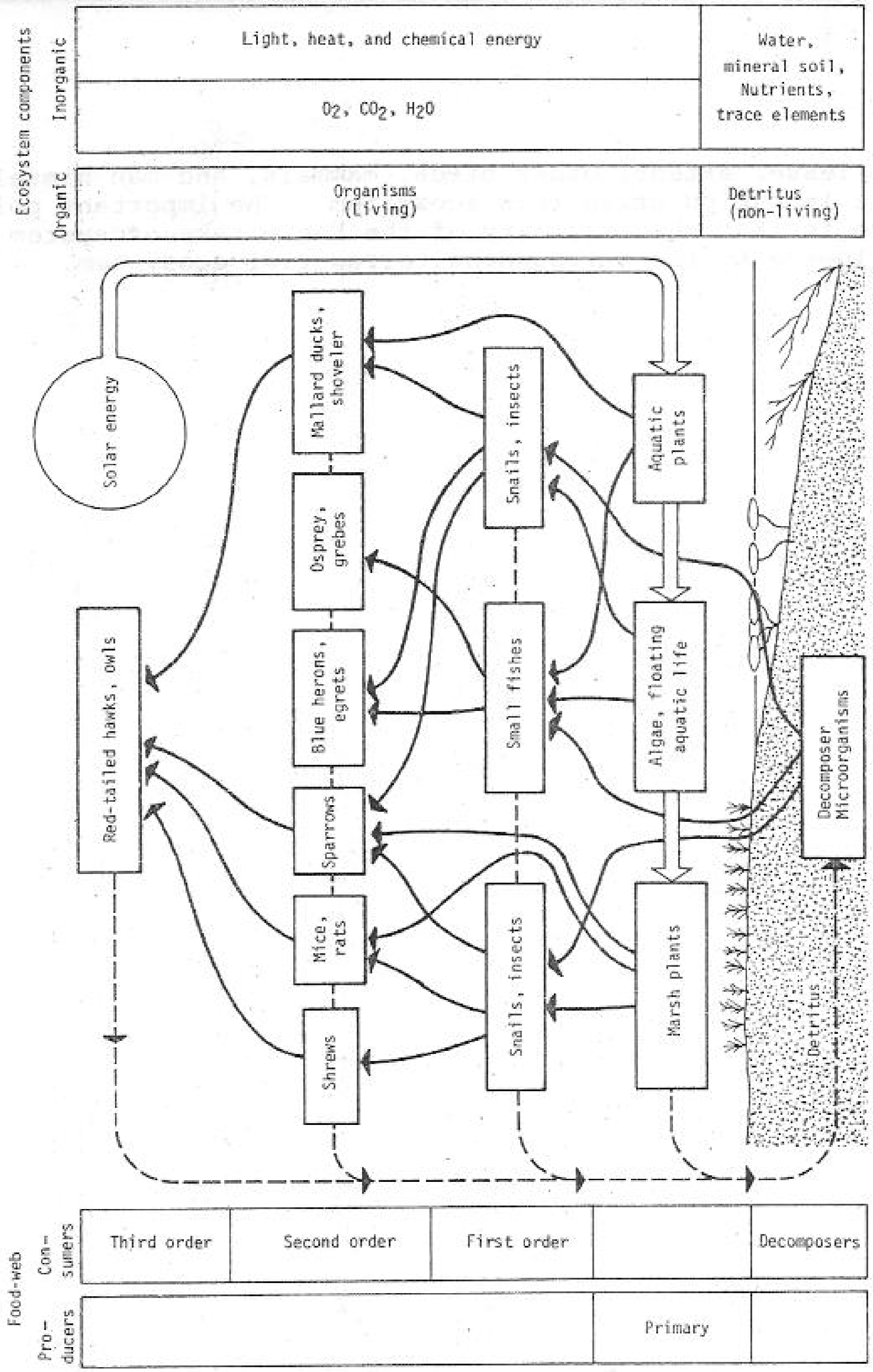
An ecosystem is the total of all relationships of the biotic (living) and abiotic (non-living) components of an environment. Biotic components include plants and animals which made up the producers, consumers, and decomposers. Abiotic components include the atmosphere, water, rock, and other materials derived from all of the above. Virtually every component of an ecosystem affects and is affected by every other component in one way or another.

Aquatic ecosystems have the same basic organization and functions as terrestrial ecosystems in that ultimately all energy which enables the system to function is derived from sunlight. This energy is repeatedly changed from one form to another by various organisms as it flows through the ecosystem until it has become completely dissipated (lost to entropy). Initially, this energy is captured by the producers (green, photosynthetic plants) and then converted to forms which are usable by other organisms. The materials necessary for this conversion include many elements and simple compounds, and are referred to as nutrients.

Nutrients enter the water from the atmosphere, soils, incoming streams, or ground water and some are transported to the water by animals. The producers assimilate these nutrients and capture sunlight to produce biomass (organic material) and oxygen, the end result of which is termed primary production. Once tied up in biomass, nutrients are no longer available to other organisms unless the producer is eaten by a consumer or the producer dies and its biomass is reduced to basic nutrients again by the decomposers (bacteria, fungi, etc.)

In the manner decribed, energy and materials are transferred from the producers through a series of organisms or trophic levels (primary, secondary, and third order consumers) with repetitions of consumption and being consumed in what is called a "food chain". To be more accurate, food chains are not isolated, linear sequences, but are interconnected with one another to form an interlocking network which is better decribed as a "food web." The figure on the next page graphically shows this series of events in a typical aquatic ecosystem.

The flow of energy and materials in the aquatic ecosystem of Eagle Lake is not completely confined to the water environment. A considerable amount of materials and energy may be transported to and from the lake by piscivorous (fish-eating) birds, the significance of which is discussed later.



Typical Aquatic Ecosystem

To a lesser extent, other birds, mammals, and man himself take part in manipulating this ecosystem. The important point here is that the viability of the Eagle Lake ecosystem is influence by the surrounding terrestrial ecosystem.

III. EXISTING CONDITIONS OF EAGLE LAKE

A. Water Quality

Since Eagle Lake is essentially a closed lake with little or no flushing (except for minor leakage through the Bly Tunnel plug), salt (or nutrient) concentrations are strongly influenced by surface elevation; the higher the surface elevation, the greater the volume, and the more dilution of dissolved salts. Consequently, past records of Eagle Lake water quality show considerable variations in chemistry as the lake level (volume) fluctuates.

The lake consists of three basins, connected by narrow channels and with considerable difference in depth between the south basin and the other two. As a result, each basin has somewhat different physical, chemical, and biological characteristics. The north basin has no appreciable surface inflow; the middle basin is greatly influenced by runoff from Pine Creek, (the major source of surface runoff for the entire lake); and the south basin is the only basin deep enough to stratify during the summer. Temperature induced isolation of surface water from bottom water is discussed in detail on pages 25-27. Variations in conductivity (an indicator of dissolved solids or salt concentrations) between the three basins and the relatively sharp changes in conductivity where basins meet suggest that the basins are well isolated from mixing and act effectively as three separate lakes. (1)

In general, Eagle Lake water can be described as a sodium-bicarbonate type that is relatively basic (high pH) and has a high total alkalinity. Water such as this is strongly buffered against changes in pH. Water hardness is moderately high largely due to an abundance of magnesium ion (Mg^{++}). The average values for alkalinity, hardness, and pH are presented below:

(1) Huntsinger, K.R. and Paul E. Maslin, "A Limnological Comparison of the Three Basins of Eagle Lake, California," California Fish and Game, 62(4): 232-245, 1976.

Alkalinity		Hardness		pH
(mg/l as $CaCO_3$)		(mg/l as $CaCO_3$)		
CO_3^{--}	HCO_3^{-}	Ca^{++}	Mg^{++}	
55	410	20	155	8.8 - 9.1

Source: K.R. Huntsinger and Paul E. Maslin

Nutrient concentrations (materials which stimulate green plant growth) are considered low to moderate; the greatest portion of which is tied up in organic forms as indicated by high plankton (microscopic organisms) growth. As soon as dissolved nutrients become available algae utilize them to produce protoplasm and in this way available nutrients usually remain fairly low. Based on samples collected during 1971 - 1973 by the California Department of Water Resources (DWR), average concentrations of two primary nutrients are listed below.(1)

	North Basin	Middle Basin	South Basin	Lake Average
Total Nitrogen (mg/l)	0.90	0.96	1.06	1.03
Total Phosphorus (mg/l)	0.03	0.04	0.05	0.05

(1) Eagle Lake Limnological Data and Nutrient Study, California Department of Water Resources, December 1974.

The following table presents a summary of other water quality parameters averaged over several years of monitoring. A considerable amount of additional water quality data may be obtained by referring to the DWR publication, Eagle Lake Limnological Data and Nutrient Study. (2)

Certain water quality tests of Eagle Lake were conducted in 1972 to determine the degree of contamination by sewage. (1) The sewage indicator tests were for coliform bacteria, chloride, and detergents. Coliform values were generally low around the lake; however, the highest values were consistently near the mouth of Papoose Creek. This was probably due to campers in the vicinity without benefit of sanitary facilities and/or cattle grazing in Papoose Meadow. The next highest values were obtained near the mouth of Merrill Creek and along the east shore between the Bly Tunnel and the Lassen Youth Camp.

The results obtained by the tests for detergents and chloride both indicated no significant contamination by sewage (detergents, less than 0.04 mg/l; chloride, 10-12 mg/l). Based on all data collected during this 1972 study, it was concluded that at that time, contamination of the lake by existing wastewater disposal systems was not sufficient to present a human health hazard. However, the use of Eagle Lake by part-time residents and campers is on the increase and conditions may be changing. The test cited investigated only sewage contamination. The effects of nutrient enrichment are discussed later in the report.

Tributary surface waters are all of excellent mineral quality, but quite different from Eagle Lake water. These waters are of a magnesium-calcium bicarbonate type that is low in total alkalinity (not well buffered) and hardness. Concentrations of chlorides, nitrates, sulfates and total dissolved solids, in general, are all in very low concentrations. Electrical conductivity measurements have been low and have never exceeded 235 micromhos. (2) Nutrient con-

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(1) Maslin, Paul, A Preliminary Analysis of Eagle Lake Water Quality, Department of Biological Sciences, California State University, Chico, 1972.

(2) Eagle Lake Limnological Data and Nutrient Study, California Department of Water Resources, December 1974.

WATER QUALITY OF EAGLE LAKE

		South Basin (mg/l)	North Basin (mg/l)
Calcium	Ca^{+2}	8.9	8.6
Magnesium	Mg^{+2}	34	36
Potassium	K^{+}	20	21
Sodium	Na^{+}	105	108
Sulfate	SO_4^{-2}	0.0	0.3
Chloride	Cl^{-}	11	11
Carbonate	CO_3^{-2}	41	67
Bicarbonate	HCO_3^{-}	418	389
Nitrate	NO_3^{-}	0.00	0.00
Phosphorus, Total		0.02	0.02
Ortho-Phosphate		0.00	0.00
Copper	Cu^{+2}	0.00	0.00
Iron	Fe^{+2}	0.04	0.03
Manganese	Mn^{+2}	0.00	0.00
Zinc	Zn^{+2}	0.00	0.01
Ammonium	NH_3^{-}	0.01	0.00
Organic Nitrogen		0.8	0.9
Dissolved Oxygen	O_2	8.1	8.3
Conductivity	μmhos/cm at 25°C	754	790

SOURCE: Maslin, Paul E. and Gerald L. Boles, "Use of a Multiple Addition Bioassay to Determine Limiting Nutrients in Eagle Lake, California," Hydrobiologia, Volume 58, 3, pp. 261-269, 1978.

centrations of incoming surface waters also average quite low and occur mainly in organic forms. The mean values for various tributary surface water quality parameters determined by the DWR in 1972 - 1973 are listed on the next page.

The Department of Water Resources estimates that Pine Creek contributes 75 percent of total surface inflow. Using this estimate, the average weighted nutrient concentration for all tributary surface waters would be 0.29 mg/l for nitrogen and 0.04 mg/l for phosphorus.

Limited data exists for the quality of ground water samples taken from wells adjacent to Eagle Lake. In general, ground waters are bicarbonate in character and have low levels of dissolved solids, total alkalinity, and hardness. The electrical conductivity of well samples have not exceeded 325 micromhos according to the DWR. (1) Seven wells located along the south, west, and north shores of the lake were sampled periodically during 1972 - 1973 and analyzed for nitrogen and phosphorus. These nutrients were found in low concentrations and mainly as nitrate-nitrogen and orthophosphate which are both readily assimilated by plants. The mean water quality characteristics for each well sampled by the DRW are listed below:

	Eagle Camp-Ground	Merrill Camp-Ground	Eagle Lodge	Eagle Lake Resort	Spaulding Tract	BLM Camp-Ground
Total Nitrogen (mg/l)	0.18	0.13	0.12	0.32	0.30	0.44
Total Phosphorus (mg/l)	0.04	0.02	0.02	0.04	0.07	0.22
pH	7.6	-	-	-	7.2	8.1
Conductivity (μmhos)	300	-	-	-	195	168
Total Alkalinity (mg/l) (as $CaCO_3$)	130	-	-	-	105	90

(1) Eagle Lake Limnological Data and Nutrient Study, California Department of Water Resources, December 1974.

MEAN VALUES FOR

VARIOUS WATER QUALITY PARAMETERS OF TRIBUTARIES

	Pine Creek	Merrill Creek	Papoose Creek	Minor Tributaries
Total Nitrogen (mg/l)	0.32	0.16	0.25	0.26
Total Phosphorus (mg/l)	0.04	0.02	0.02	0.10
Temperature (°F), spring	49	50	50	46
pH	7.8	7.2	7.5	8.0
Conductivity (µmhos)*	53	74	138	112
Turbidity (JTU units)	16	10	5	5
Total Alkalinity (mg/l) (as $CaCO_3$)	25	35	50	-

*µmhos = micromhos

SOURCE: Eagle Lake - Alternative Plans for Controlling Lake Levels, California Department of Water Resources, November 1972.

Eagle Lake Limnological Data and Nutrient Study, California Department of Water Resources, December 1974.

The average concentrations for all wells located in the Eagle Lake basin are 0.25 mg/l for nitrogen and 0.44 mg/l for phosphorus. The extent of ground water movement into the lake and the resulting nutrient enrichment is presently undefined; however, preliminary studies mentioned earlier strongly suggest substantial ground water inflow. The fact that ground water sampled from wells all about the lake is chemically different from the Eagle Lake water strongly suggests that the hydraulic head of basin ground water is great enough to cause the net movement of ground water toward the lake. (1)

B. Lake Bottom Sediments

The reconnaissance bottom sampling of Eagle Lake by the DWR has determined that there are four main types of bottom sediments under the lake. Their approximate location and extent are shown in the figure on the next page. Some isolated rock and gravel areas occur, but they are not shown on this figure due to their limited size and distribution. The four types are tufa, sand/shell/tufa, sandy silt and clay, and organic mud.

1. Tufa

Tufa is a grayish-white calcareous deposit which is acid soluble and is also known as caliche, marl, or freshwater limestone. This material may be formed organically by primitive organisms and by direct chemical precipitation of dissolved salts. Calcium carbonate, which is abundant in this sediment, plays a major role in the carbonate buffering system of Eagle Lake water.

2. Sand/Shells/Tufa

Sand/shells/tufa is a light- to dark-colored mixture of sands, snail shells, and small pieces of tufa. These materials underlie approximately 25 percent of the lake. The proportions of the three materials which make up this sediment vary considerably from place to place.

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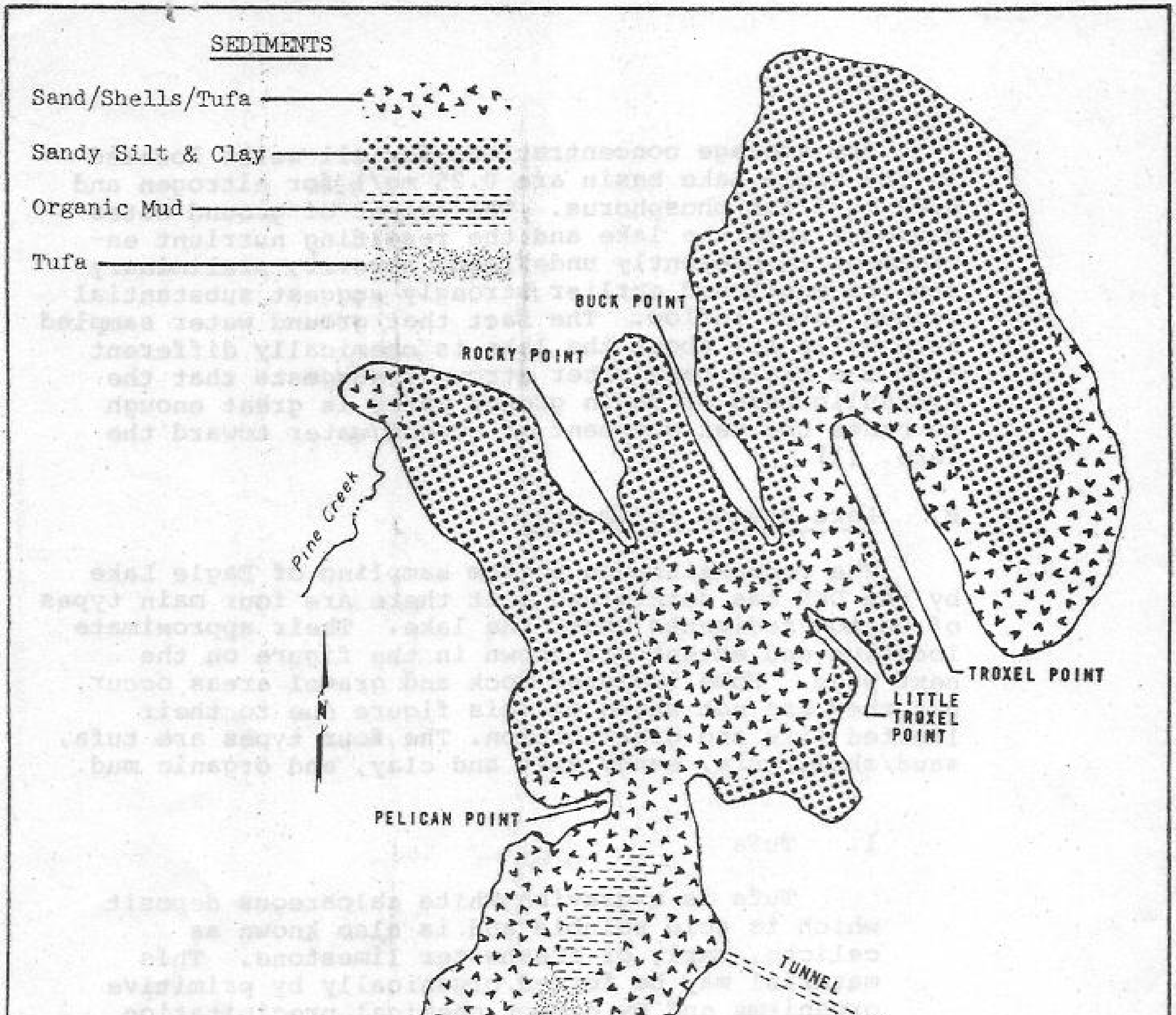
(1) Maslin, Paul, A Preliminary Analysis of Eagle Lake Water Quality, Department of Biological Science, California State University, Chico, 1972.



Sediment Distribution Map of Eagle Lake

3. Sandy Silt and Clay

Sandy silt and clay is a light-brown-colored material consisting mainly of silts and clays and with varying amounts of fine sand. This material, found predominantly in the north and middle basins, is firm in consistency when undisturbed.

4. Organic Mud

Organic mud is a dark-brown, fine-grained sediment that appears as a loosely compacted ooze with a high organic content consisting of detritus (the decaying remains of plants and animals). The material contains varying amounts of silt and clay and has a soft jelly-like consistency. Organic mud is found in the deeper zones of the south basin where the forces of wave action and currents have been dissipated, permitting extremely fine particles of suspended material to settle out.

Unfortunately, the bottom sampling program conducted by the DWR did not include chemical analysis of the sediments; only visual and general characteristics were reported. (1) Definitive chemical analyses of the Eagle Lake sediments have not been conducted as of this writing. However, results obtained from preliminary research conducted at the Eagle Lake Field Station (E.L.F.S.) suggest the possibility of significantly high concentrations of soluble phosphorus just below the undisturbed top layers of bottom sediment. The availability of this critical nutrient has special significance and will be discussed in detail later.

C. Eagle Lake Flora and Fauna

Within a stable ecosystem, each plant and animal performs a specific function which provides a path for energy and materials to flow. The more species involved (diversity), the more complex the food webs and the more stable the ecosystem when subjected to environmental stress. In other words, an ecosystem

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(1) Eagle Lake Limnological Data and Nutrient Study, California Department of Water Resources, December 1974.

with diverse species composition will provide more alternative pathways for the flow of energy and materials. Interruption of a single pathway (loss of a species) is less critical since other species in the system can take over that function. Clearly, high species diversity ensures a viable and persistent biotic community.

Freshwater lakes may be divided into several distinct life zones, since each zone has a different set of environmental parameters. Consequently, biotic communities inhabiting each are quite distinct in themselves. The major zones supporting distinctly characteristic communities are as follows:

(1) Limnetic Zone

(a) Trophogenic Zone (euphotic)

(b) Tropholytic Zone (aphotic)

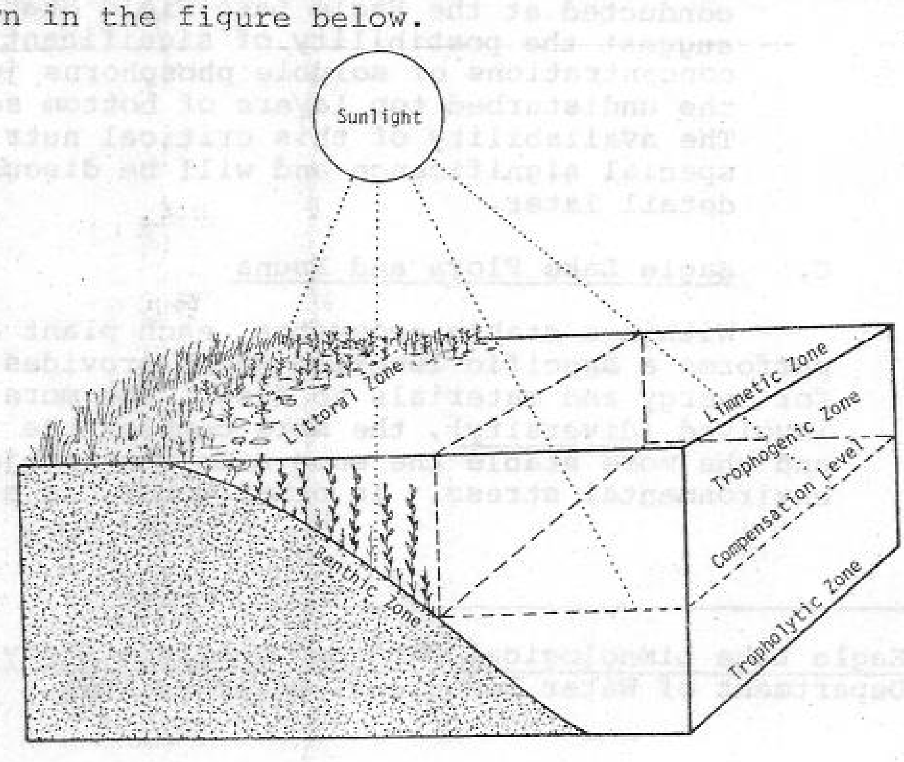
(2) Littoral Zone

(a) Emergent Zone

(b) Intermediate Zone (floating leaf zone)

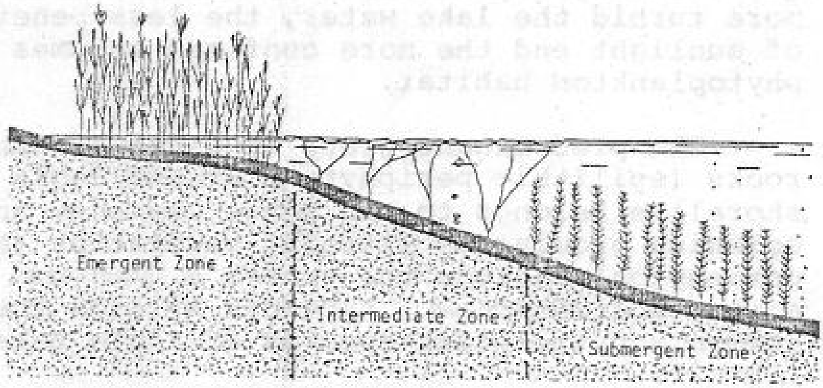
(c) Submergent Zone

The major horizontal and vertical life zones are shown in the figure below.



THE MAJOR HORIZONTAL AND VERTICAL LIFE ZONES OF A LAKE

Horizontally, a lake may be divided into the littoral zone which extends from the water's edge to the limit of rooted plants and the limnetic zone where no rooted plants occur. Vertically, a lake may be divided into the trophogenic zone and the tropholytic zone. The trophogenic zone is that region where light penetration is sufficient to support green (photosynthetic) plants. The zone below this, the tropholytic zone, has insufficient light to support green plants. The interface between, where plant photosynthesis just balances plant respiration, is known as the compensation level. The littoral zone may be further divided into three more sub-zones based on the type of shoreline vegetation inhabiting each. These are shown in the figure below.



SUBDIVISIONS OF THE LITTORAL ZONE OF A LAKE

1. Rooted Shoreline Plants

The emergent zone is characterized by rooted plants with stems extending distinctly above the water's surface. Typically, these are various grasses, tules, cat-tails, rushes, and sedges. The intermediate zone is inhabited by rooted plants which do not extend above the surface, but have leaves floating at the surface. These typically are various water lilies and pond weeds. The submergent zone is inhabited by plants which are completely submerged and may be considered wholly aquatic. They are characterized by long, sinuous leaves or by a brushy growth form with fine, highly branched leaves. Typical species include milfoil and various species of the genus *Potamogeton*. The primary significance here is that shoreline vegetation is limited to specific regions within the littoral zone which are determined by the surface elevation.

2. Food-chain Organisms

In the limnetic zone, photosynthetic plants are limited primarily to <u>phytoplankton</u> (floating microscopic algae). Typical phyoplankton genera are *Fragilaria, Anabaena, Microcystis,* and *Pedisatrum.* Limnetic phytoplankton can persist only in the well-illuminated trophogenic zone since they require sunlight to carry on photosynthesis. The more turbid the lake water, the less penetration of sunlight and the more confined becomes the phytoplankton habitat.

The predominant group of algae growing on rocks (epilithic periphyton) around Eagle Lake's shoreline belongs to the genus *Gomphonema* and algal colonies growing on littoral vegetation (epiphytic periphyton) include the genera *Bulbochaeta, Coleochaete, Nostoc,* and *Gomphonema*. Appendix A lists the more common aquatic plant species of Eagle Lake.

Similarly, associated with each of these distinct types of plant communities, are types of animal life just as distinct and unique as the plants they depend on.

Floating or suspended in open water are tiny animals called zooplankton which feed upon phytoplankton. Most are microscopic, but some are barely visible to the naked eye. These animals are primary consumers since they are the first trophic level to feed upon the producers. They, in turn, are fed upon by larger animals (secondary consumers).

Aquatic animals in close association with lake bottom sediments are referred to as benthic organisms or simply <u>benthos</u>. They consist of various species of aquatic insects, terrestrial insect larvae, roundworms, flatworms, snails, and a multitude of microscopic organisms, to name but a few. In Eagle Lake, the greatest diversity of insects and other invertebrates (animals without backbones) is found along the periphery of the lake in areas where the sediments consist of cobbles, rocks, or large chunks of tufa and at depths between 5 to 20 feet. The least productive areas of the lake occur at greater depths where bottom sediments consist of organic mud.(1)

3. Eagle Lake Fishery

The practice of introducing exotic species of fish into Eagle Lake began in 1879 and continued through 1956. During this period, 12 warm-water and salmonoid fish species were introduced, only two of which ever became established. These were the brown bullhead *(Ictalurus nebulosus)* and largemouth bass *(Micropterus salmonoides)*.

At the present time, only six species of fish are known to inhabit the lake, five of which are native, and the other is the brown bullhead just mentioned. Interestingly, the only successful exotic fish in Eagle Lake (the brown bullhead) has no record of being introduced by the Department of Fish and Game. It is believed that both largemouth bass and brown bullhead disappeared about 1937 when poor water quality associated with low lake levels prevented successful reproduction. However, the brown bullhead reappeared about 1970 when water quality conditions were probably again suitable for its reproduction because of higher lake levels.

Of the six remaining species of fish, the Eagle Lake trout *(Salmo gairdnerii aquilarum)* is the most famous. Its popularity with sportsmen has placed Eagle Lake on the fisherman's map. However, from an ecological point of view, the tui chub *(Siphateles bicolor)* may well be the most important fish to the lake and basin ecosystem, since it is a primary forage for the Eagle Lake trout and for the many piscivorous birds in the basin. This is a unique situation, since in most lakes and streams tui chub are considered "trash fish" and efforts are made to eliminate them.

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(1) Eagle Lake Limnological Data and Nutrient Study, California Department of Water Resources, December 1974.

(a) Eagle Lake Trout:

Considerable controversy exists with regard to the ancestry of the Eagle Lake trout. Some believe that it evolved from the rainbow trout of the western slopes of the Sierra Nevada range which could have crossed the Sierra divide by capture of the headwaters of the Pit and Feather rivers or which could have been introduced by native American Indians or early settlers. Others think it originated from the Lahontan cutthroat trout, a native of the Lahontan drainage system, which has markings similar to those of the Eagle Lake trout. And still others believe that it is the result of hybridization between the rainbow trout and the cutthroat trout. Research involving chromosome and protein analysis are underway through the Eagle Lake Field Station and UC Davis in an attempt to resolve this question.

Originally, a mature Eagle Lake trout depended upon Pine Creek and, to a much lesser extent, on other small tributaries for natural spawning. However, due to various land and drainage alterations within the basin, their natural spawning areas became unsuitable and their population declined precariously close to extinction. Some estimates placed the low point at less than 25 individuals. Due to the near extinction, a management plan was initiated by the Department of Fish and Game to ensure the continuation of the species.

Eggs taken from the spawning run of Eagle Lake trout at the Pine Creek Egg Station are reared in hatcheries and provide the basis for stocking the lake with about 150,000 yearling trout annually (1978). No other fish species are stocked in Eagle Lake. Today, the Eagle Lake trout fishery is one of the most intensely and most successfully managed fisheries in California.

(b) Tui Chub:

The tui chub is the most common minnow in Great Basin water. Throughout most of their range, these fish tend to be less than 10 inches long, but the variety of chub inhabiting Eagle Lake grows to 16 inches in length or more.

Adult chubs have established a distinct migration pattern in Eagle Lake. In the spring, they move from deep water at the south end of the lake to the shallows where they spawn on submerged aquatic plants. After spawining, the adults return to deep water again. There may also be a winter migration toward shore, since adult chubs have been reported in the Pine Creek estuary in December. The adhesive eggs are distributed throughout the lake on floating fragments of plants that are broken off by wind and feeding waterfowl. In this manner, each crop of fry is distributed throughout the lake. Within a few days, the eggs hatch after which the young are found along the shoreline in enormous numbers. Almost immediately upon hatching, the fry begin to feed on plankton. This combination of an efficient dispersal system and abundance makes the tui chub an excellent forage for the Eagle Lake trout and piscivorous birds. There is also the possibility that tui chub may play an important role in maintaining the nutrient balance of Eagle Lake by consuming plankton then later providing forage for piscivorous birds.

(c) Tahoe Sucker *(Catostomus tahoensis):*

In Eagle Lake, the Tahoe sucker is an unobtrusive fish that makes a grand appearance once each year. When Pine Creek begins to flow in the spring, large schools of these fish migrate from the lake to spawn. Some also spawn in the littoral zone of Eagle Lake. The mature males have a bright red strip on their sides and casual observers commonly mistake them for rainbow trout. Tahoe suckers are not as abundant as tui chub in Eagle Lake; however, they undoubtedly have some value as forage for fish and wildlife.

(d) Lahontan Redside *(Richardsonius erequis):*

The Lahontan redside is another species of fish that is seen when it schools during the annual spring spawning migration up Pine Creek (spawning also occurs in littoral zone of lake). In Eagle Lake, redsides are not considered numerous enough to be an important forage; however, due to a lack of information, they may not be given sufficient credit as forage fish. Although they seldom grow beyond "bite size," they may provide important forage for other species when small tui chubs are unavailable.

(e) Lahontan Speckled Dace *(Rhinichthys osculus robustutus):*

These small, slender minnows are the least numerous of the Eagle Lake fish. Speckled dace are secretive, unprolific, and nonschooling. As such, they cannot be considered an important forage in Eagle Lake. The adults occupy rocky or gravelly areas around the lake. Spawning takes place in the littoral zone of the lake and in Pine Creek at about the same time the other stream spawning fishes are in the creek.

(f) Brown Bullhead:

Brown bullheads are the only introduced species still living in Eagle Lake. They were abundant before the lake receded in the 1930's and have essentially disappeared until recently. Bullheads may have been reintroduced illegally by "sportsmen" or may have migrated to Eagle Lake from ponds in the Pine Creek drainage. If bullheads (or other exotics) become numerous, they may utilize a substantial portion of the lake's productivity and depress the populations of native fishes, including the Eagle Lake trout.

4. Piscivorous Birds

Although birds are not generally regarded as a component of aquatic ecosystems, the large number of fish-eating birds within the Eagle Lake Basin have a definite influence on the flow of materials in this aquatic ecosystem. Fish-eating birds that forage at Eagle Lake, but nest elsewhere and defecate elsewhere could effectively cause a net removal of nutrients from the lake. This could include the common loon, white pelican, snowy egret, black-crowned night hawk, California gull, ring-billed gull, Bonaparte's gull, goldeneye, and the bufflehead. Osprey and eagles, could also assist the removal of nutrients; however, probably to a much less degree due to their comparatively small populations. Furthermore, fish-eating birds which hatch at Eagle Lake and increase in biomass while feeding on Eagle Lake fish then die outside the basin would cause a substantial removal of nutrients. The quantity of nutrients removed annually by piscivorous birds has never been determined; however, it is possible that the thousands of piscivorous birds that forage annually at Eagle Lake could effectively provide a necessary path for nutrient removal which is important in maintaining a nutrient balance (see: <u>Nutrient Sources, Storage, and Export</u>).

D. <u>Eagle Lake Dynamics</u>

1. Limiting Nutrients

A fundamental principle of ecology, long studied by investigators in the field, explains that an organism process that is dependent upon many distinct environmental factors for its operation will be limited by a single factor whose value is farthest from the process requirements. Ecologists call this the *Principal of Limiting Factors*.

Every species within a community requires particular conditions for its growth or survival. If one of these conditions is absent, the species will die or growth and development will be restricted. If one of these requirements is a particular nutrient and it is present in small amounts, the population size of the species will be limited. For example, if phosphate is scarce, phytoplankton will grow and reproduce until available phosphate has been used up. Further growth will be minimal.

One of the primary factors in maintaining the aesthetic beauty and present ecological stability of Eagle Lake is controlling the amount of algae in the lake. At the present time, Eagle Lake has relatively clear water; however, this condition could rapidly be changed by improper use of the lake and surrounding basin. Studies at the Eagle Lake Field Station have determined that the growth of algae in Eagle Lake is now a function of nutrient availability; a manifestation of the Principle of Limiting Factors.(1)

Experimental tests determined that phosphorus (P), nitgrogen (N), iron (Fe), and sulfur (S) were all important for algal growth at one time or another. However, (P) was the most limiting nutrient in both the north and south basins. Iron was not as limiting as (P) in the south basin, but it was as limiting in the north basin. Iron in the north basin probably precipitates out irrevocably due to <u>aerobic</u> conditions (oxygen rich) at the bottom. Due to the anaerobic conditions (oxygen poor) near the bottom of the deeper south basin, sediments regenerate and release (Fe) (see <u>Nutrient Cycling</u>, next page). Eagle Lake water enriched with (P), (N), (Fe), and (S) in a laboratory has shown a 100-fold increase in algal growth within seven days compared to normal Eagle Lake water.(2)

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(1) Maslin, Paul E. and Gerald L. Boles, "Use of a Multiple Addition Bioassay to Determine Limiting Nutrients in Eagle Lake, California," <u>Hydrobiologia</u>, Volume 58, 3, pp. 261-269, 1978.

(2) Maslin, Paul E., "Use of Eagle Lake Basin Consistent with Maintaining the Natural Beauty of the Lake," July 24, 1976.

Manganese additions sometimes proved to be an algae stimulant.

A All the nutrients found to be limiting algal growth in Eagle Lake typically are plentiful in sewage. Sewage entering the lake either directly or through septic system seepage into inflowing ground water would provide a rich supply of "limiting nutrients" and as discussed earlier, preliminary hydrologic studies strongly suggest a substantial inflow of ground water into Eagle Lake. A particularly insidious characteristic of ground water contamination is due to the slow rate of travel - it may not be discovered until after several years of injection have taken place. By that time, several more years of contaminated ground water is irrevocably on its way. Furthermore, secondary treatment of sewage does not remove soluble nutrients. Discharge or seepage of secondary treated sewage effluent would also provide a rich supply of nutrients. As pointed out in the geology report, the Eagle Lake basin is mantled with lava basalts which can transmit subsurface waters very quickly.

2. Nutrient Cycling (1)

A lake is a complicated interacting system of water, biota, and bottom sediments. Not all nutrients added to this system stay in solution. Some are precipitated chemically, some are tied up into biomass which then dies and becomes incorporated into the bottom sediments. Nutrients go from sediments back to the water by biochemical solubilization and leaching or by direct uptaking by organisms such as worms or rooted plants which ultimately die and decompose.

Thus, the availability of nutrients to algae is as much a function of internal cycling as the rate of loading to the lake from external sources. This internal cycling is closely related to the phenomenon of stratification. Warm water is

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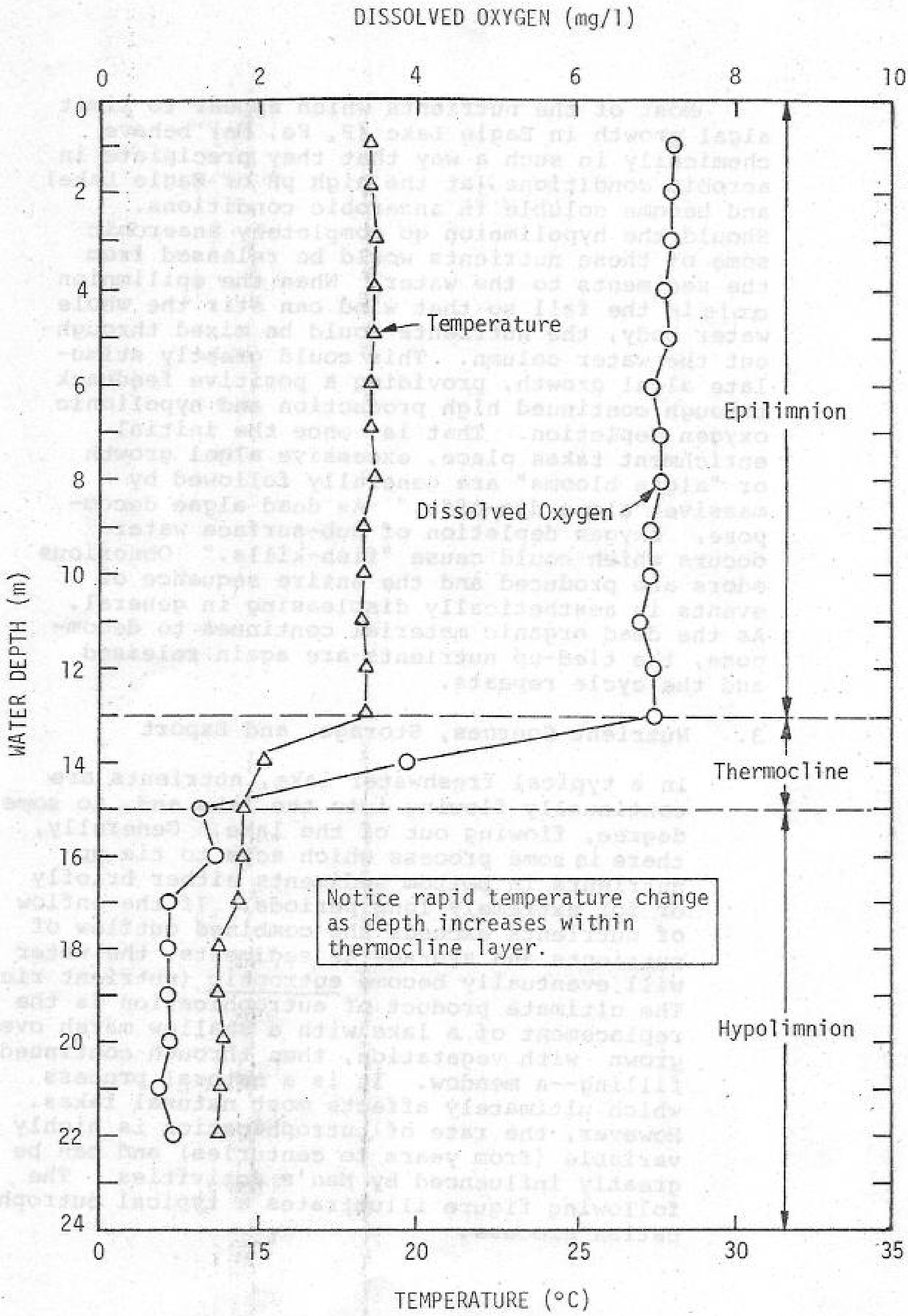
(1) Huntsinger, K.R. and Paul E. Maslin, "A Limnological Comparison of the Three Basins of Eagle Lake, California," California Fish and Game, 62 (4): 232-245, 1976.

lighter (less dense) than colder water. As the surface water of a lake warms in spring, it tends to resist mixing with the underlying colder water. Wind action will mix it down to some depth depending on intensity and timing of heating and wind, but if the lake is deep enough, it will form a stable summer stratification. The upper warm layer, called the epilimnion (upper lake), is in contact with the atmosphere and is continually mixed by the wind. The lower, colder layer, called the hypolimnion (lower lake), is completely isolated from the atmosphere and is not mixed. The thin intermediate layer, where the temperature changes rapidly with depth, is called the thermocline. Eagle Lake's south basin stratifies in this fashion around mid-July and remains stratified until mid-October. The following figure shows August 17, 1972 temperature-oxygen profiles for the south basin just off Miner's Bay. The thermocline is located between 13 and 15 m. These profiles are typical for the south basin in later summer. Since the north and middle basins are shallow (5 - 6 m), they mix completely to the bottom, never developing a durable stratification.

This figure also shows that dissolved oxygen in the hypolimnion is very low. Since the hypolimnion is isolated from air at the time stratification is set up and is below the depth of sufficient light penetration for photosynthesis, it has no source of oxygen to replenish that which is used up during the summer. Organic material produced photosynthetically in the epilimnion rains down into the hypolimnion where its decomposition uses up oxygen. Should the lake increase in productivity, for example, due to minor nutrient enrichment, the clarity of water would decrease, reducing the depth to which oxygen could be produced by photosynthesis. At the same time, more organic matter would rain down into the deeper water to be decomposed. Thus, the hypolimnion could go completely anaerobic and the thermocline could also become depleted. Such a pattern of deep-water oxygen depletion in later summer is typical for eutrophic (nutrient rich) lakes which are discussed in the next section.



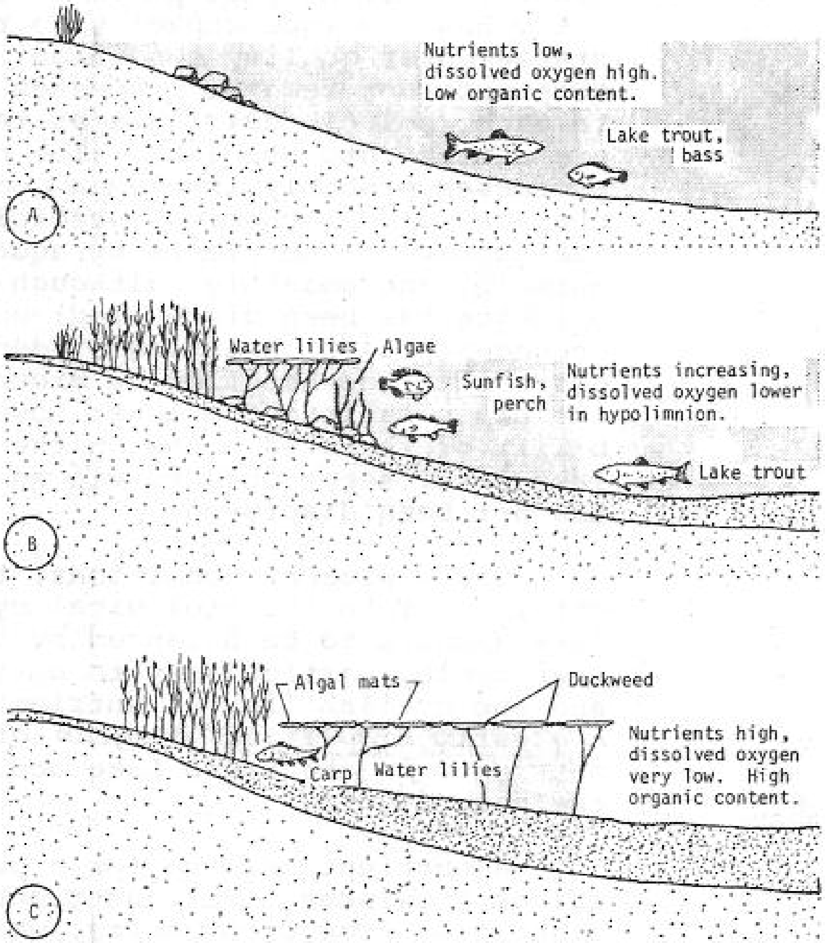
Vertical Distribution of Temperature and Oxygen in the South Basin of Eagle Lake, August 17, 1972.

Most of the nutrients which appear to limit algal growth in Eagle Lake (P, Fe, Mn) behave chemically in such a way that they precipitate in aerobic conditions (at the high pH of Eagle Lake) and become soluble in anaerobic conditions. Should the hypolimnion go completely anaerobic some of these nutrients would be released from the sediments to the water. When the epilimnion cools in the fall so that wind can stir the whole water body, the nutrients would be mixed throughout the water column. This could greatly stimulate algal growth, providing a positive feedback through continued high production and hypolimnic oxygen depletion. That is, once the initial enrichment takes place, excessive algal growth or "algae blooms" are generally followed by massive "algae die-offs." As dead algae decompose, oxygen depletion of sub-surface water occurs which could cause "fish-kills." Obnoxious odors are produced and the entire sequence of events is aesthetically displeasing in general. As the dead organic material continues to decompose, the tied-up nutrients are again released and the cycle repeats.

3. Nutrient Sources, Storage, and Export

In a typical freshwater lake, nutrients are continually flowing into the lake and, to some degree, flowing out of the lake. Generally, there is some process which acts to tie up nutrients in bottom sediments either briefly or for extremely long periods. If the inflow of nutrients exceeds the combined outflow of nutrients and storage as sediments, the water will eventually become eutrophic (nutrient rich). The ultimate product of eutrophication is the replacement of a lake with a shallow marsh overgrown with vegetation, then through continued filling--a meadow. It is a natural process which ultimately affects most natural lakes. However, the rate of eutrophication is highly variable (from years to centuries) and can be greatly influenced by Man's activities. The following figure illustrates a typical eutrophication process.

Eutrophication. (A) An oligotrophic lake. Typically clear, cold, and deep, the lake contains few nutrients. (B) As nutrients are washed into the lake and as sediment and organic matter increase, productivity builds. Plant life is abundant. (C) A eutrophic lake. Sediment fills in the deep portions of the lake; abundant nutrients encourage algae and duckweed blooms. Few fish can survive the low oxygen levels. Portions of the bottom are anaerobic.



Typical Eutrophication of Lakes

The studies of the DWR during 1971-1973 lead to the conclusion that the concentration of nutrients in the lake has remained essentially the same.(1) It would, therefore, appear that Eagle Lake was near an equilibrium condition during that period. The lake apparently has a unique capacity to remain in a stable water quality condition; and, therefore, some nutrient removal processes must be actively removing soluble nutrients as rapidly as they are coming into the lake. The nutrient removal processes probably involve a combination of chemical and biochemical precipitation, biological uptake of nutrients by aquatic plants and animals, and possibly (although no conclusive evidence has been discovered) outflow into groundwater.(2) Existing evidence strongly suggests that the net flow of groundwater within the basin is into the lake; however, the possibility of isolated areas on the lake floor where lake water seeps outward via an unknown aquifer has not been disproven.

Under present conditions, the rate of nutrient input into the biological cycle within the lake appears to be balanced by the losses from that cycle, particularly to bottom sediments, and the availability of nutrients remains low.(3) A greatly simplified diagram of the flow of nutrients in the Eagle Lake ecosystem is shown in the next figure.

A nutrient balance for a body of water requires knowledge of all nutrient sources, the quantities from each source, what happens to the nutrients within the system, and their final disposition. Since these factors have not yet been quantified, a true nutrient balance for Eagle Lake cannot be made at this time. However, in general terms, one can say that most nutrients probably enter the lake by surface and groundwater transport and they are derived from

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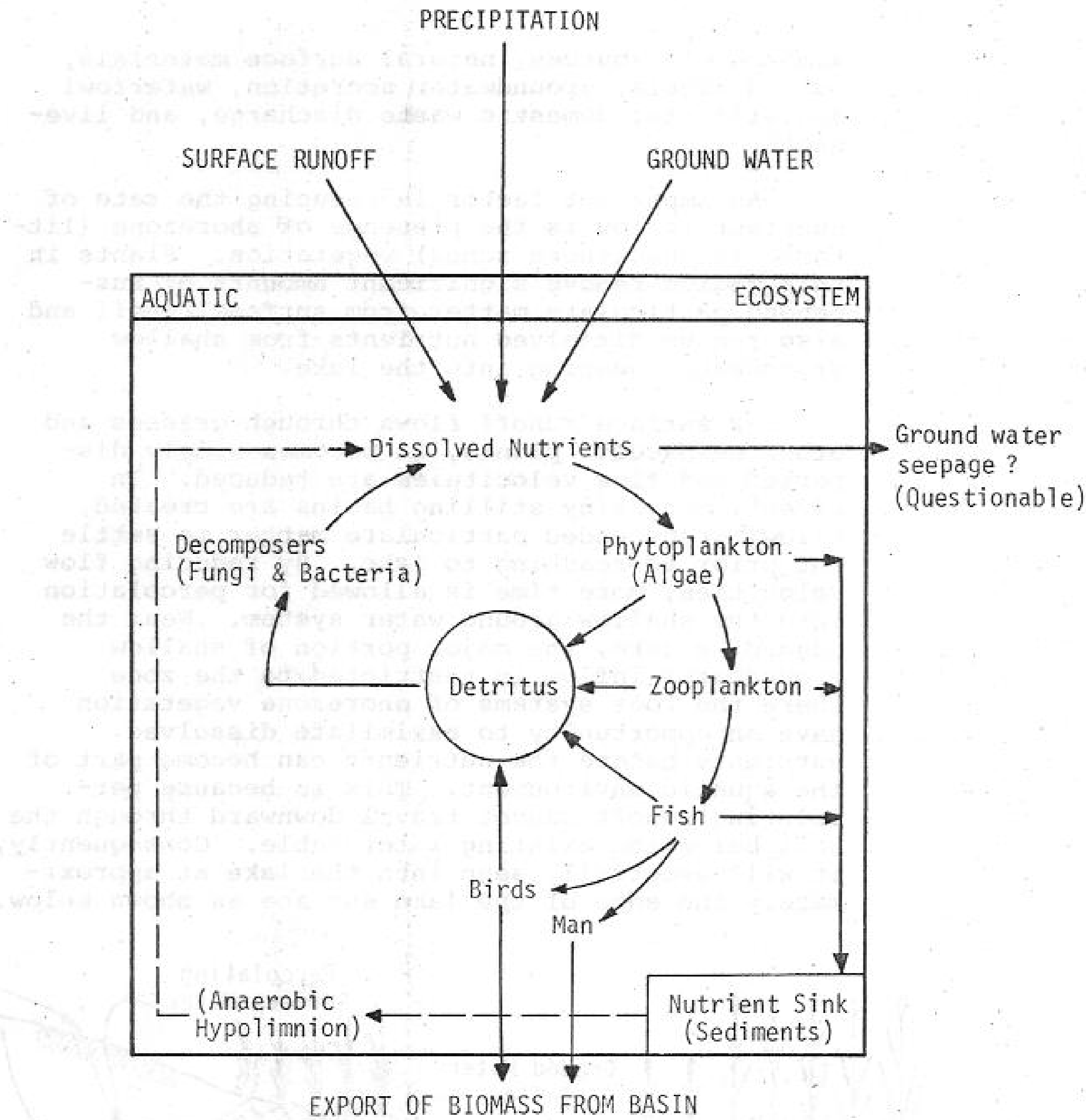
(1) (2) Eagle Lake Limnological Data and Nutrient Study, California Department of Water Resources, December 1974.

(3) Maslin, Paul E., "Use of Eagle Lake Basin Consistent with maintaining the Natural Beauty of the Lake," July 24, 1976.



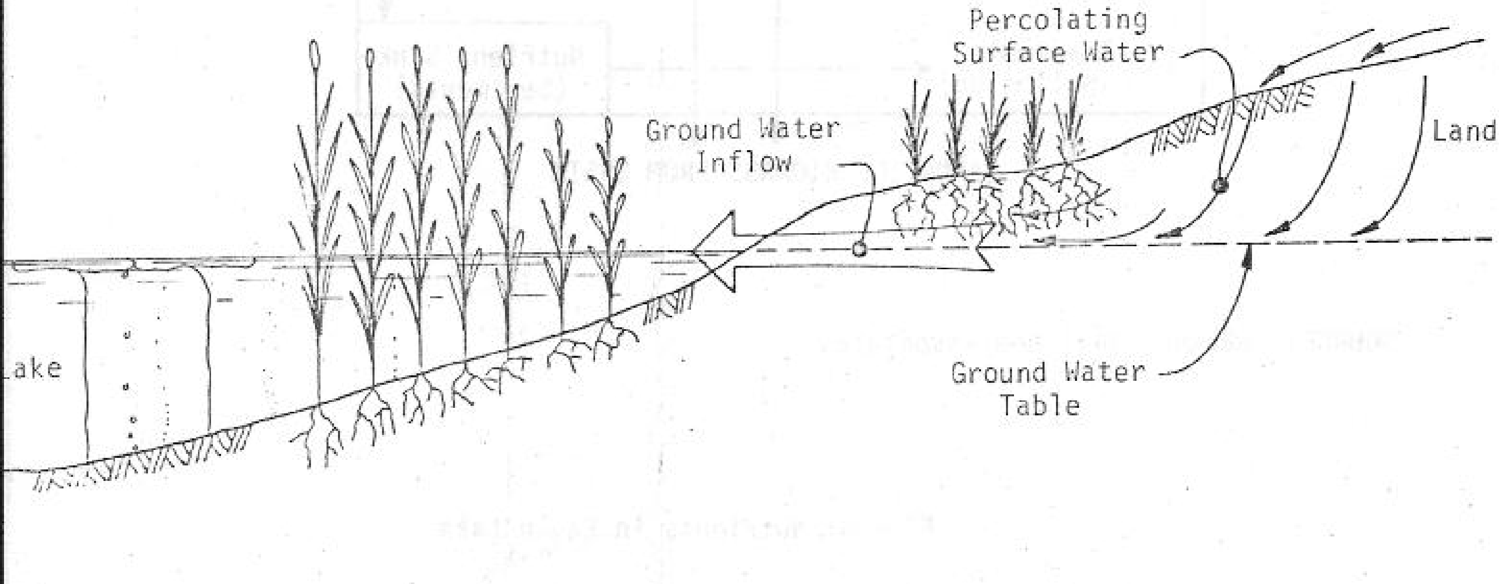
SOURCE: Raymond Vail and Associates

Flow of Nutrients in Eagle Lake

atmospheric sources, natural surface materials, burned debris, groundwater accretion, waterfowl and wildlife, domestic waste discharge, and livestock.

An important factor in reducing the rate of nutrient inflow is the presence of shorezone (littoral and backshore zones) vegetation. Plants in this region remove significant amounts of suspended particulate matter from surface runoff and also remove dissolved nutrients from shallow groundwater seeping into the lake.

As surface runoff flows through grasses and other herbaceous plants, it becomes widely dispersed and flow velociteies are reduced. In effect, many tiny stilling basins are created, allowing suspended particulate matter to settle out prior to reaching to lake. By reducing flow velocities, more time is allowed for percolation into the shallow ground water system. Near the edge of a lake, the major portion of shallow groundwater inflow is restricted to the zone where the root systems of shorezone vegetation have an opportunity to assimilate dissolved nutrients before the nutrients can become part of the aquatic environment. This is because percolating runoff cannot travel downward through the soil below the existing water table. Consequently, it will eventually seep into the lake at approximately the edge of the lake surface as shown below.



The importance of maintaining a prolific vegetation belt around the shoreline becomes more obvious when you consider that most of the backshore soils surrounding the lake are fractured basalt or beach gravel. Materials such as this have no mechanism for removing nutrients. They can be removed only by tight soils with well-developed plant communities.

There are other benefits to be derived from a well-vegetated shorezone. It provides critical habitat for waterfowl, nesting birds, and other aquatic birds; littoral vegetation is a primary requirement for successful spawning of tui chub; and, certainly not the least importance, it greatly enhances the aesthetic quality of the shoreline.

As mentioned earlier, some nutrients are removed from Eagle Lake water by biological uptake by aquatic plants and animals. However, this does not, by itself, result in a net removal of nutrients from the ecosystem. Eventually these organisms will die and decompose or be eaten by successively larger organisms which ultimately will die and decompose, thereby releasing nutrients back into the lake. The only way a net removal of nutrients can result from biological uptake is by a removal of aquatic plant or animal biomass from the basin. At Eagle Lake, the main paths for biomass removal are probably fish eating birds and man himself (assuming man catches more pounds of fish than he plants). Unfortunately, insufficient data exists to determine just how important man or bird is in maintaining the nutrient balance of Eagle Lake. Until this can be defined, the myopic conclusion that increased fishing pressure could be employed to offset eutrophication would be like playing Russian Roulette with Eagle Lake. Many other crucial factors are involved and must be considered prior to a decision to increase fishing activity. The Department of Fish and Game is probably in the best position to make this decision.

Although considered to be a relatively minor factor (in terms of total nutrient removal), the removal of nutrients by means of the Blye tunnel leakage should be discussed. Only certain ions, particularly calcium (Ca^{++}) and carbonate ($CO_3^{=}$), are precipitated in the bottom sediments. The export of more soluble ions such as sodium (Na^+) and chloride (Cl^-) by means of Blye tunnel leakage may be important, however, in maintaining ionic ratios compatable with freshwater life[1]. The peculiar arrangement of canal and tunnel relative to prevailing winds and lake currents results in an accumulation of floating debris in the canal. This debris includes a large amount of dead fish, aquatic plants (including algae), and other organic material. As this organic material decomposes, it releases captured nutrients which are carried from the system due to the net flow of water out of the lake. It has been estimated that this phenomenon accounts for the export of approximately 210 metric tons (235 U.S. tons) of phosphorus and 1400 metric tons of nitrogen (1568 U.S. tons) annually. (1)

4. Three Basins Like Three Separate Lakes (2) (3)

A comparison of the three basins of Eagle Lake was made to determine how limnological factors were affected by lake <u>morphometry</u> (shape, size, and depth). Light extinction, dissolved oxygen, specific conductance, chlorophyll-"a" concentration, primary production, and plankton were investigated in each basin.

Temperature isopleths (lines of constant temperature) for the south basin are shown in the following figure. As can be seen at (a), a primary thermocline formed at 10 -5 m near the beginning of July 1971. A thermocline is indicated on

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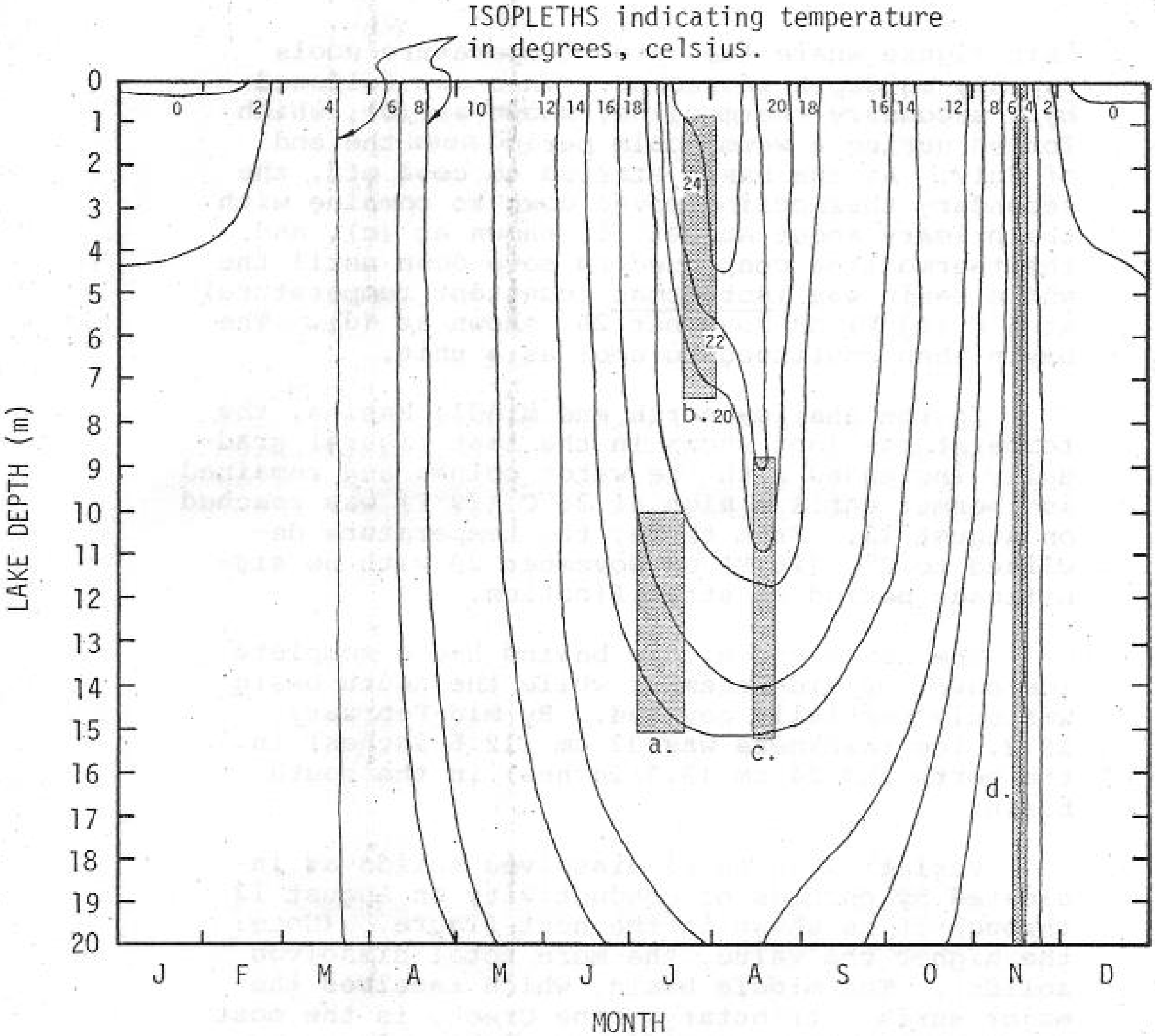
(1) Maslin, Paul, <u>A Preliminary Analysis of Eagle Lake Water Quality</u>, Department of Biological Sciences, California State University, Chico, 1972.

(2) <u>Environmental Analysis Record Eagle Lake Tunnel Reduction and Seal</u>, 1971.

(3) Huntsinger, K. R., and Paul E. Maslin, "A Limnological Comparison of the Three Basins of Eagle Lake, California," <u>California Fish and Game</u>, 62 (4): 232-245, 1976.



SOURCE: K. R. Hunsinger and Paul E. Maslin (7.)

Distribution of Temperature with Depth and Time in Eagle Lake's South Basin (1971).

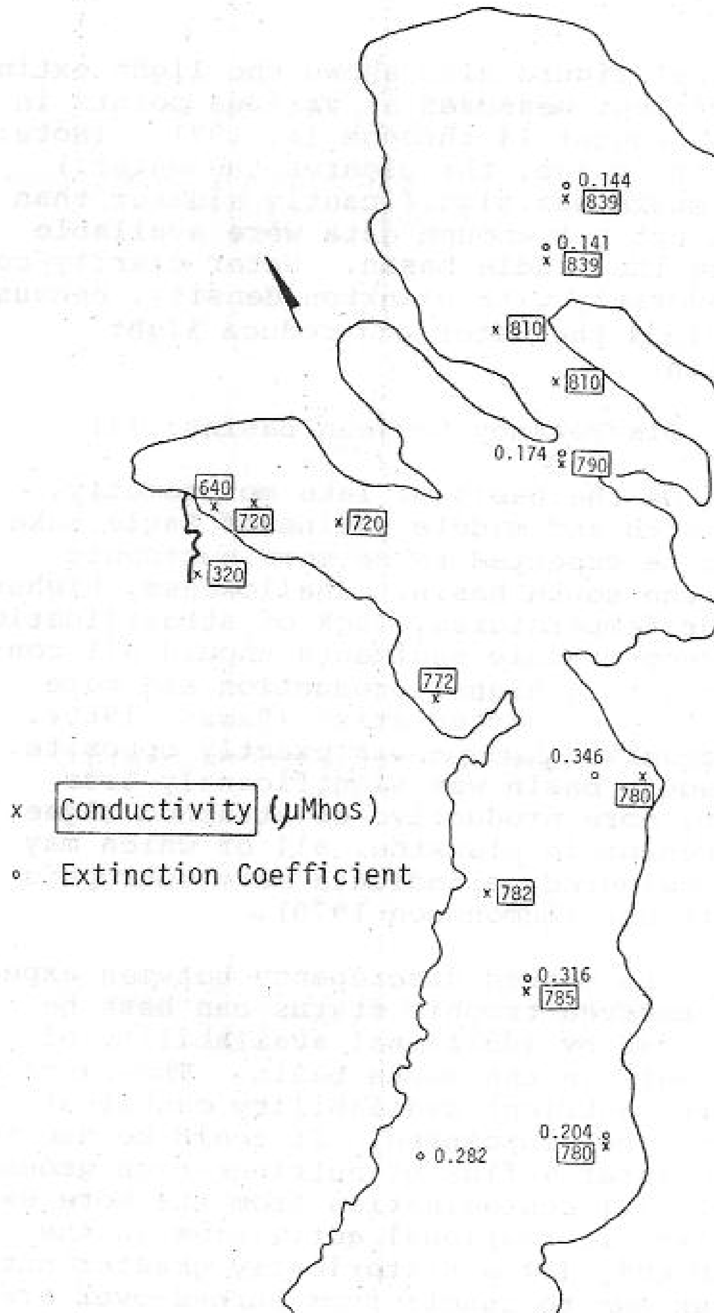
this figure where the water temperature cools rapidly as depth increases. This was followed by a secondary thermocline, shown at (b), which formed during a warm, calm period near the end of July. As the basin started to cool off, the secondary thermocline moved down to combine with the primary about August 15, shown at (c), and the thermocline continued to move down until the whole basin was isothermal (constant temperature) at 6°C (43°F) on November 20, shown at (d). The basin then continued to cool as a unit.

In the shallow north and middle basins, the temperatures (not shown in the last figure) gradually increased with the water column and remained isothermal until a high of 26°C (79°F) was reached on August 12. From there, the temperature declined to -2°C (26°F) on November 20 with no significant period of stratification.

The north and middle basins had a complete ice cover by Mid-December while the south basin was only partially covered. By mid-February 1972, ice thickness was 32 cm (12.6 inches) in the north and 24 cm (9.8 inches) in the south basin.

Variation in total dissolved solids as indicated by changes of conductivity on August 12 through 16 is shown in the next figure. (Note: the higher the value, the more total dissolved solids). The middle basin, which receives the major surface tributary, Pine Creek, is the most dilute and shows a significant change along the narrow arm leading toward Pine Creek. The other two basins are internally uniform in conductivity with the north basin being most concentrated.

Productivity of phytoplankton in the south basin is generally higher than that of the north and middle basins. The mean productivity per unit volume or per unit area in the south basin is significantly higher than either north or middle basin which do not differ significantly from each other.



SOURCE: K.R. Hunsinger and Paul E. Maslin (7.)

6 Variation in Vertical Light Extinction and Conductivity in Eagle Lake During Mid-August 1971.

The next figure also shows the light extinction coefficient measured at various points in the lake on August 14 through 16, 1971. (Note: the lower the value, the clearer the water.) The north basin was significantly clearer than the south, but not enough data were available to evaluate the middle basin. Water clarity correlates inversely with plankton density, because plankton cloud the water and reduce light transmission.

a. Discrepancy Between Basins: (1)

On the basis of lake morphometry, the north and middle basins of Eagle Lake would be expected to be more eutrophic than the south basin. Shallowness, higher summer temperatures, lack of stratification, and deep organic sediments should all contribute to a higher production and more eutrophic characteristics (Rawson 1960). The observed pattern was exactly opposite. The south basin was significantly less clear, more productive of attached algae, and denser in plankton, all of which may be considered to indicate more eutrophic conditions (Edmondson 1970).

The marked discrepancy between expected and observed trophic status can best be explained by additional availability of nutrients in the south basin. The cause of greater nutrient availability cannot at present be pinpointed. It could be due to: (1) greater influx of nutrient-rich ground water, (2) contamination from the more extensive, recreational activities in the south end, (3) a historically greater nutrient influx due to runoff from burned-over areas, (4) a more efficient recycling of critical nutrients in the stratified south basin.

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(1) Maslin, Paul, A Preliminary Analysis of Eagle Lake Water Quality, Department of Biological Sciences, California State University, Chico, 1972.

Quite probably all of these factors contribute to the greater degree of eutrophication in the south basin. Whatever the cause of the present discrepancy in algal production, the fact that the south basin is already richer, coupled with the possibility of hypolimnic anaerobiasis, causing nutrient release from sediments, makes this basin particularly susceptible to deterioration from nutrient addition.

The north and middle basins should be less sensitive to nutrient addition than the south basin. Being shallow, they can never stratify and thus will always be oxygenated by wind action. Accordingly, their rate of internal nutrient cycling would not be expected to change as dramatically due to minor nutrient addition and they would not develop the positive feedback inherent in the stratification of the south basin. This does not imply that the north and middle basins cannot become eutrophic. They too would eventually respond to prolonged, increased nutrient loading. All three basins would respond immediately to an increased nutrient input; however, the north and middle basins would probably recover more quickly than the south basin if the input decreased again.

IV. POTENTIAL PROBLEMS FROM FUTURE DEVELOPMENT WITHIN THE EAGLE LAKE BASIN

A. Nutrient Enrichment of Eagle Lake

This could arise from many different actions, most of which would be due to improper construction practices, carelessness, or ignorance of the possible effects of certain actions.

- Until it is clearly established that there is no possible chance for septic system seepage to enter Eagle Lake via ground water inflow, it would be very risky to permit septic systems in the basin. The upper regions of the Pine Creek drainage basin are the most likely recharge areas for most ground water entering Eagle Lake; however, other areas in the basin may also be significant recharge areas. It has been estimated that approximately 75 square miles of this drainage basin are prime candidates as recharge areas.(1) Nutrients released in these recharge areas, 10 to 15 miles from the lake, could still reach the lake virtually unchanged even though it could take years or decades to reach the lake.
- Improper construction practices of many types could lead to increased erosion and subsequent siltation of Eagle Lake.
- Increased residential use in the basin will encourage increased dispersal of fertilizers for lawns and gardens. Common fertilizers contain high concentrations of Eagle Lake "limiting nutrients." Wash-down by surface runoff, percolation into ground water, or accidental spills could add nutrients to the lake.
- Nutrient enrichment by any means would accelerate the eutrophication process which now appears to be quite slow. Occasionally, even now, minor algae blooms occur in the spring. Enrichment could aggrevate this condition.

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(1) Behnke, Jerold J., A Preliminary Hydrologic Analysis of Eagle Lake.

- Nutrient enrichment could have a serious adverse effect on the Eagle Lake trout fishery. Nutrient enrichment in the south basin would increase plankton growth which would increase oxygen depletion in the hypolimnion. The more turbid water would warm more rapidly near the surface and cause the thermocline to form at shallower depths. The trout would be restricted to live in the thermocline with reduced dissolved oxygen and higher temperatures. The resulting oxygen and temperature stress could cause a decline in growth rates and production of the trout. If weather conditions during unusual years cause an unusually shallow thermocline to develop, heavy trout mortality could result. (1) (See also Item F.)

B. Increased Grazing Pressure In Shorezone

- When cattle feed and defecate in the shorezone, they accelerate biomass conversion and recycling of nutrients.
- By foraging on rooted aquatic plants, cattle inhibit their productivity, increase available nutrients by defecation, and stimulate algal growth along the shoreline.
- Loss of shorezone vegetation results in the loss of their nutrient uptake benefits, thereby, allowing more nutrients to enter Eagle Lake via surface runoff and shallow ground water inflow.
- Cattle destroy critical habitat for nesting and shoreline birds.

C. Timber Harvesting Near Lake

- Soil disturbance and destruction of ground cover could increase the silt load of runoff.

D. Dredging Operations

- Definitive chemical analyses of bottom sediments

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(1) Maslin, Paul, A Preliminary Analysis of Eagle Lake Water Quality, Department of Biological Sciences, California State University, Chico, 1972.

have not been conducted; however, research at the Eagle Lake Field Station has determined that large quantities of soluble phosphorus salts are beneath the surface of bottom sediments. Stirring of these sediments could release large quantities of this critical "limiting nutrient." (1)

E. Projects Altering Lake Surface Elevation

Projects capable of altering the surface elevation of Eagle Lake (i.e. Bly Tunnel modifications) could have a significant influence on Eagle Lake fish and wildlife.

- A reduction of surface elevation to 5,100 feet or lower would eliminate much littoral vegetation which is critical to the reproduction and distribution of tui chubs. Due to the key position which tui chubs occupy in aquatic and terrestrial food chains in the basin, any significant adverse impact on tui chubs will adversely affect Eagle Lake trout and piscivorous birds in the basin. Loss of littoral vegetation would also adversely affect birds nesting, feeding, or seeking cover in these regions. As littoral vegetation decreases, it would be replaced by barren mud-flats with little aesthetic appeal and a low potential for re-establishment of new littoral vegetation.

- If the surface elevation were allowed to drop to elevation 5098 or lower, Eagle Lake trout would be seriously threatened with extinction. This species is presently dependent on the fish trapping facility at the mouth of Pine Creek for reproduction. Since natural spawning is no longer possible, the lake surface elevation must be at least 5098 feet for the facility to operate and provide future brood stock.

- Estimates have been made of what would occur if the surface elevation were lowered to elevation 5096 (minimum recorded elevation is 5091). It was determined that the south basin would probably develop

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(1) Maslin, Paul E., Unpublished letter, November 1978.

an anaerobic hypolimnion which would result in the release of "limiting nutrients" from bottom sediments (see Nutrient Cycling). This would accelerate the eutrophication process associated with nutrient enrichment (discussed earlier). In addition, this reduction of surface elevation would cause the middle and north basins to become so shallow that wave action would stir up soft, nutrient-rich sediments in both basins causing great increases in algal production and turbidity. Being shallower, the middle and north basins would become warmer, earlier in the summer and cause prolonged oxygen deficiency. Conditions such as this would render the middle and north basins unsuitable for trout habitat, and all Eagle Lake trout would be forced to crowd into the south basin. It is anticipated that these conditions would seriously reduce trout productivity.(1) Although research of the effects of lowering surface elevation has been quite limited, it is apparent that lowering of the surface will adversely affect the lake ecology in proportion to the amount of lowering.

- Maintaining the existing surface elevation would perpetuate the status quo which appears to be stable.

- Increasing surface elevation would generally benefit both fisheries and local wildlife. From the standpoint of fish and wildlife preservation, elevations above 5100 feet, and in particular 5106 feet, are most favorable.(2) At the present time, there are no predictable, adverse effects on fish or wildlife that would follow an increase of surface elevation.(3) However, if the lake level is to be raised, paved areas which would be inundated should have pavement removed in advance. This would permit establishment of littoral vegetation in the new shorezone to replace that which is lost by inundation.

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(1) (3) Maslin, Paul, A Preliminary Analysis of Eagle Lake Water Quality, Department of Biological Sciences, California State University, Chico, 1972.

(2) Eagle Lake - Alternative Plans for Controlling Lake Levels, California Department of Water Resources, November 1972.

APPENDIX

EAGLE LAKE FLORA

EAGLE LAKE FLORA (1)

Macrophytes (rooted shoreline plants)

Wire rush	*Juncus balticus*	two dominant species
Common tule	*Scirpus acutus*	
Sago pondweed	*Potamogeton pectinatus*	
Water persicaria	*Polygonum amphibium*	
Common bladderwart	*Utricularia vulgaris*	
Milfoil	*Myriophyllum sp.*	

Typical Phytoplankton Genera (floating algae)

Fragilaria
Anabaena
Microcystis
Pediastrum

Typical Periphyton Genera (attached algae)

Epilithic (on rocks):

Gomphonema (predominates)

Epiphytic (on macrophytes):

Gomphonema
Bulbochaeta
Coleochaete
Nostoc

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(1) Huntsinger, K.R. and Paul E. Maslin, "Contribution of Phytoplankton, Periphyton, and Macrophytes to Primary Production in Eagle Lake, California," California Fish and Game, 62(3): 187-194, 1976.