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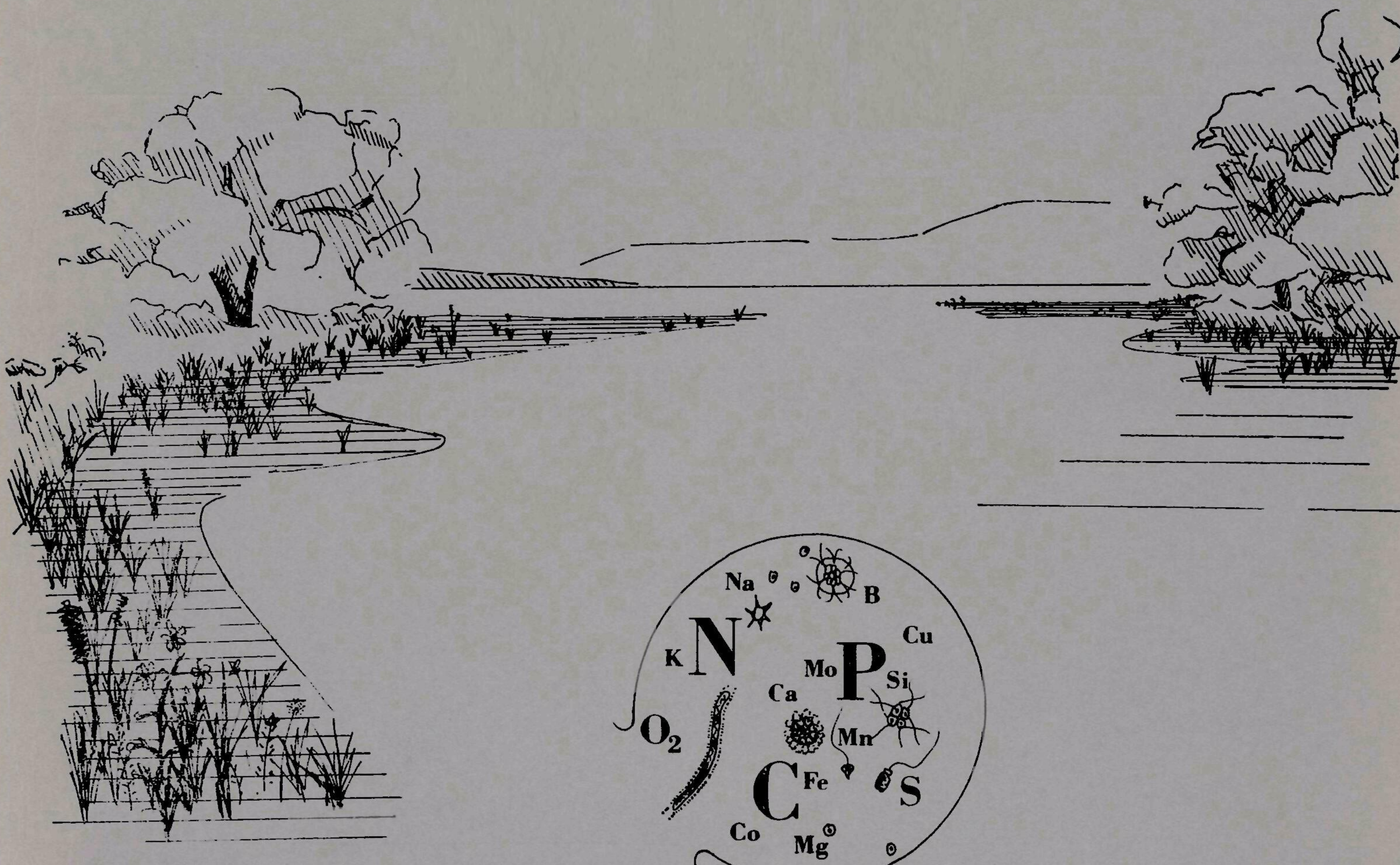

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EUTROPHICATION OF SURFACE WATERS – LAKE TAHOE

by

Lake Tahoe Area Council
South Lake Tahoe
California 95705

for the

ENVIRONMENTAL PROTECTION AGENCY

Grant No. 16010 DSW

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ABSTRACT

A study of the factors leading to the eutrophication of surface waters, with special emphasis on Lake Tahoe, was conducted over a 5-year period (1966-1971) through a series of Demonstration Grants to the Lake Tahoe Area Council by the various federal agencies now (1971) known as the Water Quality Office of the Environmental Protection Agency. Increasing enrichment of national waters leading to objectionable algal blooms, plus a widespread public interest in preserving the unique clarity of Lake Tahoe, was justification for the project. Pursuant to a research plan, a survey of the nutrient and other chemical constituents was made of surface waters from developed and undeveloped land areas, sewage effluents, seepage from septic tank percolation systems and refuse fills, drainage from swamps, precipitation, and Lake Tahoe Water. Simultaneously, the algal growth stimulating potential of samples from these sources was made by flask bioassay, utilizing the alga *Selenastrum gracile* as a test organism. Both the maximum growth rate (μ) and the maximum cell count (X) attained in a 5-day growth period were used to measure algal response to nutrients.

Continuous flow assays of the biomass of indigenous Lake organisms produced by various concentrations of sewage effluent in Lake Tahoe Water were then made in ponds simulating the shallow portions of the lake. Other sources of nutrients proved too dilute to justify pond assays but flask assays and chemical analyses were made for more than 2 years on 3 major creeks. Twenty-eight other creeks and precipitation were monitored by chemical analysis only.

An evaluation of the eutrophication potential revealed by the results led to many conclusions. Among the most significant were that Lake Tahoe is nitrogen sensitive and responds to this nutrient in proportion to its concentration. Creeks draining developed land carried twice as much nitrogen as those draining relatively undisturbed watersheds. During active development periods this ratio rose to 3/1 to 10/1. The combination of all surface streams plus precipitation contained about twice the concentration of nitrogen as Lake Tahoe or the undisturbed areas. Evidently human activity in the Lake Tahoe Basin doubles the natural inflow of nitrogen to the lake.

It was estimated on the basis of hydrological and chemical data that exporting all sewage would remove some 70 percent of the total nitrogen from the basin. However the 30 percent over present lake concentrations contributed by streams and precipitation on the lake surface is equivalent to the secondary sewage effluent of more than 33,000 people, when the concentration of nitrogen in the lake is taken as a baseline value.

Recommendations are made for protection of the shallows and for evaluating the effect of influent sediments.

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SECTION I

SUMMARY AND CONCLUSIONS

SUMMARY

A study of the factors leading to the eutrophication of surface waters was initiated in June 1966 through a demonstration grant to the Lake Tahoe Area Council by the Federal Water Pollution Control Administration (currently the Water Quality Office of the Environmental Protection Agency). The need for such a study was made evident by a decline in the quality of surface waters in the United States despite the concentrated efforts of pollution control agencies. Specific interest in utilizing Lake Tahoe as the locale for such a study derived both from the desire of millions of citizens to preserve the unique clarity of the Lake, and from the fact that the lake represented one of the few bodies of water in the world where eutrophication had not already progressed beyond the point where its triggering mechanism could no longer be discovered. Thus Lake Tahoe offered an excellent opportunity to explore on a laboratory and pilot scale the types of inputs which accelerate the natural rate of eutrophication of water and at what concentrations they might have a triggering effect.

The overall approach to the study was first to discover, by the best available methods of analysis and bio-assay, what concentrations of nutrients might be present in a number of possible sources, and to demonstrate their effect on algal growth stimulation in Lake Tahoe water.

Survey of Waters in the Lake Tahoe Area

The sources selected for survey included sewage effluents following various degrees of treatment; surface runoff from inhabited and uninhabited land areas; seepage from septic tank percolation fields, refuse fills, and spray irrigation systems; drainage from swamps; and water confined in keys and marinas. Waters from such sources in the Lake Tahoe area were systematically analyzed. Flask assays utilizing the alga *Selenastrum gracile*, were used to evaluate the growth stimulating effect of various concentrations of samples in Lake Tahoe water; and of the lake water itself. In later phases of the study *S. capricornutum* was substituted for *S. gracile* because a changeover from ocular counting of cells to machine counting by a Coulter Counter required an organism with minimum tendency for algal cells to persist in colonies. Growth stimulation in all flask assays was measured both by the maximum number of cells produced during an assay period (X), and by the maximum growth rate (μ) attained during that period.

Pond Assays of Wastewater Effluents

Results of the survey of sources indicated that although no one was advocating discharge of such material into Lake Tahoe, sewage effluents were the only important waste waters of sufficient stimulating potential to justify their study on a pilot scale. Consequently, a series of pilot ponds simulating the shallow portions of Lake Tahoe were operated during the summer and fall seasons of 1968 and 1969. Continuous flow of Lake Tahoe water through these ponds was provided, and biomass production was measured during detention periods ranging from 3 to 10 days, with various concentrations of sewage effluents. Indigenous organisms (mostly pennate diatoms) served as test organisms in both natural and enriched lake water.

Increase in volatile suspended solids (VSS) was used to measure biomass. Flask assays were made of the pond effluent and cell counts (X) and growth rates (μ) used to measure its residual growth stimulating ability.

Assay of Surface Waters

The effect of human activity in the Tahoe Basin was observed over a period of 3 years by analyses and flask assays of waters from creeks emanating from undeveloped land, developed land, and land undergoing intensive development. Ward Creek and General Creek represented relatively undisturbed conditions until development on the Ward Creek watershed began in 1969. Incline Creek, draining an area undergoing rapid development of land for living and recreational purposes, provided a basis for evaluating this type of human activity. The Upper Truckee – Trout Creek system gave a clue to the effect of long established human occupancy of land in enriching surface waters. Rapid expansion of population in the Lake Tahoe Basin limited the purity of assumption in each of the watersheds selected for study, but when results were compared with those from Lake Tahoe water as a background the assumptions proved valid and the differences between creeks were unmistakable.

Evaluation of Eutrophication Potential

The final phase of the project involved an estimate of the relative potential of sewage effluents and other sources of nutrients to accelerate eutrophication. The results of a program of chemical analysis of 31 creeks, including the four previously mentioned; estimates of the nutrient input by precipitation; and miscellaneous information concerning the inflow and outflow from Lake Tahoe were compared with the observed concentration of nutrients in the lake. The result was more of an inventory of nutrients than a nutrient balance but it made possible an estimate of the importance of removing sewage from the basin. Also, from the comparative data on undisturbed land (Ward Creek) and developed land (Truckee – Trout) an estimate of the relative effect of nature and man on enrichment of the lake was made. Projecting all creek inputs to the equilibrium at any growth of population level gave some clue as to what the growth of population may mean to Lake Tahoe in terms of rate of enrichment.

Auxiliary Studies

In parallel with the foregoing series of studies experiments were run to compare the continuous flow (chemostat) assay method with the flask assay method of measuring growth response. The kinetics of growth response were determined by use of the computer and statistical reliability was determined. The theory and results of this aspect of the study were reported in a series of Annual Progress Reports (1, 2, 3). At the low levels of nutrients prevailing in Lake Tahoe the method, despite its theoretical advantages, could not be made to produce satisfactory results in time to be used in achieving the objectives of the study. Consequently, this aspect of the project activity is not discussed in detail in this report.

CONCLUSIONS

The principal findings and conclusions relative to the several phases of the project summarized in the preceding section include the following.

Survey of Waters in The Lake Tahoe Area

1. Maximum growth rates of S. gracile in Lake Tahoe water were increased by the addition of sources of nitrogen but unaffected by similar additions of phosphates, indicating that Lake Tahoe is nitrogen sensitive rather than phosphorus sensitive as are most oligotrophic lakes.

2. Comparative growth rates between surface water from Lake Tahoe and the same water with added sodium nitrate were of the order of 29 percent per day versus 86 percent per day.

3. The ratio of nitrogen to phosphorus (N/P ratio) for all samples surveyed (with one exception) ranged from 0.4 to 7.36, averaging 2.08, whereas the N/P ratio for algal cells is reported (20) to range from 6.9 to 18. The exception was septic tank seepage in which the N/P ratio was 714/1 because of the vast ability of soils to adsorb phosphates.

4. At a concentration of 1% sample in Lake Tahoe water sewage effluents of all types (primary, secondary, tertiary, oxidation pond, and seepage from septic tank fields); surface drainage from storm water; and rain water all produced a growth rate of S. gracile considerably greater than the 29 percent per day ($\mu_b = 0.29\ \text{day}^{-1}$) observed for Lake Tahoe water alone. Moreover, the rate difference increased with concentration (10% and 50%).

5. Although the growth response was but little different between 1% and 10% rain water chemical analyses showed beyond doubt that precipitation is an important contributor of nitrogen to Lake Tahoe.

6. Melted snow, unlike rain which often occurs during thunderstorms, did not differ from Lake Tahoe water in growth response at any concentration.

7. At the time when disposal of effluent from the STPUD plant involved spray irrigation, direct assay of the effluent showed a marked ability to stimulate growth in S. gracile. However, samples taken from test borings in the spray irrigation field had little growth stimulating effect. This phenomenon was due to the adsorption of both phosphate and ammonia on soil colloids and too short a time interval between application and sampling for soil bacteria to convert nitrogen to the soluble nitrate form. Where such time period did exist, as in septic tank percolation fields, the growth stimulating effect of percolating sewage effluent was approximately 2 to 4 times that of Lake Tahoe waters, depending upon the concentration.

8. Evidence of leaching from a refuse dump was observed as an increase in organic nitrogen in a small stream as it passed the dump site. A comparison of dry weather and rainy weather analyses of the stream, following a winter frost heave, showed that increased nutrient concentration appeared in wet weather. Therefore it is concluded that the difficulties of maintaining the physical integrity of a landfill under severe winter conditions justifies a policy of excluding such fills from the Lake Tahoe Basin.

9. Assays of growth response of a test alga, such as characterizes the flask assay method, can measure only the residual potential of a water to stimulate growth. Therefore, at times of the year when nutrients are tied up in an algal bloom such an assay might show no evidence of eutrophication potential when eutrophication is obvious to any observer. This phenomenon was evident in assays of water from keys and marinas in the survey phase of the project.

10. At the time of the survey (1967-68) Meeks Creek and Ward Creek were indistinguishable from Lake Tahoe in the matter of growth response of S. gracile in flask assays.

11. Incline Creek, being in the early stages of development on its watershed showed little evidence of increased response at the time of the Survey. (See "Assay of Surface Waters" for subsequent developments.)

12. Upper Truckee — Trout Creek, draining an area of well established human occupancy showed a definite increase in growth stimulation with increased concentration in Lake Tahoe water.

13. General conclusions derived from the survey of possible sources of nutrients in the Lake Tahoe Basin, beyond the specific findings reported above were that:

    a. Sewage effluents represent the most important source of nutrients which might trigger eutrophication of surface waters in the Tahoe Basin, hence are suited to further study on a pilot scale.

    b. Septic tank leachings do not differ particularly from other sewage effluents in their ability to produce algal growth in Lake Tahoe water However, it was infeasible to collect them in sufficient amounts for pilot pond studies.

    c. Pond assays at various concentrations of waters from the Upper Truckee—Trout Creek system might be useful, but were impractical because of geographic relationships between source and pond installations.

    d. Other creeks (see 10 and 11, above) could be assayed in ponds only at 100% concentrations — an undertaking neither feasible nor especially useful under the project plan.

Pond Assays of Waste Water Effluents

14. Attempts to utilize S. gracile as a test alga in unfiltered Lake Tahoe water in continuous flow steady state pilot ponds were unsuccessful because the organism was soon overwhelmed by indigenous lake organisms (mostly pennate diatoms).

15. Filtration of lake water to remove indigenous organisms was not feasible except at an unacceptable sacrifice of time and expense in re-equipping the pond system. Consequently, indigenous organisms were used as test organisms and the increase in volatile suspended solids (VSS) in comparison with a similar increase in Lake Tahoe water was used to measure growth response to added nutrients.

16. Growth stimulating response of organisms increased with concentration of sewage added to Lake Tahoe Water.

17. Biomass produced by 0.1% secondary effluent in LTW was about the same as that produced by a 1.0% tertiary effluent (STPUD Water Reclamation Plant).

18. There was no evidence that growth response was reduced, in either Lake Tahoe water or other samples assayed, by cold weather which sent water temperatures below the 10°C level at which biological activity is normally seriously reduced.

19. Wind disturbance of the near-shore area of the lake was found to result in pickup of both inorganic and organic solids. However, the effect on biomass production when this occurred was damped out by the 5- day residence period in the pond.

20. From an inventory of nitrogen compounds it was concluded that with limited exceptions, a decrease in all forms of nitrogen occurred during the bioassay which correlated well with the observed increase in VSS.

21. Under steady state pond assays of secondary sewage effluent in Lake Tahoe water at concentrations of 0.1% and 1.0%, nitrogen was determined to be the growth limiting nutrient. Phosphorus was limiting in assays of 1% and 2% tertiary effluent.

22. Simulated secondary effluent based on the addition of NH_3-N, PO_4-P, iron, and micronutrients produced a different growth response than did secondary effluent of the same apparent analysis. It is concluded that life processes themselves contribute growth stimulants which the analyses adopted for the study did not reveal.

23. In pond assays of tertiary effluents the growth response was so severely phosphorus limited that neither the materials balance nor the kinetic equation yielded statistically significant correlation coefficients. The apparent reason is that all data fall on the flat region of the cell mass versus residence time curve.

24. The tertiary effluent assayed in the study was secondary sewage treatment plant effluent which had been subjected to phosphate removal, carbon filtration, and nitrogen reduction by ammonia stripping. However, because the tertiary process itself was a new demonstration unit undergoing devel opment, the residual NH_3-N in the effluent was in the range of 12 to 17 mg/ℓ.

25. From the calculated percent of inorganic nitrogen in volatile suspended solids produced during pond assays it is concluded that a good materials balance for nitrogen was achieved; and hence that reasonable confidence in the overall results of the nutrient inventory presented is justified.

26. In water as pure initially as Lake Tahoe water the total volatile suspended solids at the end of pond bioassays is an accurate measure of biomass produced.

27. From flask bioassays of the effluent from ponds it is evident that in situations when one nutrient is severely limiting to algal growth a bioassay of the water might lead to a false conclusion concerning its nutrient value. If the limiting factor is phosphorus and Lake Tahoe is, as evidence indicates, nitrogen sensitive, a major growth stimulant (nitrogen) in a discharge to the lake could pass a bioassay test and still do harm to the lake.

Assay of Surface Waters

28. From both chemical analysis and flask assays of growth response over the period of study, it was concluded that there was no significant difference between samples taken at a mid-lake station and those taken at the near-shore station from which water was pumped for pond assays. Consequently, it was further concluded that for the purposes of the study the near-shore sample could be taken as representative of at least the top few meters of Lake Tahoe water.

29. Five instances were found in the year 1970 when wind and storms resulted in a disturbance of the near-shore sediments. On these occasions Total SS exceeded VSS to a more than normal degree in near-shore waters, and both exceeded the concentration of similar solids in mid-lake samples.

30. Suspended solids in the shallow portions of the lake depreciated its aesthetic quality locally when wind direction and velocity was right for pickup of silt discharged to the lake as a result of land development.

31. From flask assays of Lake Tahoe water which had been enriched with added nutrients in the form of secondary effluents and allowed to support algal growth prior to flask assay of filtered samples, it was found that a residual growth potential remained in excess of that normally existing in Lake Tahoe water. Consequently algae removal from a waste water could not by itself protect Lake Tahoe.

32. In analysis of growth rates, VSS, and chemical constituents over a one year period, evidence was found of the "residual potential" phenomenon noted in Conclusion 9. However, because Lake Tahoe is nitrogen poor it supports such a small biomass that the results of flask assays are not measurably in error because of nutrients tied up in biomass. (In pond assays, where large volumes of water were involved, the relative productivity of VSS by raw on enriched Lake Tahoe water was readily determined).

33. Because, algal assays of membrane filtered samples measure only the residual ability of a water to stimulate algal growth, the flask assay technique is more useful in evaluating the growth potential of a waste water not already producing algae than in assessing the eutrophication of surface water, except in unique cases such as Lake Tahoe and some of its tributary creeks.

34. During 1968 Ward Creek, which drained relatively undisturbed land, was no different than Lake Tahoe in growth potential. Simultaneously, as development of land on the Incline Creek watershed was beginning, both Incline and Upper Truckee – Trout creeks averaged about 1.6 times the growth stimulating potential of Lake Tahoe.

35. During the first 6 months of 1969, Ward Creek continued to parallel Lake Tahoe. At the same time increased activity on the Incline watershed caused Incline Creek to exceed the Upper Truckee – Trout Creek system in productivity. Both continued to exceed Ward Creek and Lake Tahoe in stimulatory potential.

36. In the latter half of 1970, activity in the Ward Creek area initiated a response similar to that of Incline Creek. Upper Truckee – Trout Creek continued to exceed Lake Tahoe in growth potential, although less than either of the two (Ward and Incline) more disturbed watershed.

37. Flask assays were shown to be capable of detecting changes in those water quality factors which increase the rate of eutrophication of surface waters, although no one can interpret the growth rates attained in such assays in terms of the biomass which might result in an individual outdoor situation.

38. Cell counts ($\hat{X}_5$) and growth rates ($\hat{\mu}_{b\ell}$) correlated well with nutrients concentrations present in creek waters.

39. Algal growth in waters from undisturbed areas showed best correlations with the concentration of the more stable forms of nitrogen and phosphorus, as might be expected.

40. Human occupancy of land under well developed conditions (e.g. Upper Truckee – Trout Creek) showed an appreciable excess in algal growth stimulating nutrients over that from land under natural conditions.

41. Runoff from relatively undisturbed land as, for example, the Ward Creek watershed in 1968 and the General Creek watershed in 1970, reflect essentially the same growth stimulating properties as Lake Tahoe water.

42. Land undergoing development is especially productive of algal growth stimulating nutrients, at least under practices which have prevailed in the Lake Tahoe Basin.

43. The presence of humans and human activity on a watershed definitely increases the rate of eutrophication of its surface waters.

44. It is concluded that a definite increase in nutrients in creek waters occurs as the level of occupancy and development of land increases, which was evident in both chemical analyses and bioassays.

45. Land management and land use controls are essential to a program designed to minimize the rate of eutrophication of surface waters.

Evaluation of Eutrophication Potential

46. Chemical analyses of samples from 31 creeks discharging into Lake Tahoe were on a periodic and systematic basis for the period 1969 to 1970, with especial emphasis on organic -N, NH_3-N, $(NO_2 + NO_3)$-N, Total -N, PO_4-P, Total -P, chlorides and conductivity.

47. The average values of the foregoing parameters differed very little from that of the three major streams (Ward Creek, Incline Creek, and Upper Truckee – Trout Creek) previously reported and included in the 31, except in the forms of nitrogen making up the Total N. Generally there was more soluble organic nitrogen and less ammonia in the over all composite than in the 3-creek composite.

48. Total nitrogen in the creeks averaged about 2 times that in Lake Tahoe, whereas phosphorus in the creeks averaged 3 times as great.

49. The concentration of Total nitrogen in melted snow was more than 2.5 times that in Lake Tahoe Water, while total phosphorus was about double that in the lake.

50. Rain water showed a much higher nutrient content than melted snow. However, snow in January 1968 showed essentially the same growth stimulating potential as Lake Tahoe Water in flask assays. Snow samples in 1970 showed a quite different distribution of nutrients than in 1968 with 2 to 3 times the Total -N content. The data suggest that greater attention should be given to meteorological conditions at times of precipitation sampling, particularly with respect to thunderstorm activity which may fix nitrogen.

51. By procedures detailed in the report it was possible to establish rainfall-runoff relationships for 61 sub-basins of the Lake Tahoe Basin, including the 31 creeks monitored by chemical analysis.

52. From rainfall-runoff relationships, estimates of evaporation, and records of lake discharges and water levels a hydrologic inventory of the Lake Tahoe Basin was prepared. Similarly a nutrient inventory was developed and from the two an estimate was made of the various nutrients entering Lake Tahoe as a result of stream flow and precipitation.

53. It was shown from data on 6 streams for which continuous flow records are available that about two-thirds of the annual stream flow occurs in the months of April, May, and June. However, because of the short period (15 months) of record for 28 of the 31 streams it was considered infeasible to weigh the nutrient data on a monthly basis instead of a simple yearly average.

54. Precipitation directly on the lake surface plus runoff from the land has averaged 644,000 acre feet per year during the past 10 years. i.e. about 1/190 of the estimated total volume of Lake Tahoe (122 x 10^6 acre feet).

55. Nutrient concentration in the 644,000 a.f. was approximately twice that found in Lake Tahoe.

56. The similarity of Ward Creek water to Lake Tahoe water suggests that the quality of lake water is about the same as the runoff from undeveloped land, in terms of nitrogen content.

57. Creeks draining populated areas show about twice the concentration of nutrients found in Lake Tahoe.

58. From 56 and 57, plus the fact that the combination of precipitation and surface runoff is also double that of Lake Tahoe, it is reasoned that precipitation must have increased in nutrient load with the years. The fact that moisture-laden air masses which lead to precipitation at Lake Tahoe first pass over the heavily urbanized San Francisco Bay Area and the intensively formed Central Valley lends credence to such a postulate.

59. It is concluded from a comparison of Lake Tahoe Water and surface flow plus precipitation that the latter reflects an influence of relatively recent origin which involves a nutrient enrichment of Lake Tahoe.

60. Secondary sewage effluent from South Tahoe used in pond assay studies averaged about 190 times as rich in Total nitrogen as was Lake Tahoe, and 87 times as rich as the combined stream flow and precipitation. For tertiary sewage effluent the corresponding factors were 114 and 52, respectively.

61. From the assumption that domestic sewage flow is 100 gallons per person per day and that the nitrogen content of secondary sewage is that observed at South Lake Tahoe (27 mg/ℓ), the 644,000 acre feet from streams and precipitation is equivalent to the secondary sewage of 66,700 people.

62. Using the same assumption as in 61, the excess of nitrogen in stream and precipitation over that of Lake Tahoe is equivalent to the secondary sewage of 36,400 people.

63. From 61 and 62 it may be estimated that if the 1970 population of the Lake Tahoe Basin averaged 100,000 people and <u>all sewage had been exported</u> about 30 percent of the man generated nitrogen in the basin would have still gone into Lake Tahoe.

64. Taking into consideration the relative crudity of some of the data, and the many subtleties which are overlooked in the foregoing estimates, it seems certain that every effort must be made to limit the flow of nutrients into Lake Tahoe. Both what we know and what we do not know support this conclusion.

65. Observation of Lake Tahoe and its biota by Dr. James E. Lackey in April 1970 led him to suggest that

    a. Even such a lake as Tahoe should now and then develop algal growths dense enough to change turbidity in the top 10 meters.

    b. Tahoe has undoubtedly for years produced an algal crop in the spring; March being indicated by project reports (3).

c. Tahoe should at all times have a standing crop with a several-fold seasonal increase.

d. Disturbance of the waterfront should be strictly limited.

e. Use of tributary streams by human population should be watched.

f. A luxuriant growth of Ulothrix was observed in the Truckee River fed on lake water, hence the lake evidently has the potential to support a heavy algal growth at times. Why such has not been reported is an unexplained question.

66. Long term studies of the biota and the limnology of Lake Tahoe are needed along with a thorough evaluation of what has already been done.

67. In spite of the difficulty of extrapolating pilot pond and laboratory findings to field conditions the findings of the study clearly indicate that man's activities in the Tahoe Basin should be subject to controls not common in less obviously critical situations.

68. For the protection of surface waters in general, and of Lake Tahoe in particular it is concluded that the historic right of men to use land may have to be infringed upon to an extent not envisioned in existing law and local zoning ordinances.

Auxiliary Studies

69. Chemostat (continuous flow) assays, such as used in pond assays, could not be made to perform on a laboratory scale at the low levels of nutrient concentration prevailing at Lake Tahoe with sufficient reliability for purposes of the project.

70. The objectives of the project did not permit the time and research necessary to develop the chemostat as a laboratory assay method, despite its theoretical advantages over the flask method.

71. Studies of the kinetics of algal growth did not reveal whether the crudity of data near the lower limit of the resolving power of chemical analyses, or the applicability of the Michaelis-Menton model to algal systems, were responsible for disappointing results of kinetic analyses made (1, 2, 3) during the study.

SECTION II

RECOMMENDATIONS

On the basis of the findings herein reported, the unevaluated factors cited, the areas where knowledge is known to be insufficient, and the current eagerness of citizen groups and public agencies to be about environment-related activities, it is recommended that:

1. The program of monitoring of creeks be continued, with the objective of definitely establishing the relationship of man's activities to water quality as a basis for:

    a. Formulating appropriate means of control.

    b. Establishing relationships through which a minimal program of monitoring might reflect the overall changes taking place in the Basin.

2. A systematic program of chemical analysis and algal growth potential assay of precipitation be initiated and conducted over a period of years for the purpose of isolating and evaluating it as an important source of nutrient inputs to Lake Tahoe.

3. The program of investigating the amount of sediment recycling in Lake Tahoe, identifying and controlling its source, and evaluating its aesthetic and limnological effects be continued and expanded.

4. A survey be made to discover the scope and nature of the numerous private and public studies presently under way in the Lake Tahoe Basin.

5. An appropriate task force, or study team, be set up to evaluate on an annual basis the aggregate findings of the numerous ongoing studies in terms of water quality, eutrophication potential, sources of pollutants, environmental effects, legislature needs, and other objectives of society, particularly in the water quality context.

6. Although not related to eutrophication at current levels, the effect on the quality of Lake Tahoe by chlorides used in pavements de-icing should be evaluated.

SECTION III

RESULTS OF STUDY

CHAPTER I

INTRODUCTION

NEED FOR STUDY

The study herein reported was initiated in 1966 pursuant to a need which derived from two major considerations: 1) a decline in quality of surface waters in the United States despite the dedicated efforts of pollution control agencies, and 2) the desire of millions of citizens to preserve the clarity of Lake Tahoe for aesthetic reasons. Although the nutrient-rich condition which characterizes eutrophication is by no means the only problem of surface water quality, the two foregoing considerations differ in this particular only in order of magnitude of the associated problem. Since 1966 the concern for both water quality in general and for Lake Tahoe in particular has increased in intensity as the public has become alarmed and man is increasingly assigned the role of villian in environmental matters. Similarly, the accelerated efforts of public agencies to put an end to water pollution has increased the urgency for knowledge of the factors which trigger eutrophication of surface waters and of the means by which they may be overcome.

In the general case of surface waters, eutrophication is not always the result of man's activities. Occasionally lakes, ponds, and streams even under wilderness conditions receive sufficient nutrients from plant and animal residues to support a rich flora and fauna. In the more common situation, however, to which this study is directed, nutrient concentrations are initially low enough that the water is well suited to such high levels of use as domestic water supply, while at the same time supporting a good fish fauna and the food chain on which it depends. Here the source of nutrients is degradation of rocks and the decay of organic matter washed in from land surfaces or blown in from bordering vegetation and, generally, recycled within the water itself. Such a natural equilibrium is disturbed when man diverts water and returns it with the burden of biochemically unstable organic wastes from human life processes. A critical situation develops when the number and concentration of people, or when a combination of human numbers, industrial activity, land fertilization, concentration of livestock, disturbance of natural cover, and so on, produces nutrients at a level which overfertilizes natural waters. Such highly eutrophic waters are objectionable to man because the excess aquatic growth that develops in such an environment renders them aesthetically unattractive or otherwise unsuited to beneficial use.

Throughout the United States the percentage of the water resource which has eutrophic characteristics has grown rapidly in recent years as both the on-shore and water using activities of man, as well as his numbers, have multiplied. Green scums, hairlike filaments on shoreline rocks, and shallows clogged with weeds have increasingly appeared in waters formerly free of such nuisance. Algal blooms have aroused public indignation and have increased the cost of obtaining satisfactory water. In severe cases they have limited the use of surface waters and so impoverished the lives of recreationists and brought financial disaster to sectors of the recreational industry. To combat the loss of water quality and its social and economic effects, regulatory agencies have enunciated stricter water quality criteria, standards, and regulations intended to preclude the discharge of growth stimulating factors into receiving waters.

The specific situation in which there is a need to evaluate the applicability to Lake Tahoe of measures generally suited to the control of eutrophication, exists because the lake is unlike anything generally found in the world. Its water is exceptionally low in phosphorus, nitrogen, and other growth stimulating factors. It is deep, well mixed, and water temperatures are low due to altitude and the snowmelt which feeds it. The lake occupies a large percentage of the Lake Tahoe Basin;

consequently water export must be limited if the integrity of the lake is to be maintained. Finally, no one knows the exact degree to which nutrient enrichment of the lake is reduced by export of sewage effluents; the measures necessary to permit retention of waste waters in the basin; or the precise percentage increase in natural fertilization of the lake resulting from human activities. Moreover, the lake is under extremely heavy population pressure with attendant motivation to develop shoreline facilities and a regional economy along accustomed patterns in which unique environmental aspects are not so important a factor.

But what are the growth stimulating materials that lead to eutrophication; what is their origin; and in what concentrations are they significant? The need for study is related to all three aspects of this question.

The obvious source of nutrients is effluent discharged as municipal, agricultural, and industrial waste water. First attention to such wastes, however, was logically directed in the past to its oxygen demanding properties (BOD) and to their deleterious effect on aquatic life and on the aesthetic quality of water which various other beneficial uses require. Consequently, the art of sewage treatment developed around biostabilization of degradable organic matter and until quite recently treatment processes have become progressively more sophisticated only in their ability to oxidize organic matter. Unfortunately, the oxidized forms of nitrogen and phosphorus are in themselves significant growth stimulants, and their presence in waste water, along with biosynthesized vitamins, amino acids, trace elements, and other growth factors found in biologically treated wastes, raises serious questions as to the suitability of conventional waste treatment for control of nutrients influencing eutrophication.

In response to these questions the concept of nutrient removal from sewage effluent has recently had widespread appeal in water quality management. Because a few of the blue-green algae, one of the most important representatives of nuisance algal blooms, can fix nitrogen from the atmosphere, and because of the increasing quantities of nitrogen in rain, it is widely suggested that phosphorus is the critical nutrient and should be the first to be removed from sewage effluents. Nitrogen and phosphorus removal has been advocated and is already being practiced in the South Lake Tahoe area.

There is, therefore, a need to determine several factors in relation to sewage effluents, including:

1. The concentrations at which nitrogen and phosphorus will trigger or support serious algal growth.

2. The algal growth stimulating effect of sewage from which nitrogen and phosphorus has been removed.

3. The ability of practical nutrient removal processes to reduce nitrogen and phosphorus to levels below that critical to algal growth.

The assumption that domestic and industrial waste water effluents are the principal source of nutrients is not necessarily valid. In many instances in the lake country of the middle west fertilizing of agricultural land and animal manure disposal practices are the critical factors in eutrophication of lakes. On every hand the activities of agriculture, the development of housing subdivisions, highway construction and similar works disturb the natural ground cover and by disrupting the equilibria of natural systems render the surface more subject to erosion. Pavement, roof areas, land drainage, storm sewers, and straightening and lining of stream channels hasten the delivery of surface wash to receiving waters. Consequently there is a need to evaluate the relative role of sewage effluents and other sources of nutrients in the stimulation of algal growth in surface waters.

Such a need is especially important in the Lake Tahoe area where the basin is forested, population is burgeoning, and land use encourages erosion by following the same pattern as other urban developments. Export of sewage effluents from the basin is well advanced both in practice and in planning for the future. Therefore both the need and the opportunity exists to study such aspects of the problem as:

1. The residual ability of nutrient-stripped (tertiary) sewage effluents to stimulate algal growth.

2. The ultimate fate of nutrients removed from sewage in the Tahoe Basin.

3. The overall amount of nutrients reaching Lake Tahoe annually from the normal processes of nature in the basin, including precipitation.

4. The effect of man's near-shore and shoreline modifications and activities on the biology and natural beauty of the Lake.

5. The significance of findings of laboratory and pond assays in terms of the overall complex limnological system which is Lake Tahoe.

In relation to the foregoing needs it has been suggested that it would be particularly ironical and tragic if the nitrogen stripped from sewage found its way into the lake via rainfall and phosphate via pickup from landfill, while the purified water from which they were removed was needlessly exported from the basin. Although it has not been shown that such is the case, the speculation underscores the need for studies of the type herein reported.

Because shoreline development and construction may influence both the input of nutrients and the way the lake responds to them, there is a need to interpret the results of assays in relation to:

1. Development of flood plains, meadows, and marshlands.

2. Construction of marinas, lagoons, and breakwaters.

3. General construction practices throughout the watershed.

OBJECTIVES OF STUDY

The general objectives of the study are implicit in the need outlined in the preceding section. Specific objectives include:

1. To determine, by the most effective laboratory bioassay techniques available, whether there is present in effluents from waste water treatment processes, or in surface wash or groundwater seepage from inhabited or uninhabited areas, materials capable of stimulating algal growth in surface waters; and at which concentration they may be significant.

2. To demonstrate by studies on artificial ponds the applicability to Lake Tahoe of the results of laboratory assays or possible inputs to the lake.

3. To evaluate the danger to Lake Tahoe of man's waste effluents and land practices in the basin, on the basis of results of studies in pilot-scale experimental ponds and a survey of the various nutrient sources within the basin.

4. To compare the growth stimulating characteristics of tertiary effluent in Lake Tahoe water with that of the same effluent when ponded in Indian Creek Reservoir. (Supplemented by Demonstration Grant No. 16010 DNY.)

5. To prepare an authoritative document (Final Report) on eutrophication of surface waters based on the findings of the study throughout its total grant period and current knowledge of the problem at the time of reporting.

NATURE AND SCOPE OF REPORT

As noted in the Preface, the report herein presented is of the nature of a Final Report covering five years of study of the eutrophication of surface waters with special reference to Lake Tahoe. It is concerned primarily with previously completed and reported [1,2,3] work pursuant to the first and second objectives (above); with both previously reported and new findings pertinent to objective number three; and with data evaluation pertinent to the fifth objective. Results of study related to the fourth objective, for which a supplementary grant (Demonstration Grant No. 16010 DNY) has been made to the Lake Tahoe Area Council by the Federal Water Quality Administration, are reported separately in previous [4] and forthcoming reports on Indian Creek Reservoir.

No single theoretical consideration characterizes the approach to the study. Consequently scientific theory is introduced in the report only when it seems necessary to an understanding of the subject matter under discussion. The overall intent was to discover the significant sources of nutrient enrichment of surface waters and to demonstrate their importance in the rate of eutrophication of Lake Tahoe. The study procedure was first to select from available assay and analytical methods those best suited to measuring nutrients at the low concentration levels known to exist in Lake Tahoe. Next, assays were made by the selected techniques of a wide variety of waste water effluents and of surface, ground, and meteorological waters which might transport nutrients into any body of surface water, regardless of whether or not they presently represent known discharges into Lake Tahoe. From an analysis of the results of this second phase of the study it was determined which of the possible sources of nutrients might profitably be further investigated in pilot plants. Pilot plant studies were then conducted to explore the potential of selected wastes to trigger algal blooms in Lake Tahoe water, and at what concentrations a significant effect might occur. Finally, the emphasis of the study was directed to an estimate of the amount of nutrients generated in the Lake Tahoe Basin and discharged to the lake as a result of a combination of natural cycles and man's presence and activities in the basin.

Although many of the several phases of the project proceeded simultaneously at some stage of the study the report is divided into a series of chapters related to the objectives in the sequence noted in the preceding section. Specifically:

1. Chapter II reports the problems and conclusions relative to assay techniques and analytical methods.

2. Chapter III reports the evaluation of sources of possible nutrient enrichment of Lake Tahoe.

3. Chapter IV deals with pilot pond assays of Lake Tahoe water from which might be predicted the effect of various concentrations of waste water in the shallow portions of the lake.

4. Chapter V presents data and estimates of the nutrients contributed to Lake Tahoe by surface runoff from various types of land use, precipitation, etc.

5. Chapter VI compares the observed nutrient content of Lake Tahoe water with the estimated content and evaluates the potential of man's occupancy of the Basin to accelerate eutrophication of the lake.

6. Chapters VII and VIII present an overall evaluation of the study in terms of eutrophication of surface waters, and summarize the conclusions and recommendations which the study supports.

CHAPTER II

ASSAY TECHNIQUES

INTRODUCTION

The first of the five objectives listed in Chapter I require both the selection of available methods of biological and chemical assay best suited to the study, and their application to a variety of possible influents which might transport significant concentrations of nutrients into surface waters. In the interests of clarity these two aspects of objective number one are herein discussed in separate chapters. Chapter II is concerned with the rationale and the experimental results which led to the adoption of particular methods, and with the details of the methods themselves. Application of the techniques to achieve the second aspect of objective one is the subject of Chapter III. Further details of the assay techniques are added as appropriate to an understanding of procedures and results throughout the report.

BIOASSAY TECHNIQUES

General Considerations

The concept that the capability of a waste water discharge to hasten the eutrophication of a receiving water might be measured on either an absolute or a relative scale by some method of bioassay has long intrigued researchers and regulatory officials. After a number of years of study of the factors affecting algal growth, Oswald [5,6] suggested the term Algal Growth Potential and defined it as the "weight of algae which will grow at the expense of algal nutrients in a water when no factor other than nutrient is limiting to growth." Two basic methods which might be used for such bioassays have long been used in various chemical and biological industries and in research. They are the batch and the continuous flow processes. As a bioassay procedure the first involves flask assays; the second depends upon the use of devices commonly known as "chemostats." Both methods were used in the study herein reported for reasons and purposes noted in the appropriate context.

Flask Assay

The flask assay depends upon culturing a selected test organism in a medium containing the waste water to be assayed over a range of concentrations and under standard conditions of lighting, temperature, and mixing. Algal growth is then measured in one or another manner and the result related to the concentration of the growth-limiting factor or nutrient. Although subject to limitations discussed in a subsequent section of this chapter, flask cultures have been widely used in the field of biology and accumulated experience suggested it as a method suited to the purposes of the study unless parallel findings with continuous flow systems should prove superior.

Test Organism. The alga *Selenastrum gracile* (Reinsch) was initially (1966) selected and utilized as a test organism on the basis of consideration of the characteristics of an ideal test organism [1] and of favorable results reported by Skulberg [7] with the same genus. It has the disadvantage of producing large cells under nutrient rich conditions, thus making it difficult to establish a relationship between cell count and biomass. In addition, newly formed cells tend to remain attached, but because they rarely exceed four in a group, cells are easily distinguished by "hand" counting under the microscope. These limitations, however, were considered minor for the nutrient-poor conditions prevailing in the Tahoe situation as long as the hand counting method was used. In July 1969 machine counting by use of the Coulter counter was initiated. Because this instrument records as a single particle any colony of cells passing between its electrodes the test organism was changed to Selenastrum capricornutum, which has similar characteristics to S. gracile but does not tend to clump.

With either of the two species of Selenastrum a basic culture was maintained at a constant growth rate by the continuous flow culture method, using a residence time, θ, of 5 days and a nutrient solution of Skulberg's medium (Appendix A), which is specially designed for culturing Selenastrum. The purity of this basic culture was verified periodically by microscopic examination.

Assay Procedure. In making a flask assay of any nutrient source, the sample to be assayed was first filtered to remove any organisms which might compete with the test alga for nutrients, and any debris which might be mistaken for organisms by the counter. The sample was then diluted to the desired concentration with filtered Lake Tahoe Water (LTW) and 150 mℓ placed in each of 5 sterile 250 mℓ Erlenmeyer flasks. Cells of the test alga in good physiological condition were centrifuged and washed twice with LTW to minimize the chance of nutrient carry over from the stock culture to the assay flasks. An equal volume of the washed suspended cells was then added to each test flask in the amount needed to introduce approximately 50 cells/mm^3 into the 150 mℓ of liquid.

Loose fitting plastic beakers were inverted over the tops of the inoculated test flasks, prior to being placed in a 20°C constant temperature room and incubated on a gently moving (30 cycles/minute) shaker table for a period of 5 days. Illumination of approximately 550 ft-c (5920 lux) intensity was provided by four 40 watt G. E. fluorescent lamps, No. F40-CW, Coolwhite, four feet in length. A typical flask assay used in the study is shown in Figure 2-1.

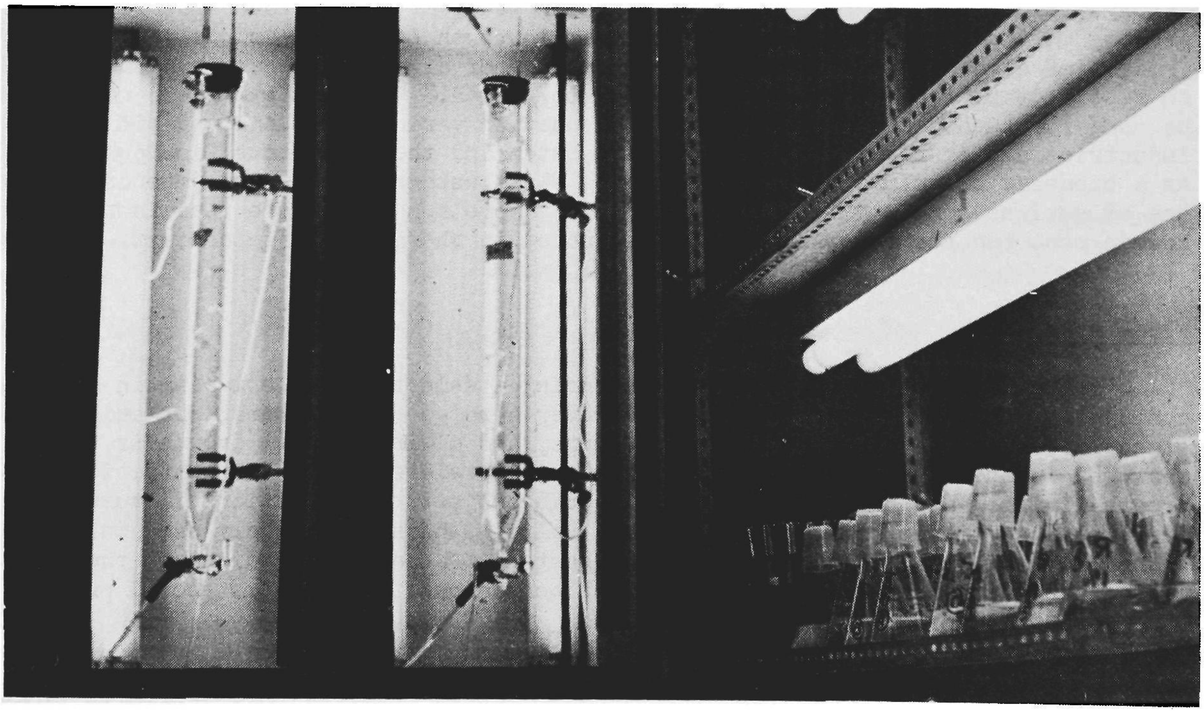

FIGURE 2-1 TYPICAL FLASK (AND CHEMOSTAT) ASSAY APPARATUS USED IN STUDY

Cell concentration in the test flasks was determined by cell counts at the end of one, three, and five days, preliminary tests having shown the maximum cell growth rate to be attained within that period. For hand counting under the microscope, a 10 mℓ aliquot was removed from each flask after 1, 3, and 5 days of incubation. This aliquot was then centrifuged for 10-15 min at 2000 rpm (approximately 800 times gravity). After centrifugation, 8-9 mℓ of the supernatant were removed with a Pasteur pipette and the pellet of cells resuspended in the remaining liquid medium. A drop of the suspension was then put on a Spencer Bright-Line hemocytometer for counting under the microscope. Duplicate counts were made for each flask and five replicates were performed for each concentration; thus a total of 30 counts were made for each concentration of sample tested. The duplicate counts for each flask were averaged, and the resulting values were then averaged to obtain a mean count for the five replicates constituting the assay.

The method used in the Coulter counter technique involved removing a 10 mℓ aliquot from each flask. The aliquot was then diluted with a saline solution so that the final concentration ranged from a maximum of 50 percent to that concentration which provided a final count of less than 10,000 particles (counting capacity of the Coulter counter) for a 0.5 mℓ diluted sample. As in the case of the hand count method, a mean value was obtained for the five replicates.

Continuous Flow Assay

The continuous flow assay involves culturing a single alga or group of organisms in a chemostat under standard conditions of lighting and temperature and under steady state conditions of nutrient input and algal cell production. The concentration of algal cells in such a system is thus a function of the concentration of the growth-limiting nutrient or growth stimulating factor in the water assayed.

Chemostat. A typical laboratory scale (one liter) chemostat used in the study is shown in Figure 2-1. Each unit was cabinet mounted and illuminated with two 30 watt G. E. Coolwhite fluorescent lamps No. 30T8-CW, providing 200-250 ft-c (2150 to 2700 lux) light intensity. A small Dyna pump (not shown in the figure) discharged air through a sterile cotton filled tube into the base of the chemostat at a rate sufficient to maintain a slow rise of bubbles through the liquid. This served to keep the algal cells in suspension and to disperse influent water to be assayed. This latter was injected into the chemostat by a small Sigmamotor pump through a wye in the air influent line. Displaced liquid was collected from an overflow tube at the top of the unit. The entire assembly was installed in a 20°C constant temperature room.

Assay Procedure. In making a continuous flow assay the chemostat was first filled with the sample to be assayed. It was then inoculated with the test alga (*S. gracile*) at a concentration level of 20 to 50 cells/mm^3. The sample was then fed in at a continuous rate sufficient to provide the desired residence time (normally 5 days) and cell concentration in the overflow was determined by cell counts at two day intervals. When 3 successive counts checked within ± 20 percent with no indicated trend, the system was assumed to be at steady state. Thereafter data were taken for at least two additional residence periods. To develop data for kinetic constant evaluation, at least 3 different residence times, θ, were made within a 5 to 15-day range.

Expression of Results

There are several ways to express the results of bioassays. One is the maximum cell concentration, $\hat{X}$, reached by an organism in a specific time period. For example, the 5-day concentration of *S. gracile* in flask assays at Lake Tahoe was designated as $\hat{X}_5$ and is herein reported as number of individual cells/mm^3. In situations where the individual cells are of a single genus and of relatively uniform size, the relationship between cell count and biomass is readily determined by simple experimental parameters.

In flask assays the concentration of cells, $\hat{X}$, is not a straight line function of time because of depletion of nutrient, intra-culture competition for food, and the varying nutrient requirements of cells of different ages. In the continuous flow system, however, where cells are of constant age and where both nutrient depletion and cell concentration are at steady state, $\hat{X}$ might be a good measure of the potential of any given nutrient concentration to support algal growth, but different values of $\hat{X}_5$ are to be expected in flask and continuous flow assays of the same water with the same test alga. In either case maximum growth rate might be a preferable measure of algal response to the growth stimulating factor in the assayed water.

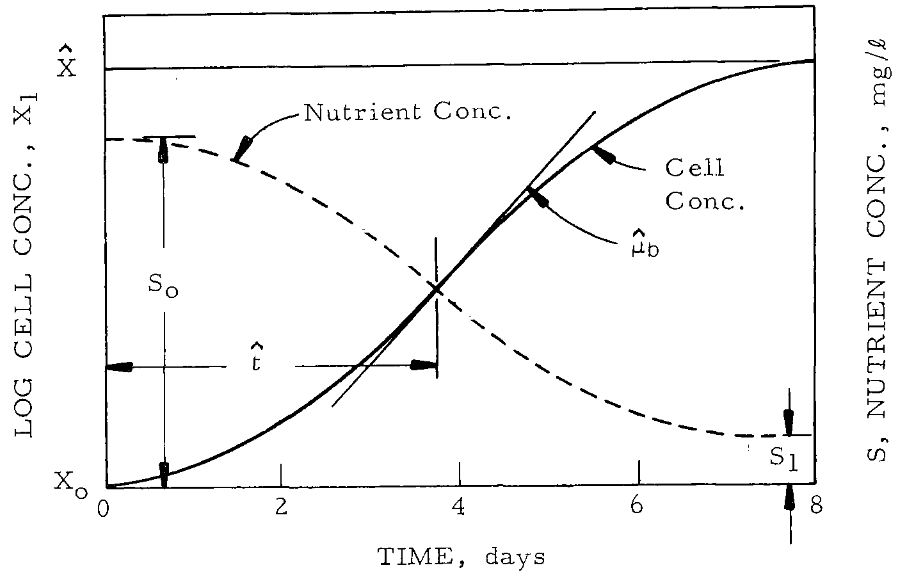

FIGURE 2-2 TYPICAL MICROBIOLOGICAL GROWTH CURVE, FLASK

Figure 2-2 shows typical growth rates and nutrient depletion curves for flask culture of microbial systems. Experiment has shown that the same situation applies to algal cultures. When the concern for nutrient concentration present in the environment is its effect on growth rates of specific algae, as in the case of algal blooms resulting from eutrophic conditions, most observers suggest that the maximum rate of growth is a better measure of algal response than is cell concentration. This measure is designated as $\hat{\mu}$, and represents the steepest slope of all possible tangents to the cell concentration curve plotted from periodic cell counts by microscopic examination, Coulter counter, or other means. For the batch method, or flask assay, the symbol is given the subscript b, i.e., $\hat{\mu}_b$ represents the maximum growth rate in a flask assay (batch type reactor).

$\hat{\mu}$ is expressed as percentage increase in cells per unit of time. Thus, for example, $\hat{\mu}_b$ = 0.25 days^{-1} means that in a particular flask assay the maximum rate of cell increase was 25 percent per day.

Maximum growth rate may be computed by a regression analysis of cell counts versus time, preferably by the use of a computer. This measure is herein designated as $\hat{\mu}_{b\ell}$ for flask assays, or in general, $\hat{\mu}_\ell$. It is expressed in the same units as $\hat{\mu}_b$. In some experiments previously reported [2] by the authors, $\hat{\mu}_{b\ell}$ showed a somewhat higher statistical significance than $\hat{\mu}_b$, probably because of the mathematical precision of its computation.

Another method of measuring the results of bioassay is to measure the reduction in concentration of added C^{14} in a culture as a result of algal growth, and to relate it to biomass on the basis of the normal carbon content of algal cells. It has the advantage of reducing the time necessary for cell counting by hand but does not exceed the 13 seconds per count attained in the study by the Coulter Counter.

Finally, the increase in volatile suspended solids (VSS) during a period of incubation can be used to measure the growth response of organisms to nutrient sources. It is essentially the only practical way to assess the response of a heterogeneous mixed population of organisms such as exist under natural field conditions.

INTERPRETATION OF RESULTS

Interpretation of the results of flask and continuous flow bioassays involve two principal factors:

1. The limitations, both practical and theoretical, of the tests themselves, and

2. The ability of laboratory tests to reflect actual response of organisms in natural environments.

Each of these factors is the subject of continuing scientific study, speculation, and disagreement far beyond the scope of this report. Therefore in this, and the section immediately following, the attempt is to summarize those considerations especially pertinent to an evaluation of the results of the study in terms of its stated objectives (Chapter I).

Theoretical Considerations

In the interest of eutrophication control it is highly desirable that growth rate be predictable on the basis of analytical measurements of the nutrient present in any water sample because the rate of growth of specific algae may be the key to objectional algal blooms. One major advantage of a continuous steady state assay method is that it permits the determination under laboratory conditions of the level of standing crop of any organism that can be supported in a particular hydraulic system at a specified residence (detention) time by some known concentration of nutrient.

Working with microorganisms rather than algae it has been shown by Michaelis-Menten [8], Monod [9], Caperon [10], Maddux [11], Williams [12], Jannasch [13], Dugdale [14], Pearson [15], and others that the specific growth rate is a first-order or first-zero order (Michaelis-Menten) function of the substrate (nutrient) concentration. That is, $\mu = kS$ or $\mu = \frac{\hat{\mu}\ S}{K_s + S}$. When the final value of S (Figure 2-2) = 0, i.e., $S_1 = 0$, as at low levels of initial rate limiting nutrient (S_o), a cell continuity and a kinetic equation can be developed [2] which takes the following forms:

$$\frac{1}{\theta_c} = \mu - k_d = Yq - k_d = \frac{Y(S_o \quad S_1)}{X_1 \theta} - k_d \qquad (1)$$

and

$$\frac{1}{\mu} = \frac{1}{Yq} = \frac{K_s}{\hat{\mu}}\left(\frac{1}{S_1}\right) + \frac{1}{\hat{\mu}} \qquad (2)$$

In which:

q = specific nutrient removal velocity

$$\frac{\text{gms nutrient removed}}{\text{gms cells - day}} \; (\text{day}^{-1})$$

μ = specific growth rate $\left(\frac{\text{gms cells produced}}{\text{gm cells - day}}\right)$, time^{-1}

S_o = influent concentration of rate limiting nutrient

S_1 = concentration of rate limiting nutrient in the reaction system

X_1 = concentration of cells in reaction system

θ = hydraulic residence time of system, i.e., $\theta = V/F$

θ_c = cellular residence time (i.e., mean cell age in system)

$\frac{1}{\theta_c}$ = net cellular growth rate

k_d = specific decay rate, i.e., $\left(\frac{\text{gms cells destroyed}}{\text{gm cells - day}}\right)$

Y = yield coefficient, i.e., $\left(\frac{\text{gms cell produced}}{\text{gm nutrient removed}}\right)$

$\hat{\mu}$ = maximum specific growth rate, time^{-1}

K_s = nutrient concentration at one-half the maximum specific growth rate, mass per unit volume.

To determine the rate constants and coefficients in Equations 1 and 2 a computer program can be prepared to analyze the effect of various nutrients found by chemical analysis during flask or continuous flow assays. The benefits to be derived from such analysis of a continuous flow system and its application to eutrophication problems, provided the equations apply to algal systems as effectively as to microbial cultures, are as follows:

1. A given level of rate limiting nutrient (i.e., $S_1 = NO_3^-$, $PO_4^{\equiv}$, etc.) in the receiving water determines the specific growth rate, μ, that can be supported by that rate limiting concentration [i.e., $\mu = f(\bar{S}_1)$].

2. For a given level of S_1 and μ and yield coefficient, Y, the mean cell concentration, X_1, (standing crop) is determined by the residence time for the system:

$$X_1 = \frac{Y(S_o - S_1)}{\theta\,\mu}$$

3. The net or gross cellular growth rate that will follow from any level of nutrient concentration can be estimated once the rate constants and coefficients have been determined for the organism and nutrient from the relationship:

$$\frac{1}{\theta_c} = \mu - k_d$$

Limitations of Bioassay Techniques

A major limitation in applying the results of either flask or continuous flow assays to field conditions is the fact that at best they represent simple ecosystems rather than the complex systems of nature in which predators, competitors, and parasites live in some dynamic balance subjected to seasonal and numerous other environmental factors which often permit one or another species to predominate periodically. Moreover, even a single test alga in a protected simple system responds in different ways when environmental and nutritional changes occur. The flask assay has the additional drawback that at its inception cells of the test alga in the log phase of growth have a wealth of food, whereas at the end of the assay nutrients are depleted and cells at all stages of growth and having a wide range of nutritional requirements are living in their own wastes amid their dead and decaying ancestors. On the other hand, the assay requires little time, equipment, or operational skill. If growth of the test alga is stimulated by any concentration of nutrients it is evidence that the material assayed did indeed have a potential to accelerate eutrophication of receiving waters although a numerical value of this potential under field conditions may not be assignable. However, at the very low concentrations of nutrients present in Lake Tahoe, failure of a flask assay of lake water to produce growth does not necessarily mean that the lake is unproductive of algae at some limited level.

The continuous flow assay overcomes the competition within a species by maintaining a population of a relatively uniform age and in the log phase of growth. Beyond that it shares the limitations of all simple ecosystems plus the added difficulty of maintaining steady state conditions at a laboratory scale of apparatus; and a longer time requirement because of the necessity to achieve a steady state. Most serious, perhaps, during the period of study herein reported was the problem of making the results of assays and the assumed kinetic model sufficiently compatible to permit taking advantage of the three benefits of a kinetic model cited in the preceding section.

CHEMICAL ASSAY METHODS

Chemical and related analyses necessary to the objectives of the study are listed in the various chapters and in related appendix material. The particular problem initially was that of selecting or adopting methods of analysis sufficiently sensitive to detect significant changes in the low concentrations of nutrient compounds present in Lake Tahoe and in some of its tributary waters.

Preparation of Samples

Preliminary preparation of samples for physical and chemical analyses varied somewhat depending on the specific method chosen for each assay. Samples selected for flask culture, including Lake Tahoe water used for dilution, were filtered through Whatman glass fiber filter pads (GF/C) and finally through HA Millipore(R) filters (0.45 μ pore size). They were then stored in tightly covered polyethylene containers and frozen, unless the test was to begin within five days. Due to the large quantity of water required for pond studies, sewage effluents used in the continuous flow pond assays were not filtered.

Aliquots of the samples, both the unfiltered and those passed through the previously described glass fiber and millipore filters, were analyzed chemically for a number of constituents. Samples were kept in tightly capped 2-ℓ polyethylene containers and stored in a refrigerator at temperatures approaching 0°C until all chemical determinations were completed. Glassware employed in conjunction with the assay was dry heat sterilized.

Analytical Procedures

Chemical analyses were made according to Standard Methods [16] in determining biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, alkalinity, ammonia, chlorides, and conductivity. Methods described by Strickland and Parsons [17] were considered more suitable for iron, nitrite, nitrate, and reactive inorganic phosphorus at the low concentrations prevailing in the Tahoe samples. Similarly, procedures recommended by Jenkins [18], were found more appropriate for soluble organic phosphorus and soluble organic nitrogen. Details of individual analyses are presented in Appendix A.

The technique for measuring total suspended solids (SS) and volatile suspended solids (VSS) was patterned from a combination of the procedures outlined in Standard Methods [16]; Strickland and Parsons [17]; and Maciolek [19]. Whatman glass filters (GF/C) were used in solids separation. The filters were prepared by soaking in distilled water to wash the fibers free of salts. They were then placed in a muffle furnace for 30 minutes at 450°C to destroy any organic matter present without fusing the glass fibers. After cooling, the filters were dried in a hot air oven at 75°C and tared quickly on a Mettler semimicro balance, to avoid error due to the extremely hydroscopic nature of the dried filter. In making the solids determinations the sample was applied to the filter until the volume had passed through or until the filter was completely clogged. The volume of filtrate was noted. The filter pads with their load of suspended solids were dried overnight at 75°C and the dry weight recorded to the nearest 0.01 mg. They were then saved for further analyses by placing them in marked envelopes and stored in a refrigerator freezer. Samples in which the VSS value was desired were redried and reweighed to verify the suspended solids value. Thereafter the filters were ignited at 550°C for 2 hours, soaked with a few drops of distilled water to rehydrate the mineral matter, dried overnight at 75°C, and weighed. The difference between the SS weight and the weight after ignition was then used to determine the VSS in mg/ℓ.

In some cases it was necessary to revise the suggested methods in order to expand the scope of the analysis to encompass the wide range of nutrient concentration encountered in the various samples assayed. The procedure was to prepare two standard curves for the Beckman Model B spectrophotometer, one using a 1-cm pathway cuvette and the other a 5-cm cuvette. The range of concentration using the two pathway cells was from 1 μg/ℓ to 200 μg/ℓ. Samples in which the level of the constituent exceeded the maximum range of concentration were diluted to the concentration range of the cells by a calibrated volume of deionized water.

EVALUATION OF ASSAY TECHNIQUES

Bioassays

Preliminary flask assays were run to determine the appropriate period of assay necessary to insure that the maximum growth rate was achieved. Using 1%, 10%, and 50% concentrations of various sewage effluents, it was found [1] that the percent of assays showing a maximum value of $\hat{\mu}_b$ (maximum growth rate) within 3 days was 64, 73, and 63 percent, respectively. All reached a maximum value within 5 days. In analyzing Lake Tahoe water alone, with added nitrogen, and with added nitrogen and phosphorus, the percent reaching maximum growth within 3 days was 66, 78, and 53 percent, respectively. Of some 300 experiments, all reached the maximum rate within 5 days.

Studies were made [1] of possible error in converting cell size of S. gracile to biomass. Volume of individual cells were related to cell size by measurement of the length and breadth of numerous cells with an ocular micrometer and assuming that the geometry of the cell was described by two cones connected base to base. Cells were found to be relatively uniform in volume, predominantly about 75 μ^3, although the variation ranged from 50 to 150 μ^3. Assuming, on the basis of packed cell volume experiments and information on other types of algae, that cells of S. gracile have a specific gravity of 1.15, cell volume was converted to mass.

No parallel experiments with chemostats were possible prior to the beginning of assays of the various influents to the lake (Chapter III) because of the time factor and the long period required to master the chemostat technique in a situation where extremely low concentrations of nutrients make it all but impossible to achieve and maintain steady state conditions.

Chemical Analyses

Early attention was directed to establishing reliable results from the chemical laboratory. All chemical determinations were subjected to replicate analysis on aliquots of the same sample to determine the precision attainable by the project staff and the analytical procedures used under the conditions prevailing at Lake Tahoe. The results showed that with the exception of organic nitrogen and total phosphorus in Lake Tahoe water, where concentrations are extremely small, the chemical work was of good accuracy as measured by the coefficient of variation of results. Wild values appeared occasionally but their effect was minimized by the great number of analyses made in the course of any particular study. Techniques and accuracies soon became quite refined and reliable. A statistical analysis of the two methods of filtration in the laboratory (0.45 μ HA Millipore and GF/C Whatman glass fiber paper) indicated that there is no essential difference in the accuracy of the two methods.

Carbon^{14}

Experiments with C^{14} were made to determine whether tracer techniques might speed up the work by eliminating counting of cells under the microscope. Although other workers had reported good results with this technique no reliable procedure could be established, even with their assistance, hence the possibility of tracer methods was abandoned early in the project. This does not mean that the method is unsuitable but that the timing and the objectives of the project precluded a program of research on the application of the C^{14} technique to the immediate needs.

RESULTS

From theoretical considerations, consultation with knowledgeable biologists and limnologists, practical factors, and the results of preliminary experiments it was decided to approach the study basically in the following manner:

1. Utilize flask assays in evaluating the algal growth response in studies of

    a) Lake Tahoe water, alone and with added nutrients

    b) Miscellaneous sources of nutrients

    c) Effluent from pilot ponds

    d) Monitoring of creeks.

2. Run chemostat assays in parallel with initial flask assays so that the method might be adopted without loss of data should it prove feasible.

3. Report results of bioassays in terms of cell count, $\hat{X}$, and growth rates $\hat{\mu}$ and $\hat{\mu}_{\ell}$.

4. Make statistical analyses of results to determine which measure of growth stimulation is most appropriate.

5. Analyze all data by cell concentration and kinetic equations to evaluate its conformity to the Michaelis-Menten model.

6. Operate pilot ponds as large continuous flow assay systems, using a test alga or test algae.

7. Apply pilot pond assays to such possible influents to surface waters as might prove significant in initial flask assay surveys.

CHAPTER III

SURVEY OF WATERS IN THE LAKE TAHOE AREA

INTRODUCTION

Pursuant to the second aspect of objective number one (Chapter I), flask assays were made to determine the effect of water from each of 15 different possible sources of nutrients in Lake Tahoe. Assays of Lake Tahoe Water (LTW) provided a background for interpretation of results. Other samples to be assayed were diluted with LTW to reduce their concentration to 1, 10, and 50 percent of the original. Duplicate assays were made with and without added inorganic nutrients. The results, presented in detail in a previous report [1] are hereinafter condensed and summarized to present their essential conclusions.

FLASK ASSAYS

Lake Tahoe Water

The growth response of S. gracile in LTW with and without added phosphate or nitrogen is summarized in Table 3-1. Although the maximum growth rate, $\hat{\mu}_b$, varied considerably and the experiments reported do not permit a correlation between nutrient concentration and growth rate, both the range and mean values of $\hat{\mu}_b$ showed an increase in growth response when the nitrogen concentration was increased. For example, the mean value of maximum growth rate increased from 29 percent/day in LTW to 86 percent/day in LTW plus $NaNO_2$. No such increase occurred when phosphate was added. Although the data are admittedly rough, this supports the conclusion that Lake Tahoe is nitrogen sensitive rather than phosphorus sensitive as are most other oligotrophic lakes.

Other Sources (Chemical Analyses)

That most of the samples assayed were short of nitrogen in comparison to phosphorus is evident when the N/P ratios reported in Table 3-2 are compared to the N/P ratio of algal cells. Neglecting the very large value (714) shown in the table for septic tank seepage because of the known ability of soil to remove phosphates, the N/P ratio of all sources assayed averaged 2.08, whereas the ratio for algal cells is reported [20] to range from 6.9 to 18.

It should be noted that the values in Table 3-2 are reported in micrograms per liter ($\mu g/\ell$) rather than in the more common mg/ℓ to avoid decimal values at the lower concentrations observed.

The data reported in Table 3-2 derive from a single analysis of each of the several different sources of samples. Therefore the N and P concentrations shown are not indicative of the long term means nor the temporal variations in nutrient concentration in the sources assayed. A more complete chemical analysis of the various sources assayed during the period November 1966 through December 1968 is presented in Table B-1, Appendix B.

Other Sources (Growth Response)

Table 3-3 summarizes the mean values and range of values of maximum growth rate, $\hat{\mu}_b$, observed in flask assays of 56 samples of surface runoff, rain, snow, sewage effluents, seepage, and water confined in keys and marinas during the survey of waters in the Lake Tahoe area.

TABLE 3-1

MAXIMUM GROWTH RATES OF S. gracile IN LAKE TAHOE WATER
Alone and With Added Inorganic Nutrient Samples

No. of Assays	Nature of Sample Assayed	Range of Concentration	$\hat{\mu}_b$, days^{-1} Range	$\hat{\mu}_b$, days^{-1} Mean
25	Lake Tahoe water (LTW)	natural surface	0.05-0.47	0.29
17	LTW plus KH_2PO_4 - µg P/ℓ	50- 8,800	0.08-0.29	0.17
23	LTW plus KNO_3 - µg N/ℓ	20-12,000	0.11-1.20	0.66
21	LTW plus NH_4Cl - µg N/ℓ	20,000-20,500	0.20-1.17	0.70
12	LTW plus $NaNO_2$ - µg N/ℓ	6-10,000	0.22-1.40	0.86

TABLE 3-2

NITROGEN AND PHOSPHORUS CONCENTRATIONS
IN VARIOUS WATER SAMPLES

Source of Sample	N and P Concentrations				N/P Ratio
	μg/ℓ as N			μg/ℓ as P	
	NH_3	NO_3	NO_2	PO_4	
Lake Tahoe Water	< 5	4	3	< 5	0.4 ±
Oxidation ponds	350	8	3	2,500	0.14
Seepage from spray irrigation field, sewage	30	8	5	30	1.14
Oxidation ponds	-	5,800	9	3,400	1.71
Seepage from spray irrigation field, sewage	150	107	5	100	2.62
Seepage from septic tank leaching field	30,000	26	10	42	714*
Storm drain	680	25	6	110	6.46
Surface stream at refuse dump	110	48	22	77	2.08
Storm drain	850	< 1	< 1	160	5.31
Raw sewage	7,600	14	15	5,800	1.30
Primary effluent	23,000	1	9	13,500	1.70
Creek waters	200	90	4	40	7.36
Primary effluent	41,000	80	< 1	18,000	2.28
Secondary effluent	2,000	24,300		17,600	1.49
Primary effluent	21,500	1	19	30,200	0.71
Secondary effluent	9,500	2,980	520	5,000	2.60
Secondary effluent	12,000	1,390	460	13,000	1.07
Secondary effluent	9,400	1,450	550	19,500	0.58
Secondary effluent	8,800	8	8	8,800	1.00+
Oxidation ponds	70	10	3	4,500	0.02
Average					2.08

*Value not used in calculating average.

TABLE 3-3

MAXIMUM GROWTH RATES OF S. gracile ATTAINED WITHIN 6 DAYS IN FLASK ASSAYS OF VARIOUS SAMPLES

$\hat{\mu}_b$, day^{-1} / Source of Sample	Concentration of Sample						No of Samples Assayed
	1%		10%		50%		
	Mean	Range	Mean	Range	Mean	Range	
Meeks Creek	0.24	0.16-0.42	0.23	0.14-0.39	0.30	0.20-0.45	4
Ward Creek	0.24	0.20-0.27	0.20	0.17-0.21	0.18	0.13-0.20	4
Incline Creek	0.13	0.06-0.17	0.20	0.06-0.53	0.33	0.14-0.67	4
Upper Truckee-Trout Creek	0.32	0.16-0.48	0.61	0.58-0.64	0.85	0.74-0.96	2
Rain	0.49	0.49	0.56	0.56	0.78	0.78	1
Melted snow	0.36	0.36	0.28	0.28	0.27	0.27	1
Storm drain	0.57	0.34-0.79	0.53	0.35-0.64	0.78	0.54-1.04	4
Marinas and keys	0.19	0.15-0.24	0.25	0.09-0.41	0.32	0.30-0.34	4
Raw sewage	0.51	0.45-0.58	0.74	0.72-0.75	1.12	1.08-1.15	2
Primary effluents	0.78	0.70-0.92	1.18	0.92-1.40	0.90	0.60-1.07	3
Secondary effluents	0.72	0.35-1.27	0.93	0.61-1.27	0.83	0.36-1.53	11
Tertiary effluents	0.76	0.72-0.80	1.01	0.83-1.19	1.15	0.93-1.37	2
Oxidation pond	0.46	0.24-0.71	0.68	0.47-1.09	0.65	0.44-0.88	3
Swamp seepage	0.28	0.13-0.43	0.48	0.44-0.53	0.52	0.41-0.63	2
Spray irrigation filed, sewage	0.21	0.11-0.30	0.41	0.14-0.58	0.30	0.17-0.54	3
Leaching field, septic tank	0.46	0.36-0.57	0.55	0.27-1.01	0.84	0.64-1.14	3
Surface Stream at refuse dump	0.28	0.20-0.42	0.35	0.26-0.39	0.39	0.28-0.45	3

When the growth rates reported in Table 3-3 are compared with those observed for Lake Tahoe water (Table 3-1), several facts are apparent. At the 1% concentration of sample, where the added nutrient effect should be the least, sewage effluents, seepage from septic tank leaching fields, surface drainage from storm water, and rain water all showed growth stimulation of *S. gracile* appreciably greater than the 0.29 (29 percent/day) reported for LTW. That this was the result of a true response rather than of limited validity of data is evidenced by the fact that all of these sources showed an increasing growth rate as the concentration increased to 10% and 50%. The lone exception was storm drain water which showed no difference between 1% and 10% concentrations, but a very large increase when it constituted 50% of the sample assayed. The difference between the 1% and 10% rain water was small, but the data in Table 3-3 leave no doubt that rain is an important source of nutrient (nitrogen) in Lake Tahoe.

The melted snow assay (Table 3-3) did not differ from LTW in algal growth response, although in Total N content it was about twice as concentrated as the lake water (285 vs 140 μg/ℓ). In comparison with the rain water assayed, which occurred during a thunderstorm, however, the snow had only 36% as much nitrogen (285 vs 1030 μg/ℓ); (Table B-1, Appendix B). Subsequently, in 1970 (see Table 6-9, Chapter 6) snow was shown to be a significant contributor of nitrogen to the lake.

It might be expected that storm drains picking up washings from streets, roofs, paved parking areas, fertilized lawns and vegetated areas would represent a source of nutrients in Lake Tahoe. The data show clearly that this is the case although there is no way of determining how much is attributable to rainfall and how much to soluble nutrients on the surfaces washed by storm water.

The data on seepage from spray irrigation used as a method of sewage effluent disposal are worthy of particular comment. The reported observations were made at a time when the South Tahoe Public Utility District (STPUD) was developing its water reclamation plant and had not yet begun export of effluent from the Basin. At that time disposal of effluent involved spray irrigation on forest land. Although direct assay of the sewage effluents showed (Table 3-3) a marked ability to stimulate growth of the test alga (*S. gracile*), the same effluent had little effect on the seepage from test borings in the spray irrigation area. The answer is obvious in Table 3-2 which shows both ammonia nitrogen and phosphate at low concentrations in the leachate and high concentrations in the applied sewage effluent. The well known ability of soil to absorb both ammonia and phosphates accounts for the reduction. A relatively low value of nitrate nitrogen (107 μg/ℓ) indicates that soil bacteria has not yet had time to convert ammonia to the soluble nitrate form.

What can happen under the full potential of nitrogen in seepage from land disposal of sewage is evident in the results observed in the septic tank leaching field. In this case the sample was obviously taken from borings in a coarse material which had not absorbed the ammonia and was close to the tile field itself. Algal growth stimulation was comparable to that of secondary effluents at the 50% concentration. Although it is not likely that nitrogen would reach Lake Tahoe from septic tank seepage in the form of ammonia, its ultimate conversion to soluble nitrates is certain and can be expected eventually to enrich the lake via a combination of routes:

1. Movement as soluble nitrogen in ground water directly or through outcropping in surface streams.

2. Surface wash from decaying vegetation which grew more luxuriant as a result of nitrogen in the ground water.

In relation to the first of these routes the time factor is a major unknown. The second poses a more complex question: the time factor, the extent to which nitrogen is recycled to the atmosphere by vegetation, and the percentage of such nitrogen that might be returned to the lake via rainfall. Nevertheless, the data show that septic tank leachate has the potential to stimulate algal growth in Lake Tahoe.

From Tables 3-2 and 3-3 it is evident that the surface stream at the refuse dump was not particularly different than creek waters in nutrients, suggesting therefore that leaching might not have been occurring at the time of sampling. On the other hand the original data (1) showed organic nitrogen at 900 μg/ℓ downstream from the refuse dump and only 350 μg/ℓ upstream from it. Ammonia likewise doubled (50 to 110 μg/ℓ) in passing the dump site. Later data obtained in 1970, after heavy frost (may have damaged the fill structure) showed organic nitrogen and total nitrogen in the stream at the refuse dump essentially to double during a heavy frost rainstorm. Although the data are not conclusive they would seem to justify a policy of excluding refuse fills from the Tahoe Basin.

The results reported for marinas and keys (Table 3-3) are particularly deceptive. Although they show an increasing response to increasing concentration of mixtures of such waters with water from the open lake, the maximum value of $\hat{\mu}_b$ is no greater than that reported for LTW in Table 3-1. The most important reason for this was reported [3] in relation to pilot pond assays and in observation of confined water at North Tahoe. This is that even in a highly eutrophied water in which the most casual observer may see a rich growth of plants, an assay of filtered water reveals only the residual ability of the water to stimulate growth. When nutrients are tied up in living cells no assay of the water in which they live can reveal the level of nutrient which produced the existing biomass.

Of the creek waters reported in Table 3-3, Meeks Creek and Ward Creek were essentially the same as LTW alone in the matter of growth response. Both in magnitude of growth rate and indifference to concentration this fact was evident. At the time of the survey both of these creeks were experiencing little intensive land development on their watersheds. Development on the Incline Creek watershed was in an early stage and although the water appeared of high quality, mean values of $\hat{\mu}_b$ showed a definite increase in response as concentration increased. If the results were strictly interpreted on the assumption that all values are statistically highly valid, one might see at the 1% concentration evidence of toxicity. However, this is not borne out by the results of greater concentration. Therefore it must be assumed that within the limited number (4) of samples assayed and within the range of accuracy of analysis lies the variation, and that Incline Creek was little different than Lake Tahoe at the time of the survey (a condition which did not persist subsequently; see Chapter V).

In contrast with the other creeks assayed, the Upper Truckee-Trout Creek system showed a definite increase in stimulatory effect with concentration in LTW. This might be expected because the drainage area of this system of surface streams represents a land area on which development is well established.

Conclusions

The assays reported in Table 3-3 were, of course, of the nature of a survey to determine which possible sources of influent nutrient to Lake Tahoe might be worthy of further study by pond assays on a pilot scale. The conclusions from the flask assay survey were that:

1. Sewage effluents were the most important source of nutrients which might trigger eutrophication of surface waters such as Lake Tahoe.

2. Septic tank leaching field effluents were not particularly different than other sewage effluents but are too difficult to collect in adequate quantities for pond assays of the scale planned (see Chapter IV).

3. The source of nutrients in the Upper Truckee-Trout Creek system should be explored, but pond assays were impractical because of the long distance (approximately 25 miles) between the creeks and the pilot pond installation.

4. Other creeks surveyed could not effectively be assayed by pond assay unless 100 percent concentration of the creek water could be used. This was infeasible because the water quantities needed for continuous flow studies could not be delivered to the ponds, which, as shown in Chapter IV, are not a portable installation.

5. The influence of land development evident in the comparison between Upper Truckee-Trout Creek and other creeks surveyed should be monitored through a program of long term flask assays of the creek waters and evaluated in terms of a similar continuing monitoring of Lake Tahoe water. (See Chapters V and VI for results.)

CHEMOSTAT ASSAYS

Pursuant to the objective of applying the most effective method available to the determination of the algal growth stimulating potential of various possible sources of enrichment of surface waters, assays with laboratory scale chemostats were undertaken simultaneously with flask assays. Using continuous flow equipment such as illustrated in Figure 2-1 and the theoretical considerations set forth in Chapter II, fifty experiments were conducted to determine the growth response of S. gracile in four types of samples:

1. Surface runoff

2. Sewage effluents

3. Waste water seepage

4. Added chemical nutrients (nitrogen and phosphorus).

Because of the difference in the period of time required for the flask and chemostat assays, it was impossible to run parallel tests on the same sample simultaneously. However, when duplicate growth assays of the same sample were conducted, excellent agreement in results were obtained although the numerical values of $\hat{\mu}_b$ were dissimilar because of the different growth conditions prevailing in the two systems. (See Chapter II, "Limitations of Bioassay Techniques.")

It was soon evident from the studies that a great deal more research and development of technique was necessary in order to make the laboratory chemostat a reliable method of bioassay despite its theoretical advantages over the flask method. It was particularly evident that a poor place to begin such needed development was in a situation such as at Lake Tahoe where the nutrient concentrations in the lake water were near the bottom limit of resolving power of analytical chemical methods; and where the objective was to determine at what threshold algal growth stimulation was detectable. Great difficulty was experienced in maintaining steady state conditions at statistically valid levels with the small number of cells supportable by low nutrient concentrations.

Assuming that the maximum growth rate in a chemostat during the transient period before a steady state is reached ($\hat{\mu}_{tr}$) is analagous to the maximum growth rate ($\hat{\mu}_b$) in flask assays, 25 pairs of data were compared. The results indicated a relationship roughly as follows:

$$\hat{\mu}_{tr} = 1.78\ \hat{\mu}_b \quad .$$

Thus it might be postulated that neither the flask assay nor the chemostat assay in its transient state represent the maximum growth rates that could be maintained in a near steady-state continuous culture. This would mean that the flask assay growth rate is less sensitive than might result from a system which maintains a culture in the log phase of cell growth. As noted in Chapter II, this might lead to failure of the assay to identify the exact nutrient concentration where growth stimulation of the test alga begins, but it does not negate the conclusion that if cells multiply in a flask culture the nutrient source had best be excluded from Lake Tahoe in the interests of prevention of eutrophication. It may well be that such an insensitivity is more theoretical than real because as shown in Table 3-3 with tertiary effluents, a profound affect appears at low concentrations (1%) and increases with concentration. Presumably this situation would continue as it does in algal growth units until the density of the culture becomes controlled by light penetration and environmental conditions other than nutrients. Also, in any event, the relationship between the response of a test alga and the response of a complex ecosystem outdoors is at best obscure.

Kinetic constants $\hat{\mu}$, Y, K_s, and k_d (see Equations 1 and 2, Chapter II) were computed from a series of chemostat assays reported and analyzed statistically in a previous publication [1]. Although they led to some interesting preliminary findings they did not satisfactorily substantiate the applicability of the Michaelis-Menten model and left unanswered whether crudity of data or limitations of the model were at fault. They did, however lead to two important conclusions:

1. That the laboratory chemostat was not sufficiently perfected for the purposes of the study at the time it began, hence the flask assay method was the "best available method" for the study.

2. That work should be undertaken to establish a standard assay procedure for assessing the algal growth stimulating potential of nutrients which might be discharged to any surface water, or which already exists therein.

Because work on such an assay procedure was begun early in 1968 by the Federal Water Quality Administration, with full access to the Tahoe findings, and because the work of the FWQA on its Provisional Algal Assay Procedures (PAAP) test has advanced far beyond that reported by the authors [1] in 1968, the details previously reported are not repeated in this summary.

CHAPTER IV

POND ASSAYS OF WASTE WATER EFFLUENTS

INTRODUCTION

During the summer and fall seasons of both 1968 and 1969 outdoor pond assays were made to assess the algal growth response of Lake Tahoe water to various concentrations of effluent from secondary and tertiary sewage treatment processes. The ponds were designed to simulate the shallow portions of the lake where summer water temperatures are most favorable for algal growth, circulation is most likely to be impeded, and increased growth of algae would be most noticeable to people and hence most aesthetically objectionable in the initial stages of accelerated eutrophication of the lake.

The ponds were conceived and operated as continuous flow systems at a steady state where growth is balanced by the outflow of organisms. Since only two variables – residence time (θ) and input concentration (S_o) – can be controlled, this assumption implies that one factor limits the growth of living material; possibly nitrogen, on the basis of previous flask assay surveys (Chapter II). However, under outdoor conditions there are many variables which might affect the growth rates of organisms. Sunlight, temperature, foreign (allochthonous) material, seasonal variation in chemical composition of lake water and sewage effluents, residence time, and the complexity of aquatic ecosystems are all known to be determinants of productivity in nature. The possible effects of such determinants on the feasibility of attaining steady state conditions was beyond control in the pond assays. Similarly, residence times were necessarily related to attainable steady state conditions in the ponds rather than to the periods of confinement of water that might occur in natural embayments or man-made marinas and keys. Thus pond assays might yield results more favorable or less favorable than those prevailing in the lake. Nevertheless it was assumed from the beginning that if pond assays should show growth stimulation by the effluent concentrations assayed, such effluents could be expected to accelerate the natural rate of eutrophication of oligotrophic waters such as Lake Tahoe even though the values of observed growth rates ($\hat{\mu}$) might be numerically inexact.

NATURE AND OPERATION OF POND ASSAYS

Physical Nature of the Pond System

The system used in pond assays consisted of eight fiberglass-coated wooden tanks each 20 ft long, 4 ft wide, and 4 ft deep, with a water depth of approximately 3.5 ft and a capacity of about 7930-ℓ (2100 gal). As shown schematically in Figure 4-1, the ponds were installed on a wooden platform adjacent to the south wall of the Fish and Game hatchery building, which housed the laboratory, with the long axis on the meridian. At the north end of each pond a weather-tight, ventilated cabinet was constructed to house the nutrient sample containers, feed pumps, electrical controls and outlet boxes. A Jaccuzi Whirlpool submersible pump was installed in each pond and operated continuously during assay experiments to keep the pond moderately well mixed. The volume of water in the pond was maintained constant by a 1-1/2 in., galvanized iron riser standpipe threaded into an upside down floor flange built into the pond bottom near the south end of the structure. This standpipe could be removed for draining and cleaning of the pond between experiments, or assays.

Lake Tahoe Water (LTW) used in the pond assays was pumped directly from the lake by means of a centrifugal pump located near the shoreline. The pump intake

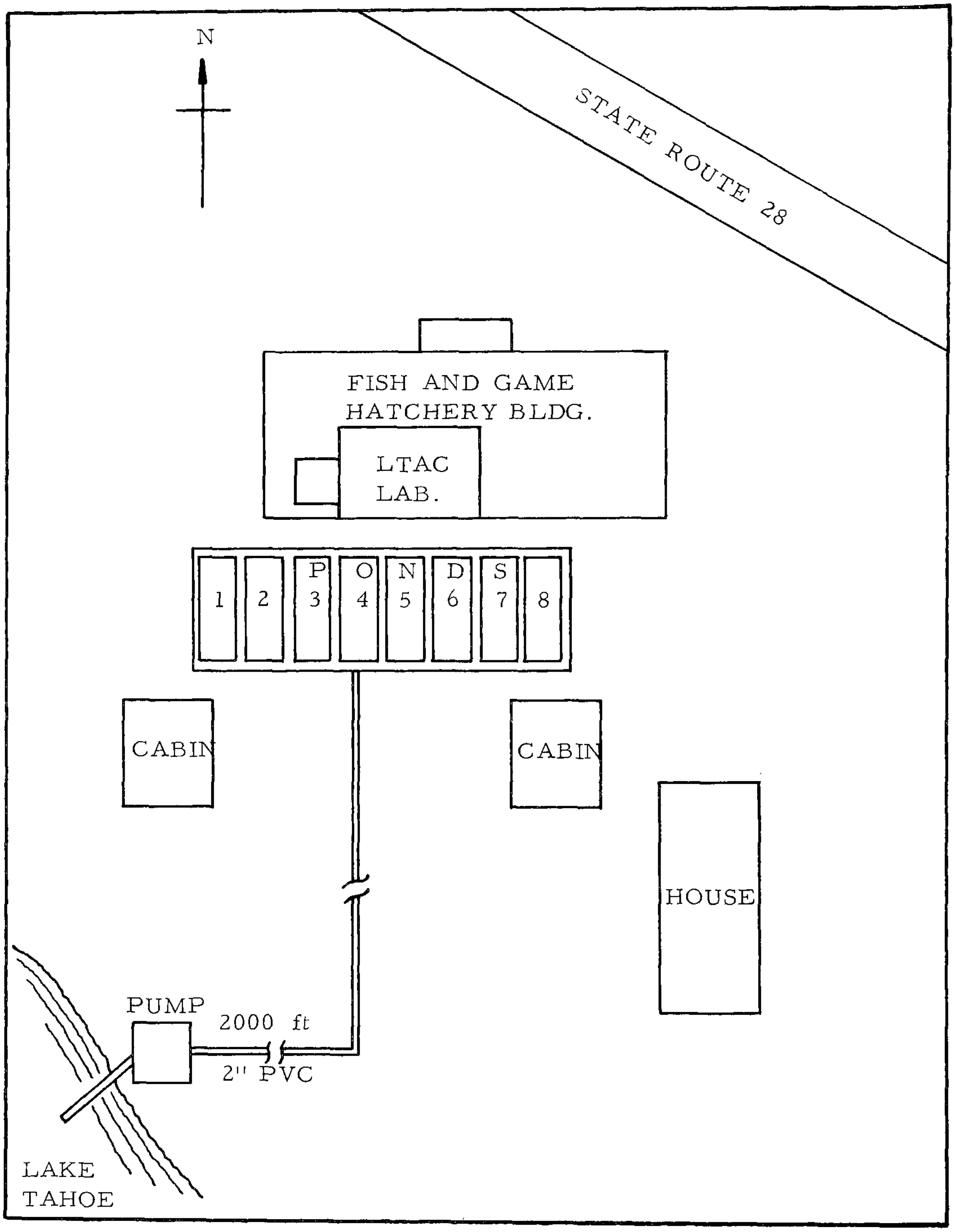

FIGURE 4-1 LAYOUT OF EXPERIMENTAL PONDS

was placed approximately 100 yd offshore in about 10 ft of water at 4 ft above lake bottom. The pump discharged through 2000 ft of 2-in. PVC pipe into a horizontal 6-in. PVC header supported on a superstructure of cabinets at an elevation of approximately 3 ft above the pond water surface and extending across the entire 8-pond installation. Flow into each pond was by gravity through a small plastic line originating in the common header and fitted with a valve, by which the rate was controlled to provide the desired detention period, or residence time. Excess water delivered to the header was discharged over the riser standpipe and returned to the lake via a natural drainage channel.

Operation of Pond Assays

Before beginning each assay the ponds were washed, rinsed, and filled with LTW. The residence time was adjusted before the assay began by regulating the quantity of LTW entering the ponds by way of the pond header pipe. The sample containing the enriching nutrient to be evaluated by assay was then pumped into the pond from a 5-gal plastic container by a Sigmamotor pump at a uniform rate appropriate to produce and maintain the desired concentration of sample in the LTW at the selected residence time, hence nutrient levels and growth of algae should approach to steady state simultaneously. Two reference ponds containing only LTW were maintained at the same residence time as the experimental ponds. In the initial pond assays an attempt was made to utilize S. gracile as a test alga as in flask assays. Stock cultures of S. gracile were grown in large quantity and introduced into both the reference and the assay ponds. However, indigenous organisms, primarily diatoms, overwhelmed the test alga in all ponds. Consequently cell counts of S. gracile were useless as a measure of growth response. Attempts to remove indigenous organisms from incoming lake water by a diatomaceous earth swimming pool filter resulted in hydraulic losses that could not be overcome except at an unacceptable sacrifice of time while new pumping equipment was being obtained. Therefore, in all subsequent pond assays indigenous organisms contained in LTW comprised the inoculum of each pond.

The experimental design used in pond assays during the 1968 and 1969 seasons are summarized in Table 4-1. The ponds were operated on a 10-, 5-, and 3-day detention time in the first series (1968). In 1969 the maximum detention time was reduced to 8-days as experience showed this to be adequate for the assay: at the various detention periods both secondary and tertiary effluent from the STPUD Water Reclamation Plant were used as the major nutrient source. Secondary effluent was obtained as grab samples from the clarifier effluent following activated sludge treatment. Tertiary effluent was obtained as grab samples from the effluent from the activated carbon filter units (before chlorination). Essentially, tertiary treatment consisted of precipitation with lime to remove phosphates, volatilization of ammonia gas in an ammonia stripping tower, pressure filtration, and activated carbon filtration. The effluent was collected and transported to the pond site as needed in approximately 100 to 200 gal lots, in 5-gal polyethylene bottles and generally used within one week after collection.

Measurement of Growth Response

As reported in Chapter III, maximum cell counts ($\hat{X}$) and maximum growth rate ($\hat{\mu}$) were used as indicators of growth response of S. gracile in flask assays. Moreover, the reasonably uniform size and specific gravity of cells made possible an estimate of biomass produced by the unialgal culture. In the pond assays, however, cell counting was infeasible because of cell diversity and allochthonous material in the system. Several techniques for estimating biomass were studied [2] and volatile suspended solids (VSS) was chosen for the pond assays because it showed the highest order of correlation with other factors determined, in addition to being easy to measure by well established and simple laboratory procedures. The biomass produced in pond assays was primarily pennate diatoms which grow attached to the submerged surface of the pond structure. Consequently in order to sample the biomass in a pond the submerged surface was first scraped thoroughly

TABLE 4-1

EXPERIMENTAL DESIGN OF POND ASSAYS

Assay No.	Residence Time days (θ)	Dates	Pond Numbers							
			1	2	3	4	5	6	7	8
		(1968)								
2[d]	10	14 Jun -2 Jul	LT[a]	0.1% III[b]	1.0% III	1.0% III	LT	0.1% II[c]	1.0% II	1.0% II
3	5	5-29 Jul	LT	0.1% II	1.0% II	1.0% II	LT	0.1% III	1.0% III	1.0% III
4	3	2-16 Aug	Seed Pond	0.1% III	1.0% III	1.0% III	LT	0.1% II	1.0% II	1.0% II
5[d]	3	16-30 Aug	Seed Pond	0.1% II	1.0% II	1.0% II	LT	0.1% III	1.0% III	1.0% III
6[d]	10	1 Sept-4 Oct	1.0% II	0.1% III	1.0% III	1.0% III	LT	0.1% II	1.0% II	1.0% II
7	5	4 Oct -1 Nov	LT	0.1% III	1.0% III	1.0% III	LT	0.1% II	1.0% II	1.0% II
		(1969)								
1	8	14 Jul -8 Aug	LT	0.1% II	1.0% II	1.0% S-II[e]	LT	0.1% II	1.0% II	1.0% S-II[e]
2	5	9-22 Aug	LT	0.1% II	1.0% II	1.0% S-II[e]	LT	0.1% II	1.0% II	1.0% S-II[e]
3	3	23 Aug-3 Sept	LT	0.1% II	1.0% II	1.0% S-II[e]	LT	0.1% II	1.0% II	1.0% S-II[e]
4	8	8 Sept-30 Oct	LT	2.0% III	1.0% III	1.0% III+TE[f]	LT	2.0% III	1.0% III	1.0% III+TE[f]
5	5	4-17 Oct	LT	2.0% III	1.0% III	1.0% III+TE[f]	LT	2.0% III	1.0% III	1.0% III+TE[f]
6	3	18-31 Oct	LT	2.0% III	1.0% III	1.0% III+TE[f]	LT	2.0% III	1.0% III	1.0% III+TE[f]

[a]Shore Lake Tahoe water.

[b]II is Secondary Effluent from the South Tahoe Public Utility District (STPUD) Water Reclamation Plant.

[c]III is Tertiary Effluent from STPUD.

[d]Ponds were seeded initially with Selenastrum gracile.

[e]S-II is simulated secondary effluent prepared by adding macronutrients, iron, and trace elements in excess plus NH_3-N and PO_4-P equivalent to the concentration measured in the secondary effluent (see Table C-6, Appendix C).

[f]III+TE is tertiary effluent with quantities of iron and essential trace elements added (see Table C-6, Appendix C).

with a rubber squeegee and the dislodged material dispersed throughout the pond water by circulating it for approximately one-half hour before samples were withdrawn for VSS analysis.

Physical and Chemical Analyses

Physical and chemical analyses of the pond water were made at regular intervals during each assay. Grab samples for such analyses were collected just below the water surface at the midpoint of the pond at the time of sampling for VSS. Routine chemical analyses were performed on both filtered and unfiltered pond samples. Analyses of the unfiltered samples were: SS, VSS, organic-N, NH_3-N, and total phosphorus. The filtered pond samples were analyzed for: organic-N, NH_3-N, NO_2-N, NO_3-N, total-N, PO_4-P, total-P, Fe, conductivity, and pH. Chemical analysis of the nutrient source to the pond included, in addition to the above, COD and BOD of the unfiltered samples; and calcium, chloride, and alkalinity in the filtered samples. Bioassays by means of flask cultures were also performed routinely when the pond was considered to be operating under steady state. Results of analyses made during the 1968 assays (Table 4-1) are presented in detail in Table C-1 and Table C-2, Appendix C. The somewhat more comprehensive analyses made during the 1969 pond assays (Table 4-1) likewise appear in Appendix C as Tables C-3 and C-4.

Environmental Data

Records were kept of some of the environmental conditions prevailing during the periods when pond assays were in progress. Solar radiation, sky conditions, precipitation, daily temperature range, barometric pressure, wind direction and velocity, and pond water temperature were among the data obtained from a variety of sources or by direct observation. Only such details of these as are pertinent to an interpretation of the pond assay results are presented in this chapter. Detailed tables appear in previous annual reports [2,3] of the project.

Analysis of Data

The computer was utilized to analyze data, especially to obtain values of maximum growth rates, $\hat{\mu}$; log maximum growth rate, $\hat{\mu}_\ell$; mean value of maximum cell growth at end of period, $\hat{X}$; nutrient coefficient, K_s; yield coefficient, Y; and the decay rate k_d. The computer was also utilized to determine statistical parameters and correlation factors used in evaluating the results of assays.

RESULTS OF POND ASSAYS

Environmental Factors

Figure 4-2 shows graphically the variation in three important environmental factors during the pond assays of 1968 and 1969: solar radiation, mean water temperature, and mid-range air temperature. The mid-range air temperature is the calculated average of daily high and low values observed at the U. S. Coast Guard Station less than one-quarter of a mile from the pond installation. Obviously it is not necessarily the mean air temperature over 24 hours, but in the absence of a continuous temperature record it is taken as a fair approximation of such a mean for the purposes of this study. Table 4-2, computed from more extensive data [3] for 1969 shows that during the period of pond assays in that year (July 10 - October 31) the variation in pond water temperature was only about 20 percent of that of the air.

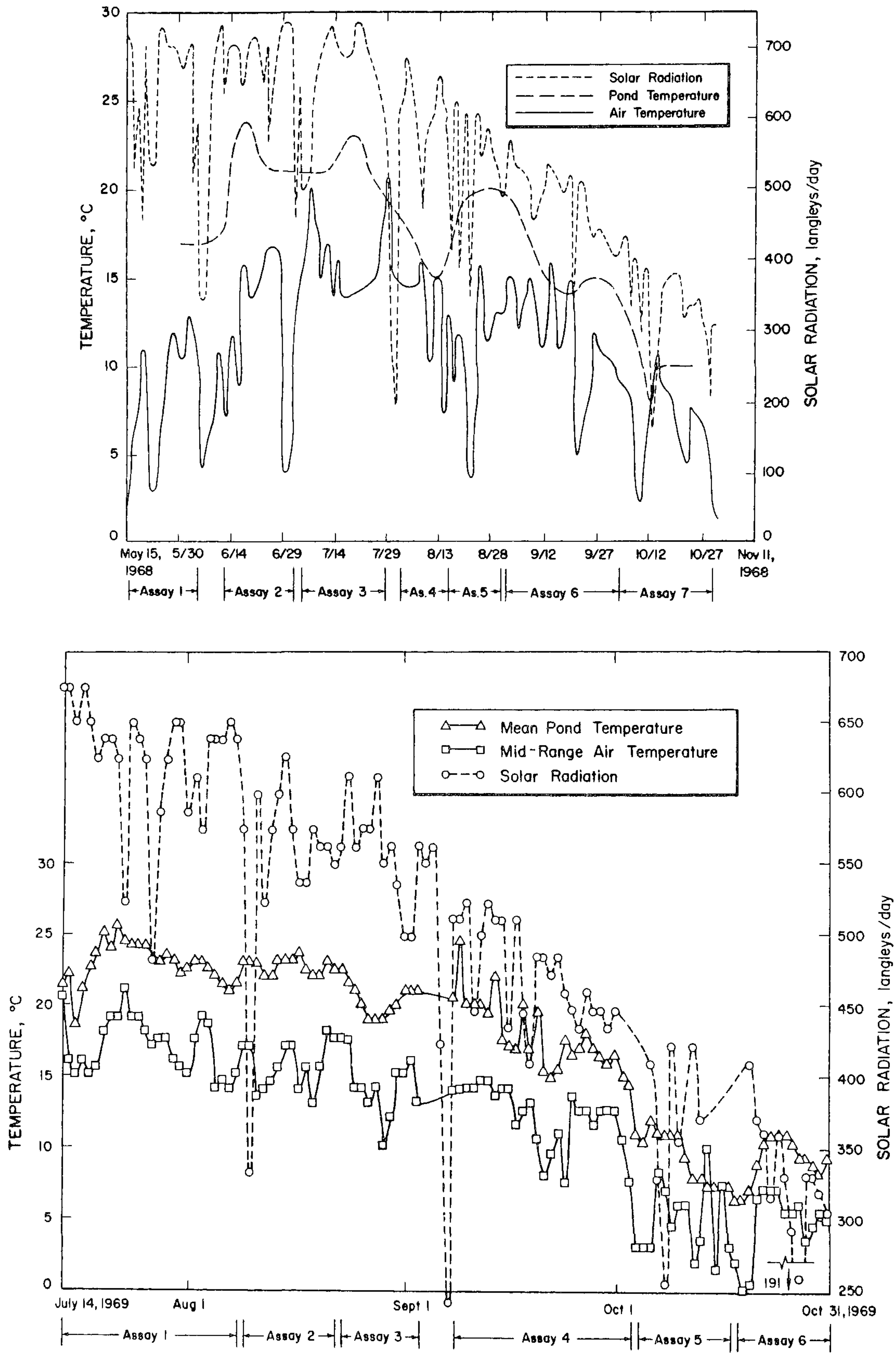

FIGURE 4-2. VARIATION IN ENVIRONMENTAL FACTORS DURING POND ASSAYS

TABLE 4-2

DAY-TO-NIGHT VARIATION IN AIR AND WATER TEMPERATURES (1969)

Month (1969)	Air		Pond Water	
	Range of Temperature Variation (°F)	Average Temperature Variation (°F)	Range of Temperature Variation (°F)	Average Temperature Variation (°F)
Jul	19 42	35	6 - 9	7
Aug	34 47	41	5 - 9	7
Sep	18 46	35	3 - 8	6 (-)
Oct	6 - 39	25	1 9	4.7
Jul 10-Oct 31	6 - 47	34 (-)	1 9	6.6

From Figure 4-2 it is evident that the mean water temperature tended to follow the mid-range air temperature. However, the changes were less abrupt. Two factors combine to bring about this slower response. The first is the limited thermal capacity of air as compared to water. The second is that the temperature of Lake Tahoe water at the pump intake depth (approximately 7 ft below the water surface) tends to be somewhat constant from day to night. Consequently, variation in pond water temperature is a function of air-water temperature relationships at the ponds only; and the effect is least evident as the hydraulic residence time is decreased.

From Figure 4-2 it may be seen that the mean daily pond water temperature was fairly uniform during the period when Assays 1 through 3 were in progress, whereas it steadily decreased during the fall season when Assays 4 through 7 were made. In contrast with the curves of air and water temperature, the curve of solar radiation shows essentially a constant downward trend from mid-July through October. During September and October the trends of air and pond water temperature curves generally parallel the trend of solar radiation, although during the warmer summer months when back-radiation from the earth at night is greatest, both air and water temperatures showed the expected lower rate of decrease with time than did solar radiation.

Decreasing pond water temperatures as well as reduced solar radiation input directly affects aquatic growth. For example, a "rule of thumb" for bacterial systems is that the "growth rate doubles for each 10°C increase in temperature." Presumably the reverse is also a valid assumption. It is noteworthy that during Assays 5 and 6 in the 1969 series the pond water temperature was at or below the level (10°C) at which biological activity becomes seriously reduced. Therefore although Figure 4-2 in itself shows nothing unusual from a climatological viewpoint, it does show changes during some assays which may be useful in interpreting the results of such assays in terms of growth stimulation in relation to available nutrients.

Biomass Measurements

The growth response of indigenous organisms in Lake Tahoe in terms of VSS pertaining at steady state in pond assays of sewage effluents are presented in detail in Tables C-3 and C-5 of Appendix C. Paired ponds were used in all assays; although in different assays of any individual effluent the position of the pairs in the 1-to-8 sequence (Figure 4-1) was changed in order to randomize any effect of the geometry of the system. However, because LTW served as the control, ponds No. 1 and No. 5 (Figure 4-1) were constantly used to assay the raw lake water. Theoretically, the biomass levels at steady state should be the same in duplicate ponds.

Results of the pond assays are shown in Table 4-3. For purposes of identification the letters E (east) and W (west) are used in the table to denote the relative positions of paired ponds. Pond numbers from Figure 4-1 are also included in the table. An analysis of variance for paired ponds was made. Underscored values in the table show that in 6 of the 31 assays the biomass level in paired ponds was significantly different at the 95 percent confidence level.

From Table 4-3 it is evident that the growth stimulating response of organisms increased with concentration of sewage effluent added. Biomass produced by 0.1% secondary effluent was about the same as that produced by 1.0% tertiary effluent. Contrary to what might be expected from the low temperatures shown in Figure 4-2, there was no evidence that growth response was reduced in either LTW or other samples by the cold weather prevailing during assays No. 5 and No. 6 in 1969.

Some variation in the response of LTW is evident but the pattern is not clear. In Chapter V this is shown to be a seasonal phenomenon in terms of nutrients. Figure 4-3 shows the variation in suspended solids (SS) and volatile suspended solids (VSS) delivered to the pond headers from the near-shore pumping station intake during the July-October 1969 assay period. Similar but not comparable data were reported [2] for the 1968 assay period but related to the ponds rather than the influent because it had not at the time been established that VSS was the biomass measure finally to be used.

From Figure 4-3 it is evident that on occasion the SS concentration fluctuated more than that of the VSS, indicating a more than normal input of inorganic solids. A careful analysis of this phenomenon [3] showed wind disturbance of the shallow portion of the north end of the lake to result in pickup of sediments, both inorganic and organic, particularly during assay No. 5. From Table 4-3 it is evident that any effect on the biomass produced was damped out by the 5-day residence period in the pond, or was less significant than other factors which lead to variation in biological systems response.

Inventory of Quality Parameters in Pond Assays

Elaborate statistical studies were made [2] in an attempt to relate biomass production to nutrient concentration. However, an inventory and rough materials balance proved to be one suitable way to account for the major constituents of the pond water involved in changes in biomass. For this purpose calculations were made from the initial (Table C-4, Appendix C) and final (Table C-3, Appendix C) concentrations of several water quality parameters or constituents. Suspended (SS) and volatile (VSS) suspended solids; organic-N, NH_3-N, (NO_2 + NO_3)-N, total inorganic-N, and total N; PO_4 and total-P; and conductivity were the parameters inventoried. The results of the most pertinent of these inventories are presented hereinafter in a series of tables which summarize only the final relationship of input to output of a particular quality factor. A positive (+) sign is used in the table to indicate an input in excess of output of material in its original (input) form. Conversely, a negative (-) sign indicates that more material appeared in the effluent than entered the system as a given compound or factor.

The tables do not represent a strict mass balance of material because of several generally unavoidable assumptions, including:

1. No material entered the ponds except by way of Lake Tahoe water and the added nutrient feed.

2. Evaporation and precipitation were negligible.

3. Constituent concentrations in the ponds were equal to concentrations in the outflow.

TABLE 4-3

COMPARISON OF BIOMASS ESTIMATES BETWEEN PONDS RECEIVING THE SAME EFFLUENT

Assay No.	Mean Biomass Value[a], mg/l VSS													
	LTW		0.1% II		1.0% II		1.0% S-II		2.0% III		1.0% III		1.0% III+TE	
	E	W	E	W	E	W	E	W	E	W	E	W	E	W
(1968)	(5)	(1)			(8)	(7)					(4)	(3)		
2	0.93	0.88			2.17[b]	2.77[b]					1.59	1.77		
	(5)	(1)			(4)	(3)					(8)	(7)		
3	0.33	0.39			2.23	3.09					1.24	1.72		
					(8)	(7)					(4)	(3)		
4					2.09	2.32					0.89	0.76		
					(4)	(3)					(8)	(7)		
5					2.45	3.00					1.34	1.47		
					(8)	(7)					(4)	(3)		
6					2.36	2.65					0.92	1.04		
	(5)	(1)			(8)	(7)					(4)	(3)		
7	0.48	0.58			5.10	4.10					0.68	0.76		
(1969)	(5)	(1)	(6)	(2)	(7)	(3)	(8)	(4)						
1	0.91	0.79	1.39	1.29	5.17	5.12	4.88	5.31						
	(5)	(1)	(6)	(2)	(7)	(3)	(8)	(4)						
2	0.77	0.71	1.29	1.09	6.30	6.72	5.66	6.50						
	(5)	(1)	(6)	(2)	(7)	(3)	(8)	(4)						
3	0.66	0.58	0.91	1.36	4.65	5.62	3.23	4.46						
	(5)	(1)							(6)	(2)	(7)	(3)	(8)	(4)
4	0.84	0.57							1.14	1.10	1.14	0.63	1.24	1.16
	(5)	(1)							(6)	(2)	(7)	(3)	(8)	(4)
5	0.86	0.84							1.48	2.17	1.42	0.95	1.46	1.64
	(5)	(1)							(6)	(2)	(7)	(3)	(8)	(4)
6	0.87	0.74							3.79	4.81	1.74	1.90	1.84	1.75

NOTE: Values in parentheses in columns headed "E" and "W" indicate pond numbers from Figure 4-1.

[a]LTW Lake Tahoe water; II secondary effluent; III tertiary effluent; S-II is simulated secondary effluent prepared by adding macronutrients, iron, and trace elements in excess plus NH_3-N and PO_4-P equivalent to the concentration measured in the secondary effluent (see Table C-6, Appendix C); III+TE is tertiary effluent with quantities of iron and essential trace elements added (see Table C-6, Appendix C).

[b]Underscored values indicate that replicate ponds were significantly different at P > 0.95.

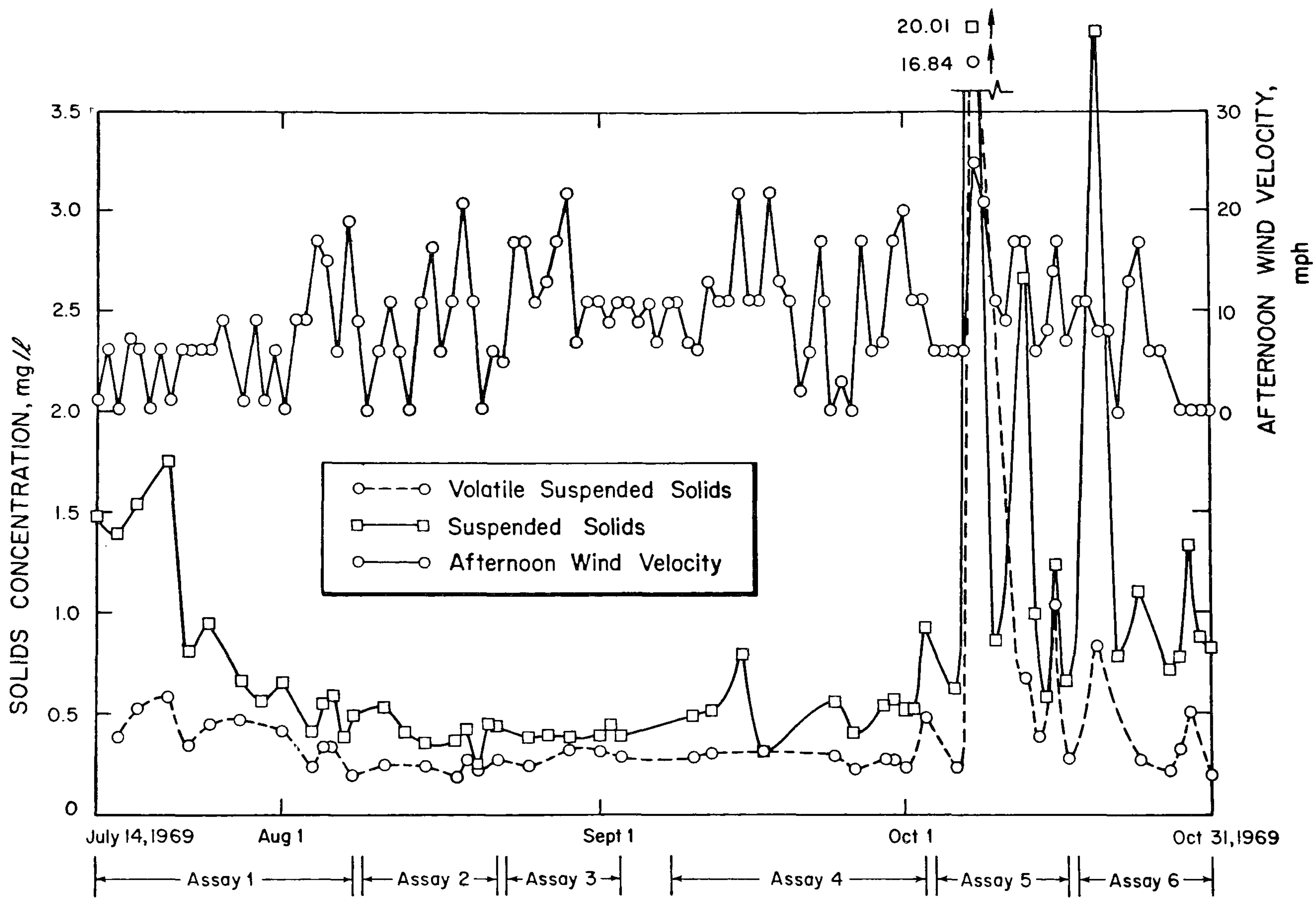

FIGURE 4-3. VARIATION IN SOLIDS CONCENTRATION IN NEAR-SHORE LAKE TAHOE WATER DURING POND ASSAYS (WIND VELOCITY ADDED)

Such assumptions are of varying degrees of validity. The first is perhaps the most visionary. Allochthonous material transported by the wind did indeed get into the ponds in varying amounts and at no predictable or constant rate. Moreover, some of it settled, some stayed in suspension, some was presumably soluble, and some floated on the surface.

Except for one period in October near the end of Assay No. 5 there was no precipitation of consequence. However on that one occasion about 1.7 in. of rain fell in two days. What it brought into the ponds in terms of particulate matter and nutrients is not readily estimated. As for evaporation, values of 0.1 to 0.2 in. per day are possible in the area but vary with the season. Measurement was beyond the scope of the study, hence no evaporation data were available.

Assumption number 3 is reasonably valid in the case of dissolved material, because of constant mixing of the tank contents by whirlpool pumps. It is of less validity in the case of attached solids or settleable solids too large to be significantly disturbed at the mixing rate which prevailed, because the indigenous lake algae responsible for biomass increase and utilization of nutrients are mostly attached forms of diatoms. As noted previously the sides and bottom of the tank were squeezed and the tank contents thoroughly mixed before each sampling for biomass (VSS, mg/ℓ) determination. This minimized the error in growth rate calculations; and maximized it for solids inventory because it led to the assumption that the observed solids concentration pertained throughout the period between samplings. In reality, the solids thus obtained represented those constantly present in the pond effluent, plus those that had accumulated since the last squeegeeing and mixing routine. The imprecision inherent in assumption 3 is not a result of faulty experimental design. Rather it is the penalty which must be paid when outdoor pilot experiments simulate natural conditions, with all the uncontrollable variables associated with such conditions.

SS and VSS

Tables 4-4 and 4-5 summarize the results of inventories of suspended and volatile solids for all ponds and all pond assays. Subject to the limitations discussed in the preceding paragraph, they account for algal growth which took place in the ponds during the six assay experiments. An inspection of these tables shows that most values are negative. This is consistent with the concept, and the observed fact, that algal cells increased during the assay at the expense of dissolved nutrients.

TABLE 4-4

INVENTORY OF SUSPENDED SOLIDS IN PONS ASSAYS
(all values in grams)

Pond No.		Assay Number (See Table 4-1)					
		1	2	3	4	5	6
1	LTW	- 19	- 26	32	- 14	+ 19	- 47
5		- 17	- 27	- 40	- 5	+ 9	- 28
2	Sewage	- 53	- 55	- 47	- 17	+ 9	- 265
6	Effluents	26	- 41	- 54	+ 17	- 3	- 270
3	Sewage	113	- 211	- 186	- 19	- 4	- 137
7	Effluents	- 119	235	228	3	+ 20	- 78
4	Chemical	- 90	- 263	168	- 18	- 5	- 111
8	Nutrients[a]	- 123	- 269	286	3	- 13	- 93

[a]Assay 1 to 3 was simulated secondary effluent; Assay 4 to 6 was tertiary effluent plus trace elements.

TABLE 4-5

INVENTORY OF VOLATILE SUSPENDED SOLIDS IN POND ASSAYS
(all values in grams)

Pond No.	Assay Number (See Table 4-1)					
	1	2	3	4	5	6
1	- 9	8	9	- 1	1	11
5	10	7	9	- 1	1	11
2	- 18	18	13	- 6	13	82
6	- 14	13	30	+ 14	18	105
3	- 65	95	109	8	18	42
7	- 67	107	151	2	3	25
4	- 52	109	79	13	13	34
8	- 63	113	111	5	20	34

An evaluation of Table 4-4 and 4-5 in the light of Table 4-1 reveals that the negative values, indicative of cell growth, tend to increase as the added nutrient concentration increases. For example, Pond No. 1 and 5, containing unfortified LTW show the lowest increase; and Ponds No. 3 and 7, containing 1% secondary effluent show the greatest. The tables also show in most instances a reasonable degree of compatability between the two ponds constituting an assay of any particular material. The widest deviations from this general case appears in Table 4-4, Assay No. 5, when input exceeded output. As discussed in relation to Figure 4-3, Assay No. 5 was in progress in October when wind and weather conditions brought in a very large amount of suspended solids which were not volatile. It is notable that volatile solids in Assay No. 5 (Table 4-5) failed to show the positive values or wild fluctuation evident in suspended solids.

Nitrogen Compounds

Tables 4-6, 4-7, and 4-9 summarize the change in various nitrogen compounds during each of the several pond assays. In each case where nutrients were added (i.e., Ponds 2,6; 3,7; and 4,8) essentially all of the values are positive, indicating by the convention adopted (see page 30) that more nitrogen went into the assay in the forms indicated in the table headings than came out of the ponds in that same form. In the case of the Lake Tahoe water (LTW) control ponds (i.e., Pond 1,5, all assays) the consistency between duplicate ponds was not as great for nitrogen as for volatile solids or suspended solids. The greatest disagreement between Ponds 1 and 5 seems to have occurred with ammonia. Only Assay No. 5 showed a consistent loss of ammonia. In other assays gains and losses appear quite random. This inconsistency is a result of both the small amount of ammonia present, the limitations of assumption, the precision of measurement possible at low concentrations, and unobserved biochemical changes which probably occurred in the pond biomass. The more conservative forms of nitrogen, (NO_2 + NO_3), although in low concentration, showed a somewhat more consistent check in LTW ponds. Inorganic and total nitrogen showed more gains than losses in Assays 4, 5, and 6.

Relative to assays of LTW with added nutrients, the most consistent pattern is evident in Ponds 4 and 8 to which chemicals in the form of K_2HPO_4, NH_4Cl, iron,

TABLE 4-6

INVENTORY OF SOLUBLE AMMONIA-N IN POND ASSAYS
(values in mg)

Pond No.	Assay Number (See Table 4-1)					
	1	2	3	4	5	6
1	- 44	65	- 87	- 277	296	- 354
5	623	43	6	- 687	262	- 521
2	600	609	872	1238	1858	5180
6	874	214	184	225	734	4015
3	3903	4945	5376	427	806	1949
7	4585	4549	5662	1044	630	1501
4	2072	3814	4865	827	1400	1800
8	2143	3735	4886	461	945	1914

TABLE 4-7

INVENTORY OF SOLUBLE $(NO_2 + NO_3)$-N IN POND ASSAYS
(values in mg)

Pond No.	Assay Number (See Table 4-1)					
	1	2	3	4	5	6
1	87	46	21	3	187	127
5	88	63	24	- 6	121	153
2	220	76	80	- 381	14	118
6	209	68	172	- 80	97	52
3	834	356	832	50	20	80
7	880	334	838	53	18	73
4	123	52	127	- 55	96	- 239
8	138	51	153	- 24	132	- 151

TABLE 4-8

INVENTORY OF SOLUBLE TOTAL INORGANIC-N IN POND ASSAYS
(values in mg)

Pond No.	Assay Number (See Table 4-1)					
	1	2	3	4	5	6
1	44	111	- 108	273	483	227
5	712	21	29	693	383	367
2	820	684	952	858	1844	5298
6	1083	282	356	145	831	4066
3	4737	5300	6209	478	826	1868
7	5465	4883	6499	1097	648	1575
4	2195	3866	4992	772	1304	1562
8	2281	3785	5037	436	812	1762

TABLE 4-9

INVENTORY OF SOLUBLE TOTAL-N IN POND ASSAYS
(values in mg)

Pond No.	Assay Number (See Table 4-1)					
	1	2	3	4	5	6
1	451	179	66	- 795	- 2898	135
5	633	230	1184	- 687	39	2397
2	499	106	- 2480	703	2044	2344
6	1202	604	- 1479	1011	1448	3702
3	4875	5228	2390	574	404	801
7	4696	4584	3676	1250	381	325
4	1609	2994	1398	798	595	1982
8	604	2295	2983	27	1161	2270

and trace elements were added to LTW in Assays 1, 2, and 3 to provide P and N at approximately the same levels observed in the effluent fed to Ponds 3 and 7.

From the inventory of nitrogen compounds it may be concluded that with limited exceptions a decrease in all forms of nitrogen occurred, indicating that biomass was increasing, as previously shown by an increase in volatile solids (Table 4-5).

Phosphorus

Changes in the amount of phosphorus entering and leaving the ponds, as measured by analyses for PO_4-P and total P, are summarized in Tables 4-10 and 4-11. Phosphorus concentration being extremely low in Lake Tahoe water, the inconsistant inventory data shown in the tables for Ponds 1, 5 are not surprising. PO_4-P values are consistent between replicate ponds in essentially all cases during Assays 1, 2, and 3, in which secondary effluent was the added source of nutrients (except Ponds 4 and 8; chemically fortified LTW). Assays 4, 5, and 6, involving various dilutions of tertiary effluent show a much smaller loss of phosphorus than Assays 1, 2, and 3; and (Table 4-5) a correspondingly low increase in volatile solids. Because phosphorus removal was a major aspect of tertiary treatment the results may mean that this element (P) was the growth limiting factor in Assays 4, 5, and 6.

TABLE 4-10

INVENTORY OF SOLUBLE PO_4-P IN POND ASSAYS
(values in mg)

Pond No.	Assay Number (See Table 4-1)					
	1	2	3	4	5	6
1	10	21	3	9	10	24
5	4	3	3	18	17	3
2	157	113	167	55	68	128
6	122	143	188	44	60	105
3	1974	1416	1854	50	8	43
7	1898	1474	2057	37	41	62
4	2209	1738	1955	64	32	32
8	2304	1801	2103	52	41	14

TABLE 4-11

INVENTORY OF SOLUBLE TOTAL P IN POND ASSAYS
(values in mg)

Pond No.	Assay Number (See Table 4-1)					
	1	2	3	4	5	6
1	30	- 672	98	33	97	74
5	26	- 236	- 56	34	119	26
2	- 93	- 80	77	11	172	163
6	90	- 265	- 264	82	221	187
3	1656	981	1865	74	247	138
7	1527	1142	- 2121	- 48	217	107
4	1909	1410	1970	130	272	85
8	1889	1536	2108	73	101	46

Growth Limiting Nutrient

To evaluate the presumptive evidence that phosphorus was growth limiting in Assays 4, 5, and 6 the nitrogen/phosphorus ratio was computed for two cases — NH_3-N vs PO_4-P; and total inorganic N vs PO_4-P. The results are presented in Table 4-12. Because the purpose of the computation was to identify the growth limiting factor rather than to separate the stimulatory effect of LTW and added nutrients the data in the table reflect the actual situation in the pond within the limits of error and assumption. LTW (Ponds 1 and 5) is omitted from the table because at the low concentration of nutrients in LTW negative values are experimentally unavoidable (see Tables 4-5 and 4-11).

In interpreting the data in Table 4-12 use may be made of the general rule that an N/P ratio less than 10 identifies a nitrogen limiting situation, whereas a N/P ratio of 15 or more indicates that phosphorus was the limiting factor. From such criteria it may be concluded that all of the secondary effluent, and simulated secondary effluent assays (Assays 1, 2, and 3) were definitely nitrogen limited; and that with but few exceptions the tertiary effluents were phosphorus limited.

Variations in data from pond to pond in Assays 4, 5, and 6 are considerable. However, it is important to remember that phosphate concentrations were low, and that the assays covered a period of time when temperatures were dropping and winds increasing. Thus it might be expected that allochthonous material would enter the ponds on a random basis; and growth rates be temperature dependent.

TABLE 4-12

N/P RATIOS IN POND ASSAYS
(values in mg/mg)

Pond No.	Based on Total Inorganic-N and PO_4-P					
	Assay Number (See Table 4-1)					
	1	2	3	4	5	6
2	5.2	6.1	5.7	15.5	27.2	41.2
6	8.8	2.0	1.9	3.2	14.0	38.9
3	2.4	3.7	3.4	9.6	106.1	43.3
7	2.9	3.3	3.2	29.7	15.8	25.6
4	1.0	2.2	2.6	12.1	41.3	48.1
8	1.0	2.1	2.4	8.4	19.8	126.4
	Based on Soluble NH_3-N and PO_4-P					
2	3.8	3.9	7.4	22.5	27.4	40.3
6	7.9	2.2	1.2	5.1	12.2	38.4
3	7.2	5.6	5.7	8.6	103.5	45.2
7	8.1	4.5	4.3	28.3	15.3	24.4
4	4.2	3.6	6.3	13.0	44.3	55.5
8	3.6	3.4	4.5	8.9	23.0	137.1

Materials Inventory

The term "inventory" rather than materials balance has been used herein because of the difficulties of making a complete mass balance in outdoor pond assays. However, the general expectation that decreases in nutrients should be reflected in an increase in volatile suspended solids can be tested from the data presented in the foregoing tables and an estimate of the nitrogen content of living cells. To this end Table 4-13 was prepared from data presented in Table 4-5 (VSS) and Table 4-8 (Inorganic-N) by assuming that the observed loss in N is entirely bound up in the observed gain in VSS.

The possiblity that iron, or such trace elements Mg, Zn, Cu, Co, B, and Mo, might be limiting was explored in Ponds 4 and 8. In Assays 1, 2, and 3, LTW was fortified with iron and trace elements in addition to ammonia-N and PO_4. During Assays 4, 5, and 6, Ponds 4 and 8 contained LTW and 1% tertiary effluent, plus iron and trace elements (see Table C-6, Appendix C). An examination of Table 4-5 shows an apparent small difference between Ponds 7,3 and 8,4 in Assays 4 and 5, but none in Assay 6. In view of the variations evident throughout other assays it cannot be concluded from the data that trace elements or iron significantly affected the growth rate of biomass as measured by VSS.

TABLE 4-13

CALCULATED PERCENT INORGANIC-N IN VSS

Pond No.	Assay Number (Table 4-1)					
	1	2	3	4	5	6
2	4.5	3.9	7.4	15.5	14.2	6.5
6	7.9	2.2	1.2	-	4.6	3.9
3	7.2	5.6	5.7	6.3	4.7	4.5
7	8.1	4.5	4.3	57.2[a]	24.4[a]	6.4
4	4.2	3.6	6.3	6.1	9.8	4.6
8	3.6	3.4	4.5	9.2	4.1	5.1

[a]Value uncertain due to operational problem in Pond 7.

The nitrogen content of various algae as summarized in the Second Progress Report [2] range from approximately 4 to 11 percent, although some species may be appreciably lower and luxury uptake of nitrogen in nitrogen-rich media may lead to higher values. A mass balance of nitrogen made on ponds during assays in 1968-1969 by the authors of this report indicated about 10 percent nitrogen in organisms indigenous to Lake Tahoe on the basis of nitrogen vs VSS. Other observations of Scenedesmus and Chlorella by the authors show 6 to 8 percent nitrogen on a dry weight basis. Whipple [21] reported the nitrogen content of Diatomaceae to be 3.66 percent. From such general information the data in Table 4-13 might be said to indicate a reasonably good materials balance in the nutrient – VSS conversion; and hence that reasonable confidence in the overall results of the inventory is justified.

Kinetic Analysis

A computer program was written to determine the rate constants and coefficients in Equations 1 and 2 of Chapter II. This was applied to the data from Tables C-3 and C-4, Appendix C, considering each of the following nutrients or combinations of nutrients as of possible importance: NO_3-N, NH_3-N, Inorganic N(NO_3-N + NH_3-N), Total N, PO_4-P, and Total P. Estimates of cell mass as measured by VSS, both observed and corrected for estimated allochthnous material, were analyzed with each of these nutrients. The results, presented and analyzed in detail in the Third Progress Report [3], were disappointing in their lack of statistical significance and reasonableness of kinetic parameters. As in the case of the flask assays, much investigative work evidently remains to be done before the kinetic parameters obtained with ponds can be reconciled with kinetic theory.

The reasons for this are both numerous and to a large degree controversial. It seems quite certain that they can not readily be resolved without greater ability to control and evaluate all variables than can be achieved under outdoor field conditions.

Flask Assays of Pond Effluent

To a very significant degree the experimental ponds used in the study herein reported are analagous to marinas or lagoons in which Lake Tahoe water is detained at temperatures more favorable to algal growth than that of the lake, and is given added nutrients as a result of human activity in the water or on the adjacent land. In such confined waters an assay measures only the growth potential remaining at any given time in the eutrophication cycle. Thus both the growth potential and the existing biomass would have to be measured in order to evaluate the productivity of any given body of water. To explore the residual growth stimulating ability of water after its original nutrients have been reduced by algal growth, flask assays were made during steady state operation of the experimental ponds. Samples for assay were collected from each of the eight ponds during six separate assays of Lake Tahoe water, and three assays each of secondary and tertiary waste water effluent during the 1969 season.

Results of these flask assays of 48 pond samples and six Lake Tahoe water samples are summarized in Table 4-14 in which are reported values of growth rates, cell concentration, coefficient of variation for $\hat{\mu}_b$ and $\hat{X}_5$, and the correlation coefficient for $\hat{\mu}_{b\ell}$. Values presented in the table for concentration of sample represent the influent waste concentration established for the pond assay and do not reflect the condition of the various samples drawn from the pond for flask assay.

All of the flask assays from the ponds yielded lower growth response than did flask assays of secondary and tertiary effluent at concentrations equivalent to that fed into the ponds for pond assay purposes. Basically the same growth response pattern was observed when measured by any of the three parameters, $\hat{\mu}_b$, $\hat{\mu}_{b\ell}$, and $\hat{X}_5$. The following discussion therefore applies to all of these parameters.

Examination of Table 4-14 shows that little change in growth response occurred in the pond effluent samples in comparison with that displayed by Lake Tahoe water reference ponds undergoing pond assay. This indicates that little growth effect is to be expected by confining Lake Tahoe water in the absence of added nutrients. Such a circumstance, however, is of little practical consequence because when any detention of Lake Tahoe water does occur, as in marinas or keys, it is impossible to prevent the entry or accumulations of nutrients which result from the human activity which the impoundments or developments were designed to attract.

Flask assays made from ponds operating on secondary and simulated secondary effluents detained as long as eight days showed that there still remained enough nutrients to support a larger biomass than normally measured in Lake Tahoe water. This means, of course, that the growth of organisms during pond bioassays did not strip out enough of the added nutrients to restore Lake Tahoe water to its original degree of purity. Interpreted in terms of lake conditions this would mean that even harvesting of algae from an enriched confined water by chemical precipitation, for example, would not prevent a residue of the nutrient which produced the growth from moving out into the lake.

Flask assays of samples from the ponds in assays 4 and 5 and receiving low concentrations of tertiary effluent produced little growth for the simple reason that the tertiary effluent had previously been subjected to both phosphate removal and a growth of organisms under phosphate limited conditions. Thus no residual ability of the pond effluent to support algal growth was identified. This apparent result, however, is misleading because in the phosphorus poor water nitrogen was not utilized and so remained in the flask. Again in terms of a nitrogen sensitive lake, the flask assay represented a situation in which a critical nutrient could be discharged to Lake Tahoe undetected by an assay based on growth stimulating potential.

From Pond Assay 6 the flask assay showed a residual nutrient concentration sufficient to support growth beyond the level found in Lake Tahoe water. The reason for this difference between results on Assay 6, and Assays 4 and 5 lies in the factor of temperature. Pond Assay 6 was conducted at the lowest temperature of all assays hence growth in the ponds was inhibited. At the optimum temperature used in

TABLE 4-14

MAXIMUM GROWTH RATES, $\hat{\mu}_b$ and $\hat{\mu}_{b\ell}$, AND MAXIMUM CELL CONCENTRATION, $\hat{X}_s$, ATTAINED AT THE END OF FIVE DAYS IN FLASK CULTURE OF POND SAMPLES COLLECTED DURING STEADY STATE OPERATION

Sampling Date, Pond and Assay No.	Source and Conc. of Sample (%)	Mean Max. Rate ($\hat{\mu}_b$, day^{-1})	Coef. Var. (%)	Mean Max. Rate ($\hat{\mu}_{b\ell}$, day^{-1})	Corr. Coef.	Cell Conc. $\hat{X}_s$ (cells/mm^3)	Coef. Var. (%)
8- 6-69 Assay 1							
Pond 1	LTW[a]	0.147	27.0	0.064	0.521	115.1	30.5
2	0.1% II[b]	0.153	35.2	0.074	0.625	125.4	21.5
3	1.0% II[c]	0.243	9.4	0.168	0.939	174.1	13.1
4	1.0% S-II[d]	0.508	11.8	0.294	0.912	285.3	10.1
5	LTW	0.140	25.3	0.084	0.757	116.1	16.8
6	0.1% II	0.105	12.1	- 0.018	- 0.236	79.2	6.9
7	1.0% II	0.423	7.6	0.255	0.928	248.7	4.9
8	1.0% S-II	0.459	8.1	0.244	0.874	246.4	13.7
LTW	Header[e]	0.142	32.4	0.017	0.201	92.5	7.8
8-20-69 Assay 2							
Pond 1	LTW	0.068	44.3	0.027	0.453	99.1	5.3
2	0.1% II	0.043	79.5	- 0.019	- 0.348	96.2	2.0
3	1.0% II	0.254	7.6	0.156	0.931	142.4	6.2
4	1.0% S-II	0.364	18.6	0.218	0.921	189.6	5.5
5	LTW	0.092	26.9	0.064	0.931	96.2	4.4
6	0.1% II	0.064	31.8	0.043	0.834	93.3	4.2
7	1.0% II	0.081	66.8	0.027	0.384	104.7	8.4
8	1.0% S-II	0.127	47.3	0.082	0.718	115.8	23.8
LTW	Header	0.171	54.5	0.107	0.765	117.7	26.5
9- 2-69 Assay 3							
Pond 1	LTW	0.416	6.0	0.317	0.958	179.0	20.4
2	0.1% II	0.408	9.5	0.299	0.967	180.1	11.8
3	1.0% II	0.576	11.2	0.354	0.906	320.1	14.6
4	1.0% S-II	0.422	22.7	0.319	0.959	220.1	10.6
5	LTW	0.436	15.2	0.276	0.911	167.3	22.5
6	0.1% II	0.299	18.6	0.198	0.948	117.1	4.1
7	1.0% II	0.416	57.6	0.237	0.554	392.8	53.3
8	1.0% S-II	0.512	10.1	0.325	0.937	467.6	12.9
LTW	Header	0.589	9.2	0.368	0.932	221.6	7.6
10- 1-69 Assay 4							
Pond 1	LTW	0.206	29.1	0.050	0.312	90.9	26.7
2	2% III[f]	0.359	20.1	0.179	0.846	119.1	11.3
3	1% III[g]	0.260	24.6	0.118	0.790	96.2	11.4
4	1% III + TE[h]	0.163	25.6	0.133	0.883	100.5	20.5
5	LTW	0.416	24.4	0.251	0.837	186.4	18.0
6	2% III	0.355	20.1	0.153	0.766	104.5	13.1
7	1% III	0.215	58.6	0.120	0.740	93.3	17.0
8	1% III + TE	0.432	55.3	0.274	0.813	182.2	44.1
LTW	Header	0.462	18.0	0.265	0.792	146.9	25.4
10-14-69 Assay 5							
Pond 1	LTW	0.545	5.8	0.347	0.944	210.6	7.7
2	2% III	0.439	13.6	0.342	0.977	192.7	8.7
3	1% III	0.569	5.8	0.365	0.946	207.5	5.8
4	1% III + TE	0.550	10.3	0.384	0.961	204.4	10.7
5	LTW	0.447	22.7	0.311	0.937	207.7	19.7
6	2% III	0.369	13.4	0.256	0.952	152.6	10.5
7	1% III	0.451	32.3	0.301	0.916	232.9	21.7
8	1% III + TE	0.432	20.6	0.312	0.962	205.4	5.9
LTW	Header	0.379	19.4	0.245	0.932	312.0	10.9
10-27-69 Assay 6							
Pond 1	LTW	0.225	15.3	0.139	0.923	252.5	5.0
2	2% III	0.191	38.9	0.118	0.854	222.6	10.7
3	1% III	0.599	5.4	0.408	0.961	693.8	8.8
4	1% III + TE	0.119	66.9	0.077	0.806	170.2	16.9
5	LTW	0.160	57.0	0.085	0.712	215.4	6.9
6	2% III	0.623	13.5	0.357	0.909	643.0	15.1
7	1% III	0.204	18.2	0.137	0.938	218.0	5.5
8	1% III + TE	0.231	16.1	0.157	0.949	174.6	4.2
LTW	Header	0.125	21.2	0.098	0.842	176.2	7.8

[a] LTW – Pond containing only Lake Tahoe water.

[b] 0.1% II – Pond containing 0.1% secondary sewage effluent from STPUD Water Reclamation Plant and LTW.

[c] 1.0% II – 1% secondary sewage effluent in LTW.

[d] 1.0% S-II – 1% simulated secondary sewage effluent (refer to Table C-6, Appendix C).

[e] *Header – Water sample collected from pond influent LTW* supply header.

[f] 2% III – Pond containing 2% tertiary sewage effluent from STPUD Water Reclamation Plant and LTW.

[g] 1% III – 1% tertiary sewage effluent in LTW.

[h] 1% III + TE – 1% tertiary sewage effluent with additions of iron and trace elements (refer to Table C-6, Appendix C).

flask assays, however, algae were able to utilize nutrients which their predecessors in the ponds could not. In terms of lake conditions this could mean that nutrients reaching embayed waters during the cold months could accumulate and then support an algal bloom in the spring. Such a bloom would, of course, disappear with the stripping of nutrients; but by that time the nutrients are in the cycle of growth, decay, and recycle; and eutrophication is advanced thereby.

CHAPTER V

ASSAY OF SURFACE WATERS

INTRODUCTION

To evaluate the danger to Lake Tahoe of man's development and occupancy of land in the Basin (Objective No. 3, Chapter I) a program of systematic sampling and assaying of Lake Tahoe and creek waters was initiated in 1967. For continuous monitoring throughout the study, Ward Creek, Incline Creek, and the Upper Truckee-Trout Creek system were selected as representing surface runoff from relatively undeveloped, newly developed, and well established urban development, respectively. Later, in 1970, General Creek was added to the list to represent undeveloped land, as the Ward Creek watershed was at that time being subjected to considerable land development activity. By comparing the nutrient content and growth stimulating properties of water from these 4 major creeks, utilizing Lake Tahoe water as a background or Control, a great deal was revealed concerning the threat of eutrophication resulting from land development. Findings of this aspect of the assay of surface waters are the subject of this chapter (Chapter V). During the 1969-70 grant period a program of analyses and bioassays of some 27 additional creeks was begun in order to evaluate the non-sewage contribution of nutrients to Lake Tahoe. Such an evaluation, based on the overall findings of the study, is the subject of Chapter VI.

QUALITY OF LAKE TAHOE WATER

Chemical Analyses

Because Lake Tahoe is a relatively large body of water (approximately 21 miles long and 12 miles wide) the question of obtaining a representative sample immediately confronts the investigator. Samples for chemical and biological assays were taken therefore both from a point near mid-lake and at the near-shore location from which lake water was pumped for the pond assays described in Chapter IV. Results of physical and chemical analyses of lake water samples from these two stations for the period June 1967 through November 1970 are presented in Table D-1, Appendix D. From a plotting of near-shore and mid-lake data reported in 1969(3) it was found that the two were not significantly different on any particular sampling date. Subsequently, in 1970, this observation was further verified by a short-term program of sampling at multiple points around the lake. The similarity evident for the more conservative nutrients such as PO_4-P, Total nitrogen, and $(NO_3 + NO_2)$-N , however, showed a seasonal variation.

Although both mid-lake and near-shore data are presented in Table D-1, only near-shore data are plotted in Figure 5-1. The figure shows that during the period of study the Total nitrogen was predominantly organic nitrogen. In 1968 and 1969 there was a high peak in the curves in the October-November period, with a moderate rise in Total-N due to a peak in the ammonia nitrogen concentration in March 1969. The 1969 and 1970 curves show a rise in mid-summer which was not evident in 1968.

Ammonia-N and $(NO_3 + NO_2)$-N concentrations in Lake Tahoe (Figure 5-1) followed a similar but less clear pattern, with explosive changes in ammonia appearing in January and March of one season, and in January and June the following year. In November 1970 a sharp rise in both NH_3 - N and $(NO_3 + NO_2)$-N gave an upward trend to the Total-N curve.

Total phosphorus showed a more consistent pattern of seasonal peaks than did nitrogen, with January and May being the typical peak periods.

From the nitrogen and phosphorus curves in Figure 5-1 it seems evident that seasonal changes in the nutrient content of Lake Tahoe water do occur. That these changes are not simply the result of wind disturbance of sediments in the

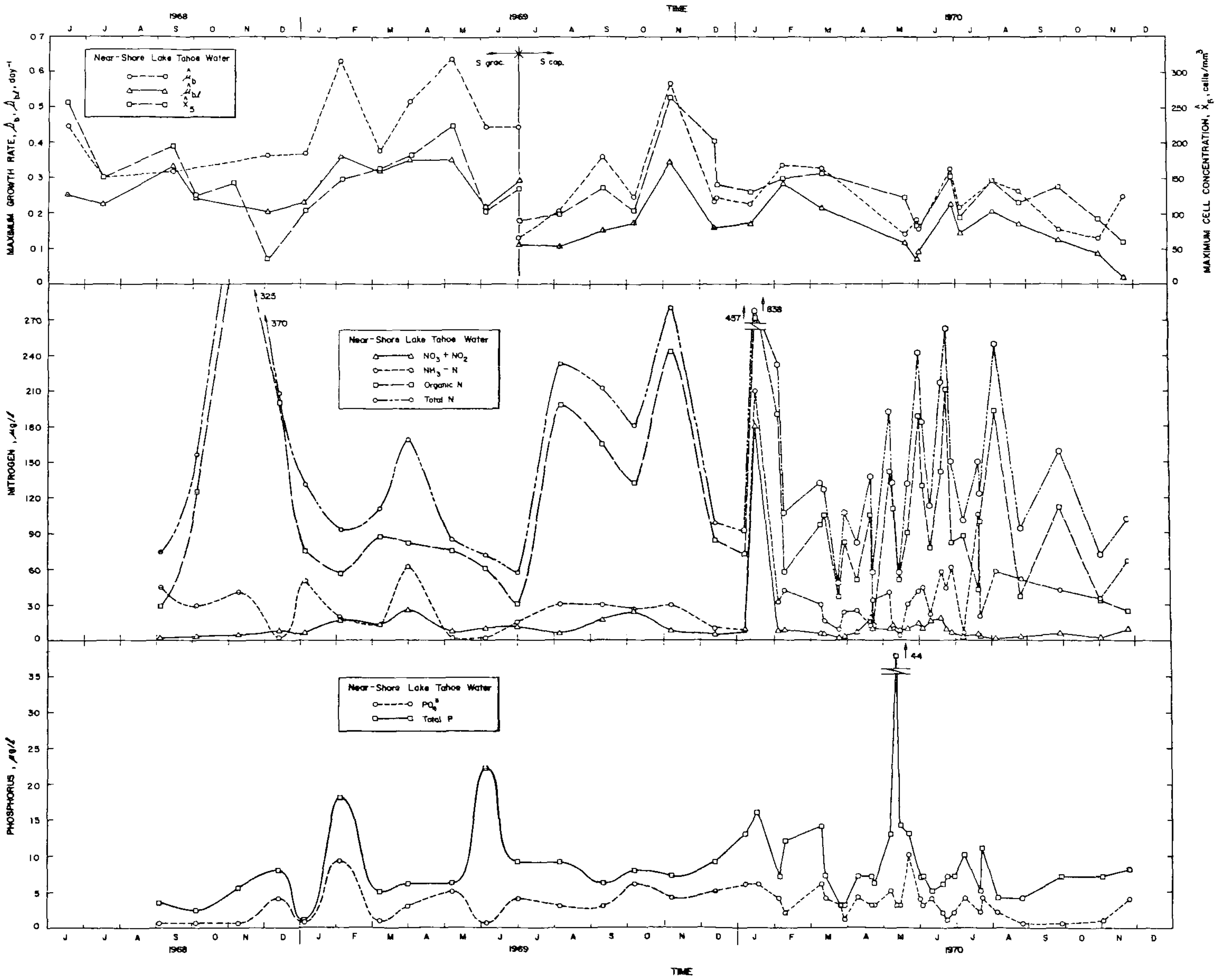

FIGURE 5-1 RELATIONSHIP OF GROWTH PARAMETERS AND NUTRIENTS, NEAR-SHORE LAKE TAHOE

shallows was shown in a previous report (3) which revealed the same variations to prevail simultaneously in mid-lake and near-shore waters. This led to the conclusion that for the purpose of the study the near-shore samples were typical of Lake Tahoe Water.

That the observed seasonal differences do not represent nutrient depletion by biomass production is evidenced by the tendency of peak concentrations to occur during seasons when a maximum of nutrient tieup in living cells might be expected. In evaluating the curves, however, it should be borne in mind that the concentration of nutrients in Figure 5-1 is expressed in $\mu g/\ell$ and therefore represents quite small amounts of chemicals even at peak values.

Growth Response

Results of flask assays of the growth response of Selenastrum are summarized in Table D-2, Appendix D. Values of three growth parameters in this table ($\hat{\mu}_b$, $\hat{\mu}_{b\ell}$, and $\hat{X}_5$) are plotted in Figure 5-1 on the same scale of time as the nutrient concentrations. On July 1, 1969 there was a distinct break in continuity of the curves as the test alga was changed from S. gracile to S. capricornutum and the Coulter Counter was substituted for ocular (hand) counting of cells under the microscope. With either organism, $\hat{\mu}_b$ seemed a somewhat more sensitive parameter than $\hat{\mu}_{b\ell}$ or maximum cell concentration, $\hat{X}_5$, during 1968-69. In 1969-70, this tendency was only slightly evident, if not indeed non-existant.

In general, the growth rate of S. capricornutum showed a tendency to fluctuate with the total nitrogen and the organic nitrogen concentration and was little related to the phosphorus content. This observation supports the recurring evidence that Lake Tahoe is nitrogen sensitive.

During 1968 and the early months of 1969, when S. gracile was the test alga, the relationship of growth rates to nutrients is unclear. The reasons for this difference in observable relationships are threefold. First, at the low levels of nutrient present in Lake Tahoe water, normal experimental error of a few micrograms may appear as a large percentage variation. Second, the analytical skill of personnel improved with time and experience with low concentration samples. Third, and perhaps most important, the Coulter Counter permitted rapid analysis (approximately 13 seconds per count), thus permitting a great many more replications of counts on a single sample than is feasible with an analyst using the microscope. Thus it is concluded that the greater accuracy of both man and machine showed up subtle relationships in 1969-70 that were difficult to detect under previous conditions.

The break in the growth curves in mid-1969 is an indication of a difference in response of S. gracile and S. capricornutum, plus or minus any changes in accuracy of method. It is interesting to note that the maximum growth rate of S. gracile during the 1968-69 period tended to average about the same as the 29 percent per day observed in the early survey results reported in Chapter III. With S. capricornutum in 1969-70, the average appears by simple visual examination of Figure 5-1 to be about 20 percent per day (0.2 day^{-1}). It is also noteworthy that with the Coulter Counter, the two measures of growth rate ($\hat{\mu}_b$, $\hat{\mu}_{b\ell}$) differed little, although, as previously noted, $\hat{\mu}_b$ continued to show on occasion slightly higher growth rates than other parameters. The response in terms of the cell count, $\hat{X}_5$, although expressed in different terms and on a different scale in Figure 5-1, followed the same pattern as did $\hat{\mu}_b$ and $\hat{\mu}_{b\ell}$. This indicates that cell count alone is a feasible parameter of growth stimulating potential at the low cell concentration levels attained in LTW.

Evaluating Results

In interpreting the growth rate and nutrient relationships in Figure 5-1, it important to recall that the nutrient analyses and flask assays reported were both made on water from which indigenous organisms had been removed by filtration. Thus both reflect the residual potential of Lake Tahoe water during or after the occurrence of any indigenous growth under lake conditions. Some fraction of the nutrients in LTW may, therefore, have been tied up in living cells or undegraded organic solids when the flask assays were made, especially in the summer season. Evidence that this phenomenon can lead to serious misinterpretation of data was suggested in Chapter III in comparing the growth rate of S. gracile observed in flask assays of a few marinas and keys (Table 3-3) with the growth rate observed in Lake Tahoe water (Table 3-1) under similar conditions. In isolated observations not herein tabulated, extensive growths of attached algae were observed growing in a marina in which the water understandably showed very limited ability at that time to support growth in flask assays.

To evaluate the degree to which the results of flask assays of either mid-lake or near-shore waters represent the true eutrophication potential of nutrients in the Lake it is necessary to examine the seasonal variation in VSS in LTW for both the flask and pond assays. A wide fluctuation in VSS and nutrients between winter and summer seasons would be expected of eutrophic waters under the seasonal variation in climatic conditions prevailing at Lake Tahoe. On the other hand a completely oligotrophic water should remain quite constant in VSS and nutrient concentrations except at times of sediment disturbance by storms or influx of surface wash.

Table D-1 (Appendix D) shows that during the Jan.-Dec. 1970 period, when VSS measurements were made of LTW, the biomass, as measured by that parameter, was continuously low. Only on 3 occasions was a value greater than 1 mg/ℓ VSS observed in near-shore waters, where variations in suspended matter are more profound than elsewhere in the lake.

On each of these occasions (January, May, and July) the total suspended solids were vastly greater than normal, as was the ratio of total-to-suspended VSS. Each is explainable by one of the phenomena which have been observed to create such conditions, i.e. 1) storm runoff carrying sediments stripped from disturbed soil, and 2) wind or storm disturbance of the sediments on the lake bottom in shallow water. In this particular case an exceptionally severe storm occurred in January; a snowmelt took place in May; and in July a strong wind traversing the lake from south to north produced a profound disturbance of the bottom sediments in the area of near-shore sampling at North Tahoe.

Table C-4 (Appendix C) shows that on two other occasions (in 1969) values of volatile solids were greater than 1 mg/ℓ. On one of these occasions (Oct. 8, 1969) a sudden explosive rise in solids at the near-shore sampling station (see Figure 4-3, Chapter IV) was wind generated [3] during a storm. Unfortunately, the dangers and difficulties of mid-lake sampling during high wind or storm periods prevented a securing of comparative mid- and near-shore data on the four occasions cited.

In five instances when mid- and near-shore lake sampling was done on the same day (i.e. 8/4, 8/26, 9/29, 11/2, and 11/23, 1970) (see Table D-1) there was a clear tendency for:

1. VSS and Total SS concentrations at mid-lake to be identical.
2. Total SS concentration to be somewhat larger than VSS in near-shore samples.
3. The solids in near-shore samples to exceed those at mid-lake.

Such data are rationally to be expected because sedimentation is a near-shore phenomenon; disturbance of sediments by water movement is greatest in shallow water; and the abundance of life, whether in lakes, estuaries, or the ocean, is greatest in the near-shore zone.

The foregoing findings suggest that flask assays of the near-shore samples should reflect a residual growth-stimulating potential somewhat less than appears in the lake in general. Examination of the chemical analyses of mid- and near-shore waters in Table D-1 reveals some evidence to support this suggestion. In four of the five situations cited in the preceding paragraph the Total-N at mid-lake exceeded that at the near-shore station. PO_4-P was likewise higher at mid-lake in 4 of 5 instances. Both of these facts would indicate conditions less favorable to algal growth at mid-lake than near the shore.

The question as to whether this expected difference in mid- and near-shore lake water characteristics is of any significance when the growth response in LTW is used as a control, and LTW is used to dilute other waters for assay purposes, can be answered by considering several facts. First as shown in Table D-1 there is no identifiable seasonal pattern in the biomass as measured by VSS in 1970, except perhaps a modest peak during the month of July which bore little if any relation to nutrient content reported. Next, growth rates in Figure 5-1, particularly $\hat{\mu}_{b\ell}$ and X_5 showed a decline in the winter season in 1968-69 when outdoor conditions are least favorable to indigenous growth, and consequently nutrients should be, and were, in greatest abundance. Moreover, mid-lake growth rates reported in Table D-2 (Appendix D) and in Table 5-1, show that although values fluctuated somewhat more widely than did near-shore rates, there was no identifiable seasonal trends; and the general average was not observably different for the two locations.

Considerations such as the foregoing supported the conclusion that near-shore samples taken at the site of the pump intake used in the Pond Assays were representative of the upper stratum of Lake Tahoe and suitable as a background against which to compare the growth response of creek waters in flask assays. This conclusion, of course, added further validity to the results reported in Chapters III and IV in which it was shown that several types of possible inputs to Lake Tahoe exceed LTW in algal growth stimulating potential; and that sewage effluent in Lake Tahoe would produce algal growth in proportion to the concentration of effluent until limited by some growth factor.

QUALITY OF CREEK WATERS

Chemical Analyses

Table D-3 of Appendix D reports the results of chemical and related analyses of samples from Ward, Incline, and Upper Truckee— Trout Creek for the period June 1968 through November 1970; and for General Creek from July through November 1970. Data from this table are plotted in a series of figures hereinafter presented to show the variation in several parameters of quality throughout the period of study.

Inorganic Nitrogen Series. Figure 5-2 shows the relationship and the variation with time of three forms of soluble nitrogen in Creek Waters. From an examination of the curves for NH_3-N it seems likely that both the activities of man in the Lake Tahoe Basin and seasonal variations are reflected in the curves. Incline Creek, draining an area which was undergoing land development, particularly in 1968 and 1969, shows a pattern of comparatively high concentrations of ammonia seasonally. In both 1968 and 1969 a peak in the curve appeared in September. In 1970 this summer peak occurred about two months earlier. In February 1969 and 1970, and again in April 1970, Incline Creek reached a peak value at a time when the ammonia content of both Ward and Truckee — Trout Creeks was declining. High peaks occurred in both April 1969 and April 1970. As previously suggested [3], this annual peak may well have resulted from surface runoff occurring at a time when fertilizing of a golf course through which Incline Creek flows might be appropriate. However, no specific data on this point are at hand.

In April 1969 all three creeks showed a rise in NH_3-N at the time of melting of an unusually heavy snow pack. The milder winter which followed did not produce a similar rise in the ammonia content of Ward and Truckee — Trout Creeks in April 1970. The presumptive evidence, therefore is that a climatological and seasonal factor is involved. Such a seasonal effect is further supported by the tendency of all three creeks to show essentially the same concentration of NH_3-N in the winter (Nov.-Dec.) season. However, this is also the season when man's activities on the drainage area has the minimum of effect, and when temperatures are not conducive to the biodegradation of organic matter that produces ammonia.

With the exception of the high peaks in NH_3-N in Incline Creek in mid- or late-summer there was some tendency for all creeks to behave alike during the dry summer months, just as in the winter.

On the basis of the 1968-69 data it was concluded in 1969 (3) that the NH_3-N curves of Figure 5-2 showed quite clearly that active development of land released nutrients far in excess of that to be expected from undisturbed land. It was stated (3) that "...If the Ward Creek data are assumed to reflect what might be expected under natural conditions, the NH_3-N concentration in April was about doubled by human activity on the Upper Truckee — Trout drainage area, and increased by a factor of eight by activity in the Incline Creek basin." Reviewing the data (Figure 5-2) for March-April period of 1970 leads again to essentially that same conclusion.

Examination of the NH_3-N curves from May to December 1970, however, suggests that a longer period of observation is in order. During that period, development of the Ward Creek Basin began. Thereafter, for the first time Ward Creek became essentially like Upper Truckee — Trout Creek in ammonia content, and exhibited even higher peaks than the latter during the summer. This effect of human activity was made further evident by comparing Ward Creek with General Creek, which was added to the list in July because of the more natural state of the land in its drainage area. As the winter season approached, the tendency of all four creeks to behave alike at that season in terms of NH_3-N again appeared.

Although on the basis of the NH_3-N curves there is little doubt that land development activity in the Ward Creek watershed increased its nutrient content, data for another season or two are needed to determine whether it will react as explosively as did Incline Creek. There are some reasons to suggest that it may more quietly assume the status of Upper Truckee — Trout Creek. These lie in a greater public awareness of the problems associated with land development and more strict institutional controls of land development procedures.

In the case of Incline Creek the data from May to December 1970 seems to suggest that as its land development is completed it, too, may become more like Truckee — Trout in its nutrient contribution to Lake Tahoe. Again it will require another two years of data to determine whether under more watchful management and maturing of the development itself the explosive concentrations of NH_3-N of past years will not reoccur. Possibly the curves reflect only the effect of an early Fall season in 1970, but the alternate possibility of a more limited contribution of nutrients to the Lake can not be discounted until the record is clarified by future observations.

<u>$(NO_2 + NO_3)$-N</u>. The plot of values of nitrite plus nitrate nigrogen in Figure 5-2 shows for Incline Creek the same pattern of values as observed for ammonia in 1969. In early 1970, however, the high peak for oxidized nitrogen preceded by two months the high point in NH_3-N. Whereas in 1969 the two peaks were coincident. One possible reason for this phenomenon is the difference in weather cycles of the two years. 1968-69 was a winter of excessive snow which

was slow in melting. In January 1970, however, there was excessive rainfall, followed by snow which melted later. Fertilizing practice evidently differed in the Incline Creek watershed for the two years. In early February 1969 the ratio of NH_3-N to $(NO_2 + NO_3)$-N was 1.3/1; and in April, 1.66/1. In contrast the corresponding values in 1970 were about 0.6/1 and 12.8/1, respectively, with only the April NH_3-N values for the two years being of comparable magnitude. The mid-summer peaks in ammonia and oxidized nitrogen concentrations coincided in 1970 just as they did in September 1969, but the values were much smaller, thus supporting again the possibility that Incline Creek may decline in its future nutrient content.

Although it is unclear just why the peak concentrations of nitrogen differed in the two years of study, their magnitude in comparison with that of Ward and Truckee – Trout Creeks leaves no doubt that human activity was the source of the nutrient. In both years of study Upper Truckee – Trout Creek showed an appreciable rise in the more stable forms of nitrogen as the fall of the year set in. However, one need only observe the watershed area to conclude that the Truckee – Trout system reflects in its nutrient content the presence of humans. In the matter of $(NO_2 + NO_3)$-N, Ward Creek remained similar throughout the period of study, exhibiting in ammonia content its principal nitrogen response to land development.

Curves for Inorganic -N, being the summation of the NH_3-N and $(NO_2 + NO_3)$-N concentrations, show little that has not already been discussed in relation to Figure 5-2.

Organic and Total Nitrogen. Figure 5-3 shows that in February and April 1969, the nitrogen content of Incline Creek included soluble organic nitrogen as well as ammonia and $(NO_2 - NO_3)$-N. In 1970, however, organic nitrogen was associated only with the $(NO_2 + NO_3)$-N rise in February. Thereafter it fluctuated throughout the summer and early fall. Upper Truckee – Trout Creek, after a high rise in February 1970, fluctuated throughout the summer, then rose sharply in September but to a level of only about one-half of its similar fall peak in 1969. Ward and General creeks were similar in their low values of organic nitrogen, presumably due to less disturbed land conditions on their watersheds.

The total nitrogen curves in Figure 5-3 show no phenomenon not previously considered in relation to the nitrogen fractions which are summed up to produce them.

Ortho and Total Phosphorus. The PO_4-P and Total-P values reported in Table D-3 (Appendix D) are presented graphically in Figure 5-4. As in the case of nitrogen two very sharp peaks are apparent for Incline Creek in February and April 1969, indicating that some more balanced fertilizer than nitrogen alone was present in the creek on the sampling dates reported. In 1970 the PO_4-P rise was associated in February with peak values of $(NO_2 + NO_3)$-N and Organic N. It coincided with the July peaks of NH_3-N and other nitrogen compounds but was near its lowest observed level when the exceptionally large concentration (536 $\mu g/\ell$) of ammonia appeared in Incline Creek in April 1970 (see Figure 5-2). Throughout the entire period reported Incline Creek carried a higher concentration of PO_4-P than any other of the four creeks monitored. In contrast Upper Truckee – Trout Creek was lowest in PO_4-P content a great portion of the time. On the assumptions that Ward and General creeks represent the somewhat normal case, the conclusion is inescapable that human occupancy of the newly developed Incline area increased the contribution of soluble ortho-phosphate, whereas on the more stabilized watershed of Truckee – Trout the effect was to reduce PO_4-P.

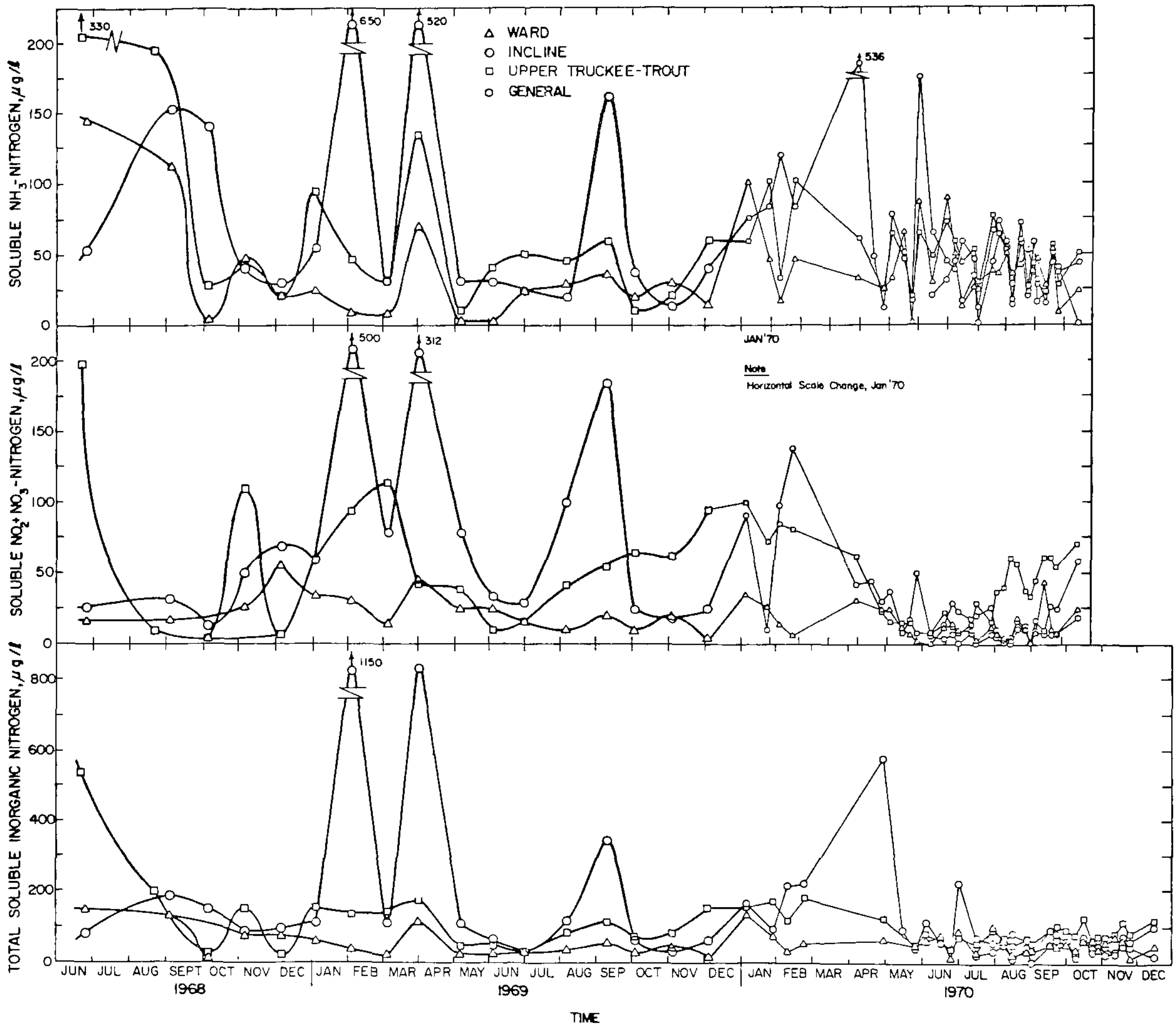

FIGURE 5-2. VARIATION IN CONCENTRATION OF NITROGEN COMPOUNDS IN CREEK WATERS

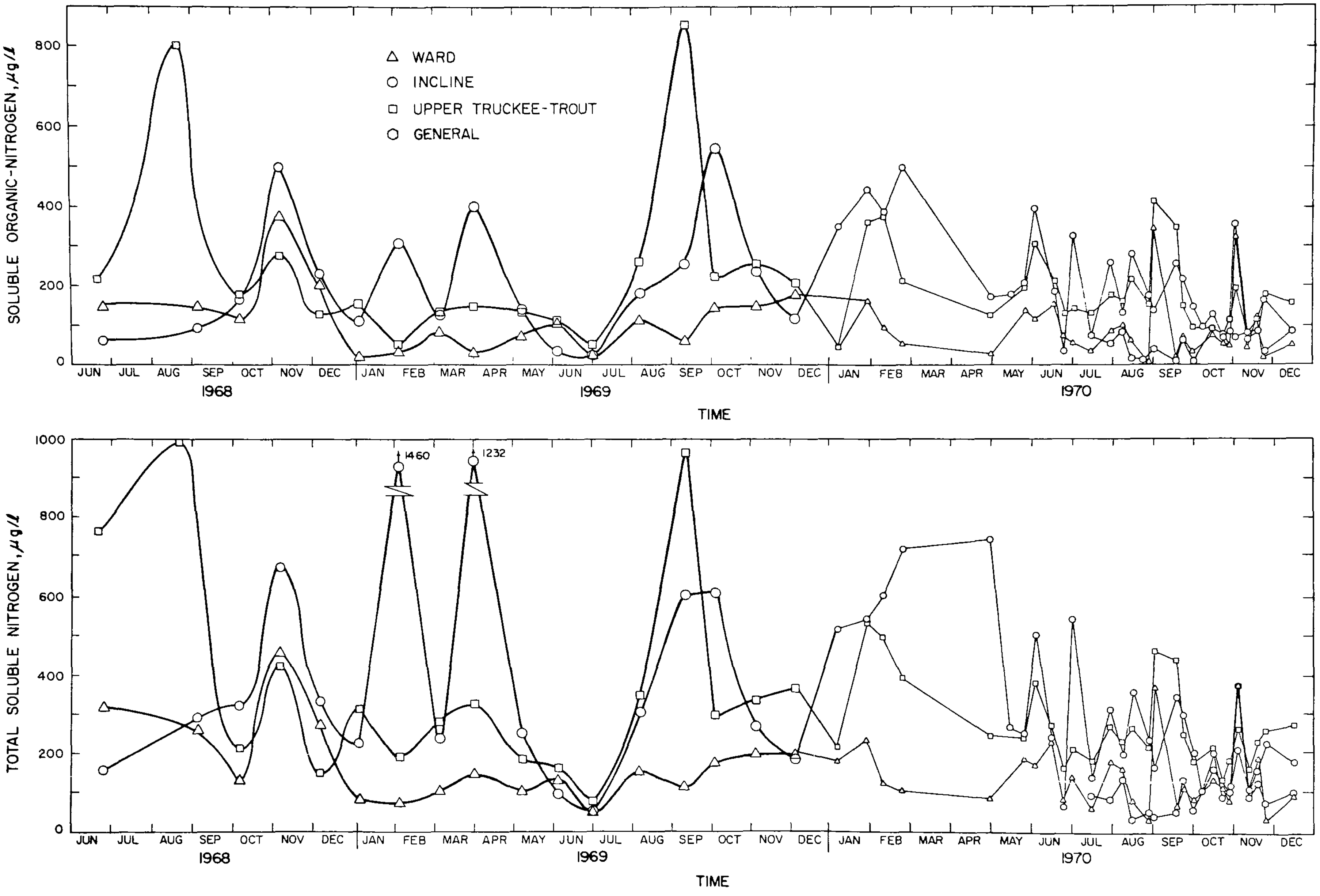

FIGURE 5-3. VARIATION IN ORGANIC AND TOTAL NITROGEN IN CREEK WATERS

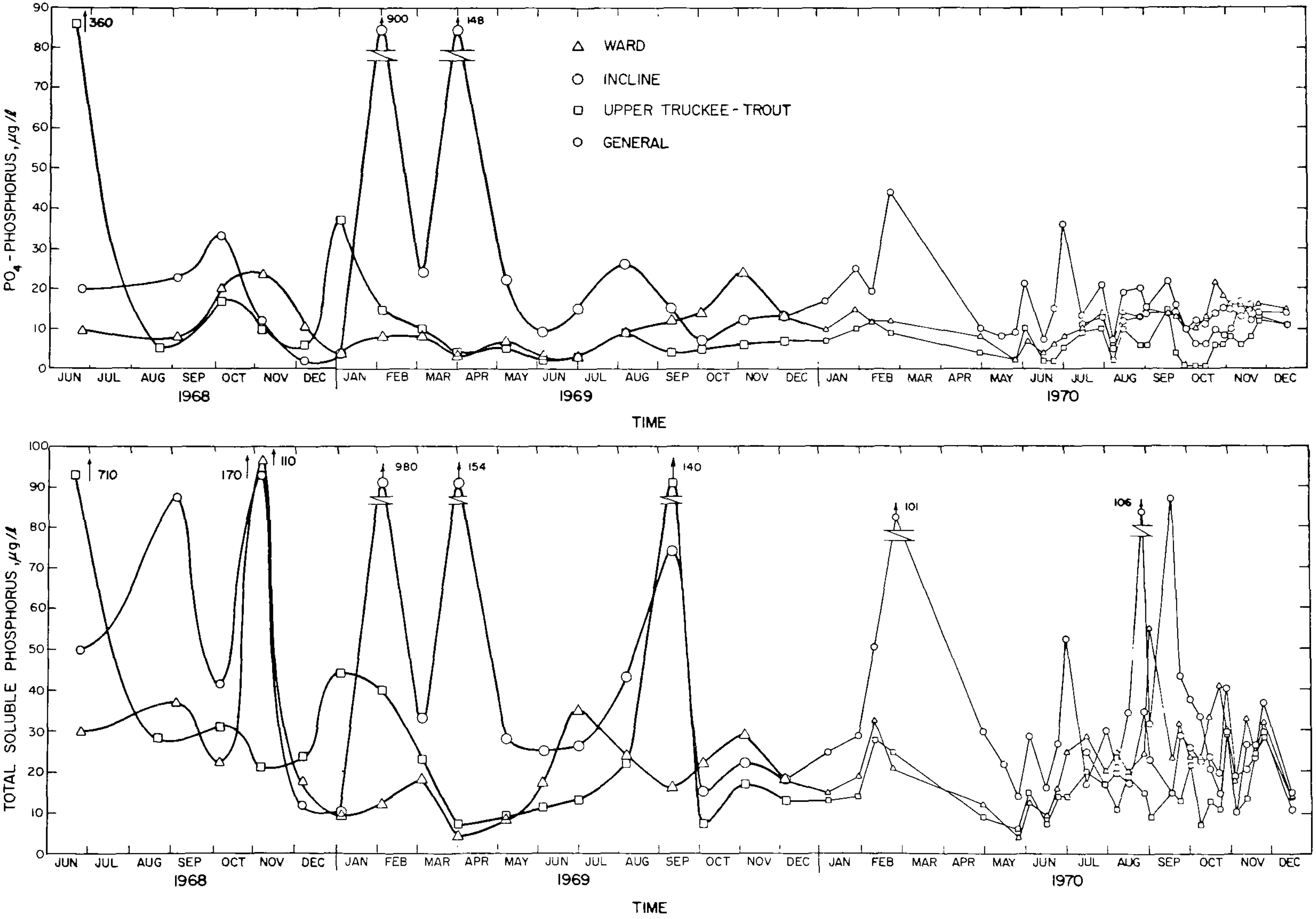

FIGURE 5-4. VARIATION IN PO_4-P AND TOTAL P IN CREEK WATERS

Total -P followed the same pattern as PO_4-P with the exception that in September each year Incline Creek showed a very high concentration of Total -P which was obviously not ortho-phosphate. It was postulated in 1969 (3) that the unusual amount of Total -P in Upper Truckee – Trout Creek in that year was the result of some unusual discharge to the creek. The failure of Truckee – Trout to show a similar rise in the fall season of 1970 supports such a possibility. Following the beginning of development of the Ward Creek basin in 1970 it showed an increase in Total -P not apparent in 1969 nor in the PO_4-P curve of Figure 5-4.

All of these several observations are explainable, although the data to document any individual explanation are not at hand. Fertilization of grass and landscaping, together with the disturbance of soil cover, can readily account for most of the nitrogen and PO_4-P relationship and variations reported. The source of total phosphorus not in the ortho state is presumably the degradation of vegetation, as leaves and pollen, well known storehouses of phosphorus, are broken down to a soluble organic state. Tables of Chapter VI show that an increase in total phosphorus in the late summer and fall is characteristic of creeks in general in the Tahoe basin.

Other Water Quality Factors. Values of such water quality factors as calcium, conductivity, iron, chlorides, pH, and alkalinity are plotted in Figure 5-5. The various curves indicate that in general all creeks followed similar seasonal patterns. Chlorides in Incline Creek showed two fairly sharp peaks in February and April 1968 paralleling what occurred in the nitrogen and phosphorus series. However, there was a tendency for Upper Truckee – Trout Creek to show the highest concentrations of chlorides throuhout the period of study. A particularly sharp rise above normal limits appeared in the Truckee – Trout system in the fall of 1970. Because the Truckee – Trout basin is a populated area and because of the use of salt to reduce ice on pavement, it is to be expected that chlorides will be one of the important quality degrading factors contributed by human activity in the Lake Tahoe Basin, althouth it is not a factor in eutrophication at the levels presently found.

Total and Volatile Suspended Solids. Values of Total and VSS reported in Table D-3 (Appendix D) are summarized in Figure 5-5 for the year 1970. They show strikingly the disparity between Incline Creek and other creeks. Of particular significance is the increase in both volatile and suspended solids during the construction period, beginning immediately following a heavy rain in June and extending through the dry summer months to the end of September. Although the values reported do not represent especially turbid water, they do show up some differences between the surface runoff from developing, developed, and undisturbed natural land conditions.

GROWTH RESPONSE IN CREEK WATERS

The results of flask assays of undiluted samples of creek waters are presented in Table D-4, Appendix D. From these data the growth rates $\hat{\mu}_b$ and $\hat{\mu}_{b\ell}$ and the cell concentration X_5, were computed for Incline, Ward and Upper Truckee – Trout creeks for the period of study (1968-70) and for General Creek for the latter half of 1970. Figure 5-7 shows the temporal variation in values of the three measures of algal growth response. As in the case of Lake Tahoe water which served as a control, ocular (hard) counting of cells of S. gracile was utilized (see Chapter II) from June 1968 to July 1, 1969. Thereafter the Coulter Counter was applied and S. capricornutum was the test alga used. The effect of the change over in counting method and test organism is apparent in Figure 5-7 just as it is in Figure 5-1 (Lake Tahoe Water).

As in the case of assays of LTW, the three measures of growth response (Figure 5-7) followed essentially the same pattern of seasonal variation. By

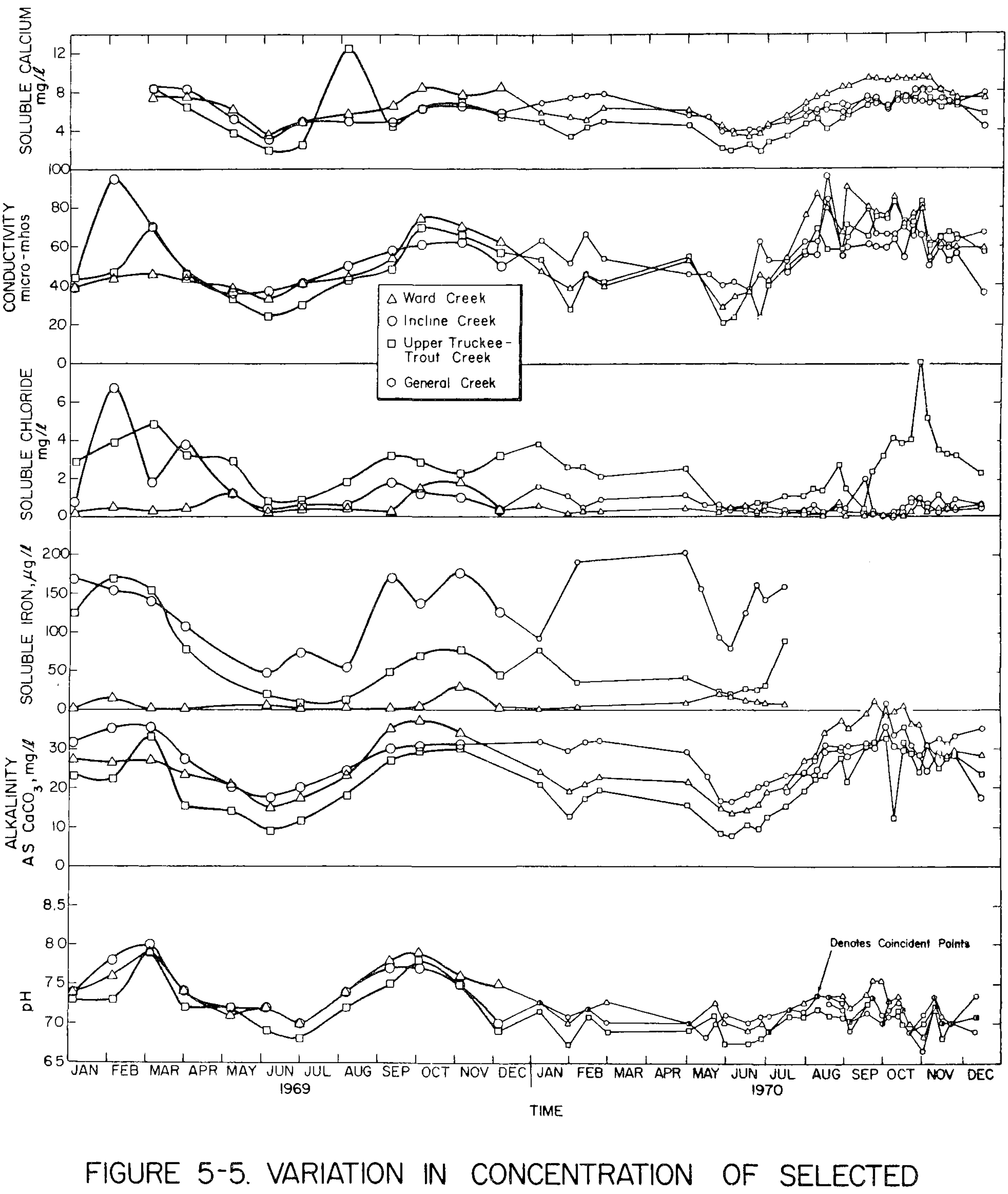

FIGURE 5-5. VARIATION IN CONCENTRATION OF SELECTED WATER QUALITY FACTORS IN CREEK WATERS

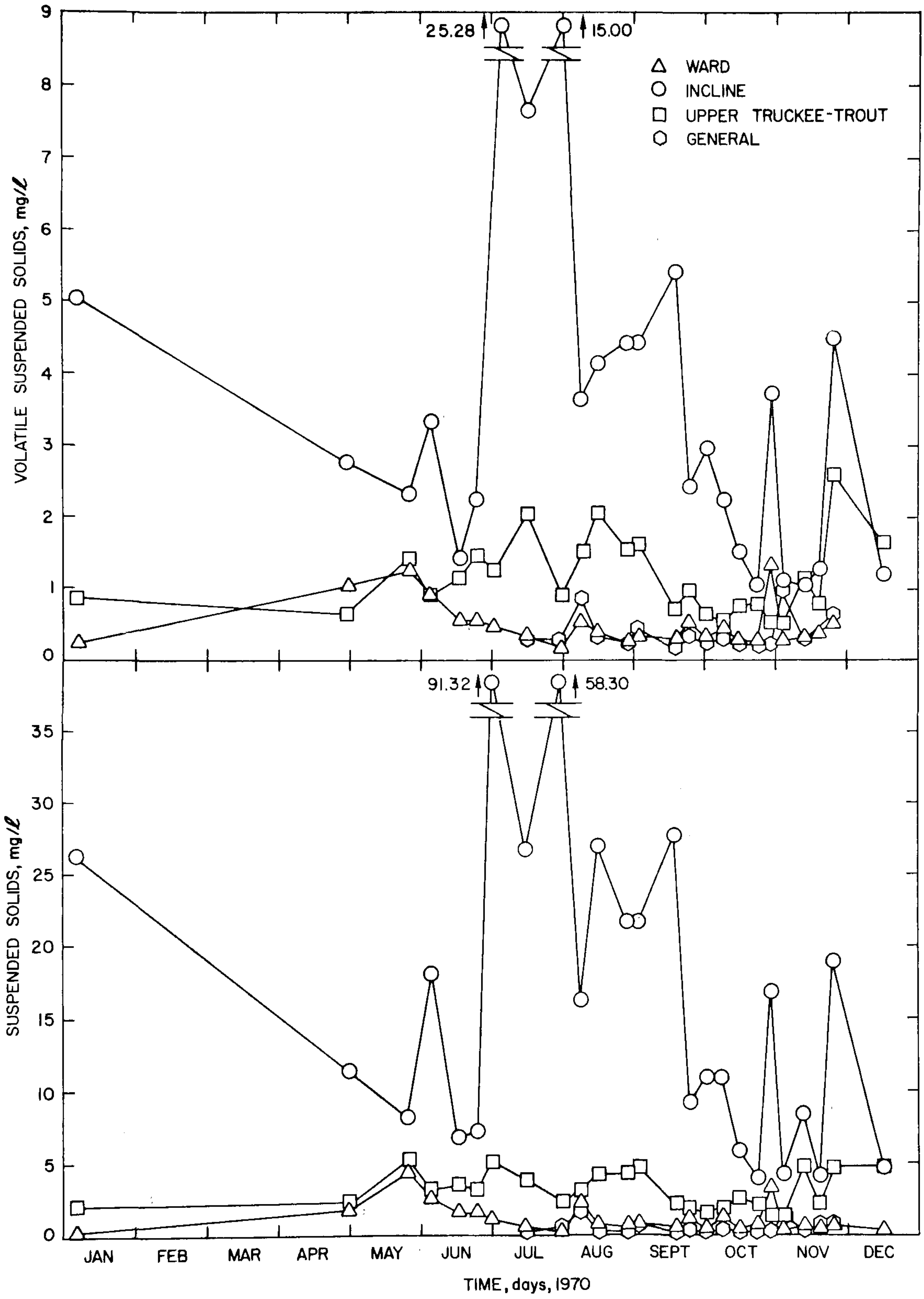

FIGURE 5-6. VARIATION IN SUSPENDED SOLIDS AND VOLATILE SUSPENDED SOLIDS IN CREEK WATERS

any measure Incline Creek was by far the most productive of algal growth prior to mid-summer 1970. Truckee — Trout was next in order and during 1968 did not differ much from Incline. Both were generally more productive than Ward Creek during the 1968 period.

Throughout the year 1969 there was a spectacular difference in cell concentration, X_5, between Ward Creek at the lower extreme and Incline Creek at the upper. Except at the time of an explosive rise in Incline Creek in April 1969 the Truckee — Trout system was not spectacularly lower in growth response than Incline Creek in terms of cell concentration. Essentially the same may be said of the growth rate as measured by $\hat{\mu}_{b\ell}$, with one notable exception. Following the change to S. capricornutum on July 1, 1969 there was no particular difference in the growth response of the three creeks as measured by $\hat{\mu}_{b\ell}$ during the fall season of 1969. A similar situation applied to $\hat{\mu}_b$ during the fall of 1969 except that Truckee — Trout was appreciably higher than the other two during one month. Prior to July 1969, however, $\hat{\mu}_b$ did not reveal the consistent difference in growth rates evident in either the $\hat{\mu}_{b\ell}$ or X_5 curves (Figure 5-7).

From January to July 1970 Incline Creek again showed the highest growth response as measured by all three parameters. Truckee — Trout and Ward creeks alternated somewhat for second position from month to month, but all three parameters ($\hat{\mu}_b$, $\hat{\mu}_{b\ell}$, and X_5) showed essentially the same pattern. From July to December 1970 cell concentrations were low in all creeks and although the number of all fluctuated from month to month count alone could not be said to differentiate one creek from another until December, 1970, at which time Truckee — Trout and Incline, in that order, greatly exceeded the other 3 creeks in growth response.

Both $\hat{\mu}_{b\ell}$ and $\hat{\mu}_b$ detected an appreciable increase in growth rate in Incline Creek in early September (1970) which was not revealed by the cell concentration curve.

Relation of Growth Response to Nutrients

A comparison of Figure 5-7 with Figures 5-2 to 5-5 shows that during 1968 and 1969 the growth responses in Incline Creek corresponded very well with increases and decreases in concentrations of NH_3-N, $(NO_2 + NO_3)$-N, total inorganic nitrogen, Total nitrogen, and total phosphorus. PO_4-P showed little relation to growth response during the 1968-69 period and no apparent growth response resulted from a slight rise in the nitrogen and phosphorus in December 1969. There was little apparent correlation between changes in constituent concentrations and growth response in Upper Truckee — Trout creek; and none at all in Ward Creek.

The rapid growth rate in Incline Creek in the January to May period of 1970 is related to a similar pattern in concentration of $(NO_2 + NO_3)$-N, Total -N, organic nitrogen, Total -P, and PO_4-P. NH_3-N (Figure 5-2) showed an increase at that time but its effect alone can not be suggested because the growth by all parameters fail to reflect any growth response to the inorganic nitrogen and the very high NH_3-N content of Incline Creek at the end of April, 1970. The factors involved in the less spectacular algal growth rates in Incline Creek during the period May to September are not quite so clear. However, Total -N, NH_3-N, organic nitrogen, and Total -P were adequate for growth during that period. During the final 6 months of 1970, Total -N, organic N, NH_3-N, and PO_4-P, fluctuated in the same pattern as did $\hat{\mu}_{b\ell}$, particularly. Thus it is evident that the growth response of Incline Creek was well correlated to available nutrients. Like NH_3-N in April, a very large rise in Total -P in August-September 1970 had no observable effect on the growth response of Incline Creek.

The growth pattern of upper Truckee — Trout Creek, especially as measured by $\hat{\mu}_{b\ell}$ and $\hat{\mu}_b$, corresponded well to the increases and decreases in Total -N, PO_4-P, organic nitrogen, and NH_3-N. The same was essentially the case with Ward Creek.

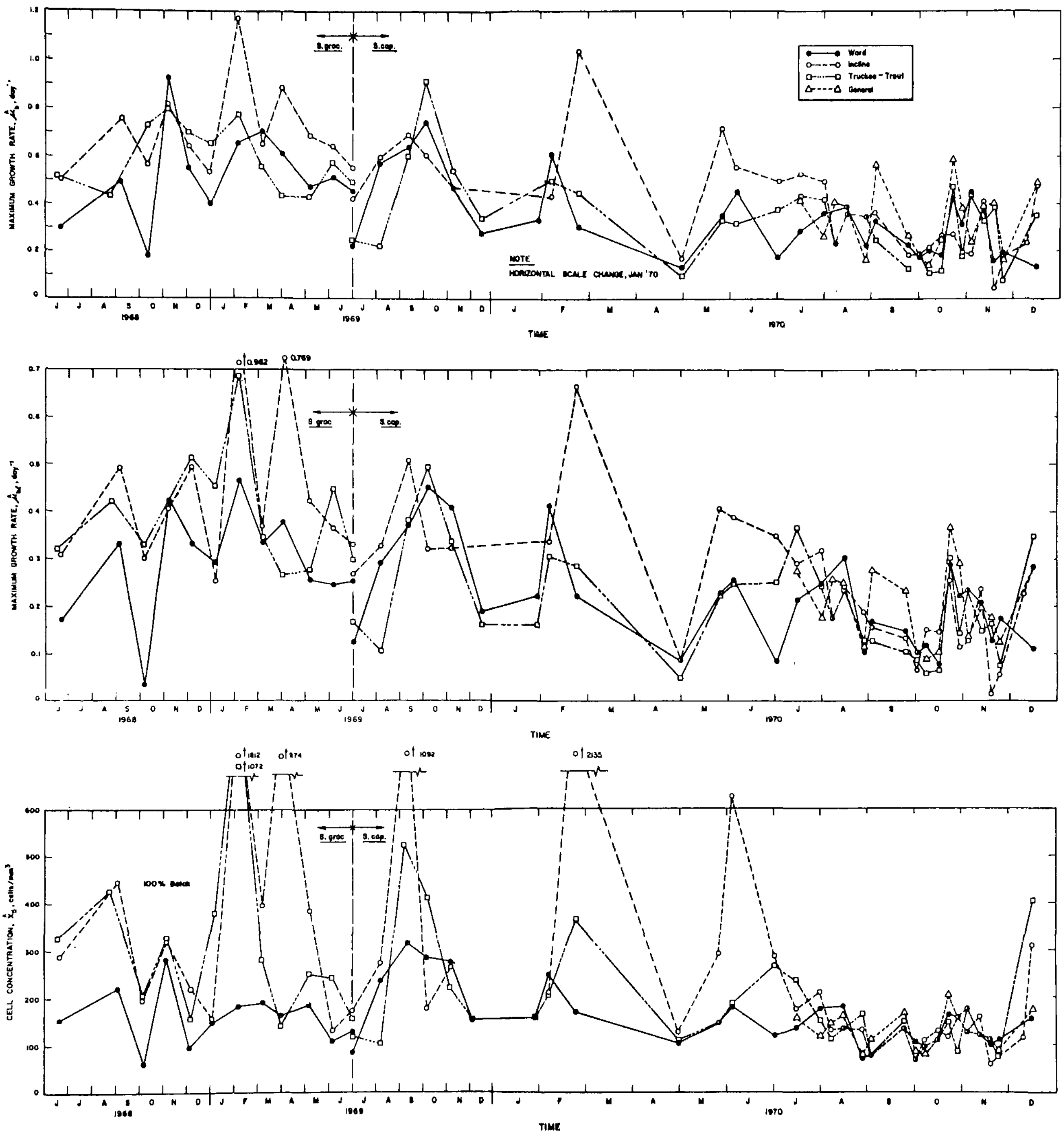

FIGURE 5-7. COMPARISON OF ALGAL GROWTH RESPONSE PARAMETERS IN FLASK ASSAYS OF CREEK WATERS

TABLE 5-1

SUMMARY OF THE RANGE OF ALGAL GROWTH RESPONSE IN CREEK WATERS AND LTW

Year	Source of Sample	Range of Growth								
		$\hat{\mu}_b$ days $^{-1}$			$\hat{\mu}_{b\ell}$ days $^{-1}$			$\hat{X}_5$ cells/mm^3		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
1968	Near Shore[a]	0.389	0.22	0.634	0.254	0.207	0.336	147.6	13	304
	Ward Creek	0.497	0.192	0.926	0.260	0.166	0.432	161.0	57.2	290.6
	Incline Creek	0.665	0.508	0.842	0.408	0.247	0.495	295.4	155.0	448.6
	Upper Truckee-Trout Creek	0.645	0.450	0.824	0.408	0.332	0.519	290.2	153.2	443.6
1969 Jan. to July	Near Shore[a]	0.490	0.372	0.640	0.303	0.220	0.360	150.8	102.6	223.0
	Ward Creek	0.541	0.395	0.701	0.317	0.246	0.463	158.3	107.8	189.6
	Incline Creek	0.748	0.528	1.168	0.495	0.250	0.962	574.7	129.6	1812.8
	Upper Truckee-Trout Creek	0.556	0.432	0.769	0.395	0.264	0.683	355.8	140.4	1072.0
1969 July to Dec.	Near Shore[b]	0.287	0.135	0.571	0.176	0.110	0.349	147.2	90.0	263.9
	Ward Creek	0.537	0.280	0.736	0.343	0.190	0.451	252.7	154.9	315.9
	Incline Creek	0.565	0.379	0.705	0.359	0.276	0.509	416.9	177.4	1092.0
	Upper Truckee-Trout Creek	0.522	0.219	0.910	0.296	0.107	0.495	283.0	103.0	524.8
1970	Near Shore[b]	0.228	0.127	0.337	0.145	0.017	0.283	115.4	59.6	156.2
	Ward Creek	0.294	0.131	0.606	0.189	0.079	0.413	137.3	69.3	247.3
	Incline Creek	0.356	0.044	1.033	0.225	0.014	0.663	251.6	57.3	2134.8
	Upper Truckee-Trout Creek	0.315	0.093	0.614	0.188	0.058	0.366	158.5	69.7	403.5
	General Creek	0.337	0.140	0.589	0.203	0.087	0.367	127.6	74.4	202.9

[a] *Selenastrum gracile* used as a test organism.

[b] *Selenastrum capricornutum* substituted for *S. gracile* at this sampling point.

General Creek as measured by $\hat{\mu}_{b\ell}$, showed a growth response well related to organic nitrogen and Total -P, but little related to other nutrient parameters. In terms of cell concentration the pattern of growth follows that of Total -N, $(NO_2 + NO_3)$-N, and Total -P. Thus, as might be expected of a creek draining an essentially undisturbed land environment, the algal growth in General Creek was related to the stabilized forms of nitrogen and phosphorus in sharp contrast with Incline Creek and to some degree Truckee — Trout Creek, where ammonia and orthophosphate were among the major stimulants.

In growth response as well as in nutrient concentration the final 6 months of 1970 suggests that there may be a tendency for all creeks to approach some similar equilibrium. Once again, however, it may be simply a seasonal phenomenon as creeks have been noted to be similar during past winters. Only observations through subsequent seasons can provide the answer.

In comparing the growth response curves for $\hat{\mu}_b$, $\hat{\mu}_{b\ell}$, and $\hat{X}_5$ in Figure 5-7, and especially in relating these growth response curves to the nutrient curves in Figures 5-2 to 5-5, it is clear that $\hat{\mu}_{b\ell}$ and $\hat{X}_5$ were the best measures of growth response. Alternate approaches to data interpretation could change the value of $\hat{\mu}_b$ and might improve its correlation with nutrient in water. A discussion of these alternatives is beyond the scope of this report. As a basis for comparing LTW with creek waters, therefore, $\hat{\mu}_{b\ell}$ and $\hat{X}_5$ are hereafter used because of their generally observable relationship to the quality of the waters assayed.

COMPARISON OF GROWTH RESPONSE: LAKE TAHOE AND CREEK WATERS

The comparative ability of Lake Tahoe water and water from Incline, Ward, Upper Truckee-Trout, and General creeks to stimulate growth of Selenastrum in flask assays is summarized in Table 5-1 for the period of study 1968 through 1970, inclusive. To minimize the effect of seasonal variations, change in test alga, temporal changes in water quality, and other time-related factors, values of algal growth parameters are computed for four time periods. The term "Near Shore" is used in the table to identify Lake Tahoe water. As noted in the preceding section $\hat{\mu}_{b\ell}$ and $\hat{X}_5$ are used in evaluating the findings.

Bearing in mind that the $\hat{\mu}_{b\ell}$ represents the maximum rate of growth attained during 5 days of assay and represents percent increase in cell counts per day (i.e. 0.254 day^{-1} means 25.4% increase per day) Table 5-1 reveals the following findings:

1. During 1968 when development of land on the Incline Creek watershed was beginning, Incline and Upper Truckee — Trout creeks each averaged 1.6 times the growth stimulating potential of Lake Tahoe water (i.e. .408/.254 = 1.6). Simultaneously, Ward Creek, which drained relatively undisturbed land, was no different than Lake Tahoe in growth potential.

2. During the first 6 months of 1969, Ward Creek continued to parallel Lake Tahoe, but increased activity on the Incline watershed caused Incline Creek to be more capable of stimulating algal growth than the more stable Truckee Trout area. Nevertheless, Truckee — Trout continued to exceed LTW and Ward Creek in stimulatory potential.

3. In the latter half of 1970 activity on Ward Creek produced a response similar to that of Incline Creek. Upper Truckee — Trout Creek continued greater than Lake Tahoe, although less than the two more disturbed watersheds in growth potential.

4. During 1970 the growth rates are computed for the entire year, thus the early high growth rates apparent in Figure 5-7 are obscured by the lower rates prevailing in the last 6 months of the year. Nevertheless, Incline Creek continued to be the most productive, but activity on Ward Creek made it comparable to Truckee — Trout in growth stimulating ability. General Creek, which was monitored only for 6 months appears more productive in terms of $\hat{\mu}_{b\ell}$ than indicated in Figure 5-7.

5. Almost exactly the same facts revealed by $\hat{\mu}_{b\ell}$ are evident in the cell counts, $\hat{X}_5$. The principal difference is the low value shown for General Creek in 1970, which is more in line with observations shown in Figure 5-7.

6. Seasonal variation in growth rates readily observed in Figure 5-7 show up in the mean values of growth response when 1968 and early 1969 data are compared.

7. Annual averages of growth rates obscure the seasonal peaks which could, although in this study they did not, represent an algal bloom of serious nuisance proportions.

CONCLUSIONS

Results of the assays of surface waters in the Lake Tahoe area, specifically of the lake and 3 principal streams draining surrounding land areas, support the following major conclusions.

1. Flask assays are capable of detecting changes in water quality which increase the eutrophication potential of such water, although no one can interpret the growth rates attained in such assays in terms of the biomass which might result in an individual outdoor situation.

2. Cell counts ($\hat{X}_5$) and growth rate ($\hat{\mu}_{b\ell}$) correlated well with nutrients present in creek waters.

3. Waters from undisturbed areas showed best correlation with the more stable forms of nutrients, possibly because of the predominance of such nutrients from such areas.

4. Human occupancy under conditions of reasonably well developed land (e.g. Upper Truckee – Trout Creek) shows an appreciable increase in algal growth stimulating nutrients over that of land under natural conditions.

5. Land undergoing development is especially productive of growth stimulating nutrients, at least under practices which have prevailed in the Tahoe Basin.

6. Relatively undisturbed land as, for example, Ward Creek in 1968 and General Creek in 1970, reflect essentially the same growth stimulating properties as does Lake Tahoe water.

7. The evidence shows that Lake Tahoe water is nitrogen poor and supports such a small biomass that the results of flask assays are not measurably in error because of nutrients tied up in biomass.

8. Algal assays measure only the residual ability of a water to stimulate algal growth, hence could theoretically show no potential at all in a water visibly covered with an algal bloom. Thus, except in unique cases such as Lake Tahoe, it is more useful in evaluating waste water discharges than in assessing the eutrophication of surface waters.

9. The presence of humans and human activity on a watershed definitely increases the rate of eutrophication of its surface waters.

10. Land management and land use controls are essential to a program designed to maintain the highest possible water quality in an area.

CHAPTER VI

EVALUATION OF EUTROPHICATION POTENTIAL

INTRODUCTION

Findings of the surveys, and of the pond and surface water assays reported in preceding chapters, reveal significant facts concerning the concentration and algal growth stimulating effects of nutrients from various possible sources within the Tahoe Basin. They do not, however, give scale to any possible effects in terms of nutrient enrichment of Lake Tahoe. With sewage and household refuse exported from the Basin, the remaining sources of nutrients, whether resulting from natural phenomena or from man's activities, may or may not be of foreseeable significance.

Considering the Lake Tahoe Basin as an ecosystem, the unanswered question then is: What effects do nutrients imported by man or nature, together with those released by disturbing the soil mantle, have on the rate of eutrophication of Lake Tahoe?

To answer such a question adequately is beyond the limits of present scientific information. It would require both an inventory of all growth stimulating materials entering and leaving the basin, plus a vast refinement of knowledge of what constitutes a growth stimulant and under what conditions. Moreover, it would entail more knowledge than man presently posesses concerning the natural interchange of nutrients between vegetation and the atmosphere, and of the variation of such interchange with meteorological and climatological conditions. Finally, it would require a knowledge of the interactions of Lake Tahoe and its environment which no one presently posesses. Such a scientific effort is presently infeasible and the time span of such an approach would probably make it irrelevant to the fate of Lake Tahoe.

A guide to human judgement, if not an answer to the foregoing question, might result from considering what may go into the lake under some natural equilibrium within the Basin, estimating the similar input under the impact of man, and comparing these two estimates with each other and with the observed nutrient content of the lake water. It is the purpose of this chapter to present such an analysis based on data obtained during the period of study (1967-1971); to evaluate the limitations of the analysis; and to suggest what further work might be productive of results translatable into action in time to materially affect the course of eutrophication of Lake Tahoe.

The Basic Approach

The basic procedure hereinafter developed in some detail involves the following tasks, although not strictly in the sequence listed:

1. Monitor by chemical analysis the quality of surface water entering Lake Tahoe via 31 creeks, including the four major creeks discussed in Chapter V.

2. Estimate the nutrient input to Lake Tahoe by this system of streams on the basis of chemical analyses and the fraction of the annual runoff to the lake represented by each stream.

3. Estimate the annual input of nutrients to Lake Tahoe via direct precipitation on the lake water surface.

4. Calculate the annual hydrological balance of the lake on the basis of available inflow, outflow, and evaporation data.

5. Calculate the theoretical nutrient content of Lake Tahoe, on the basis of observed nutrient concentrations, for various combinations of undisturbed and developed land.

6. Compare the observed and calculated concentration of nutrients in Lake Tahoe water.

7. Outline and discuss the factors relating to eutrophication of Lake Tahoe which may not be evaluated by the foregoing approach.

8. Present conclusions and recommendations based on interpretation of a combination of observed data and undocumented possible relationships.

CHEMICAL ANALYSES

Chemical analyses of three major creeks discharging into Lake Tahoe (Ward, Incline, and Truckee – Trout) were made over a three year period (1968-70). The results, previously discussed in Chapter V, are presented in detail in Table D-3, Appendix D. These represent the most extensive surface water records made during the study, except for Lake Tahoe itself. Data on the various forms of nitrogen, PO_4-P, Total -P, Ca, Cl, pH, alkalinity, and conductivity were obtained at approximately monthly intervals beginning in 1969, although some similar data were obtained in 1967-68. During the year 1970 the sampling frequency was increased to approximately bimonthly. Results reported in Table D-3 for the foregoing water quality factors were obtained from filtered water samples. Beginning in August 1969 the scope of analysis was expanded to include total suspended solids, volatile suspended solids, and COD of unfiltered samples of water from the three major creeks. As noted in Chapter V, General Creek was added to the list of major creeks in July of 1970. For purposes of later calculations pertinent to an evaluation of the eutrophication potential of Lake Tahoe, the most important data on Ward, Incline, and Truckee – Trout creeks are summarized in Table 6-1. Summary data of the same type for mid- and near-shore Lake Tahoe are summarized in Table 6-2 from more detailed analytical results reported in Table D-1, Appendix D. Chemical and related analyses for 31 creeks for the period November 1969 to February 1971 are presented in detail in Table E-1, Appendix E. Records for some of these streams are discontinuous because some cease to flow in dry weather and others are inaccessible when snow is deep. Data on temperature and dissolved oxygen are included for some sampling dates. For all creeks the data on nitrogen and phosphorus concentration and for pH and conductivity are more continuous than for solids and chloride concentration. Averages for all 31 streams are included in Table E-2, Appendix E, along with other information discussed in a subsequent section.

Table E-3, Appendix E, presents the results of chemical analyses of precipitation, mostly in the form of snow, made during the winter of 1969-70 and 1970-71. Of particular significance to the eutrophication of Lake Tahoe is the high content of ammonia and organic nitrogen precipitated during the winter season. Average values of nutrients reported in Table E-3 are compared with those of other sources in Table 6-3, based on data from Tables 6-1, 6-2, E-2, and E-3. From an inspection of the table it is evident that:

1. The average of all 31 creeks differs very little from that of the three major creeks (included in the 31) except in the forms of nitrogen which make up Total - N. In general, there was more organic nitrogen and less ammonia in the over all composite than in the three-creek composite.

2. Total nitrogen in the creeks averaged about 2 times that in Lake Tahoe, whereas phosphorus in the creeks averaged about 3 times as great.

TABLE 6-1

ANALYSES OF SELECTED CONSTITUENTS FROM CREEKS REPRESENTING SUB-DRAINAGE BASINS IN DIFFERENT STAGES OF LAND DEVELOPMENT[a]

Creek	Year	Nitrogen as N				Phosphorus as P		Cl	Cond (10^{-6})
		Organic	NH_3	$NO_2 + NO_3$	Total	PO_4	Total		
		μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	mg/ℓ	mhos
Ward	1968	171	58	24	253	13	38	0.73	58
	1969	84	21	21	127	9	14	0.55	49
	1970	89	41	14	144	12	24	0.36	62
	Average	99	38	17	154	11	23	0.46	58
Incline	1968	194	78	40	312	16	62	1.50	58
	1969	205	127	114	446	26	41	1.60	55
	1970	196	70	31	297	16	35	1.06	61
	Average	199	87	54	340	18	40	1.05	59
Truckee-Trout	1968	290	118	65	473	15	30	2.50	54
	1969	216	47	57	320	9	29	2.70	48
	1970	184	50	41	275	7	16	2.48	57
	Average	207	58	48	314	8	21	2.54	54
Composite Avg.		169	62	41	272	13	29	1.34	57

[a]Filtered Samples

TABLE 6-2

ANALYSES OF SELECTED CONSTITUENTS FROM MID AND NEAR-SHORE LAKE TAHOE WATER

Sample	Year	Nitrogen as N.				Phosphorus as P.		Cl mg/ℓ	Cond (10^{-6}) mhos
		Organic µg/ℓ	NH_3 µg/ℓ	NO_2 + NO_3 µg/ℓ	Total µg/ℓ	PO_4 µg/ℓ	Total µg/ℓ		
Mid	1968	118	41	4	163	1	6	1.4	83
	1969	69	19	9	97	6	9	1.5	79
	1970	79	49	9	138	3	8	1.1	90
	Average	83	36	8	127	4	8	1.3	84
Near-Shore	1968	151	33	4	188	1	4	1.5	83
	1969	107	24	12	143	4	9	1.8	81
	1970	95	35	8	138	3	10	1.4	91
	Average	105	31	9	145	3	9	1.5	86
Composite	1968	133	37	4	174	1	5	1.3	83
	1969	89	21	11	121	5	9	1.6	80
	1970	90	39	9	138	3	9	1.3	91
	Average	97	34	9	140	3	8	1.4	86

[a] Filtered Samples

3. The concentration of Total nitrogen in melted snow was more than 2.5 times as great as in Lake Tahoe Water, while total phosphorus in the creeks averaged about double that in the lake.

TABLE 6-3

COMPARISON OF AVERAGE VALUES OF SELECTED CHEMICAL CONSTITUENTS 1968-1971

Source	Nitrogen as N				Phosphorus as P		Cl	Cond.
	Organic	NH_3	$NO_2 + NO_3$	Total	PO_4	Total		
Lake Tahoe	97	34	9	140	3	8	1.4	86
3 Creeks (Table 6-1)	169	62	41	272	13	29	1.34	57
31 Creeks (Table E-2)	184	48	41	273	10	22	1.1	50
Precipit. (Snow)	191	117	56	357	9+	15-	1.43	10

It is particularly noteworthy that the precipitation reported in Table E-3 (Appendix E) was richer in nutrients than is Lake Tahoe itself. The same was true for the influent streams. At simple face value this would mean that if Lake Tahoe could be quickly drained and refilled with surface waters such as observed during the 1967-71 period, or with snowmelt such as observed in 1970 and 1971, it would be appreciably more eutrophic than it is at present. Obviously, in the 600 to 700 years it would take to re-establish the Lake, a lot of conditions would change. But the quality of the Lake Water today suggests either that a lot of things have been different in the past or that the lake has a capacity to dispose of nutrient inputs which are not reflected in simple chemical analyses.

An inadequately answered question is the growth stimulating ability of melted snow. Unfortunately the data reported in Table E-3 (Appendix E) were obtained for the purpose of evaluating the nutrient inputs to the lake and no flask assays were made. However, results reported in Tables 3-1 and 3-3 of Chapter III, and in the several figures of Chapter V, reveal an increasing growth rate in waters which corresponds to the pattern of increasing Total nitrogen content. It can therefore be presumed, although not documented, that the snowfall summarized in Table 6-3 would be more stimulatory to algal growth in flask assays than either the creek or Lake Tahoe waters.

In Table 3-3 of Chapter III, a flask assay of a single January snow showed it to be similar to Lake Tahoe water in growth stimulating properties, whereas a single rainstorm in August produced a much greater stimulatory response. To present the data in which the observations are based, Table 6-4 is compiled from 1967 and 1968 records and limited data selected from Table E-3 on the basis of corresponding seasonal dates of snowfall and maximum values.

The data in Table 6-4 generally follow a logical pattern, but suggest a need for more extensive meteorological observations at the time of precipitation in order to estimate the probable variation from mean values of nutrient content.

For example, the rainstorm of 8/24/67 was accompanied by lightning. Thunderstorms are not uncommon in February in the Sierra Nevada mountains. The high NH_3-N content of snow on 2/18/71 in comparison with the January 1970 snows suggests that lightning may have accompanied the February storm, although no record was kept. In any event it seems clearly demonstrated that precipitation of any type is normally richer in nitrogen than is Lake Tahoe.

TABLE 6-4

COMPARISON OF SELECTED DATA ON PRECIPITATION

Date	Type of Sample	Nitrogen as N (μg/ℓ)					Phos.(μg/ℓ)		$\hat{\mu}_c$
		Organic	NH_3	$NO_2 + NO_3$	Total In.	Total -N	PO_4	Total	
8/24/67	Rain	450	390	200	590	1040	1	40	0.78[a]
11/4/70	Rain + Snow	159	212	157	369	528	15	20	[b]
1/30/68	Snow	80	150	55	205	285	[c]	[c]	0.27[a]
1/20/70	Snow	252	90	24	114	366	9	11	[b]
1/24/70	Snow	264	115	29	144	408	7	25	[b]
2/18/71	Snow	92	479	220	699	791	9	17	[b]

[a] 50 percent concentration in Lake Tahoe Water (LTW) (Comparative growth rate in LTW = 0.29 day^{-1}).

[b] No flask assay of growth response made.

[c] Data on phosphates inaccurate due to contaminated glassware.

HYDROLOGIC AND NUTRIENT BUDGETS

Hydrological Factors

The basis of both a hydrologic budget and a nutrient budget in the Lake Tahoe Basin depends upon the quantity and distribution of precipitation in the Basin and on its runoff to the Lake. Information on precipitation was obtained by use of the isohyetal map, Figure 6-1, presented in a 1969 Report of the U. S. Geological Survey (22). Admittedly a highly refined isohyetal map of the Tahoe Basin is not possible to construct at the present time because of the limited number of gaging stations in the area and the abrupt changes in elevation which affect the intensity of local precipitation. However, for purposes of the study herein presented, Figure 6-1 is assumed to be the best available estimate of precipitation distribution at Lake Tahoe.

To estimate the rainfalls and ultimately the runoff and nutrient contribution of each surface stream, the entire Lake Tahoe Basin was divided into 61 subdrainage basins as shown in Figure 6-2. Thus it corresponds to a 63 — sub-basin map prepared in 1963 (23) and widely used by many agencies, except that two of the original boundary lines were eliminated for reasons of evident similarity of adjacent areas.

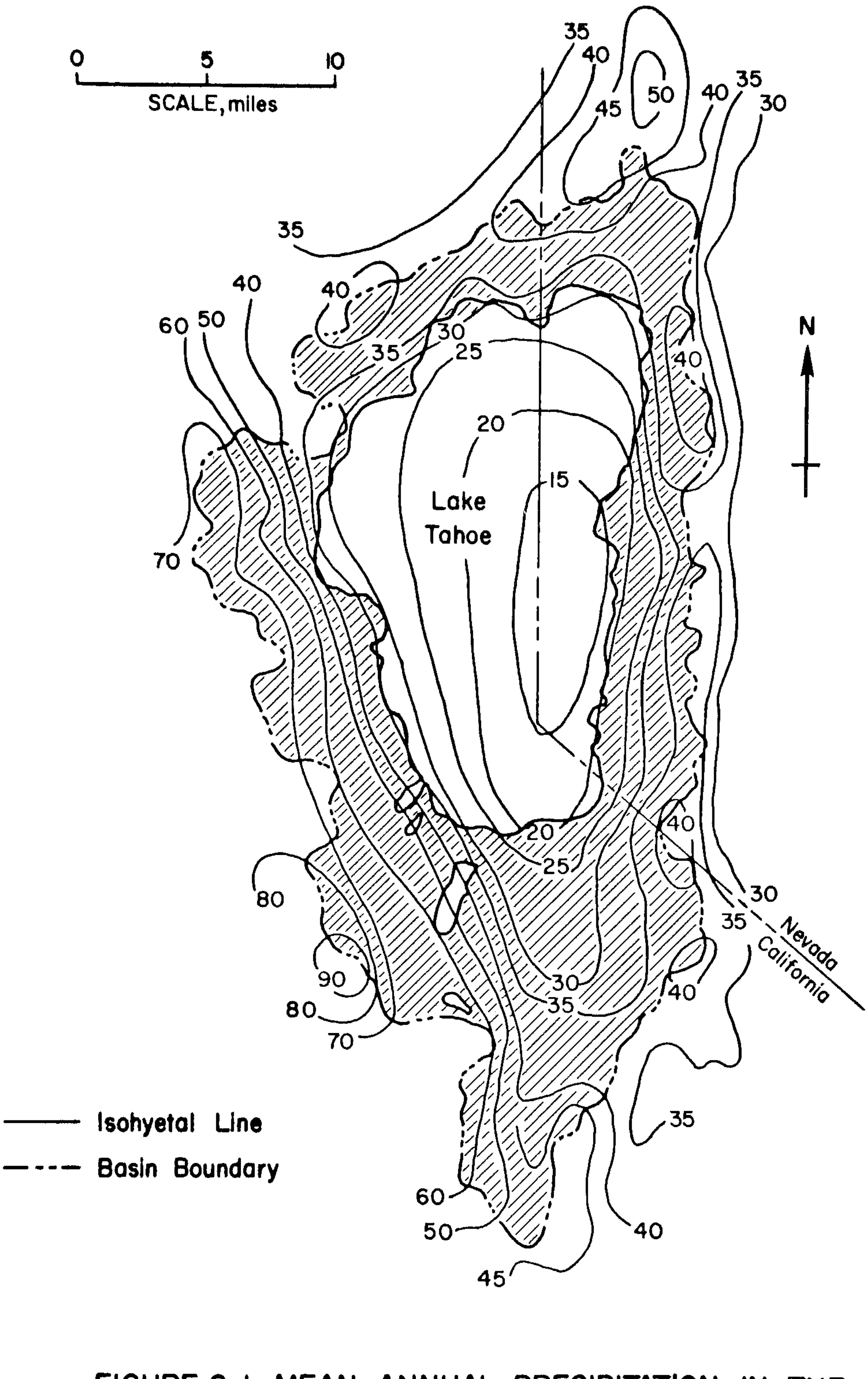

FIGURE 6-1. MEAN ANNUAL PRECIPITATION IN THE TAHOE BASIN

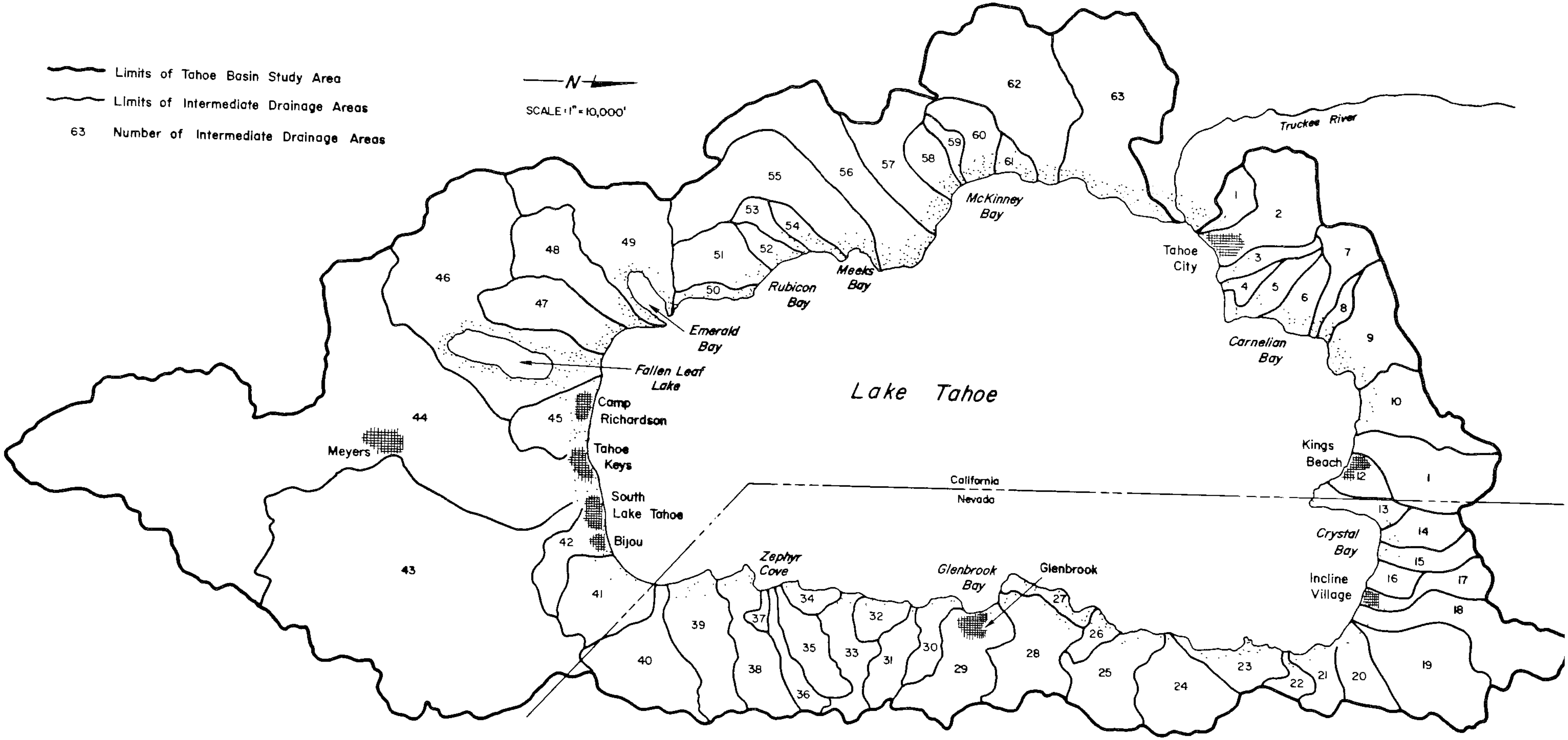

FIGURE 6-2. DRAINAGE AREAS WITHIN THE TAHOE BASIN

The geographic relationship of the several subbasins are shown graphically in Figure 6-2, prepared from a similar large scale map in the 1963 Report (23). Because of limited scale problems the names of creeks as areas draining the 63 subbasins are omitted from Figure 6-2. They are, however, identified by both map reference number and current title in Table 6-6, and Table E-2 (Appendix E). Elimination of two boundary lines, as previously noted, resulted in including area No. 27 in area No. 25, and No. 51 in No. 50.

Estimating Precipitation. To estimate the annual precipitation on each of the 61 sub-basins, use was made of Figure 6-1 and precipitation data from three weather Bureau stations in the Tahoe Basin as reported in Table 6-5 for the water years 1960 through 1969. These three stations — Tahoe City and Meyers, California and Glenbrook, Nevada — are located on a triangular grid pattern within the Tahoe Basin.

In Table 6-5 a percentage of the yearly precipitation for the three stations is ascribed to each station for each year of record. The cumulative 9-year mean percentage for each station is also shown. From the results it is apparent that in terms of percentage of annual precipitation there is little variation from year to year at any one station. Over the nine year period Tahoe City averaged 36.5%, Meyers 42.8%, and Glenbrook 20.7% of the average yearly total. From these two observations it was concluded that any one of the three stations could be used as a reference to adjust the quantity of precipitation on the isohyetal map (Figure 6-1). Tahoe City was selected as the reference station both because it was intermediate between the other two and had a precipitation record that extended over a 60-year period.

The isohyetal map (Figure 6-1) which, as previously noted, represents the best available estimate of the long term average in the Lake Tahoe Basin. It shows that the long-term average at Tahoe City is approximately 30 inches per year. Assuming 30 inches at Tahoe City as a base line value an annual precipitation factor was calculated for each of the water years (1961 to 1970) in Table 6-5. The results showed that the annual precipitation for these 10 years varied from the isohyetal map (Figure 6-1) average by factors ranging from 0.79 in 1965-66, to 1.75 in 1968-69. On a ten-year basis it is estimated (Table 6-5) that during the past 10 years the rainfall has averaged 120% of the long term average represented by the isohyetal map (Figure 6-1).

From the foregoing analysis it was concluded that the annual rainfall on each of the 61 sub-basins might reasonably be calculated from the isohyetal map using 30 inches at Tahoe City as the reference value. Annual precipitation values estimated for each of the 61 sub-basins are shown in Column 4 of Table 6-6. The overall basin average was approximately 33 inches; 40 inches per year for land areas and 22 inches per year on the lake surface.

Estimating Runoff. To estimate the runoff from each of the 61 sub-basins the area of each sub-basin was planimetered from 15-minute quadrangle sheets obtained from the U. S. Geological Survey. The results, reported in Column 3 of Table 6-6 total to within but a few hundred acres of the generally reported totals for the Lake Tahoe Basin and are therefore adequately accurate for the approach used in the study.

From rainfall and areal estimates, precipitation was converted to acre-feet on each sub-basin.

TABLE 6-5

REPRESENTATIVE TAHOE BASIN WEATHER BUREAU STATIONS

Weather Station	Water Year																				Overall Average 1960-1969	
	60-61		61-62		62-63		63-64		64-65		65-66		66-67		67-68		68-69		69-70			
	in.	%	in.	%	in.	%	in.	%	in.	%	in.	%	in.	%	in.	%	in.	%	in.	%	in.	%
Tahoe City, Calif.[a]	24.41	37.1	30.04	37.1	45.71	38.2	25.26	35.8	51.18	37.2	23.74	36.2	44.88	34.1	24.57	34.6	52.59	37.5	36.66	-	35.82	36.5
Meyers Station, Calif.[b]	26.85	40.8	36.33	44.9	53.28	44.5	30.26	43.0	60.30	43.8	27.41	41.8	55.02	41.8	30.46	42.8	57.85	41.2	-	-	41.97	42.8
Glenbrook, Nevada[c]	14.57	22.1	14.56	18.0	20.76	17.3	14.94	21.2	26.11	19.0	14.47	22.0	31.82	24.1	16.08	22.6	29.82	21.3	-	-	20.35	20.7
Total	65.83	100.0	80.93	100.0	119.75	100.0	70.46	100.0	137.59	100.0	65.62	100.0	131.72	100.0	71.11	100.0	140.26	100.0	36.66	-	98.14	100.0
Yearly Precipitation ratio at Tahoe City based on an assumed annual average of 30 in.	0.81		1.00		1.52		0.84		1.71		0.79		1.50		0.82		1.75		1.22		1.20 (10 yr avg)	

[a]Index station no. 8758-03, Placer County; elev. 6230; lat. 39°-10': long. 120°-08'.

[b]Index station no. 5572-03, El Dorado County: elev. 6342: lat 38°-51'; long. 120°-01'.

[c]Index station no. 3205-01, Douglas County; elev. 6400; lat. 39°-05'; long. 119°-56'.

To establish rainfall-runoff coefficients for each of the 61 sub-basins an analysis was first made of six major streams in the basin on which the U. S. Geological Survey (22, 24) operates continuous flow recorders. Of these a 12-year runoff record is available for Blackwood Creek, Trout Creek, and the Upper Truckee River. Taylor Creek has been gaged for two years; and Incline Creek and Third Creek for one year.

A record of the monthly flow data for each of the six streams is summarized in Table E-4, Appendix E. The percentage of the yearly flow which occurs each month is also shown in the table in order to make possible a nutrient inventory based on monthly flows and monthly chemical analyses. Such percentages are also shown graphically in Figure 6-3. From this figure it is apparent that in spite of the difference in length of record for the various streams the composite percentage of annual flow occurring each month differs little from one stream to another. This uniformity of pattern, coupled with the uniformity of precipitation distrubution previously discussed, indicates that the hydrological relationships are relatively uniform throughout the Basin.

Calculated Rainfall-Runoff Coefficients for the six streams cited are reported in Table E-5. Because flow gaging stations on the Upper Truckee River and in Trout and Taylor creeks are located some distance upstream from the lake only the actual drainage area above the gaging station was used in calculating the value used in the table.

Rainfall-Runoff relationships for the 6 streams subject to continuous gaging records for various periods are plotted in Figure 6-4. It is noteworthy that the three streams having the longest period of observation (Truckee, Trout, and Blackwood) showed a strictly straight line relationship. Even those of short period of record deviate but little from this line. Obviously the curve would be expected to drop off as the runoff approaches zero, as it is extremely unlikely that the annual rainfall which produces no runoff is as great as 20 inches.

Because of the straight line relationship of Figure 6-4, the figure was used to estimate runoff in inches depth on the drainage area for each of the 61 sub-basins in Table 6-6 on the basis of rainfall values previously entered in Column 4 of that table. The results of this interpolation are reported in Column 6 of Table 6-6. Thus the runoff coefficient and the runoff in acre-feet for each sub-basin are readily computed, leading to an estimate of 310,000 acre-feet as the average annaul input to Lake Tahoe when precipitation at Tahoe City is 30 inches per year. In making this estimate, runoff values were rounded off to the nearest 100 acre-feet.

Hydrologic Inventory. The data developed in the preparation of Table 6-6 provide much of the information needed to develop a hydrologic inventory. The components of such an inventory may be expressed symbolically by Equation 6-1.

$$\Delta S = P_L + R.O. \quad E \quad D \qquad (6\text{-}1)$$

in which:

ΔS = Change in the volume of Lake Tahoe
P_L = Precipitation falling directly on Lake Tahoe
R.O. = Runoff directly into Lake Tahoe
E = Evaporation from the surface of Lake Tahoe
D = Discharges directly from Lake Tahoe, or from the Lake Tahoe Basin.

All values involved in Equation 6-1 have already been developed in the preceding pages or can be obtained from records, with the exception of evaporation. Therefore the equation may be rearranged as follows:

$$E = P_L + R.O. \quad \Delta S \quad D \qquad (6\text{-}2)$$

TABLE 6-6

ESTIMATED RUNOFF IN TAHOE BASIN

	Sub-Basin	Area	Precipitation			Runoff	
No.	Name	acres	in.	ac-ft	in.	Coef.	ac-ft
1	Tahoe State Park	977	34	2,800	11	0.32	900
2	Burton Ck.	3,333	37	10,300	13	0.35	3,600
3	Barton Ck.	1,002	36	3,000	13	0.36	1,100
4	Lake Forest Ck.	664	30	1,700	8	0.27	400
5	Dollar Ck.	1,042	34	3,000	11	0.32	1,000
6	Cedar Flats	1,195	36	3,600	13	0.36	1,300
7	Watson	1,619	38	5,100	14	0.37	1,900
8	Carnelian Bay Ck.	937	38	3,000	14	0.37	1,100
9	Carnelian Canyon	2,272	38	7,200	14	0.37	2,700
10	Tahoe Vista	3,540	36	10,600	13	0.36	3,800
11	Griff Ck.	2,864	40	9,500	16	0.40	3,800
12	Kings Beach	1,015	33	2,800	10	0.30	800
13	East State Line Pt.	666	34	1,900	11	0.32	600
14	First Ck.	1,079	39	3,500	15	0.39	1,300
15	Second Ck.	1,127	38	3,600	14	0.37	1,300
16	Unnamed Ck. No. 1	660	33	1,800	10	0.30	500
17	Rose Knob (Wood) Ck.	1,388	40	4,600	16	0.40	1,900
18	Third	3,972	41	13,500	17	0.41	5,600
19	Incline Ck.	4,358	35	12,700	12	0.34	4,400
20	Mill Ck.	1,457	37	4,500	13	0.35	1,600
21	Tunnel Ck.	996	38	3,200	14	0.37	1,200
22	Unnamed Creek No. 2	672	40	2,200	16	0.40	900
23	Sand Harbor	1,351	38	4,300	14	0.37	1,600
24	Marlette Ck.	3,094	38	9,800	14	0.37	3,600
25	Secret Harbor Ck.	5,852	31	15,100	8	0.26	3,900
26	Bliss Ck.	616	24	1,200	2	0.83	100
27	Deadman Point	679	16	900	0	-	100
28	Slaughter House		(Included with Sub-Basin No. 25)				
29	Glenbrook Ck.	3,530	27	7,900	5	0.19	1,500
30	North Logan House Ck.	1,052	24	2,100	2	0.83	200

31	Logan House Ck.	1,401	29	3,400	7	0.24	800
32	Cave Rock	903	22	1,700	1	0.45	100
33	Linclon Ck.	1,811	28	4,200	6	0.21	900
34	Skyland	573	20	9,500	0	-	100
35	North Zephyr Ck.	1,712	30	4,300	8	0.27	1,100
36	Zephyr Cr.	940	31	2,400	8	0.26	600
37	South Zephyr Ck.	430	22	7,900	1	0.45	100
38	McFaul	2,502	30	6,300	8	0.27	1,700
39	Burke	3,405	29	8,200	7	0.24	2,000
40	Edgewood Ck.	3,660	33	10,100	10	0.30	3,000
41	Bijou Park	2,490	29	6,000	7	0.24	1,500
42	Bijou	1,602	27	3,600	5	0.19	700
43	Trout Ck.	26,406	33	7,300	10	0.30	22,000
44	Upper Truckee River	37,325	48	149,300	23	0.48	71,500
45	Camp Richardson	1,625	30	4,100	8	0.27	1,100
46	Taylor Ck.	12,133	60	60,700	33	0.55	33,400
47	Tallac	2,698	49	11,000	24	0.49	5,400
48	Cascade	3,104	56	14,500	30	0.54	7,800
49	Eagle Creek	5,702	61	29,000	35	0.57	17,000
50	Bliss State Park	2,583	39	8,400	15	0.38	3,200
51	Rubicon Ck.		(Included with Sub-Basin No. 50)				
52	Paradise Flat	728	40	2,400	16	0.40	1,000
53	Lonely Gulch Ck.	735	46	2,800	21	0.46	1,300
54	Sierra Ck.	741	43	2,700	19	0.44	1,200
55	Meek's Ck.	5,540	55	25,400	29	0.53	13,400
56	General Ck.	5,690	42	19,900	18	0.43	8,500
57	McKinney Ck.	3,592	62	18,500	35	0.56	10,500
58	Quail Ck.	735	53	3,200	27	0.51	1,700
59	Homewood Ck.	747	57	3,500	31	0.54	1,900
60	Madden Ck.	1,394	45	5,200	21	0.47	2,400
61	Eagle Rock	398	45	1,500	21	0.47	700
62	Blackwood Ck.	7,551	64	39,600	37	0.58	23,300
63	Ward Ck.	8,149	52	35,300	27	0.52	18,300
		202,014		666,300			310,900

$\frac{666,300}{202,014}$ = 39.6 in. on land portion in the Tahoe Basin

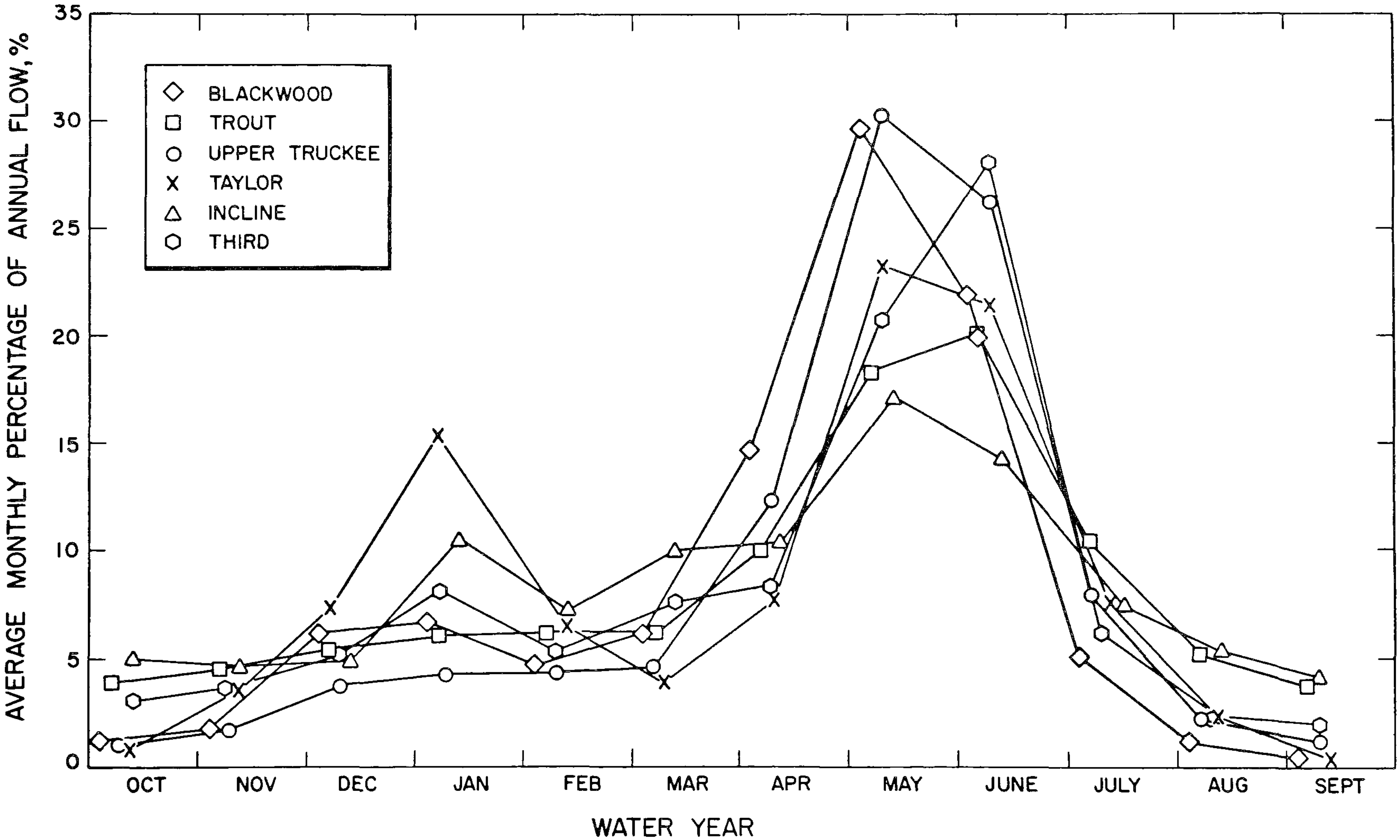

FIGURE 6-3. AVERAGE MONTHLY FLOW PERCENTAGES FROM CONTINUOUSLY GAGED STREAMS IN THE TAHOE BASIN

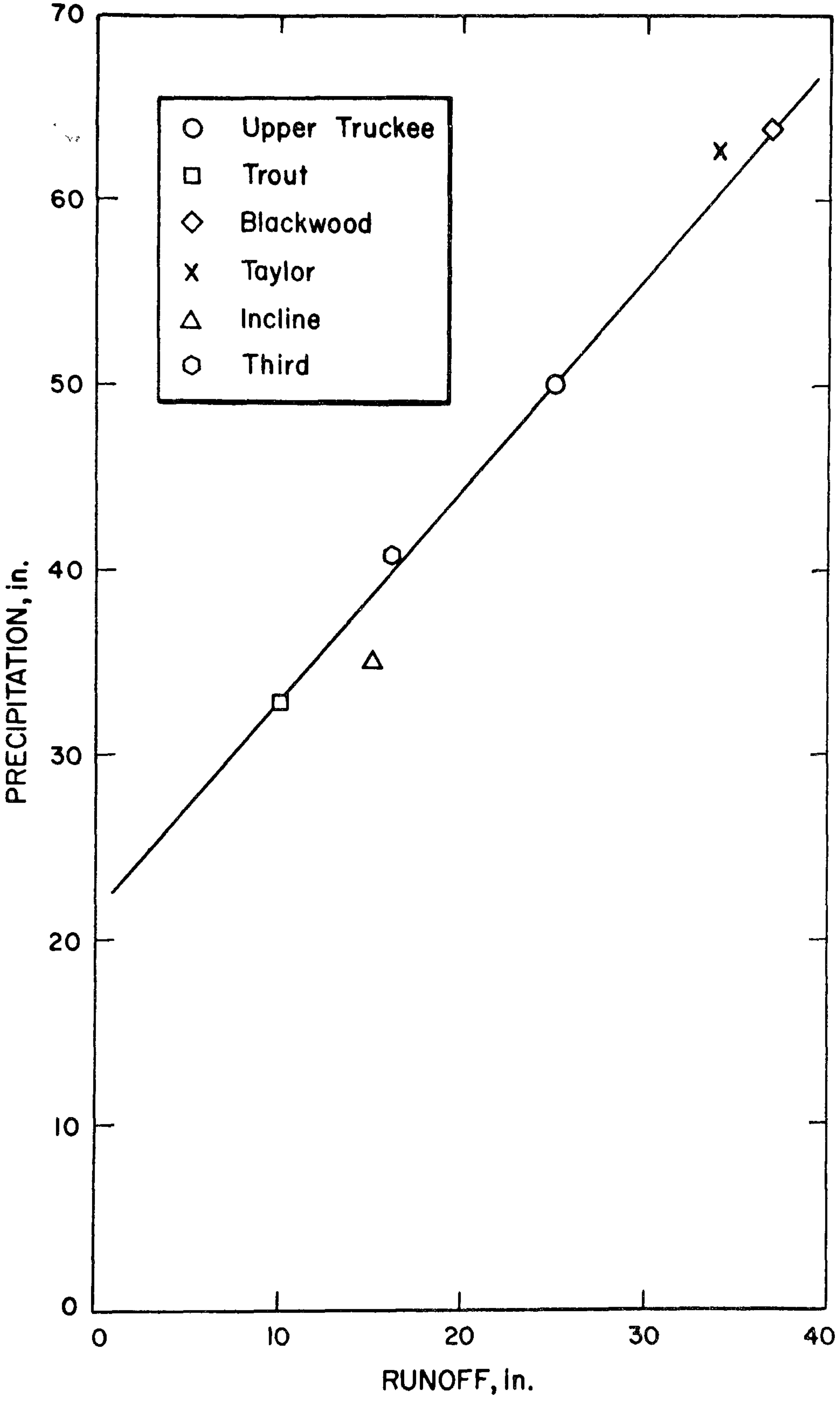

FIGURE 6-4. CALCULATED PRECIPITATION VS MEASURED RUNOFF IN THE TAHOE BASIN

Estimation of evaporation by Equation 6-2, of course has the effect of lumping water loss by evaporation and all errors in the budget into a single term. Therefore it is important to make use of such information as is available in the Tahoe Basin as a guide to judgement. Evaporation rates are normally measured at the Tahoe City weather station during the summer months but the year-round loss of water by this route is unknown. In 1963 (23) it was postulated that the annual evaporation loss from the surface of Lake Tahoe was 40 inches. Some additional evaporation pans were operated in the Basin during the 1962 water year which seemed to confirm this value. Significantly, the precipitation at Tahoe City that year approximately equaled the long term average of 30 inches.

Results of applying Equation 6-2 to data for the water years 1961 through 1970 are tabulated in Table 6-7. From the results shown for 1961-62 (441, 330 acre-feet evaporation on the 192 sq mi of lake surface) the computed value of evaporation is about 43 inches, which gives some confidence in the reasonableness of the equation.

In constructing Table 6-7, precipitation (Column 2) was computed from the isohyetal map (Figure 6-1) adjusted each year by the precipitation ratio shown in Table 6-5. Surface runoff (Column 3) was derived from the product of the precipi tation ratios of Table 6-5 and the total (310,000) of the final column of Table 6-6. Lake storage in acre-feet was obtained from the U. S. G. S. records, as were values of discharge to the Truckee River (Cols. 4 and 5, Table 6-7). Exported sewage effluent data were obtained from the records of the South Tahoe Public Utility District and the Round Hill General Improvement District. Included in the sewage export values also is effluent pumped to a cinder cone area by the Tahoe City P.U.D. Approximately one-third of the cone area lies within the Tahoe Basin and the ultimate fate of sewage discharged to the cone is unknown. However, for the purpose of the study herein reported it is assumed to be exported from the Basin. Miscellaneous discharges (Column 7) include three water rights under which water is diverted into Nevada from Marlette Lake and Third Creek, and into California from Echo Lake.

Figure 6-5 summarizes in graphical form the hydrologic inventory of the Lake Tahoe Basin based on average values reported in Table 6-7.

Nutrient Inventory

The quality and quantity of streams discharging into Lake Tahoe are tabulated in Table E-2, Appendix E. The table is a composite of the runoff from each of the 61 sub-basins and the quality values obtained by laboratory analyis of 31 streams summarized in Table E-1 (Appendix E). About 89 percent of the runoff from the land into Lake Tahoe is carried by these 31 streams. Thus the percentage of error in any nutrient inventory resulting from failure to monitor flow from the remaining 30 sub-basins is minimal. Many of these sub basins, as noted in a previous section were either seasonal in their discharge or essentially inaccessible during part of the winter season. To estimate their contribution of nutrients to Lake Tahoe values were interpolated between monitored sub-basins or, in a few instances, estimated on the basis of analyses from other areas apparently similar in cover and land development.

Referring back to Figure 6-3 it may be seen that about two-thirds of the total flow of the year occurs in the months of April, May, and June. Therefore if several years of analytical data were available it would be more accurate to use an average weighted in proportion to monthly flow, rather than simple mean values, in making a nutrient inventory. However, because data on 28 of the 31 streams monitored covered only a period of 15 months (Nov. 1969 to Feb. 1971) average values for the period of observation were used.

TABLE 6-7

LAKE TAHOE BASIN HYDROLOGIC INVENTORY

Water Year	Precipitation Directly on Lake Tahoe ac-ft	Surface Runoff into Lake Tahoe ac-ft	Δ Lake Storage ac-ft	Discharges: Lower Truckee River ac-ft	Discharges: Sewage Effluent ac-ft	Discharges: Miscellaneous ac-ft	Evaporation from Lake Surface ac-ft
1960-1961	184,300	251,800	- 177,410	83,140	-	5,000	525,370
1961-1962	227,500	310,900	+ 46,150	45,920	-	5,000	441,330
1962-1963	345,800	472,600	+ 317,660	24,010	-	5,000	471,730
1963-1964	191,100	261,200	- 120,700	98,190	-	5,000	469,810
1964-1965	389,000	531,600	+ 376,500	85,250	-	5,000	453,850
1965-1966	179,700	245,600	- 246,100	208,800	-	5,000	457,600
1966-1967	341,300	466,400	+ 211,700	227,400	-	5,000	363,600
1967-1968	186,600	254,900	- 99,300	143,120	1,200	5,000	391,480
1968-1969	398,100	544,100	+ 55,200	443,200	2,800	5,000	436,000
1969-1970	277,600	379,300	- 40,500	316,600	3,800	5,000	372,000
10 yr Total	2,721,000	3,718,300	+ 323,200	1,675,630	7,800	50,000	4,382,770
Average	272,100	371,840	+ 32,320	167,563	-	5,000	438,277

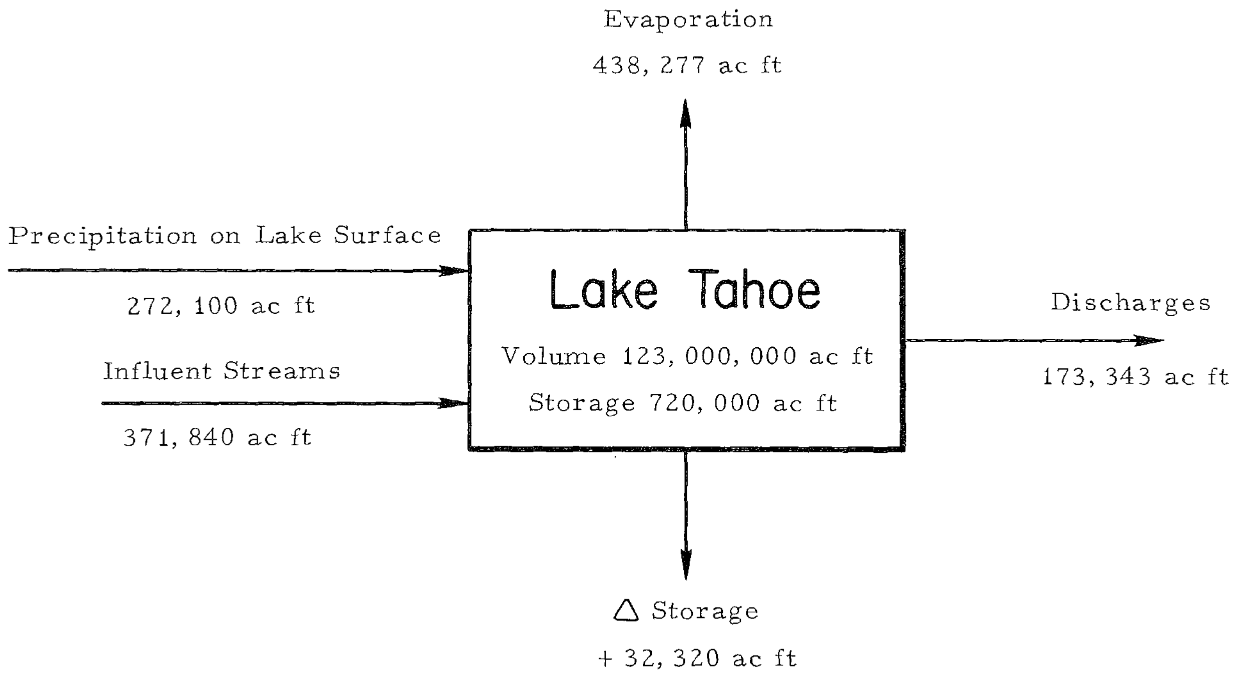

FIGURE 6-5. AVERAGE ANNUAL HYDROLOGIC INVENTORY OF THE LAKE TAHOE BASIN FOR THE WATER YEARS 1961 THROUGH 1970

The value for conductivity was converted to grams by the "rule of thumb" that 1.0×10^{-6} mhos equal 0.7 mg/ℓ of total dissolved solids. Thus, conductivity expressed in grams is a rough measure of the quantity of total dissolved solids.

The nutrient inventory in the basin can be described by Equation 6-3.

$$\Delta n = I \quad O \quad \Delta S \qquad (6\text{-}3)$$

in which:

Δn = Change in the analyzed constituent
I = Input of the constituent
O = Output of the constituent
ΔS = Amount of the constituent that is increased or decreased by storage.

Equation 6-3 could be expressed in a more convenient form, using the same nomenclature as developed in the hydrologic Equation 6-1, i.e.

$$\Delta n = P_L + R.O. - D \quad \Delta S \qquad (6\text{-}4)$$

Applying this equation to hydrological and chemical data previously presented a series of tables similar to Table 6-7 were developed for organic - N, NH_3-N, $(NO_2 + NO_3)$-N, Total -N, PO_4, Total -P, chlorides and conductivity. However, because only a single average value for each of these constituents was available no accuracy resulted from applying it to each year separately prior to averaging the results. Instead average values of precipitation, runoff, lake storage, and lake discharge were computed and averaged prior to computing the Input, Output, and other values summarized in Table 6-8.

In Table 6-8 the "Input" of any constituent is the average value of that constituent (e.g. organic nitrogen) reported in Table E-3 multiplied by the 10-year average precipitation in acre-feet on the lake surface (Table 6-7). Similarly, the surface runoff input was derived from Table 6-7 and Table E-2 (Appendix E). Values in the Output Column were obtained from an average of the summation of discharges in Table 6-7 multiplied by the concentration of the appropriate constituent reported for the Truckee River in Table E-1 (Appendix E). For "storage" the constituent concentration came from the "composite" average in Table 6-2 times the lake storage (averaged) from Table 6-7.

The final column Δn, of Table 6-8 represents the calculated difference between inputs, outputs, and change in storage, expressed by Equation 6-4. A positive (+) value indicates that there was a greater input than output. Conversely, a negative (-) value indicates that there was a net loss in the specific constituent as a result of discharge, dilution, sedimentation, utilization, etc.

EVALUATION OF RESULTS

Comparison of Nutrient Concentrations

For the purpose of evaluation of results Table 6-9 is presented. Although it concerns only the nutrients which are soluble in water it does reveal a number of factors specifically pertinent to Lake Tahoe. For example:

1. Precipitation directly on the lake surface, plus runoff from land surface, has averaged about 644,000 acre-feet per year (over a 10-year period) carrying nutrients at a concentration approximately twice as great as that observed in Lake Tahoe during the period of study. Because the lake contains about 122 million acre-feet of water, the inflow of surface and precipitation is in the ratio of 1/190. The effect of a nutrient ratio of 2/1 is at best difficult to evaluate. But the question is raised as to whether the lake through sedimentation, tieup in biomass, discharge, loss to the atmosphere

TABLE 6-8

ANNUAL NUTRIENT INVENTORY IN THE LAKE TAHOE BASIN[a]

Constituent	Input (+)					
	Precipitation Directly on Lake Tahoe			Surface Run-off into Lake Tahoe		
	ac-ft	μg/ℓ	(x 10^3) kg	ac-ft	μg/ℓ	(x 10^3) kg
Organic -N	272,100	191	64.11	371,840	184	84.39
NH_3-N	272,100	117	39.27	371,840	48	22.02
$(NO_2 + NO_3)$-N	272,100	56	18.80	371,840	41	18.81
Total-N	272,100	357	119.82	371,840	273	125.21
PO_4-P	272,100	9	3.02	371,840	10	4.59
Total-P	272,100	15	5.03	371,840	22	10.09
Chloride	272,100	1,430	480.00	371,840	1,100	505.00
Conductivity[b]	272,100	4,900	1640.00	371,840	35,000	16,000.00

Constituent	Output (-)			Δ Storage (±)			Δ n (±)
	Discharges[c] from the Lake Tahoe Basin			Change in Yearly Lake Tahoe Storage			Constituent
	ac-ft	μg/ℓ	(x 10^3) kg	ac-ft	μg/ℓ	(x 10^3) kg	(x 10^3) kg
Organic -N	173,343	158	33.78	32,320	97	+ 3.87	+ 110.85
NH_3-N	173,343	32	6.84	32,320	34	+ 1.36	+ 53.09
$(NO_2 + NO_3)$-N	173,343	11	2.35	32,320	9	+ 0.36	+ 34.90
Total-N	173,343	201	42.98	32,320	140	+ 5.58	+ 196.47
PO_4-P	173,343	6	1.28	32,320	3	+ 0.12	+ 6.21
Total-P	173,343	17	3.63	32,320	8	+ 0.32	+ 11.17
Chloride	173,343	970	207.00	32,320	1,400	+ 56.00	+ 722.00
Conductivity[b]	173,343	39,900	8530.00	32,320	60,200	+2,400.00	+6,710.00

[a]Average values for the water years 1961 through 1970.

[b]Based on the assumption that 1.0 micro-mho equals 700 μg/ℓ.

[c]Lower Truckee River, Sewage Treatment Plant Effluents, and Miscellaneous Discharges (Water Rights for Marlette Lake, Third Creek, and Echo Lake).

TABLE 6-9

COMPARISON OF VARIOUS OBSERVED AND COMPUTED NUTRIENT VALUES

Source	Measure Evaluated	Nitrogen as N				Phos. as P		Cl	Cond. (mg/ℓ)
		Organic	NH_3	$NO_2 + NO_3$	Total	PO_4	Total		
Lake Tahoe	μg/ℓ	97	34	9	140	3	8	1,400	60.2
Stream + Precipitation	Kilograms (10 yr. avg.) in 644,000 af	147,670	61,290	35,590	245,030	7,600	15,140	984,510	17,700 x 10^3
Stream + Precipitation	μg/ℓ (from data Table 6-8)	186	77	45	308	10	19	1,240	2.23
Ward Creek	μg/ℓ (Table 6-1)	99	38	17	154	11	23	460	40.5
Incline Creek	μg/ℓ (Table 6-1)	199	87	54	340	18	40	1050	41.3
Truckee — Trout Creek	μg/ℓ (Table 6-1)	207	58	48	314	8	21	2540	37.8
Secondary Sewage STPUD	μg/ℓ (Table C-4, averaged)	2,170	21,445	3,000	26,630	9,330	9,734	25,700	350
Tertiary Effluent STPUD	μg/ℓ (Table C-4, averaged)	447	14,695	461	15,920	147	172	26,300	385
Precipitation	μg/ℓ (Table 6-3)	191	117	56	357	9+	15-	1,430	7

or other complex phenomena manages to purge itself of the effect of influent and evaporative factors which tend to increase its nutrient content. If not, then the proposition must be entertained that over the past 200 years the input to the lake has not been as great as estimated for the past 10 years on the basis of short term observations.

When Ward Creek data are compared with Lake Tahoe data there is a striking similarity in the nitrogen series, to which the lake has been shown to be sensitive. However, as noted in a previous section, an increase in nitrogen about twofold in value appears when Ward Creek is compared with Incline or the Upper Truckee — Trout Creek system. Because Ward Creek, until recently, drained an area not greatly disturbed by man, and the other two creeks reflect human activity, it is concluded herein that the "stream and precipitation" data in Table 6-8 reflect an influence of relatively recent origin which involves a nutrient enrichment of Lake Tahoe.

The relative contribution of precipitation and surface streams to such an enrichment is not possible to isolate. Both are of about the same magnitude and bear about the same relationship to Lake Tahoe water. It is easy to assume that because precipitation is a natural phenomenon it has undergone less change in nutrient content than have surface streams draining land undergoing development by man. However, the growing pollution of Earth's atmosphere in general, and the specific geographic location of Lake Tahoe with respect to urban areas and agricultural land along the route of planetary circulation, make any such assumption a doubtful one.

2. The relative importance of precipitation, surface runoff, and domestic waste water in the Lake Tahoe Basin can be estimated from the Total nitrogen values presented in Table 6-9. For example, secondary sewage effluent used in the Pond Assays (Chapter V) averaged about 190 times as rich in Total nitrogen as Lake Tahoe and 87 times as rich as the combined stream and precipitation inputs. For tertiary effluent the corresponding values were 114 and 52, respectively.

   In terms of sewage based on 100 gallons per capita per day, the total nitrogen contributed by 644,000 acre feet of runoff and precipitation is equivalent to the secondary effluent from about 66,700 people (assuming 26.63 mg/ℓ represents the concentration of Total N in Secondary sewage); or about twice the annual resident population of the Tahoe Basin.

Considering only the excess of Total nitrogen over that observed in the lake (i.e. 168 = 308 140, Table 6-9), and ascribing this excess to human activity on the basis of the similarity of Ward Creek and Lake Tahoe; the 1970 potential of streams and precipitation to enrich the waters of Lake Tahoe is equal to the Secondary sewage effluent of some 36,400 people — about that of the resident population of the Basin.

Assuming the 1970 summer population for 3 months to be about 8 times the year-round population, it can be calculated on the basis of water analysis alone, that the activities of man in the Tahoe Basin represent at least 30 percent of the total potential of man to enrich Lake Tahoe with nitrogen. (i.e. If all human sewage had been exported in 1970 it would have removed 70 percent of the nitrogen ascribable to human activity within the basin). Of the total nitrogen discharged to the Lake by man and nature in combination, sewage export of <u>all sewage</u> might have accounted for only 60 percent of the total.

It should be borne in mind that the foregoing analysis is developed to give some scale to the effects associated with man's occupancy of the basin. It necessarily assumes that analysis of soluble nutrients in waters measures their algal growth stimulating potential; that all sewage is exported from the basin;

that precipitation prior to man's occupancy was no richer in nutrients than the lake water analysis reflects; and a number of other refinements too lengthy to catalog here. Some of these limitations are discussed in the following section. However, it seems probable that Table 6-9 suggests that all measures possible should be taken to limit the influent of nutrients to the Lake, on the basis of both what we know and what we don't know. Such a conclusion is supported by the 1963 Report (23) in which Dr. Karl Wuhrmann evaluated Lake Tahoe in the light of his observations there and of his long experience with European lakes. Of Lake Tahoe he said "...the relationship between nitrogen and phosphorus may be of controlling importance. It appears that at concentrations of 10 μg P/ℓ no blooms would occur with nitrogen concentrations below about 50 μg/ℓ. Heavy growth is likely, however, should nitrogen (NH_3-N plus (NO_2 + NO_3)-N) exceed 100 μg/ℓ for the same level of phosphorus." Wuhrmann went on to predict the nitrogen sensitivity of Lake Tahoe demonstrated in various sections of the study herein reported. On the basis of his criterion, the "stream and precipitation" input to Lake Tahoe reported in Table 6-9 is capable of supporting growth that the lake itself does not harbor. Such a potential was further reflected in an analysis (3) by Dr. James B. Lackey of a few creek discharges at Lake Tahoe in April 1970.

Evaluation of Other Factors

As pointed out in a preceding section, an evaluation of the eutrophication of surface waters in general requires a great deal more attention to the biota existing in a water than is readily attainable by laboratory water analyses and bioassays. In the pilot pond assays herein reported, however, biomass was measurable by suspended solids increase because the VSS in Lake Tahoe water was constantly small and varied throughout the year in no detectable pattern (see Table 4-3). This was due in no small part to a lack of the abundance of species of phytoplankton which characteristically follow each other in a sequence of blooms in eutrophic waters. In contrast, the dominant organism observed in Lake Tahoe during the study were attached diatoms, including Synedra and Gomphoneis. Synedra was a particularly large component of the biomass attained in the pond assays, although a few other species and a few small flagellates were not uncommon. On occasion very large mats of Gomphoneis rose to the surface and drifted ashore at the north end of the lake. Previous estimates (23) of plankton in the top 100 meters of Lake Tahoe in 1962 included Copepods (1100/m^3); Cladocera (500/m^3); and Rotifera (10,400/m^3) in samples taken in May. In previous and subsequent months the numbers of such plankton were drastically reduced.

In April 1970 Dr. James B. Lackey made a short-term field study and a review of literature related to Lake Tahoe. His comments on abatement of eutrophication of the lake are worthy of reporting here in some detail.

"1. One thing generally not recognized is that even such a lake as Tahoe should now and then develop algal growths, dense enough to change its turbidity at least for a while, and probably in the upper 30 or 40 feet. This would possibly be seasonal – the heavy precipitation in the basin is from November to March, and the heaviest run-off would follow a sudden thaw, or the spring temperature elevation.

This run-off should bring down such nitrate and phosphate as has accumulated in the litter on the basin floor. There is some indication of this in a table of the 1963 report (23), for four of the 60 tributary streams, although the table indicates the largest water inflow to be in May-June-July. At any rate, no natural lake, even one in which the nutrients are as low as they are in Lake Tahoe, will fail to have an algal (and other) population unless toxic materials are present, and any increase of nutrients will bring an increase in algal cells. So it must be recognized that for ages Tahoe has each year produced an algal crop, probably highest in the spring or summer when the temperature is most favorable. In the third annual report (3) the indication is that this high peak is in March.

"2. Another point recognized by algologists, but usually not by chemists and engineers is the extremely small amount of orthophosphate and nitrate nitrogen needed to support a good-sized crop of plankton algae. In the 1963 report (23) Table 11-XXII certainly shows enough for such support. This report, and subsequent ones indicate diatoms as being the dominant algae, and this table also indicates that silicon is not limiting for the diatoms. In other words, Tahoe should have at all times a standing crop of plankton algae and the amounts of nutrients will vary month to month, but sometime during the year there will be enough buildup to support a several-fold increase in the standing crop. This statement is borne out, insofar as algal cells are concerned, by Table 9 in the Third Annual Report (3).

"3. There have been statements in regard to filamentous algae, and also diatoms, attaching to rocks, expecially in shallow areas such as Tahoe Keys. Absence of such growths would be most unusual. These growths are a normal consequence of being close to the interface, where settled out organic matter is being mineralized. The crux here is whether or not such growths are excessive. Such growths in many places (Lakes Waubesa, Kegonsa in Wisconsin, some ... oxidation ponds in California, Great South Bay in New York) entrap gas, rise to the surface, die in the hot sun, and become real nuisances. If this happens in Tahoe, there is a problem. If it does not happen, remember that these – and other – algae, have real functions such as being part of the food chain, and tying up the soluble nutrients, then spreading out their recycling over a long period of time.

Quantitating such growths is difficult, but can be and should be done, to guard against an increase in eutrophication. It must be remembered that fishing is one part of recreation, that the fish in Tahoe probably are primarily dependent on insect larvae, which feed on algae of various sorts.

"4. Examination of Lake Tahoe growths was made at only a few places, but growths were exceedingly sparse. Only one filamentous alga, Ulothrix, was noted in sparse growth. This I have never seen to attain the tremendous biomass sometimes reached by such filamentous algae as Spirogyra. No chain diatoms were seen, and very few single ones. The lists of microorganisms in the various publications indicate a very sparse plant population and almost no protozoa. A detailed examination of centrifuged samples, scrapings from rocks, and sediment-water interface material in the late summer might yield a higher crop ....

"5. Disturbance of the waterfront was evident at several locations around the lake, and on some tributary streams. Practices to be strictly limited include: any drag line operations on the lake front or in tributary waters; dredging in tributary or lake waters; storm drainage run-off; over fertili zation of golf courses (a common practice); fertilization of lawns adjacent to the lake; any use of pesticides; and any admission of water from such commercial enterprises as laundromats or restaurants.

"6. Since the domestic sewage removal is almost complete, it would seem that most caution has to be taken relative to tributary streams. These are difficult to control as regards to natural run-off, but few seem to originate from potential sources of trouble. There is no arable or pastured land drainage, and the soil is largely granitic. Coniferous litter is nutrient poor, compared to that from deciduous forests. Therefore, the factor to be watched is use of tributary streams by the human population. This presumably is being done.

"7. One anomaly was seen. The Truckee River, from the time it left the lake, until we last saw it at Truckee, had a covering of its rocky bed by the largest and most dense growth of Ulothrix I have ever seen. Obviously this growth was supported by lake water; it appeared too quickly and too voluminously to be due to ground-water inflow into the river. The lake evidently has the potential for supporting a heavy algal growth at least sometimes, and why such growths have not been reported until now I cannot explain."

Conclusions to be drawn from Dr. Lackey's analysis are generally self evident. However, his final statement supports the initial comment in this section that field studies of biota are a necessary aspect of an evaluation of eutrophication. Long term studies of the limnology of Lake Tahoe are needed, and some have been underway for a number of years. Unfortunately the results have not been brought together and evaluated in any scientific report and such information as has appeared in public lectures, scientific papers, and the public press has not made possible its evaluation in the context of this report. Plans to include further work by Dr. Lackey and others during the 1970-71 grant period had to be abandoned for lack of approval of a budgetary request for consultant services. Consequently, the relationship between water quality and bioassays measurements on a laboratory and pilot pond scale, and biological findings in the Lake itself remains inadequately evaluated. Nevertheless, the findings herein presented seem clear in their indication that man's activities in the Tahoe Basin should be subject to controls not common in less obviously critical situations.

Other Unevaluated Factors. As environmental concern becomes more widespread and biologists increasingly turn their attention to environmental study two things, at least, become increasingly clear:

1. That water quality standards or criteria do not necessarily measure the quality of life within that water, and

2. That the critical ecological situations in lakes, ponds, and the ocean occur in the estuaries, bays, and shallow coastal or near-shore waters.

Action related to the first of these two depends upon an understanding of the second. Lackey in his report (item 5) calls attention to this. Likewise, the findings of the study herein reported (3) particularly show the dangers of confining waters along the shoreline for the purpose of attracting and concentrating human activity. Thus both the untidiness and the activity of man tends to enrich the waters in shallow keys and marinas and to add both algal growth and litter to that portion of the lake most readily observed by the public. It is then only a matter of extrapolation to assume that the entire Lake has already suffered the fate which may yet be many years in coming.

From observations of this phenomenon it is concluded that land use controls far more rigid than any yet established in the U. S. are necessary to protect Lake Tahoe from accelerated eutrophication. In fact, this conclusion applies equally well to surface waters in general, particularly in regions where animal manures, agricultural fertilization, and discharge of sewage and industrial effluents contribute nutrients on a scale not approached in the Tahoe Basin.

The second concern for critical areas in Lake Tahoe are its natural embayments and areas of discharge of surface waters. It is not uncommon, for example, to see the waters of Emerald Bay covered with pollen. That this represents a relatively insignificant contribution of nutrients to Lake Tahoe has been suggested (25). More important is the fate and nutrient contribution of sediments deposited at the point of discharge of streams. Aerial photos have shown the pattern of turbid water at times of heavy snow melt. As might be expected, deposition is greatest in the shallows where it is most obvious to the observer and where its effect on increasing or decreasing biomass is at a maximum. Random analyses of surface runoff from bare roadside land made during the study showed sediments too high to measure as suspended solids. The extent, amount, nutrient content, and ecological importance of sediments is one of the major inadequately evaluated factors at Lake Tahoe. Current studies of this problem by the U. S. G. S. and others should be expanded and continued.

SECTION IV

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SECTION V

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TABLE A-1

MODIFIED SKULBERG NUTRIENT MEDIUM [7]

Macronutrients	Final Concentration (mg/ℓ)	Micronutrients (Adapted from Myers, 1951)*	Final Concentration (mg/ℓ)
$NaNO_3$	46.7	$CO(NO_3)_2 \cdot 6H_2O$	0.0012
$Ca(NO_3)_2 \cdot 4H_2O$	5.9	$(NH_4)_6\ MO_7O_{24} \cdot 4H_2O$	0.0122
K_2HPO_4	3.1	$CuSO_4 \cdot 5H_2O$	0.0200
$MgSO_4 \cdot 7H_2O$	2.5	$Zn(C_2H_3O_2)$	0.0382
Na_2CO_3	2.1	$MnCl_2 \cdot 4H_2O$	0.050
Fe EDTA ($FeSO_4$ + Na_2 EDTA)	0.2 as Fe	H_3BO_3	0.50

*Myers, J. (1951). "Physiology of the Algae, Ann. Rev. Microbiology, 6:165-180.

TABLE A- 2

ANALYTICAL PROCEDURES

1. pH and alkalinity were determined by Standard Methods [16].

   Total alkalinity expressed as mg/ℓ $CaCO_3$ was determined by potentiometric titration. The pH recorded was the initial pH of the water before the acid was added in the titration.

2. Iron.

   The bathophenanthroline method outlined by Strickland and Parsons [17] was used for determination of total soluble iron, including ferrous and ferric iron, and complex ferric and colloidal ferrous forms.

3. BOD [16].

   BOD determinations were performed on unfiltered samples. Lake Tahoe water was used to dilute waste water samples when necessary. Generally no dilution for stream water was required.

4. COD [16].

   COD determinations were performed on unfiltered samples. Because both dilute water samples and waste water were analyzed, oxidation was accomplished by using 0.25 N, 0.05 N, and 0.025 N $K_2Cr_2O_7$.

5. NO_3 [17].

   NO_3 in water was reduced to NO_2 by passing the sample through a column of cadmium filings. The NO_2 was then determined.

6. NO_2 [17].

   NO_2 was determined by colorimetric reaction using sulphanilamide and naphthylethylenediamine solution.

7. NH_3 [16].

   NH_3 was distilled into a boric acid solution and then nesslerized. Equipment used for the analyses was divided into two sets, one for distillation of samples with relatively high concentrations of ammonia and the other for samples with low levels such as lake and creek samples.

8. Soluble Organic Nitrogen [16,17].

   The sample remaining after NH_3 distillation (usually about 24 mℓ) was digested with a sulfuric acid-selenium dioxide mixture. When the digestion was complete, the residue was diluted with NH_3-free water, made alkaline, and distilled for the NH_3 as reported above.

9. Inorganic Phosphorus (Reactive) [17].

   The sample was mixed with a reagent containing sulfuric acid, ammonium molybdate, and antimony potassium tartrate, adding afterwards ascorbic acid dissolved in ethyl alcohol. The blue color was then read directly from a Beckman spectrophotometer in a 1-cm or 5-cm cell. (The modification used was reported by Richard Armstrong, Institute of Ecology, University of California, Davis.)

10. Total Inorganic Phosphorus [16].

    Total inorganic phosphorus was determined after hydrolysis with a strong solution of sulfuric and nitric acids. A 100 mℓ sample with the acid solution was autoclaved, cooled and then made alkaline. The inorganic phosphorus was then determined as described above.

11. Chlorides [16].

    Chlorides were titrated with mercuric nitrate.

12. Calcium [16].

    Calcium determinations were made by titration with EDTA (ethylenediaminetetraacetic acid).

13. Conductivity [16].

    Specific conductance (μ mho/cm) measurements were done with a conductivity bridge, Model RC 16B2, made by Industrial Instruments, Inc.

TABLE B 1

CHEMICAL ANALYSES OF VARIOUS WATERS SURVEYED IN THE LAKE TAHOE AREA

Date	Location	Unfiltered Samples		0.45 μ Millipore Filtered Samples											
				Nitrogen as N					Phosphorus as P						
		BOD mg/l	COD mg/l	Organic μg/l	NH_3 μg/l	NO_2 μg/l	NO_3 μg/l	Total μg/l	PO_4 μg/l	Total μg/l	Cl mg/l	Fe μg/l	pH	Alk. as $CaCO_3$ mg/l	Cond. 10^{-6} mhos
1966															
11-7	Storm Drain (Bijou)			470	40	<1	410	971	38	238	3.2	200	8.0	52.0	76
11-20	Storm Drain (Bijou)	~0		110	30	2	228	370	180	215	7.7	250	7.0	27.0	
11-20	Tahoe Keys			100	200	2	<1	303	6	23	2.3	150			76
1967															
1-1	Snow		-	40	<5	2	<1	[illegible]	4	12	0.2	<100	5.8	6.0	6
5-20	Meeks Creek		19	200	40	4	9	243	<5	13	0.7	3,800	7.3	8.0	17
5-20	Ward Creek		10	350	20	5	62	437	<5	9	0.9	5,500	7.5	19.0	42
5-20	Incline Creek			70	20	7	69	100	9	104	1.4	150	7.4	33.0	52
6-4	Mid-Lake Tahoe		-	20	<5	3	4	30	<5	29	1.7	20	7.8	39.2	70
6-17	Meeks Creek	~0	22	60	<5	1	<1	65	17	30	0.7	<100	6.3	4.0	15
6-17	Ward Creek	~0	10	30	60	2	21	113	12	27	0.7	<100	6.6	12.0	32
6-17	Incline Creek	~0	23	70	5	3	54	132	20	45	0.7	200	7.3	17.0	38
6-19	Marina Carnelian Bay			60	<5	1	194	258	17	23	0.3	<100	7.3	36.0	
6-29	Oxidation Pond-Incline STP	5		200		9	5,800		3,400	5,200	4.9	260	6.7	22.0	
6-29	Effluent-Incline STP	5		100		26	13,500	-	10,800	20,000	20.6	200	6.7	17.0	
7-17	Sewage-Incline STP	110	100	550	7,500	15	14	8,179	5,800	6,100	14.4	2,000	7.6	106.0	300
7-17	Effluent-Incline STP	7	12	500	2,000	620	24,300	27,720	17,000	17,000	15.8	500	6.6	9.5	354
7-19	Ward Creek			110	40	3	10	163	<5	103	0.7	200	7.4	24.0	40
8-9	Primary Effluent-NTPUD	185		750	23,000	9	<1	23,760	13,500	17,000	32.2	3,700	7.8	280.0	550
8-9	Secondary Effluent-STPUD	34	34	1,500	18,500	70	250	20,320	20,900	27,000	22.9	260	7.8	275.0	580
8-23	Mid-Lake Tahoe			107	15	1	2	125	3	3	2.5		7.7		
8-24	Rain			450	390	9	181	1,030	<1	41	0.7	70	5.5	0.4	35
8-24	Storm Drain (Bijou)	35		[illegible]	350	<1	<1	3,451	160	255	15.0	2,000	7.6	100.0	188
8-24	Spray Seepage-STPUD	2	<5	400	300	75	125	900	<5	103	39.8	1,200	7.5	28.2	175
8-24	Hatchery Swamp	120		2,300	2,500	<1	110	4,901	<5	303	9.5	850	6.9	670.0	720
8-27	Meeks Creek	~0	-	100	40	<1	<1	141	<5	33	0.3	650	7.3	9.6	19
8-27	Ward Creek	~0	10	130	20	<1	<1	151	<5	28	0.3	400	7.6	28.2	44
8-27	Incline Creek	4		200	90	2	13	305	<5	43	0.5	180	7.6	28.4	47
9-2	Primary Effluent-TCPUD	203		800	41,000	<1	80	41,881	18,000	27,500	19.2	4,200	7.8	186.0	
9-14	Secondary Effluent-Reno-Sparks STP	10	16	2,200	9,500	520	2,980	15,200	5,000	15,000	27.0	50	7.8	146.0	350
9-15	Septic Tank Seepage	150	380	930	30,000	10	26	30,966	42	302	29.2	500	7.8	270.0	430
9-16	Raw Sewage-TCPUD	168	250	2,400	24,000	9	3	26,412	8,400	22,500	22.1	480	7.6	144.0	300
9-16	Primary Effluent-NTPUD	129		4,000	31,000	10	11	35,021	6,200	23,000	22.8	250	7.8	180.0	355
9-16	Refuse Dump Stream-Upstream			350	50	<1	47	448	40	60	0.6	70	7.7	49.0	67
9-16	Refuse Dump Stream-Downstream	1	8	900	110	2	48	1,060	77	88	0.9	70	7.9	82.0	77
9-18	Storm Drain (Bijou)	5	35	2,600	680	6	25	3,311	110	200	19.8	60	8.0	103.0	116
9-18	Trickling Filter Effluent-TCPUD	125	148	1,000	8,800	8	8	9,816	8,800	22,300	20.0	250	7.7	136.0	280
9-18	Tahoe Keys		7	500	90	4	36	630	8	16	2.6	<10	7.7	53.0	81
9-20	Oxidation Pond (Low Rate)-Incline STP	17	36	9,000	70	3	10	9,083	4,500	6,000	176.5	20	8.4	292.0	1,060
9-22	Oxidation Pond (High Rate)-Incline STP	30	520	9,800	350	3	8	10,161	2,500	3,000	55.5	30	8.3	160.0	540
10-6	Secondary Effluent-Reno-Sparks STP	7	85	350	12,000	460	1,390	14,200	13,000	14,000	24.0	25	8.1	120.0	450
10-16	Secondary Effluent-Reno-Sparks STP	14	120	250	9,400	550	1,450	11,650	19,500	20,500	21.2	<10	7.9	120.0	260
10-17	Spray Seepage-NTPUD	5	430	400	30	8	5	453	30	45	14.7	60	7.8	122.0	400
10-30	Oxidation Pond-STPUD	~1	112	4,000	1,500	45	80	5,625	1,000	2,000	34.0	120	8.4	140.2	450
10-30	Spray Seepage-STPUD	2	4	1,700	150	5	107	1,962	100	110	8.6	80	7.6	21.0	64
12-12	Secondary Effluent-Reno-Sparks STP	2	47	1,300	25,000	38	87	26,425	32,000	32,000	28.1	110	7.9	150.0	550
12-12	Incline Creek	4		200	90	2	13	305	30	60	9.9	180	7.6	28.4	47
1968															
1-20	Upper Truckee-Trout Creek	1	45	120	200	4	90	414	40	80	3.0	150	7.0	23.0	53
1-30	Snow			80	150	3	52	285	85	185	0.4	<10	5.9	0.9	9
2-13	Primary Effluent-Reno-Sparks STP	70	112	1,500	21,500	19	<1	23,020	30,200	32,900	33.6	<10	7.5	145.6	400
2-13	Secondary Effluent-Reno-Sparks STP	~1	10	2,200	21,000	9	27	23,236	34,400	34,403	31.8	<10	7.9	171.0	444
2-24	Upper Truckee-Trout Creek	~0	52	220	70	6	99	395	50	73	2.4	10	6.6	12.0	32
3-1	Hatchery Swamp	10	60	930	240	17	10	1,194	75	122	11.4	250	7.4	65.2	150
3-2	Marina Carnelian Bay	2	18	300	130	9	16	455	27	55	2.7	<10	7.8	46.2	93
3-11	Storm Drain	2	10	250	160	6	81	497	38	82	9.3	<10	7.7	59.2	142
4-2	Septic Tank Seepage	35	49	2,000	12,500	17	17	14,534	19,400	20,000	29.2	240	8.1	200.0	420
4-5	Refuse Dump-Downstream			250	145	13	44	452	68	75	9.0	<10	7.5	37.6	1,060
4-12	Raw Sewage-TCPUD	205	78	2,900	67,000	19	1	69,920	30,600	30,603	18.0	380	7.7	147.7	3,810

TABLE C-1

CHEMICAL CONCENTRATIONS IN PONDS (ASSAYS 2-6)

1968 Date	Assay No. (θ, days)	Pond No.	Influent[a] Description	Concentrations, $\mu g/\ell$					pH	Conductivity 10^{-6} mhos
				NO_3-N	NH_3-N	Total N	PO_4-P	Total P		
June 13	2	1	LTW	43	270[b]		7		7.5	91
[Assay	(10)	2	0.1 III	40	200		7		7.5	91
Started	"	3	1.0 III	43	200		10		7.5	90
June 12]	"	4	1.0 III	42	150		7		7.4	90
	"	5	LTW	41	290		7		7.4	90
	"	6	0.1 II	40	280		7		7.5	90
	"	7	1.0 II	43	270		7		7.5	90
	"	8	1.0 II	39	330		7		7.6	91
June 18	"	1	LTW	32	182		6	8[b]	7.8	108
	"	2	0.1 III	33	197		3	7	7.9	87
	"	3	1.0 III	28	220		3	4	7.4	91
	"	4	1.0 III	53	235		7	14	7.8	89
	"	5	LTW	23	235		3	6	7.7	87
	"	6	0.1 II	29	250		7	13	7.7	89
	"	7	1.0 II	64	240		20	42	7.8	92
	"	8	1.0 II	73	280		25	48	7.8	90
June 20	"	1	LTW	<5[b]	186	186	4		7.4	92
	"	2	0.1 III	<5	198	255	2		7.7	93
	"	3	1.0 III	<5	193	193	2		7.8	94
	"	4	1.0 III		178	195	2		8.0	90
	"	5	LTW	<5	216	233	4		7.8	94
	"	6	0.1 II	<5	178	178	6		7.8	91
	"	7	1.0 II	11	153	164	27		7.7	90
	"	8	1.0 II		173	214	25		8.9	93
June 25	"	1	LTW	5	200[b]		2		7.5	100
	"	2	0.1 III	2	230		<1		7.7	93
	"	3	1.0 III	13	200		2		7.7	96
	"	4	1.0 III	3	220		<1		7.6	98
	"	5	LTW	1	215		3		7.7	96
	"	6	0.1 II	<1	200		4		7.6	92
	"	7	1.0 II	<1	200		7		8.4	96
	"	8	1.0 II	1	205		6		8.1	98
June 27	"	1	LTW	1	240	241	1	7	7.7	98
	"	2	0.1 III	1	154	155	<1		7.9	94
	"	3	1.0 III	4	185	189	<1	2	8.2	96
	"	4	1.0 III	4	185	189	<1	4	8.2	97
	"	5	LTW	1	193	194	<1	-	7.9	95
	"	6	0.1 II	1	170	206	<1	3	7.8	95
	"	7	1.0 II	<1	367	427	3	11	8.4	96
	"	8	1.0 II	1	285	351	3	13	8.4	96
July 1	"	1	LTW	6	235	471	<1	2	7.8	100
	"	2	0.1 III	12	170	462	<1	3	7.5	98
	"	3	1.0 III	11	282	513	<1	7	7.9	98
	"	4	1.0 III	12	210	342	<1	12	7.8	98
	"	5	LTW	11	215	306	<1	15	7.8	98
	"	6	0.1 II	4	190	274	<1	14	7.8	95
	"	7	1.0 II	11	300	421	4	11	7.9	96
	"	8	1.0 II	5	100	196	12	28	8.0	98
Alkalinity for ponds 1, 2, 3 was 42.8, 42.8, and 43.2 mg/ℓ as $CaCO_3$ for June 30, 1968.										
July 8	3	1	LTW	7	109		12[b]		7.7[b]	100[b]
[Assay	(5)	2	0.1 II	9	105		3		7.9	96
Started	"	3	1.0 II	7	108		7		8.1	96
July 5]	"	4	1.0 II	8	96		3		8.1	96
	"	5	LTW	6	91		<1		8.0	94
	"	6	0.1 III	5	93		<1		8.0	94
	"	7	1.0 III	8	95		<1		8.0	95
	"	8	1.0 III	5	88		<1		7.9	96
July 10	"	1	LTW	2	227	326	3	41[b]	7.5[b]	90[b]
	"	2	0.1 II	3	210	288	4	12	7.6	87
	"	3	1.0 II	3	330	393	17	29	7.7	88
	"	4	1.0 II	2	225	297	22	35	7.6	88
	"	5	LTW	3	75	130	<1	4	7.7	88
	"	6	0.1 III	2	62	131	3	6	7.8	85
	"	7	1.0 III	12	35	112	1	64	7.8	90
	"	8	1.0 III	13	69	137	3	7	7.6	89
July 12	"	1	LTW	9	130					
	"	2	0.1 II	10	110					
	"	3	1.0 II	6	20					
	"	4	1.0 II	26	100					
	"	5	LTW	5	55					
	"	6	0.1 III	10	65					
	"	7	1.0 III	23	92					
	"	8	1.0 III	27	100					

TABLE C-1 (Continued)

1968 Date	Assay No. (θ, days)	Pond No.	Influent Description	Concentrations, μg/ℓ					pH	Conductivity 10^{-6} mhos
				NO_3-N	NH_3-N	Total N	PO_4-P	Total P		
July 15	3	1	LTW	7	150		1		8.0[b]	120[b]
	(5)	2	0.1 II	6	140		3		8.0	94
	"	3	1.0 II	7	80		21		8.1	96
	"	4	1.0 II	28	100		57		8.2	94
	"	5	LTW	5	62		<1		7.8	94
	"	6	0.1 III	14	37		<1		7.9	94
	"	7	1.0 III	38	80		<1		8.2	98
	"	8	1.0 III	40	100		<1		8.1	98
July 17	"	1	LTW	11	147	223	<1	6		
	"	2	0.1 II	10	132	210	3	7		
	"	3	1.0 II	8	180	248	22	24		
	"	4	1.0 II	8	120	204	19	23		
	"	5	LTW	6	140	209	<1	2		
	"	6	0.1 III	5	118	183	<1	1		
	"	7	1.0 III	37	194	318	<1	3		
	"	8	1.0 III	58	157	335	<1	50		
July 19	"	1	LTW	18	65		7			
	"	2	0.1 II	21	55		15			
	"	3	1.0 II	14	70		21			
	"	4	1.0 II	21	84		18			
	"	5	LTW	16	67		<1			
	"	6	0.1 III	16	61		<1			
	"	7	1.0 III	33	57		1			
	"	8	1.0 III	92	61		<1			
July 22	"	1	LTW	5	47		<1		7.4	101
	"	2	0.1 II	2	37		3		7.7	93
	"	3	1.0 II	5	90		15		7.9	173
	"	4	1.0 II	5	45		12		7.9	98
	"	5	LTW	12	70		23		7.8	94
	"	6	0.1 III	8	32		<1		7.5	93
	"	7	1.0 III	16	110		<1		7.6	98
	"	8	1.0 III	43	118		3		7.6	99
Alkalinity for ponds 5, 6, 7 was 42.30, 41.74, and 43.64 mg/ℓ as $CaCO_3$, July 23, 1968.										
July 24	"	1	LTW	2	145	347	<1	3	7.4	98
	"	2	0.1 II	4	145	336	3	8	7.7	98
	"	3	1.0 II	6	180	586	11	18	8.1	101
	"	4	1.0 II	4	180	534	13	53	7.8	100
	"	5	LTW	6	165	401	7	7	7.7	99
	"	6	0.1 III	6	160	396	1	4	7.8	98
	"	7	1.0 III	13	162	305	<1	6	7.9	104
	"	8	1.0 III	37	170		<1	6	7.8	105
July 26	"	1	LTW	<1	73					
	"	2	0.1 II	<1	84					
	"	3	1.0 II	2	102					
	"	4	1.0 II	4	84					
	"	5	LTW	44	140					
	"	6	0.1 III	36	123					
	"	7	1.0 III	13	198					
	"	8	1.0 III	37	120					
July 29	"	1	LTW	4	131		3		7.5	102
	"	2	0.1 II	4	129		3		8.1	96
	"	3	1.0 II	6	153		16		8.5	104
	"	4	1.0 II	5	201		18		8.4	103
	"	5	LTW	8	147		2		8.1	100
	"	6	0.1 III	9	135		<1		8.1	92
	"	7	1.0 III	27	153		<1		8.2	98
	"	8	1.0 III	50	[illegible]		<1		8.3	98
Aug 5	4	1	Seed Tank							
[Assay	(3)	2	0.1 III	5	210		1		7.6[b]	94[b]
Started	"	3	1.0 III	67	275		6		7.7	102
Aug 2]	"	4	1.0 III	65	250		7		8.0	103
	"	5	LTW	<1	205		8		7.9	104
	"	6	0.1 II	4	203		<1		7.9	93
	"	7	1.0 II	64	208		43		7.8	98
	"	8	1.0 II	68	275		42		8.0	94
Aug 7	"	1	Seed Tank							
	"	2	0.1 III	6	200	316	<1	13	7.7[b]	93[b]
	"	3	1.0 III	66	236	414	3	8	7.7	97
	"	4	1.0 III	55	312	479	4	6	7.6	98
	"	5	LTW	1	175	301	<1	13	7.7	91
	"	6	0.1 II	5	136	253	<1	8	7.8	94
	"	7	1.0 II	57	250	437	62	67	7.7	98
	"	8	1.0 II	45	200		42	88	7.7	98

TABLE C-1 (Continued)

1968 Date	Assay No. (θ, days)	Pond No.	Influent Description	Concentrations, $\mu g/\ell$					pH	Conductivity 10^{-6} mhos
				NO_3-N	NH_3-N	Total N	PO_4-P	Total P		
Aug 9	4	1	Seed Tank							
	(3)	2	0.1 III	9	162		<1			
	"	3	1.0 III	50	225		1			
	"	4	1.0 III	108	200		3			
	"	5	LTW	3	175		<1			
	"	6	0.1 II	6	175		<1			
	"	7	1.0 II	78	225		60			
	"	8	1.0 II	43	235		60			
Aug 12	"	1	Seed Tank							
	"	2	0.1 III	11	65		<1		7.6[b]	99[b]
	"	3	1.0 III	58	122		1		8.0	99
	"	4	1.0 III	62	120		<1		7.9	94
	"	5	LTW	<1	45[b]		<1		8.0	88
	"	6	0.1 II	<1	55		<1		8.1	88
	"	7	1.0 II	64	30		32		8.7	89
	"	8	1.0 II	1	26		20		8.8	97
Aug 14	"	1	Seed Tank							
	"	2	0.1 III	11	27		<1	3		
	"	3	1.0 III	44	87		2	3		
	"	4	1.0 III	54	73		<1	5		
	"	5	LTW	1	<5		<1	13		
	"	6	0.1 II	2	42		<1	7		
	"	7	1.0 II	2	10		26	38		
	"	8	1.0 II	2	5		23	29		
Aug 15	"	1	Seed Tank							
	"	2	0.1 III		29				7.4	90
	"	3	1.0 III		112				7.5	92
	"	4	1.0 III		67				7.6	90
	"	5	LTW		8				7.7	84
	"	6	0.1 II		40				7.8	88
	"	7	1.0 II		<5				8.3	89
	"	8	1.0 II		<5				8.5	89
Aug 21	5	1	Seed Tank							
	(3)	2	0.1 II	6	80		<5		7.6	88
[Assay	"	3	1.0 II	3	46		24	32	8.4	84
Started	"	4	1.0 II	17	42		37	37	8.1	84
Aug 16]	"	5	LTW	3	37		<5	-	7.8	84
	"	6	0.1 III	5	36		<5	<6	8.0	84
	"	7	1.0 III	22	41		<5	<6	8.0	87
	"	8	1.0 III	18	69		<5		8.0	87
Aug 23	"	1	Seed Tank							
	"	2	0.1 II	<1	50	164	6	6	7.8	81
	"	3	1.0 II	1	40	216	31	34	8.1	82
	"	4	1.0 II	14	38	115	29	33	8.0	83
	"	5	LTW	<1	46	181	<5	<6	7.7	82
	"	6	0.1 III	<1	57	227	<5	<6	7.8	81
	"	7	1.0 III	17	67	224	<5	<6	7.9	84
	"	8	1.0 III	30	75	255	<5	<6	8.0	86
Aug 26	"	1	Seed Tank							
	"	2	0.1 II	5	10		<5			
	"	3	1.0 II	2	8		18			
	"	4	1.0 II	2	33		15			
	"	5	LTW	3	8		<5			
	"	6	0.1 III	5	60		<5			
	"	7	1.0 III	40	64		<5			
	"	8	1.0 III	38	55		<5			
Aug 27	"	1	Seed Tank							
	"	2	0.1 II						8.1	88
	"	3	1.0 II						8.5	85
	"	4	1.0 II						8.5	93
	"	5	LTW						8.1	89
	"	6	0.1 III						8.0	87
	"	7	1.0 III						8.1	90
	"	8	1.0 III						8.0	90

1968 Date	Assay No. (θ, days)	Pond No.	Influent Description	Concentrations, $\mu g/\ell$					pH	Conductivity 10^{-6} mhos
				NO_3-N	NH_3-N	Total N	PO_4-P	Total P		
Aug 28	5	1	Seed Tank							
	(3)	2	0.1 II	4	85	789	<1	12		
	"	3	1.0 II	3	130	603	22	25		
	"	4	1.0 II	2	80	-	15	19		
	"	5	LTW	2	49	361	<1	<1		
	"	6	0.1 III	4	148	492	<1	4		
	"	7	1.0 III	4	195		<1	3		
	"	8	1.0 III	<1	106	426	<1	7		
Aug 29	"	1	Seed Tank							
	"	2	0.1 II						7.9	84
	"	3	1.0 II						8.1	88
	"	4	1.0 II						8.1	90
	"	5	LTW						8.0	88
	"	6	0.1 III						7.8	85
	"	7	1.0 III						8.0	90
	"	8	1.0 III						8.1	89
	Alkalinity for ponds 2, 3, 4 was 51.40, 52.40, and 52.60 mg/ℓ as $CaCO_3$.									
Aug 30	"	1	Seed Tank							
	"	2	0.1 II	9	118		5			
	"	3	1.0 II	11	88		26			
	"	4	1.0 II	8	76		27			
	"	5	LTW	9	68		<1			
	"	6	0.1 III	10	150		1			
	"	7	1.0 III	19	158		<1			
	"	8	1.0 III	32	150		<1			
Sept 6	6	1	1.0 II	6	110		5		7.8	87
	(10)	2	0.1 III	276	237		<1		7.9	88
[Assay	"	3	1.0 III	272	150		<1		7.9	86
Started	"	4	1.0 III	364	200		<1		7.9	84
Sept 1]	"	5	LTW	260	225		<1		7.8	86
	"	6	0.1 II	256	230		<1		7.9	85
	"	7	1.0 II	272	215		3		7.9	86
	"	8	1.0 II	272	250		3		7.8	86
Sept 9	"	1	1.0 II	9	100	184	23		8.0[b]	91[b]
	"	2	0.1 III	220	125	575	<1		8.0	91
	"	3	1.0 III	220	150	545	<1		7.9	95
	"	4	1.0 III	190	162	502	<1		7.9	94
	"	5	LTW	200	87	387	<1		7.9	92
	"	6	0.1 II	194	100	444	<1		7.9	92
	"	7	1.0 II	208	150	608	12		8.1	93
	"	8	1.0 II	230	175	510	18			
Sept 11	"	1	1.0 II	27	175		39			
	"	2	0.1 III	170	160		2			
	"	3	1.0 III	166	238		<1			
	"	4	1.0 III	160	215		<1			
	"	5	LTW	176	145		<1			
	"	6	0.1 II	170	125		<1			
	"	7	1.0 II	154	125		6			
	"	8	1.0 II	180	125		7			
Sept 13	"	1	1.0 II	33	25		31	40	7.6	94
	"	2	0.1 III	165	57		<1	8	7.9	92
	"	3	1.0 III	155	72		<1	3	8.0	95
	"	4	1.0 III	140	100		<1	3	8.0	96
	"	5	LTW	150	45		<1	12	8.1	92
	"	6	0.1 II	142	15		<1	2	8.1	94
	"	7	1.0 II	5	0		<1	4	8.4	93
	"	8	1.0 II	3	17		<1	5	8.5	91
Sept 16	"	1	1.0 II	12	60		23		7.9	94
	"	2	0.1 III	88	107		<1		7.9	93
	"	3	1.0 III	97	125		<1		8.1	94
	"	4	1.0 III	84	155		<1		8.0	94
	"	5	LTW	75	89		<1		8.0	92
	"	6	0.1 II	83	70		<1		8.1	92
	"	7	1.0 II	3	46		<1		8.9	90
	"	8	1.0 II	<1	82		<1		8.7	91
Sept 18	"	1	1.0 II	7[b]	90	257	50[b]	50	7.8[b]	95[b]
	"	2	0.1 III	85	122	387	<1	5	7.9	92
	"	3	1.0 III	103	142	325	<1	7	7.9	96
	"	4	1.0 III	85	147	332	<1	3	7.9	94
	"	5	LTW	82	91	180	3	4	7.9	93
	"	6	0.1 II	50	80	154	<1	7	8.0	92
[Aerated to	"	7	1.0 II	8	65	113	<1	5	9.2 (8.1)	94
bring down pH]	"	8	1.0 II	8	130	204	8	9	8.7 (8.0)	95

1968 Date	Assay No. (θ, days)	Pond No.	Influent Description	Concentrations, µg/ℓ					pH	Conductivity 10^{-6} mhos
				NO_3-N	NH_3-N	Total N	PO_4-P	Total P		
Sept 20	6	1	1.0 II		24					
	(10)	2	0.1 III		85					
	"	3	1.0 III		85					
	"	4	1.0 III		124					
	"	5	LTW		30					
	"	6	0.1 II		64					
	"	7	1.0 II		18				7.9	
	"	8	1.0 II		18				7.7	
Sept 23	"	1	1.0 II	4	40		15		7.6	104
	"	2	0.1 III	60	79		<1		7.9	90
	"	3	1.0 III	98	101		<1		7.9	93
	"	4	1.0 III	70	84		<1		7.9	92
	"	5	LTW	53	19		<1		7.9	89
	"	6	0.1 II	3	<5		<1		7.9	90
	"	7	1.0 II	2	<5		1		7.9	90
	"	8	1.0 II	2	<5		<1		7.9	90
Sept 25	"	1	1.0 II	7[b]	3	145				
	"	2	0.1 III	47	108	293				
	"	3	1.0 III	83	69	232				
	"	4	1.0 III	73	84	252				
	"	5	LTW	43	6	147				
	"	6	0.1 II	5	50	110				
	"	7	1.0 II	5	9	152				
	"	8	1.0 II	4	<5	124				
Sept 26	"	1	1.0 II		3[b]		31	41	7.9	96
	"	2	0.1 III		26		<1	7	7.9	90
	"	3	1.0 III		69		<1	13	7.9	93
	"	4	1.0 III		64		<1	2	7.8	93
	"	5	LTW		64		<1	7	7.9	92
	"	6	0.1 II		<5		<1	3	7.8	90
	"	7	1.0 II		4		10	18	7.9	91
	"	8	1.0 II		<5		5	16	7.9	92
Sept 30	"	1	1.0 II	1	6		38		7.8	96
	"	2	0.1 III	28	90		<1		7.9	91
	"	3	1.0 III	82	42		<1		7.9	94
	"	4	1.0 III	60			<1		7.8	94
	"	5	LTW	23	29		<1		7.9	90
	"	6	0.1 II	<1	28		<1		7.8	90
	"	7	1.0 II	<1	<5		13		8.0	91
	"	8	1.0 II	<1	26		10		7.9	92
	Alkalinity for ponds 4, 6, 7 was 45.04, 43.5, and 44.2 mg/ℓ as $CaCO_3$ on September 30									
Oct 2	"	1	1.0 II		<5		36	52		
	"	2	0.1 III		47		<1	12		
	"	3	1.0 III		40		<1	15		
	"	4	1.0 III		40		<1	3		
	"	5	LTW		20		<1	12		
	"	6	0.1 II		<5		<1	11		
	"	7	1.0 II		17		10	17		
	"	8	1.0 II		<5		15	24		
Oct 4	"	1	1.0 II	3	13				7.5	98
	"	2	0.1 III	20	66				7.9	90
	"	3	1.0 III	67	46				7.8	93
	"	4	1.0 III	52	62				7.8	94
	"	5	LTW	18	43				7.9	89
	"	6	0.1 II	<1	4				8.0	89
	"	7	1.0 II	<1	38				8.0	90
	"	8	1.0 II	<1	10				8.0	90
Oct 7	7	1	LTW	3	32		<1		7.5	96
	(5)	2	0.1 III	11	85		<1		7.7	92
[Assay	"	3	1.0 III	37	135		<1		7.9	93
Started	"	4	1.0 III	39	225		<1		7.9	93
Oct 5]	"	5	LTW	9	<5		<1		7.8	88
	"	6	0.1 II	2	<5		<1		7.8	87
	"	7	1.0 II	1	<5		12		7.9	90
	"	8	1.0 II	<1	<5		17		8.0	90
Oct 9	"	1	LTW	7	<5		1	2		
	"	2	0.1 III	13	34		<1	<2		
	"	3	1.0 III	30	125		<1	2		
	"	4	1.0 III	29	160		<1	<2		
	"	5	LTW	6	<5		<1	2		
	"	6	0.1 II	5	21		<1	3		
	"	7	1.0 II	5	<5		12	18		
	"	8	1.0 II	7	5		17	23		

TABLE C-1 (Continued)

1968 Date	Assay No. (t, days)	Pond No.	Influent Description	Concentrations, μg/ℓ					pH	Conductivity 10^{-6} mhos
				NO_3-N	NH_3-N	Total N	PO_4-P	Total P		
Oct 11	7	1	LTW	5			<1			
	(5)	2	0.1 III	10			3			
	"	3	1.0 III	28			<1			
	"	4	1.0 III	15			<1			
	"	5	LTW	7			<1			
	"	6	0.1 II	3			<1			
	"	7	1.0 II	3			18			
	"	8	1.0 II	3			18			
Oct 15	"	1	LTW	6	72	266	3	11	7.8	85
	"	2	0.1 III	6	100	281	<1	4	7.9	91
	"	3	1.0 III	13	167	330	1	3	7.8	94
	"	4	1.0 III	11	190	414	<1	2	7.7	93
	"	5	LTW	3	130	268	<1	5	7.7	85
	"	6	0.1 II	1	25	201	<1	3	7.7	82
	"	7	1.0 II	<1	92	217	4	7	8.2	82
	"	8	1.0 II	<1	45	195	11	18	8.3	84
Oct 17	"	1	LTW		61		<1			
	"	2	0.1 III		100		<1			
	"	3	1.0 III		282		<1			
	"	4	1.0 III		288		<1			
	"	5	LTW		109		<1			
	"	6	0.1 II		58		<1			
	"	7	1.0 II		110		10			
	"	8	1.0 II		63		15			
Oct 18	"	1	LTW	5						
	"	2	0.1 III	3						
	"	3	1.0 III	10						
	"	4	1.0 III	7						
	"	5	LTW	2						
	"	6	0.1 II	2						
	"	7	1.0 II	1						
	"	8	1.0 II	2						
Oct 21	"	1	LTW	5	47		<1		7.3	96
	"	2	0.1 III	4	57		<1		7.6	90
	"	3	1.0 III	10	395		<1		7.7	92
	"	4	1.0 III	7	385		<1		7.6	91
	"	5	LTW	3	53		<1		7.6	94
	"	6	0.1 II	2	42		<1		7.6	93
	"	7	1.0 II	2	52		7		7.8	91
	"	8	1.0 II	3	46		4		8.0	91
Oct 23	"	1	LTW	12	47	294	<1	6		
	"	2	0.1 III	10	83	338	<1	<1		
	"	3	1.0 III	14	280	501	<1	3		
	"	4	1.0 III	12	280	489	<1	11		
	"	5	LTW	7	59	191	<1	4		
	"	6	0.1 II	8	87	232	<1	3		
	"	7	1.0 II	6	47	203	8	13	8.3	
	"	8	1.0 II	6	59	240	6	53	8.9	
Oct 25	"	1	LTW	22	25		<1			
	"	2	0.1 III	21	50		<1			
	"	3	1.0 III	23	250		<1			
	"	4	1.0 III	25	275		<1			
	"	5	LTW	17	32		<1			
	"	6	0.1 II	17	22		<1			
	"	7	1.0 II	13	15		<1			
	"	8	1.0 II	17	<5		3			
Oct 28	"	1	LTW	11	16		4		7.4	92
	"	2	0.1 III	10	18		<1		7.5	90
	"	3	1.0 III	11	275		4		7.5	95
	"	4	1.0 III	15	238		<1		7.5	95
	"	5	LTW	12	16		<1		7.5	88
	"	6	0.1 II	8	34		<1		7.5	89
	"	7	1.0 II	8	16		7		7.7	92
	"	8	1.0 II	11	8		6		7.9	91

TABLE C-1 (Continued)

1968 Date	Assay No. (θ, days)	Pond No.	Influent Description	Concentrations, μg/ℓ					pH	Conductivity 10^{-6} mhos
				NO_3-N	NH_3-N	Total N	PO_4-P	Total P		
Oct 30	7	1	LTW	15	33	173	2	13		
	(5)	2	0.1 III	12	4	116	<1	3		
	"	3	1.0 III	14	163	264	<1	26		
	"	4	1.0 III	14	200	351	<1	5		
	"	5	LTW	9	43	152	<1	14		
	"	6	0.1 II	9	70	129	<1	3		
	"	7	1.0 II	8	5	63	3	23		
	"	8	1.0 II	9	18	164	3	13		
Oct 31	"	1	LTW							
	"	2	0.1 III							
	"	3	1.0 III							
	"	4	1.0 III							
	"	5	LTW							
	"	6	0.1 II							
	"	7	1.0 II						8.7	
	"	8	1.0 II						8.6	
Nov 1	"	1	LTW	10	<5		<1			
	"	2	0.1 III	7	<5		<1			
	"	3	1.0 III	10	200		<1			
	"	4	1.0 III	9	250		<1			
	"	5	LTW	4	24		2			
	"	6	0.1 II	6	57		1			
	"	7	1.0 II	5	23		3		7.9	91
	"	8	1.0 II	6	57		3		7.8	90

[a]Control is pond containing Lake Tahoe water only; II is secondary effluent; III is tertiary effluent; 0.1 and 1.0 refer to the percent effluent in Lake Tahoe water.

[b]For noted results samples for those 8 ponds collected on day following listed date.

TABLE C-2

RESULTS OF ANALYSES OF POND INPUT WATERS

1968 Date	Sample[a]	Suspended Solids mg/ℓ	Volatile Suspended Solids mg/ℓ	Chemical Analyses, mg/ℓ[b]														
				NO_3^-	NO_2^-	NH_3	Organic N	Total N	PO_4^-	Organic P	Total P	pH	Conductivity	$CaCO_3$ Alk.	Cl^-	Fe	BOD	COD
May 9	II	-	-	5.0	1.3	1.3	1.2	8.8	3.1	2.8	5.9	7.9	480	143	30	0.013	2	26
	III	-	-	3.8	3.6	6.2	1.3	14.9	0.43	2.5	2.9	7.8	510	160	35	<10	0	25
21	II	-	-	3.3	0.7	4.1	1.2	9.3	5.0	0.3	5.3	8.0	437	165	30	0.013	17	40
	III	-	-	2.8	0.4	5.9	1.4	10.5	2.6	0.2	2.8	7.9	455	163	39	<10	1	[illegible]
29	II	-	-	7.6	1.4	2.8	1.0	12.8	6.1	0.4	6.5	7.9	432	114	28	<10	5	31
	III	-	-	7.2	0.12	6.4	0.8	14.5	0.9	0	0.9	7.7	495	185	33	<10	1	18
June 5	II	-	-	4.0	3.2	4.8	2.5	14.5	6.4	0.2	6.6	7.9	500	148	28	0.020	9	41
	III	-	-	5.8	1.4	7.2	0.8	15.2	0.8	0	0.8	7.7	545	173	31	<10	1	27
11	II	-	-	6.8	1.6	4.0	1.0	13.4	6.2	0.3	6.5	7.7	485	119	22	<10	[illegible]	27
	III	-	-	7.4	1.1	9.7	0.65	18.8	1.8	0	1.8	7.7	540	180	34	<10	1	8
19	II	-	-	9.5	1.6	6.5	1.3	18.9	7.5	2.5	10.0	7.7	485	112	28	0.013	[illegible]	[illegible]
	III	-	-	15.7	1.7	7.8	1.0	26.2	1.0	0.6	1.6	8.2	500	187	24	<10	2	20
27	II	-	-	1.4	0.56	17.5	1.9	21.4	10.0	0.4	10.4	8.0	450	193	29	<20	0	31
	III	-	-	5.7	0.12	12.6	1.3	19.7	0.56	0.4	1.0	8.1	500	226	34	<10	0	[illegible]
July 9	II	-	-	5.0	1.2	8.2	1.5	15.9	8.8	1.4	10.2	7.9	412	143	25	0.013	8	62
	III	-	-	3.1	0.66	15.8	1.2	20.8	1.4	0.1	1.5	8.3	500	212	35	0.011	0	8
14	II	-	-	6.0	0.84	18.0	1.6	26.4	8.8	0.8	9.6	8.0	580	181	27	<10	3	68
	III	-	-	6.4	1.3	9.8	1.0	18.5	0.54	0.1	0.6	8.2	580	189	29	<10	0	54
15	MID LTW	-	-	0.005	0.001	0.060	0.095	0.161	<5	<5	<10	7.8	83	41	0.2	<10	-	-
17	II	-	-	5.1	0.58	13.5	1.3	20.5	9.8	0.4	10.2	8.1	475	162	23	0.012	6	65
	III	-	-	8.3	1.9	9.0	0.55	19.8	0.54	0.1	0.64	8.2	538	201	31	<10	0	21
21	II	-	-	3.7	0.44	23.8	1.7	29.6	9.0	0.2	9.2	8.0	539	174	31	0.012	12	87
	III	-	-	6.1	1.5	21.4	1.1	30.1	0.62	0.02	0.6	7.8	536	192	28	0.020	0	24
25	II	-	-	10.0	0.80	8.4	1.2	20.4	8.8	0.60	9.4	7.4	519	110	40	0.025	[illegible]	[illegible]
	III	-	-	7.9	0.96	14.5	0.50	23.9	0.68	0.03	0.7	7.7	500	195	48	<10	1	30
29	II	-	-	6.1	1.9	12.8	1.3	22.1	8.6	0.4	9.0	8.0	490	117	34	0.018	4	70
	III	-	-	7.9	2.1	12.4	0.80	23.2	1.0	0	1.0	8.1	500	151	44	<10	0	34
Aug 2	II	-	-	4.2	0.80	12.5	1.9	19.4	7.0	0.2	7.2	7.7	454	136	33	<10	15	75
	III	-	-	8.2	2.0	11.0	1.5	22.7	0.26	0.1	0.4	9.0	470	116	46	<10	1	52
7	II	5.02	3.20	8.2	0.54	11.2	1.2	21.1	7.6	0.4	8.0	7.7	525	154	28	0.012	11	84
	III	1.01	0.68	9.3	1.7	8.5	0.82	20.3	0.56	0.04	0.6	7.8	562	194	37	<10	0	40
9	MID LTW	-	-	<1	<1	0.018	0.070	0.088	0.005	0.005	0.010	7.7	77	50	1.4	<10	0	-
12	II	-	-	4.2	1.3	7.8	1.0	14.3	10.6	0.46	11.1	7.9	450	120	30	<10	10	64
	III	-	-	3.7	0.06	13.2	1.1	18.1	0.42	0.04	0.5	8.2	615	220	33	<10	0	[illegible]
16	II	-	-	6.4	1.1	10.0	2.3	19.8	6.6	0.1	6.7	7.9	460	138	23	0.012	6	69
	III	-	-	5.6	0.16	13.0	1.8	20.6	0.6	0.025	0.62	8.0	450	224	30	<10	0	46
23	II	-	-	0.68	1.3	23.2	1.4	26.6	7.4	1.0	8.4	7.9	454	184	22	0.012	15	40
	III	-	-	5.3	0.12	17.5	1.4	24.3	0.38	0.014	0.39	8.0	509	237	30	<10	0	14
28	II	(2) 15.6	13.74	1.8	0.5	17.8	1.2	21.3	7.6	0.6	8.2	8.0	480	191	22	0.017	14	54
	III	(2) 0.328	0.43	2.0	0.014	18.8	1.0	21.8	0.7	0.025	0.72	7.9	610	250	30	<10	0	[illegible]
Sept 9	II	3.28	3.33	9.1	0.5	11.2	1.3	22.1	4.9	0.2	5.1	7.8	400	131	22	<10	7	20
	III	0.23	0.50	2.8	0.86	15.0	1.1	19.8	0.095	0.01	0.1	8.2	576	265	21	0.020	0	5
13	MID LTW	-	-	<1	<1	0.063	0.061	0.124	<1	<1	<2	7.7	82	42	1.1	<10	-	-
	SHORE LTW	-	-	0.001	<1	0.045	0.029	0.075	<1	0.003	0.003	7.7	81	42	0.5	-	-	-
	II	-	-	2.9	1.3	9.5	1.3	15.0	5.4	0.7	6.1	8.0	410	196	20	<10	-	50
	III	-	-	6.1	0.09	9.8	1.2	17.2	0.19	0.03	0.22	8.0	540	231	23	0.011	-	2
22	II	5.46	5.82	5.0	0.28	9.7	1.3	16.3	11.4	1.0	12.4	7.7	385	122	20	<10	10	49
	III	1.74	1.68	6.7	0.04	9.8	0.78	17.3	0.44	0.05	0.49	7.9	480	256	25	0.010	2	0
29	II	12.04	11.74	0.7	0.6	22.5	1.9	25.7	6.7	0.78	7.5	8.2	540	216	22	0.053	16	96
	III	0.17	0.38	3.0	0.28	13.7	0.77	17.8	0.15	0.026	0.18	7.8	530	286	24	0.021	2	0

TABLE C-2 (Continued)

1968 Date	Sample	Suspended Solids mg/ℓ	Volatile Suspended Solids mg/ℓ	Chemical Analyses, mg/ℓ														
				NO_3^-	NO_2^-	NH_3	Organic N	Total N	PO_4^-	Organic P	Total P	pH	Conductivity	$CaCO_3$ Alk.	Cl^-	Fe	BOD	COD
Oct 3	II	-	-	0.014	0.004	21.1	1.7	22.8	5.8	0.16	6.0	8.3	442	218	32	<10	33	104
	III	-	-	0.067	0.002	28.0	0.61	28.7	0.086	0.022	0.11	7.9	520	276	37	0.012	2	34
	MID LTW	-	-	0.004	<1	0.048	0.175	0.227	<1	<1	<2	-	83	-	2.0	<10	-	-
4	SHORE LTW	-	-	0.002	<1	0.029	0.125	0.156	<1	0.002	0.002	7.7	83	43	1.7	<10	-	-
8	II	17.30	17.22	0.026	0.017	15.2	1.8	17.0	7.3	0.4	7.7	7.7	400	187	38	0.024	25	59
	III	1.13	1.13	0.014	0.003	27.8	0.65	28.5	0.185	0.01	0.2	7.6	462	241	39	0.012	4	9
11	II	24.69	21.77	0.005	0.002	3.2	1.76	4.97	5.44	0.240	5.68	8.4	460	238	23	0.020	34	82
	III	2.39	2.16	0.019	<0.001	24.0	1.00	25.0	0.11	<0.005	0.11	8.0	510	276	45	0.040	<1	25
16	II	16.09	-	0.015	0.015	28.60	1.725	30.4	7.2	0.44	7.64	8.0	525	242	34	0.007	22	68
	III	1.73	-	0.013	0.018	26.60	1.125	27.8	0.12	0.008	0.13	8.1	510	238	35	0.013	<1	22
22	II	10.52	-	0.001	0.013	29.00	1.940	31.0	7.36	0.32	7.68	8.0	520	188	30	0.045	3	25
	III	1.16	-	0.048	0.034	28.75	1.520	30.4	0.60	0.01	0.61	8.8	480	202	35	0.010	<1	~0
23	LTW	0.35	0.28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	II	-	-	0.015	0.009	25.50	1.56	27.1	7.10	0.50	7.60	8.1	420	191	28	0.012	4	48
	III	-	-	0.030	0.042	22.75	1.20	24.0	0.68	0.06	0.74	8.8	435	202	34	<5	<1	~0
27	II	17.05	-	0.009	0.021	32.5	1.65	34.2	7.00	0.30	7.30	8.0	475	203	31	0.025	23	68
	III	3.22	-	0.048	0.020	26.0	1.22	27.3	0.54	0.06	0.60	9.0	480	211	44	<5	<1	~1

[a]Explanation of Symbols

- II — is secondary effluent from STPUD.
- III — is tertiary effluent from STPUD.
- MID or SHORE LTW — is Lake Tahoe water collected in the middle of the lake or from the pipeline which feeds the pilot ponds.

[b]Explanation of Analytical Units

A dash indicates no analysis performed.

All concentrations are reported in mg/ℓ as the element with the following exceptions:

1. The minimum detectable limit for various analyses is in μg/ℓ.
2. pH is in pH units, conductivity is 10^{-6} mhos, alkalinity is as $CaCO_3$.

TABLE C-3

PILOT POND ANALYSES

Date	Pond Detention Time θ days	Pond No.	Influent Description	Temperature °C	Unfiltered Samples: Suspended Solids mg/ℓ	Unfiltered Samples: Volatile Suspended Solids mg/ℓ	Unfiltered Samples: Nitrogen as N: Organic μg/ℓ	Unfiltered Samples: Nitrogen as N: NH_3 μg/ℓ	Unfiltered Samples: Total Phosphorus μg/ℓ	GF/C Filtered Sample: Nitrogen as N: Organic μg/ℓ	GF/C Filtered Sample: Nitrogen as N: NH_3 μg/ℓ	GF/C Filtered Sample: Nitrogen as N: NO_2-NO_3 μg/ℓ	GF/C Filtered Sample: Nitrogen as N: Total μg/ℓ	GF/C Filtered Sample: Phosphorus as P: PO_4 μg/ℓ	GF/C Filtered Sample: Phosphorus as P: Total μg/ℓ	GF/C Filtered Sample: Fe μg/ℓ	GF/C Filtered Sample: Cond. (10^{-6}) mhos	GF/C Filtered Sample: pH
1969																		
7-14	8	1	LTW[a]	21.7	0.76	0.42	88	32	32	60	25	4	89				183	7.2
	Assay	2	0.1% II		1.01	0.15	85	25	32	79	<5	2	84				158	7.4
	No.	3	1% II		0.98	0.60	86	155	83	84	116	30	230				100	7.5
	1	4	1% S-II		0.92	0.43	84	330	300	104	325	<1	430				99	7.6
		5	LTW		0.69	0.69	72	39	13	93	<5	3	98				98	7.6
		6	0.1% II		0.75	0.25	54	26	232	60	<5	3	66				96	7.6
		7	1% II		0.81		100	160	73	120	72	25	217				96	7.6
		8	1% S-II		0.81	0.49	66	355	185	86	325	<1	412				98	7.7
7-16	8	1	LTW	18.7	2.15	0.60					30	<1				<1		
	Assay	2	0.1% II		2.57	0.84					40	<1				<1		
	No.	3	1% II		2.73	1.33					56	23				<1		
	1	4	1% S-II		3.40	1.18					92	<1				12		
		5	LTW		1.76	0.54					9	<1				34		
		6	0.1% II		1.66	0.70					31	<1				2		
		7	1% II		3.06	1.38					31	17				<1		
		8	1% S-II		2.46	1.14					86	<1				2		
7-17	8	1	LTW	21.1					19						33			
	Assay	2	0.1% II						22						25			
	No.	3	1% II						85						47			
	1	4	1% S-II						75						48			
		5	LTW						38						23			
		6	0.1% II						28						27			
		7	1% II						64						45			
		8	1% S-II						93						87			
7-18	8	1	LTW	22.4	1.75	0.86					39	4		3	25			7.4
	Assay	2	0.1% II		2.97	1.33					36	2		4	23			7.6
	No.	3	1% II		5.65	3.69					20	1		12	23			8.2
	1	4	1% S-II		4.02	2.10					16	<1		18	27			8.1
		5	LTW		2.10	0.76					18	2		4	43			7.1
		6	0.1% II		2.73	1.29					14	1		7	36			7.8
		7	1% II		4.20	2.33					<5	<1		15	38			8.3
		8	1% S-II		5.44	3.18					10	<1		46	66			8.4
7-21	8	1	LTW	23.8	1.99	1.38				12	64	7	83	3	26		96	7.6
	Assay	2	0.1% II		4.66	2.57				83	64	6	153	7	127		96	7.9
	No.	3	1% II		9.79	5.26				27	92	7	126	17	45		95	8.5
	1	4	1% S-II		3.85	2.63				32	62	7	101	16	112		92	8.3
		5	LTW		2.27	0.84				<5	6	8	16	3	19		94	7.9
		6	0.1% II		3.39	2.01				58	46	10	114	9	23		94	7.9
		7	1% II		9.27	4.91				116	51	7	174	19	32		97	8.5
		8	1% S-II		9.87	4.86				121	52	7	180	22	38		94	8.3

TABLE C-3 (Continued)

Date	Pond Detention Time θ days	Pond No.	Influent Description	Temperature °C	Unfiltered Samples: Suspended Solids mg/ℓ	Volatile Suspended Solids mg/ℓ	Nitrogen as N: Organic µg/ℓ	Nitrogen as N: NH$_3$ µg/ℓ	Total Phosphorus µg/ℓ	GF/C Filtered Samples: Nitrogen as N: Organic µg/ℓ	NH$_3$ µg/ℓ	NO$_2$-NO$_3$ µg/ℓ	Total µg/ℓ	Phosphorus as P: PO$_4$ µg/ℓ	Total µg/ℓ	Fe µg/ℓ	Cond. (10^{-6}) mhos	pH
7-23	8 Assay No. 1	1	LTW	24.7	1.91	0.78					54	2		4	4		97	7.9
		2	0.1% II		3.31	1.12					50	10		5	7		97	8.0
		3	1% II		7.10	3.79					56	4		12	20		99	8.5
		4	1% S-II		3.50	1.75					36	3		23	28		96	8.6
		5	LTW		2.14	0.76					39	6		5	13		95	8.1
		6	0.1% II		3.20	1.16					38	8		6	14		96	8.1
		7	1% II		10.46	5.03					28	3		8	26		98	8.5
		8	1% S-II		12.01	5.19					62	1		19	28		95	8.8
7-25	8 Assay No. 1	1	LTW	23.8	1.96	0.89					45	5		3	9			7.4
		2	0.1% II		3.85	1.48					25	4		3	10			7.9
		3	1% II		9.92	4.81					34	4		8	20			8.2
		4	1% S-II		10.89	5.00					38	6		17	24			8.1
		5	LTW		2.59	0.84					28	6		3	11			8.0
		6	0.1% II		3.54	1.43					26	2		3	9			8.0
		7	1.0% II		10.60	4.96					10	6		12	27			8.4
		8	1% S-II		11.11	5.27					70	6		14	28			8.1
7-28	8 Assay No. 1	1	LTW	23.1	0.71	0.71				13	54	4	73	1	4		95	7.9
		2	0.1% II		3.03	1.38				38	20	1	59	3	7		91	8.0
		3	1% II		9.92	4.94				55	45	2	102	15	28		99	8.2
		4	1% S-II		7.55	4.03				44	20	3	67	22	31		98	8.2
		5	LTW		2.04	0.82				30	10	2	42	3	7		92	8.0
		6	0.1% II		2.73	1.24				22	12	1	35	3	10		97	8.0
		7	1% II		10.43	5.08				46	10	<1	56	15	28		100	8.5
		8	1% S-II		10.84	4.88				76	26	<1	102	23	31		98	8.0
7-30	8 Assay No. 1	1	LTW	23.0	1.05						8	5		2	7			7.8
		2	0.1% II		2.93						8	5		3	28			7.9
		3	1% II		10.67						22	3		14	22			8.2
		4	1% S-II		8.57						10	3		22	32			8.2
		5	LTW		2.04						4	5		2	4			7.9
		6	0.1% II		2.81						18	5		3	11			7.9
		7	1% II		11.25						36	4		15	33			8.2
		8	1% S-II		10.41						30	3		23	34			8.1
8- 1	8 Assay No. 1	1	LTW	24.8	2.11	0.83					11	6		3	8			8.0
		2	0.1% II		5.50	1.87					8	7		4	20			8.1
		3	1% II		12.11	5.28					<5	8		18	31			8.4
		4	1% S-II		12.22	5.46					14	6		23	33			8.4
		5	LTW		2.85	0.90					14	7		2	5			8.0
		6	0.1% II								38	6		4	16			8.1
		7	1% II		11.97	5.43					30	8		19	32			8.3
		8	1% S-II		12.41	4.83					14	5		23	30			8.3

TABLE C-3 (Continued)

Date	Pond Detention Time θ days	Pond No.	Influent Description	Temperature °C	Unfiltered Samples: Suspended Solids mg/ℓ	Unfiltered Samples: Volatile Suspended Solids mg/ℓ	Unfiltered Samples: Nitrogen as N: Organic µg/ℓ	Unfiltered Samples: Nitrogen as N: NH_3 µg/ℓ	Unfiltered Samples: Total Phosphorus µg/ℓ	GF/C Filtered Samples: Nitrogen as N: Organic µg/ℓ	GF/C Filtered Samples: Nitrogen as N: NH_3 µg/ℓ	GF/C Filtered Samples: Nitrogen as N: NO_2-NO_3 µg/ℓ	GF/C Filtered Samples: Nitrogen as N: Total µg/ℓ	GF/C Filtered Samples: Phosphorus as P: PO_4 µg/ℓ	GF/C Filtered Samples: Phosphorus as P: Total µg/ℓ	Fe µg/ℓ	Cond. (10^{-6}) mhos	pH
8- 4	8	1	LTW	22.6	1.80	0.82				32	4	3	39	2	5		90	7.8
	Assay	2	0.1% II		3.74	1.27				35	20	2	57	4	11		92	7.9
	No.	3	1% II		12.75	5.51				62	9	2	73	13	20		94	8.6
	1	4	1% S-II		10.51	4.66				71	30	2	103	19	25		93	8.2
		5	LTW		1.91	0.68				23	15	2	40	2	4		89	8.1
		6	0.1% II		2.68	1.10				27	9	2	38	4	9		91	8.1
		7	1% II		11.50	5.04				67	15	2	84	15	22		94	8.7
		8	1% S-II		12.74	5.15				36	9	1	46	16	22		93	8.5
8- 5	8	1	LTW	21.8	2.26	1.00												
	Assay	2	0.1% II		4.52	1.55												
	No.	3	1% II		12.54	5.37												
	1	4	1% S-II		12.34	5.21												
		5	LTW		2.50	0.84												
		6	0.1% II		3.56	1.48												
		7	1% II		12.39	5.20												
		8	1% S-II		13.21	5.36												
8- 6	8	1	LTW	21.4	2.55	1.07					24	7		4	24	8		7.9
	Assay	2	0.1% II		4.42	1.70					24	6		7	34	<1		7.9
	No.	3	1% II		14.25	6.34					18	6		11	32	<1		8.3
	1	4	1% S-II		12.61	5.65					22	6		19	63	<1		8.2
		5	LTW		2.28	0.82					9	6		3	14	<1		8.0
		6	0.1% II		3.56	1.41					20	7		6	39	2		8.0
		7	1% II		13.52	5.87					6	8		18	38	<1		8.3
		8	1% S-II		14.56	6.27					18	7		13	41	<1		8.4
8- 7	8	1	LTW	21.1	2.53													
	Assay	2	0.1% II		4.07													
	No.	3	1% II		13.72													
	1	4	1% S-II		12.43													
		5	LTW		1.73													
		6	0.1% II		3.16													
		7	1% II		12.94													
		8	1% S-II		16.39													
8- 8	8	1	LTW	21.6	0.75	0.75	91	40	23	70	39	11	120	2	23		95	7.9
	Assay	2	0.1% II		2.88	1.21	89	40	35	92	24	10	126	1	31		92	8.0
	No.	3	1% II		12.59	5.24	249	35	101	87	35	10	132	12	35		92	8.2
	1	4	1% S-II		11.24	4.18	170	26	116	86	21	10	117	18	42		94	8.1
		5	LTW		2.33	0.63	62	32	22	57	44	10	111	2	20		94	8.0
		6	0.1% II		3.52	1.21	70	31	33	75	42	10	127	4	23		91	8.0
		7	1% II		11.87	4.60	154	29	110	106	28	9	143	10	22		94	8.4
		8	1% S-II		14.69	5.43	198	40	107	111	44	10	165	10	70		95	8.4

TABLE C-3 (Continued)

Date	Pond Detention Time θ days	Pond No.	Influent Description	Temperature °C	Unfiltered Samples: Suspended Solids mg/ℓ	Volatile Suspended Solids mg/ℓ	Nitrogen as N: Organic μg/ℓ	Nitrogen as N: NH_3 μg/ℓ	Total Phosphorus μg/ℓ	GF/C Filtered Samples: Nitrogen as N: Organic μg/ℓ	NH_3 μg/ℓ	NO_2-NO_3 μg/ℓ	Total μg/ℓ	Phosphorus as P: PO_4 μg/ℓ	Total μg/ℓ	Fe μg/ℓ	Conc. (10^{-6}) mhos	pH
8-11	5 Assay No. 2	1	LTW	23.2	1.66	0.70				99	35	3	138	4	64	18	96	7.7
		2	0.1% II		3.80	1.27				120	32	4	156	7	28	2	94	7.8
		3	1% II		12.52	5.44				113	24	<1	138	28	70	<1	96	8.3
		4	1% S-II		13.43	5.69				123	38	4	165	27	52	<1	94	8.3
		5	LTW		1.83	0.56				81	45	2	128	5	29	11	95	7.7
		6	0.1% II		2.67	0.91				80	63	2	145	5	44	<1	96	7.8
		7	1% II		13.56	5.64				138	55	4	197	27	62	<1	92	8.2
		8	1% S-II		13.75	5.75				149	39	2	140	17	48	<1	92	-
8-13	5 Assay No. 2	1	LTW	22.2	1.69						34	11		2	5			8.0
		2	0.1% II		3.63						45	11		7	7			8.1
		3	1% II		12.38						47	10		31	38			8.5
		4	1% S-II		15.68						33	10		30	32			8.8
		5	LTW		2.30						30	10		3	6			8.2
		6	0.1% II		2.99						20	11		8	10			8.1
		7	1% II		12.96						22	11		34	38			8.5
		8	1% S-II		13.69						25	10		17	22			8.5
8-15	5 Assay No. 2	1	LTW	23.1	2.25	0.77					42	9		1	6			8.1
		2	0.1% II		2.72	1.10					40	5		6	10			8.2
		3	1% II		11.84	6.05					50	6		34	41			8.6
		4	1% S-II		13.61	6.45					59	4		18	23			8.0
		5	LTW		2.20	0.69					39	6		2	3			8.2
		6	0.1% II		2.95	1.22					84	10		7	11			8.2
		7	1% II		12.82	7.57					87	7		26	36			8.7
		8	1% S-II		14.74	6.74					63	5		18	19			8.8
8-18	5 Assay No. 2	1	LTW	22.5	1.71	0.62				69	46	17	132	4	58		91	8.1
		2	0.1% II		3.06	1.00				96	39	17	152	9	56		88	8.1
		3	1% II		8.48	5.04				101	48	17	166	22	93		90	8.4
		4	1% S-II		14.73	5.64				98	31	18	147	18	72		88	8.5
		5	LTW		2.21	0.58				75	54	19	148	4	47		89	8.1
		6	0.1% II		2.38	0.83					39	20		8	58		88	8.1
		7	1% II		11.89	6.28				88	51	17	156	16	35		94	8.6
		8	1% S-II		13.79	6.15					30	19		16	50		92	8.0
8-19	5 Assay No. 2	1	LTW	22.0	2.74	0.81												
		2	0.1% II		4.58	1.38												
		3	1% II		11.43	7.00												
		4	1% S-II		15.00	7.03												
		5	LTW		2.52	0.75												
		6	0.1% II		2.78	1.05												
		7	1% II		11.66	6.69												8.6
		8	1% S-II		13.75	6.36												

TABLE C-3 (Continued)

Date	Pond Detention Time θ days	Pond No.	Influent Description	Temperature °C	Unfiltered Samples: Suspended Solids mg/l	Unfiltered Samples: Volatile Suspended Solids mg/l	Unfiltered Samples: Nitrogen as N, Organic µg/l	Unfiltered Samples: Nitrogen as N, NH_3 µg/l	Unfiltered Samples: Total Phosphorus µg/l	GF/C Filtered Samples: Nitrogen as N, Organic µg/l	GF/C Filtered Samples: Nitrogen as N, NH_3 µg/l	GF/C Filtered Samples: Nitrogen as N, NO_2-NO_3 µg/l	GF/C Filtered Samples: Nitrogen as N, Total µg/l	GF/C Filtered Samples: Phosphorus as P, PO_4 µg/l	GF/C Filtered Samples: Phosphorus as P, Total µg/l	Fe µg/l	Cond. (10^{-6}) mhos	pH
8-20	5 Assay No. 2	1	LTW	22.2	1.56	0.31					31	6		3	15	<1		8.0
		2	0.1% II		3.04	1.58					33	6		13	19	<1		8.1
		3	1% II		11.88	7.23					37	5		16	19	<1		8.4
		4	1% S-II		12.40	3.96					37	4		21	31	<1		8.7
		5	LTW		1.61	0.90					37	5		2	5	<1		8.0
		6	0.1% II		2.79	1.26					29	5		6	8	<1		8.2
		7	1% II		11.03	6.88					30	4		7	61	<1		8.4
		8	1% S-II		13.74	7.49					18	6		15	17	<1		8.7
8-21	5 Assay No. 2	1	LTW	22.8	1.85													8.1
		2	0.1% II		3.15													8.0
		3	1% II		12.98													8.6
		4	1% S-II		14.87													8.2
		5	LTW		1.93													8.0
		6	0.1% II		2.94													8.0
		7	1% II		11.88													8.7
		8	1% S-II		13.42													8.1
8-22	5 Assay No. 2	1	LTW	22.7	2.09	0.93	144	31	6	160	32	6	198	6	6		91	8.1
		2	0.1% II		3.92	1.42	147	16	18	185	38	5	228	9	10		91	8.1
		3	1% II		12.19	7.04	250	33	102	114	35	4	153	11	16		91	8.2
		4	1% S-II		13.40	5.20	173	37	105	94	45	4	193	32	34		93	8.1
		5	LTW		2.73	0.78	38	14	11	99	36	5	140	4	5		90	8.1
		6	0.1% II		3.35	1.27	107	12	16	61	40	5	106	7	8		93	8.2
		7	1% II		10.94	7.23	226	8	103	148	32	6	186	6	9		93	8.2
		8	1% S-II		14.50	6.50	198	6	121	106	20	3	129	12	14		92	8.3
8-25	3 Assay No. 3	1	LTW	20.8	1.77	0.63				48	48	13	109	-	4	2	91	8.0
		2	0.1% II		2.50	0.82				116	52	10	178	6	20	<1	90	8.0
		3	1% II		7.98	4.45				114	100	7	221	22	31	<1	90	8.5
		4	1% S-II		8.48	3.48				122	49	7	178	40	45	<1	92	8.4
		5	LTW		1.93	0.62				90	42	11	143	3	8		93	8.0
		6	0.1% II		2.66	1.10				95	54	6	155	4	53		93	8.1
		7	1% II		9.33	6.02				96	70	7	173	10	19	1	97	8.8
		8	1% S-II		11.78	5.17				98	44	5	147	23	28	<1	96	8.7
8-27	3 Assay No. 3	1	LTW	19.2	1.80						24	13		4	7			
		2	0.1% II		2.29						31	16		6	12			
		3	1% II		6.50						30	12		24	30			8.5
		4	1% S-II		7.20						40	8		30	37			8.5
		5	LTW		1.97						33	15		4	7			
		6	0.1% II		2.71						35	13		6	9			
		7	1% II		8.42						31	11		17	20			8.4
		8	1% S-II		10.21						36	7		23	24			8.4

TABLE C-3 (Continued)

Date	Pond Detention Time a (days)	Pond No.	Influent Description	Temperature (°C)	Unfiltered Samples: Suspended Solids (mg/l)	Unfiltered Samples: Volatile Suspended Solids (mg/l)	Unfiltered Samples: Nitrogen as N, Organic (µg/l)	Unfiltered Samples: Nitrogen as N, NH_3 (µg/l)	Unfiltered Samples: Total Phosphorus (µg/l)	GF/C Filtered Samples: Nitrogen as N, Organic (µg/l)	GF/C Filtered Samples: Nitrogen as N, NH_3 (µg/l)	GF/C Filtered Samples: Nitrogen as N, NO_2-NO_3 (µg/l)	GF/C Filtered Samples: Nitrogen as N, Total (µg/l)	GF/C Filtered Samples: Phosphorus as P, PO_4 (µg/l)	GF/C Filtered Samples: Phosphorus as P, Total (µg/l)	Fe (µg/l)	Cond. (10^{-6}) (mhos)	pH
8-29	3 Assay No. 3	1	LTW	18.8	1.24	0.62					12	16		4	13			8.1
		2	0.1% II		1.80	0.78					21	15		7	20			8.2
		3	1% II		7.50	4.33					9	11		28	51			8.7
		4	1% S-II		4.39	2.87					27	8		21	32			8.3
		5	LTW		1.96	0.68					14	13		2	30			8.0
		6	0.1% II		2.05	2.05					28	13		9	18			8.0
		7	1% II		8.37	5.83					34	7		16	37			8.5
		8	1% S-II		13.53	3.87					32	8		26	43			8.7
9- 1	3 Assay No. 3	1	LTW	20.8	1.49	0.67				48	30	13	91	4	9	10	86	8.1
		2	0.1% II		2.12	0.91				86	20	14	120	8	10	<1	87	8.1
		3	1% II		7.82	4.96				107	38	13	158	22	25	<1	91	8.3
		4	1% S-II		4.89	3.38				95	40	16	151	14	16	<1		8.4
		5	LTW		1.70	0.53				46	20	12	78	8	8	2	87	8.0
		6	0.1% II		2.75	1.12					54	14		6	7	<1	88	7.9
		7	1% II		7.95	5.68				90	29	16	135	31	32	<1		8.6
		8	1% S-II		7.48	4.04				60	42	13	115	20	23	<1		8.7
9- 2	3 Assay No. 3	1	LTW	21.2	1.36													
		2	0.1% II		2.14													
		3	1% II		7.57													
		4	1% S-II		4.49													
		5	LTW		1.13													
		6	0.1% II		2.29													
		7	1% II		8.10													
		8	1% S-II		8.16													
9- 3	3 Assay No. 3	1	LTW	21.0	1.51	0.70	77	24	10	60	10	4	72	2	8		90	7.9
		2	0.1% II		2.60	1.13	72	14	18	62	24	6	92	5	10		91	8.0
		3	1% II		8.03	4.85	156	16	92	65	18	4	87	32	38		90	8.8
		4	1% S-II		5.15	3.18	170	8	69	58	18	3	79	13	23		92	8.7
		5	LTW		1.45	0.49	58	12	8	41	13	6	60	2	7		88	7.9
		6	0.1% II		2.93	1.18	50	12	15	50	25	4	79	4	10		89	7.9
		7	1% II		6.57	4.90	156	22	85	91	23	3	117	33	39		92	8.7
		8	1% S-II		9.22	4.76	134	10	77	82	22	2	106	9	16		90	8.7
9- 8	8 Assay No. 4	1	LTW[b]	20.3			65	67	21	40	63	11	114	6	11		88	7.9
		2	2% III				65	182	19	62	315	13	390	6	11		96	7.9
		3	1% III				50	328	12	12	171	10	193	4	9		92	7.9
		4	1% III + TE				131	861	11	34	161	11	206	3	6		92	7.9
		5	LTW				122	82	9	<5	83	11	96	5	7		88	7.9
		6	2% III				88	282	12	22	300	13	335	5	11		97	8.0
		7	1% III				84	148	15	50	162	11	223	5	8		91	8.0
		8	1% III + TE				85	139	21	91	177	8	276	5	7		91	8.0

TABLE C-3 (Continued)

Date	Pond Detention Time θ days	Pond No.	Influent Description	Temperature °C	Unfiltered Sample: Suspended Solids mg/ℓ	Unfiltered Sample: Volatile Suspended Solids mg/ℓ	Unfiltered Sample: Nitrogen as N: Organic µg/ℓ	Unfiltered Sample: Nitrogen as N: NH_3 µg/ℓ	Unfiltered Sample: Total Phosphorus µg/ℓ	GF/C Filtered Sample: Nitrogen as N: Organic µg/ℓ	GF/C Filtered Sample: Nitrogen as N: NH_3 µg/ℓ	GF/C Filtered Sample: Nitrogen as N: NO_2-NO_3 µg/ℓ	GF/C Filtered Sample: Nitrogen as N: Total µg/ℓ	GF/C Filtered Sample: Phosphorus as P: PO_4 µg/ℓ	GF/C Filtered Sample: Phosphorus as P: Total µg/ℓ	Fe µg/ℓ	Cond. (10^{-6}) mhos	pH
9-10	8	1	LTW	19.9	0.39	0.34					31	10		2	5		90	8.1
	Assay	2	2% III		0.38	0.32					280	18		3	6		94	7.9
	No.	3	1% III		0.33	0.30					134	16		4	6		90	7.9
	4	4	1% III + TE		0.34	0.28					206	14		3	6		91	8.0
		5	LTW		0.38	0.31					45	8		3	4		86	7.9
		6	2% III		0.29	0.23					289	16		4	6		94	8.0
		7	1% III		0.23	0.21					160	16		5	5		91	8.0
		8	1% III + TE		0.23	0.21					139	15		2	5		91	8.0
9-12	8	1	LTW	20.1	0.35	0.26					14	10		4				7.9
	Assay	2	2% III		0.23	0.30					261	18		3				7.9
	No.	3	1% III		0.39	0.33					124	17		2				7.9
	4	4	1% III + TE		0.41	0.39					110	17		4				7.9
		5	LTW		0.39	0.34					20	12		2				7.8
		6	2% III		0.33	0.31					282	21		4				7.9
		7	1% III		0.29	0.26					122	18		5				8.0
		8	1% III + TE		0.41	0.35					117	17		3				8.0
9-15	8	1	LTW	17.6	1.19					62	70	<1	132	2	5	4		
	Assay	2	2% III		1.61					46	194	14	254	3	13	2		
	No.	3	1% III		1.40					71	134	10	215	3	6	6		
	4	4	1% III + TE		1.52					43	62	13	118	2	5	14		
		5	LTW		0.77					58	60	1	119	2	7	<1		
		6	2% III		0.79					34	229	20	283	3	6	2		
		7	1% III		0.61					65	99	10	174	3	5	<1		
		8	1% III + TE		0.90					55	100	10	165	4	4	6		
9-17	8	1	LTW	16.9	1.28						10	12		3	6			7.5
	Assay	2	2% III		1.10						208	25		3	24			7.9
	No.	3	1% III		1.48						96	10		3	4			8.1
	4	4	1% III + TE		1.46						88	23		2	4			7.2
		5	LTW		0.54						26	11		2	12			7.8
		6	2% III		1.37						263	26		2	18			7.8
		7	1% III		0.86						64	15		2	23			7.2
		8	1% III + TE		0.30						115	19		1	5			7.5
9-19	8	1	LTW	17.0	1.77	0.63					<5	10		4				7.6
	Assay	2	2% III		1.75	0.80					192	24		4				7.9
	No.	3	1% III		2.28	0.85					80	12		4				8.0
	4	4	1% III + TE		1.30	0.48					80	19		5				7.7
		5	LTW		1.37	0.44					<5	6		5				7.7
		6	2% III		1.35	0.74					239	23		5				7.7
		7	1% III		1.88	0.69					44	8		4				7.8[c]
		8	1% III + TE		1.46	1.05					86	23		4				7.6

TABLE C-3 (Continued)

Date	Pond Detention Time θ days	Pond No.	Influent Description	Temperature °C	Unfiltered Samples: Suspended Solids mg/ℓ	Volatile Suspended Solids mg/ℓ	Nitrogen as N: Organic μg/ℓ	Nitrogen as N: NH_3 μg/ℓ	Total Phosphorus μg/ℓ	GF/C Filtered Sample: Nitrogen as N: Organic μg/ℓ	NH_3 μg/ℓ	NO_2-NO_3 μg/ℓ	Total μg/ℓ	Phosphorus as P: PO_4 μg/ℓ	Total μg/ℓ	Fe μg/ℓ	Cond. (10^{-6}) mhos	pH
9-22	8 Assay No. 4	1	LTW	15.2	1.86	0.75				108	29	3	140	10	10		85	7.8
		2	2% III		1.98	1.00				62	212	33	307	4	4		86	7.7
		3	1% III		2.03	0.86				65	114	12	191	3	8		86	8.1
		4	1% III + TE		0.64	0.64				50	93	23	166	3	6		84	8.1
		5	LTW		1.02	0.43				103	25	4	132	5	8		82	8.0
		6	2% III		1.21	0.77					212	26		3	4		87	8.0
		7	1% III		0.77	0.45				46	79	11	136	3	8		83	8.1
		8	1% III + TE		1.41	0.65				46	90	22	158	5	6		84	8.1
9-24	8 Assay No. 4	1	LTW	17.6	1.33	0.69					4	7		5	7			8.0
		2	2% III		1.97	1.10					189	38		3	9			8.1
		3	1% III		2.05	1.00					76	22		2	6			8.0
		4	1% III + TE		1.78	0.93					72	29		2	4			8.1
		5	LTW		0.62	0.38					23	5		3	9			7.7
		6	2% III		1.09	0.78					204	39		3				8.2
		7	1% III		0.81	0.30					80	11		4	10			8.3
		8	1% III + TE		1.30	0.88					72	27		3	8			8.1
9-26	8 Assay No. 4	1	LTW	17.0	2.40	0.88					10	9		4	6			8.0
		2	2% III		2.82	1.24					188	162		3	5			8.2
		3	1% III		3.04	1.29					86	21		4	4			8.1
		4	1% III + TE		2.73	1.29					82	29		4	4			8.0
		5	LTW		1.61	0.58					12	8		3	4			8.1
		6	2% III		1.94	1.08					198	45		4	4			
		7	1% III		1.35	0.61					71	17		3	4			7.8
		8	1% III + TE		1.79	0.89					66	22		3	4			8.1
9-29	8 Assay No. 4	1	LTW	16.4	1.35	0.71				60	<5	21	84	6	8		86	8.0
		2	2% III		2.27	1.09				60	158	63	281	4	11		95	8.0
		3	1% III		2.29	1.12				38	68	35	141	3	15		92	8.0
		4	1% III + TE		2.93	1.37				98	76	44	218	4	7		102	8.0
		5	LTW		1.50	0.62				46	<5	23	72	4	12		86	8.0
		6	2% III		2.45	1.45				46	184	48	278	3	8		96	8.1
		7	1% III		1.84	0.97				26	76	37	139	3	25		100	7.9
		8	1% III + TE		2.80	1.27				17	80	35	132	3	20		91	8.0
9-30	8 Assay No. 4	1	LTW	16.1	2.71	1.03												
		2	2% III		4.17	1.94												
		3	1% III		3.82	1.59												
		4	1% III + TE		3.60	1.60												
		5	LTW		1.86	0.81												
		6	2% III		4.02	2.30												
		7	1% III		2.40	1.09												
		8	1% III + TE		3.59	1.57												

TABLE C-3 (Continued)

Date	Pond Detention Time θ days	Pond No.	Influent Description	Temperature °C	Unfiltered Samples: Suspended Solids mg/ℓ	Volatile Suspended Solids mg/ℓ	Nitrogen as N: Organic μg/ℓ	Nitrogen as N: NH_3 μg/ℓ	Total Phosphorus	GF/C Filtered Samples: Nitrogen as N: Organic μg/ℓ	NH_3 μg/ℓ	NO_2-NO_3 μg/ℓ	Total μg/ℓ	Phosphorus as P: PO_4 μg/ℓ	Total μg/ℓ	Fe μg/ℓ	Cond. (10^{-6}) mhos	pH
10- 1	8 Assay No. 4	1	LTW	16.3	1.60	0.89					20	10		1	14	9		7.9
		2	2% III		2.15	1.03					175	44		2	10	22		7.5
		3	1% III		3.00	0.96					86	24		2	5	7		7.9
		4	1% III + TE		2.66	1.16					78	33		2	8	3		7.8
		5	LTW		1.67	0.59					22	10		2	14	1		7.7
		6	2% III		2.63	1.40					191	36		<1	9	33		7.8
		7	1% III		1.99	0.85					86	24		2	5	45		7.7
		8	1% III + TE		3.11	1.40					75	24		<1	8	33		7.6
10- 2	8 Assay No. 4	1	LTW	15.1	1.73													
		2	2% III		2.06													
		3	1% III		2.75													
		4	1% III + TE		2.24													
		5	LTW		1.28													
		6	2% III		3.29													
		7	1% III		1.91													
		8	1% III + TE		3.31													
10- 3	8 Assay No. 4	1	LTW	14.6	1.04	0.84	99	7	3	77	25	5	107	4	6			7.8
		2	2% III		1.65		103	215	5	72	292	32	396	3	5			7.7
		3	1% III		1.80	0.56	170	92	4	44	80	20	144	2	3			7.5
		4	1% III + TE		1.94	0.05	94	92	4	86	104	28	218	3	3			7.8
		5	LTW		0.91	0.44	170	15	3	67	4	2	73	3	5			7.9
		6	2% III		5.82	3.91	92	134	5	55	196	26	277	<1	6			7.6
		7	1% III		1.38	0.14	82	101	4	96	118	18	232	3	3			7.7
		8	1% III + TE		2.46	0.94	99	97	4	60	71	18	149	4	4			7.7
10- 6	5 Assay No. 5	1	LTW	11.8	1.72	0.63				115	<5	11	128	<1	13			7.3
		2	2% III		2.28	0.83				60	182	31	273	2	13			7.3
		3	1% III		2.70	1.00				82	76	24	182	4	4			7.0
		4	1% III + TE		2.61	0.99				84	53	28	165	2	5			7.7
		5	LTW		1.32	0.45				80	<5	10	92	3	12			7.1
		6	2% III		2.00	0.97				36	287	26	349	2	6			7.7
		7	1% III		1.04	0.68					120	24		2	4			7.7
		8	1% III + TE		2.77	1.10				32	94	24	150	2	2			7.5
10- 8	5 Assay No. 5	1	LTW	11.2	2.23	0.86					28	22		6	4			7.6
		2	2% III		2.40	1.02					225	34		3	3			7.4
		3	1% III		2.88	1.19					118	31		7	3			7.5
		4	1% III + TE		2.82	1.14					119	31		4	4			7.6
		5	LTW		2.09	1.12					18	20		5	3			7.5
		6	2% III		3.16	1.93					227	30		5	3			8.0
		7	1% III		1.85	0.76					114	29		4	4			7.6
		8	1% III + TE		4.42	1.78					92	33		2	3			7.4

TABLE C-3 (Continued)

Date	Pond Detention Time θ days	Pond No.	Influent Description	Temperature °C	Unfiltered Samples: Suspended Solids mg/ℓ	Unfiltered Samples: Volatile Suspended Solids mg/ℓ	Unfiltered Samples: Nitrogen as N: Organic µg/ℓ	Unfiltered Samples: Nitrogen as N: NH_3 µg/ℓ	Unfiltered Samples: Total Phosphorus µg/ℓ	GF/C Filtered Samples: Nitrogen as N: Organic µg/ℓ	GF/C Filtered Samples: Nitrogen as N: NH_3 µg/ℓ	GF/C Filtered Samples: Nitrogen as N: NO_2-NO_3 µg/ℓ	GF/C Filtered Samples: Nitrogen as N: Total µg/ℓ	GF/C Filtered Samples: Phosphorus as P: PO_4 µg/ℓ	GF/C Filtered Samples: Phosphorus as P: Total µg/ℓ	Fe µg/ℓ	Cond. (10^{-6}) mhos	pH
10-10	5	1	LTW	10.8	0.70						2	15		6	10			8.1
	Assay	2	2% III		2.07						292	27		2	9			8.6
	No.	3	1% III		1.90						172	20		2	5			8.1
	5	4	1% III + TE		2.00						124	29		3	6			7.6
		5	LTW		1.07						4	13		3	7			8.0
		6	2% III		3.45						228	21		3	15			
		7	1% III		1.54							18		2	18			8.2
		8	1% III + TE		2.22						142	26		1	35			8.2
10-13	5	1	LTW	8.0	2.37	0.76				250	9	18	277	3	7		87	7.8
	Assay	2	2% III		3.73	1.26				75	244	36	355	2	5		86	7.9
	No.	3	1% III		4.15	1.32				82	165	36	283	2	4		88	7.9
	5	4	1% III + TE		4.59	1.41				100	167	42	309	2	5		85	8.0
		5	LTW		2.77	0.82				75	<5	27	104	2	4		84	7.9
		6	2% III		5.59	2.21				65	287	34	386	1	5		87	8.2
		7	1% III		3.15	0.95				75	165	30	270	2	6		87	7.9
		8	1% III + TE		3.88	1.41				82	156	40	278	2			84	8.0
10-14	5	1	LTW	8.8	4.14	1.30										8		
	Assay	2	2% III		6.07	1.98										3		
	No.	3	1% III		5.47	1.73										33		
	5	4	1% III + TE		4.46	1.55										16		
		5	LTW		3.37	1.09										<1		
		6	2% III		7.03	2.83										2		
		7	1% III		3.72	1.29										2		
		8	1% III + TE		6.35	4.03										16		
10-15	5	1	LTW	7.4	3.02						22	19		4	6			7.6
	Assay	2	2% III		5.83						292	32		4	5			7.8
	No.	3	1% III		5.25						163	36		4	6			7.6
	5	4	1% III + TE		4.26						129	46		3	5			7.8
		5	LTW		2.67						16	26		4	5			7.7
		6	2% III		6.67						288	30		4	6			8.0
		7	1% III		3.61						168	34		3	6			7.8
		8	1% III + TE		4.77						139	41		4	6			7.9
10-16	5	1	LTW	8.7	4.63	0.41												
	Assay	2	2% III		7.87	5.39												
	No.	3	1% III		7.46	5.26												
	5	4	1% III + TE		5.22	2.26												
		5	LTW		3.10	0.73												
		6	2% III		7.35	4.99												
		7	1% III		3.84	0.76												
		8	1% III + TE		4.81	2.30												

TABLE C-3 (Continued)

Date	Pond Detention Time θ days	Pond No.	Influent Description	Temperature °C	Unfiltered Samples: Suspended Solids mg/ℓ	Unfiltered Samples: Volatile Suspended Solids mg/ℓ	Unfiltered Samples: Nitrogen as N, Organic μg/ℓ	Unfiltered Samples: Nitrogen as N, NH_3 μg/ℓ	Unfiltered Samples: Total Phosphorus μg/ℓ	GF/C Filtered Samples: Nitrogen as N, Organic μg/ℓ	GF/C Filtered Samples: Nitrogen as N, NH_3 μg/ℓ	GF/C Filtered Samples: Nitrogen as N, NO_2-NO_3 μg/ℓ	GF/C Filtered Samples: Nitrogen as N, Total μg/ℓ	GF/C Filtered Samples: Phosphorus as P, PO_4 μg/ℓ	GF/C Filtered Samples: Phosphorus as P, Total μg/ℓ	Fe μg/ℓ	Cond. (10^{-6}) mhos	pH
10-17	5	1	LTW	7.3	3.70	1.18	29	22	33	134	42	20	196	2	8			7.7
	Assay	2	2% III		6.60	2.30	146	273	39	130	278	25	433	<1	6			7.8
	No.	3	1% III		5.17	1.85	136	112		106	125	30	261	2	6			7.6
	5	4	1% III + TE		4.14	1.44	58	136	62	103	137	33	273	<1	14			7.8
		5	LTW		1.18	0.80	48	38	17	82	24	16	122	<1	5			7.8
		6	2% III		6.79	2.90	82	275	40	34	254	26	314	1	7			7.9
		7	1% III		3.26	1.27	110	148	31	62	148	22	232	2	12			7.7
		8	1% III + TE		4.14	1.63	60	148	18	24	127	14	165	1	8			7.6
10-20	3	1	LTW	7.1	2.41	0.73				91	34	14	139	4	6		86	7.8
	Assay	2	2% III		7.01	2.26				79	194	20	293	3	7		87	8.0
	No.	3	1% III		4.16	1.47				103	61	22	186	4	7		85	8.1
	6	4	1% III + TE		3.90	1.35				38	76	29	143	6	11		87	8.1
		5	LTW		2.09	0.70				67	46	13	126	3	7		83	8.0
		6	2% III		6.86	2.75				15	225	18	258	4	6		86	8.2
		7	1% III		2.90	0.96				67	100	20	187	3	8		88	8.1
		8	1% III + TE		3.34	1.23				29	82	26	137	3	9		86	8.0
10-22	3	1	LTW	10.5	3.76						<1	6		4	5			7.8
	Assay	2	2% III		9.77						177	9		3	5			8.2
	No.	3	1% III		5.97						103	14		3	3			8.2
	6	4	1% III + TE		4.80						89	17		3	3			8.3
		5	LTW		1.75						<1	12		3	6			8.2
		6	2% III		8.76						196	8		2	5			8.4
		7	1% III		3.13						105	10		3	5			8.3
		8	1% III + TE		3.32						89	15		3	5			8.2
10-24	3	1	LTW	11.2	1.52	0.62					8	5		2	6			8.1
	Assay	2	2% III		8.82	2.94					220	10		2	8			8.1
	No.	3	1% III		5.47	1.77					182	14		3	5			8.2
	6	4	1% III + TE		4.46	1.32					153	22		4	5			8.1
		5	LTW		1.99	0.59					10	6		4	7			8.2
		6	2% III		9.86	3.74					306	12		5	6			8.3
		7	1% III		2.99	0.96					191	12		4	7			8.2
		8	1% III + TE		3.59	1.21					135	21		10	12			8.2
10-27	3	1	LTW	9.5	4.75	1.07				10	<1	10	20	3	4		89	7.9
	Assay	2	2% III		14.61	4.52				82	177	13	272	3	6		92	8.3
	No.	3	1% III		8.76	2.47				10	184	20	214	3	5		91	8.2
	6	4	1% III + TE		7.03	2.00				31	175	25	231	2	5		91	8.2
		5	LTW		3.24	1.09				70	<5	9	82	2	6		86	8.1
		6	2% III		15.17	5.60				70	201	17	288	2	6		96	8.4
		7	1% III		6.08	1.77				48	160	13	221	2	4		91	8.2
		8	1% III + TE		6.44	2.17				39	172	20	231	4	6		91	8.2

TABLE C-3 (Continued)

Date	Pond Detention Time θ (days)	Pond No.	Influent Description	Temperature (°C)	Unfiltered Samples: Suspended Solids (mg/ℓ)	Unfiltered: Volatile Suspended Solids (mg/ℓ)	Unfiltered: Nitrogen as N, Organic (μg/ℓ)	Unfiltered: Nitrogen as N, NH_3 (μg/ℓ)	Unfiltered: Total Phosphorus (μg/ℓ)	GF/C Filtered Samples: Nitrogen as N, Organic (μg/ℓ)	Filtered: Nitrogen as N, NH_3 (μg/ℓ)	Filtered: Nitrogen as N, NO_2-NO_3 (μg/ℓ)	Filtered: Nitrogen as N, Total (μg/ℓ)	Filtered: Phosphorus as P, PO_4 (μg/ℓ)	Filtered: Phosphorus as P, Total (μg/ℓ)	Fe (μg/ℓ)	Cond. (10^{-6}) mhos	pH
10-28	3 Assay No. 6	1	LTW	9.3	1.70	0.58												
		2	2% III		11.96	4.20												
		3	1% III		4.87	1.83												
		4	1% III + TE		5.33	1.76												
		5	LTW		2.30	0.82												
		6	2% III		13.75	5.65												
		7	1% III		4.71	1.71												
		8	1% III + TE		5.54	2.03												
10-29	3 Assay No. 6	1	LTW	9.2	3.43	1.00					38	26		3				7.9
		2	2% III		10.27	3.54					172	18		2				8.1
		3	1% III		4.77	1.43					96	26		3				8.0
		4	1% III + TE		5.13	1.79					156	29		2				7.9
		5	LTW		1.63	0.59					39	19		3				7.8
		6	2% III		10.67	4.38					179	22		2				8.2
		7	1% III		5.22	1.86					114	22		2				7.8
		8	1% III + TE		5.55	2.21					136	26		1				8.0
10-30	3 Assay No. 6	1	LTW	8.4	4.25													
		2	2% III		14.05													
		3	1% III		7.72													
		4	1% III + TE		7.30													
		5	LTW		3.30													
		6	2% III		14.82													
		7	1% III		6.32													
		8	1% III + TE		6.94													
10-31	3 Assay No. 6	1	LTW	9.4	3.95	1.08	32	5	10	29	4	17	50	6	7			8.1
		2	2% III		11.40	3.73	230	208	10	50	242	20	312	2	6			8.1
		3	1% III		5.91	1.63	60	108	9	38	126	21	185	2	10			8.0
		4	1% III + TE		6.36	1.84	86	275	14	40	127	32	199	3	6			8.2
		5	LTW		2.69	0.63	46	17	6	16	2	19	37	2	4			8.0
		6	2% III		12.37	4.67	280	258	11	65	258	11	334	2	4			8.4
		7	1% III		5.20	1.65	74	153	10	38	127	28	193	2	4			8.0
		8	1% III + TE		5.54	1.90	134	172	9	32	108	28	168	2	4			8.2

[a] LTW – Lake Tahoe Water.
0.1% II – 0.1% secondary effluent from South Tahoe Public Utility District's (STPUD) Waste Treatment Plant and 99.9% LTW.
1% II – 1.0% secondary effluent from STPUD Waste Treatment Plant and 99.0% LTW.
1% S-II – 1.0% simulated (chemically) secondary effluent and 99.0% LTW (see Table A-1).

[b] LTW – Lake Tahoe Water.
2% III – 2% tertiary effluent from STPUD Waste Treatment Plant + 98% LTW (tertiary effluent is collected before chlorination).
1% III – 1% tertiary effluent from STPUD Waste Treatment Plant + 99% LTW.
1% III + TE – 1% tertiary effluent from STPUD Waste Treatment Plant + trace elements (see Table A-1) + 99% LTW.

[c] Rate of influent Lake Tahoe Water to Pilot Pond 7 was found to be approximately 3-1/2 times the designed rate (for up to possibley 4 days), this, creating a "washout" effect.

TABLE C-4

PILOT POND INFLUENT CHEMICAL ANALYSES

Date of Sampling	Assay No.	Influent Type	Unfiltered Samples: Suspended Solids mg/ℓ	Unfiltered: Volatile Suspended Solids mg/ℓ	Unfiltered: Nitrogen as N, Organic μg/ℓ	Unfiltered: Nitrogen as N, NH_3 μg/ℓ	Unfiltered: Total Phosphorus μg/ℓ	Unfiltered: COD mg/ℓ	Unfiltered: BOD_5 mg/ℓ	Filtered Samples[a]: Nitrogen as N, Organic μg/ℓ	Filtered: Nitrogen as N, NH_3 μg/ℓ	Filtered: Nitrogen as N, NO_2 + NO_3 μg/ℓ	Filtered: Nitrogen as N, Total μg/ℓ	Filtered: Phosphorus as P, PO_4 μg/ℓ	Filtered: Phosphorus as P, Total μg/ℓ	Ca mg/ℓ	Cl mg/ℓ	Fe μg/ℓ	pH	Alk. as $CaCO_3$ mg/ℓ	Cond. (10^{-6}) mhos
1969																					
7-10	1	STPUD II[b]	35.29	1.28	1,250	18,400	10,000	41	20	1,600	20,250	4,000	25,850	7,800	8,200	26.6	26.9	41	7.8	159.5	501
7-14	1	SLTW[c]	1.48		68	48	13			82	52	4	138	8					7.6		103
7-16	1	SLTW	1.37	0.38							7	3	-	4				<1			
7-17	1	SLTW					39								43						
7-18	1	SLTW	1.53	0.51							13	4	.	9	16						
7-21	1	SLTW	1.75	0.59						45	77	7	129	5	12				7.8		93
7-23	1	SLTW	0.80	0.34							56	3	-	3	3				7.8		92
7-23	1	STPUD II	10.49	5.77	3,200	16,000	8,200		13	3,400	16,500	6,100	26,000	8,160	8,400	30.8	27.0				
7-25	1	SLTW	0.94	0.45							35	11	-	4	17				7.8		
7-28	1	SLTW	0.66	0.46						25	<5	2	30	3	4				7.7		96
7-30	1	SLTW	0.56								28	6	.	2	13				7.6		
7-31	1	STPUD II	23.95	22.21	1,280	20,000	12,600	76	12	1,045	16,100	1,300	18,445	11,800	12,240	30.0	28.1	58	8.1	174.0	480
8- 1	1	SLTW	0.64	0.41							25	7		2	4				7.7		
8- 4	1	SLTW	0.40	0.24						27	<5	4	34	3	5				7.4		90
8- 5	1	SLTW	0.55	0.34																	
8- 6	1	SLTW	0.58	0.34							9	8	-	3	57				7.7		
8- 7	1	SLTW	0.37																		
8- 8	1	SLTW	0.48	0.20	60	31	13			51	31	15	97	1	27				7.8		94
8-11	2	SLTW	0.52	0.25						94	27	6	127	6	25			2	7.6		118
8-12	2	STPUD II	30.85	29.35	4,710	25,240	13,400	69		4,560	25,620	270	30,460	11,800	12,400	33.6	22.0	58	7.8	194.7	500
8-13	2	SLTW	0.40								20	12	-	2	5				7.9		
8-15	2	SLTW	0.35	0.23							46	6	-	2	2				8.0		
8-18	2	SLTW	0.36	0.19							49	21	-	4	37				8.0		92
8-19	2	SLTW	0.42	0.26																	
8-19	2	STPUD II	6.90	6.13	1,462	19,620	7,660		7	1,615	27,600	3,620	32,835	7,140	7,660	38.8	24.6	16	8.1	176.5	485
8-20	2	SLTW	0.24	0.22							60	8	-	3	6			<1	7.9		
8-21	2	SLTW	0.44																8.0		
8-22	2	SLTW	0.43	0.26	32	21	7			74	44	7	125	4	8				8.0		90
8-25	3	SLTW	0.37	0.24						40	38	15	93	4	13			6	7.9		91
8-26	3	STPUD II	4.69	4.09	624	23,720	9,700	25		786	22,660	2,730	26,176	9,000	9,500	32.2	25.4	28	8.0	188.0	535
8-27	3	SLTW	0.39								46	16	-	4	5				7.5		
8-29	3	SLTW	0.37	0.32							18	19	-	4	21				7.8		90
9- 1	3	SLTW	0.38	0.31						48	36	13	97	6	7						
9- 2	3	SLTW	0.44															8			
9- 3	3	SLTW	0.39	0.27	122	18	6			89	25	5	119	3	7				7.9		89
9- 8	4	STPUD III[d]	1.97	1.09	426	11,627	152	10		405	11,579	840	12,824	132	146	46.2	22.3	7	8.2	203.8	500
9- 8	4	SLTW			98	80	25			67	62	7	136	3	6				7.9		86
9-10	4	SLTW	0.48	0.27							26	11	-	3	4				7.9		88
9-12	4	SLTW	0.51	0.30							20	14	-	3					7.6		
9-15	4	SLTW	0.61							5	57	3	65	5	6			6			
9-17	4	SLTW	0.30								18	18	-	3	10						
9-19	4	SLTW									<5	<1	-	5					7.7		
9-19	4	STPUD III	0.69	0.51	455	11,910	142	44		532	11,390			77	118	74.2	26.4	19	8.0	255.2	560
9-22	4	SLTW								32	36	14	82	3	22				8.0		83
9-24	4	SLTW	0.62	0.39							<5	7	-	7	8				7.4		
9-26	4	SLTW	0.40								10	10	-	5	5				7.6		
9-26	4	STPUD III	0.44	0.36	383	12,490	26	29	2	378	14,830	50	15,258	50	62	64.6	22.4	4	7.9	238.0	570
9-29	4	SLTW	0.54	0.26						58	15	30	103	11	17				7.9		88
9-30	4	SLTW	0.57	0.28																	
10- 1	4	SLTW	0.52	0.24							24	13	-	2	15			50	7.7		
10- 2	4	SLTW	0.52																		
10- 3	4	SLTW	0.92	0.48	16	18	3			79	14	2	95	3	5				7.4		

TABLE C-4 (Continued)

Date of Sampling	Assay No.	Influent Type	Unfiltered Samples: Suspended Solids mg/l	Volatile Suspended Solids mg/l	Nitrogen as N: Organic μg/l	Nitrogen as N: NH_3 μg/l	Total Phosphorus μg/l	COD mg/l	BOD_5 mg/l	Filtered Samples: Nitrogen as N: Organic μg/l	NH_3 μg/l	$NO_2 + NO_3$ μg/l	Total μg/l	Phosphorus as P: PO_4 μg/l	Total μg/l	Ca mg/l	Cl mg/l	Fe μg/l	pH	Alk. as $CaCO_3$ mg/l	Cond (10^{-6}) mhos
10-3	5	STPUD III	0.94	0.84	489	12,200		10		522	9,810	460	10,792	41	79	51.2	20.7	15	8.1	[illegible]	[illegible]
10-6	5	SLTW	0.61	0.23						60	6	21	87	2	57				7.1		
10-8	5	SLTW	9.62[e]								20	26	-	5	5				7.4		
10-8	5	STPUD III	1.14	0.94	527	16,990	334	20	<1	479	13,880	630	14,989	295	297	38.7	26.4	9	8.2	198.0	470
10-10	5	SLTW	0.86								<5	15	-	2	13				8.0		
10-13	5	SLTW	2.66	0.68						77	4	35	116	2	6				7.6		83
10-13	5	STPUD III			297	22,000	160			383	19,620	433	20,436	146	150						
10-14	5	SLTW	0.98	0.39																	
10-15	5	SLTW	0.58								30	24	-	4	13				7.7		
10-16	5	SLTW	1.23	1.06																	
10-17	5	SLTW	0.64	0.28	48	20	7			41	38	13	92	3	6				7.7		
10-17	6	STPUD III	0.52	0.52	411	15,740	134	31		503	15,310	215	16,028	104	134				8.2	282.0	550
10-20	6	SLTW	3.89	0.83						<5	18	23	44	4	8				8.0		85
10-20	6	STPUD III	1.00	0.89	310	18,800	392	31	<1	169	18,770	120	19,059	364	409	62.0	28.1	2	7.8	268.3	610
10-22	6	SLTW	0.77								<5	13	-	3	10				8.2		
10-24	6	SLTW	1.10	0.26							9	6	-	2	5				8.0		
10-24	6	STPUD III	0.54	0.42	489	15,590	157	60	4	627	16,840	60	17,527	148	168	79.2	34.3	9	8.0	281.5	575
10-27	6	SLTW	0.72	0.22						20	<5	12	34	4	5				8.2		36
10-27	6	STPUD III	1.47	1.28	278	16,020	153	58	10	474	15,780	140	16,394	110	151	69.8	29.5	<1	8.1	258.2	525
10-28	6	SLTW	0.77	0.32																	
10-29	6	SLTW	1.33	0.50							27	25	-	3					7.4		
10-30	6	SLTW	0.87																		
10-31	6	SLTW	0.83	0.20	32	10	6			26	<5	22	50	2	11				7.9		

[a]Effluent from South Tahoe Public Utility District's (STPUD) Waste Treatment Plant was passed through 0.45 μ Millipore filters. Shore-Lake Tahoe Water (SLTW) was passed through GF/C filters.

[b]STPUD II – South Tahoe Public Utility District's Waste Treatment Plant's secondary (II) effluent.

[c]SLTW – Shore-Lake Tahoe Water pumped to the pilot ponds through 2,000 ft of 2 in. PVC pipe from a location near the U. S. Coast Guard Pier.

[d]STPUD III – South Tahoe Public Utility District's (STPUD) Waste Treatment Plant's tertiary (III) effluent before chlorination.

[e]Stormy day.

TABLE C-5

BIOMASS MEASUREMENTS

Date 1968	Assay No. (θ)	Pond No.	Suspended Solids mg/ℓ	Volatile Suspended Solids mg/ℓ
June 28	2	1	2.00	0.91
	(10 days)	2	2.24	0.94
[Assay	"	3	3.39	1.43
Started	"	4	4.74	1.95
June 12]	"	5	2.53	0.90
	"	6	2.58	0.86
	"	7	6.85	2.85
	"	8	5.28	2.06
June 30	"	1	3.01	0.81
	"	2	2.87	0.93
	"	3	5.07	1.70
	"	4	4.83	0.79
	"	5	2.76	1.04
	"	6	3.12	1.32
	"	7	6.46	2.70
	"	8	5.44	2.43
July 2	"	1	2.34	0.93
	"	2	2.59	0.68
	"	3	6.90	2.17
	"	4	5.97	2.04
	"	5	2.56	0.84
	"	6	3.09	1.08
	"	7	6.88	2.77
	"	8	5.13	2.01
July 8	3	1	0.90	0.54
	(5 days)	2	0.48	0.53
[Assay	"	3	0.94	0.83
Started	"	4	0.87	0.84
July 5]	"	5	0.88	0.53
	"	6	0.88	0.46
	"	7	0.80	0.60
	"	8	0.78	0.38
July 10	"	1	0.60	0.22
	"	2	0.70	0.29
	"	3	0.73	0.27
	"	4	0.67	0.22
	"	5	0.69	0.14
	"	6	0.68	0.22
	"	7	0.68	0.15
	"	8	0.65	0.13
July 12	3	1	0.59	0.31
	(5 days)	2	0.89	0.41
	"	3	1.49	0.77
	"	4	1.34	0.61
	"	5	1.21	0.42
	"	6	1.29	0.45
	"	7	1.13	0.60
	"	8	1.13	0.18
July 15	"	1	0.85	0.33
	"	2	1.75	0.61
	"	3	2.33	1.06
	"	4	2.09	1.01
	"	5	1.76	0.61
	"	6	1.83	0.64
	"	7	2.20	1.03
	"	8	1.67	0.91
July 17	"	1	0.71	0.22
	"	2	1.78	0.46
	"	3	2.50	1.01
	"	4	3.00	1.20
	"	5	1.77	0.40
	"	6	1.83	0.59
	"	7	2.65	0.90
	"	8	2.12	0.65
July 19	"	1	0.48	0.21
	"	2	1.74	0.46
	"	3	3.65	1.56
	"	4	3.50	1.61
	"	5	1.20	0.06
	"	6	1.54	0.50
	"	7	2.70	1.14
	"	8	2.55	1.09
July 22	"	1	2.02	0.40
	"	2	1.48	0.46
	"	3	6.14	2.57
	"	4	4.05	1.84
	"	5	1.20	0.25
	"	6	1.43	0.35
	"	7	3.93	1.33
	"	8	2.68	1.04

TABLE C-5 (Continued)

Date 1968	Assay No. (θ)	Pond No.	Suspended Solids mg/ℓ	Volatile Suspended Solids mg/ℓ
July 24	3	1	1.61	0.41
	(5 days)	2	1.94	0.81
	"	3	10.97	4.40
	"	4	4.59	2.15
	"	5	1.96	0.47
	"	6	2.77	0.62
	"	7	9.78	2.91
	"	8	5.18	1.71
July 26	"	1	1.62	0.53
	"	2	1.53	0.86
	"	3	6.83	3.19
	"	4	4.27	2.40
	"	5	1.00	0.33
	"	6	1.30	0.41
	"	7	4.16	1.41
	"	8	2.98	1.07
July 29	"	1	0.76	0.23
	"	2	1.21	0.50
	"	3	5.04	2.21
	"	4	4.51	2.52
	"	5	0.84	0.26
	"	6	1.46	0.48
	"	7	3.61	1.25
	"	8	2.90	1.13
Aug 5	4	1		
	(3 days)	2	0.52	
[Assay	"	3	0.50	
Started	"	4	0.50	
Aug 2]	"	5	0.35	
	"	6	0.59	
	"	7	0.67	
	"	8	0.69	
Aug 7	"	1		-
	"	2	0.57	0.26
	"	3	0.63	0.23
	"	4	0.63	0.24
	"	5	0.74	0.27
	"	6	0.67	0.30
	"	7	0.66	0.31
	"	8	0.70	0.32
Aug 9	4	1		..
	(3 days)	2	0.53	0.33
	"	3	0.65	0.30
	"	4	0.64	0.33
	"	5	0.66	0.34
	"	6	0.62	0.35
	"	7	0.79	0.47
	"	8	0.75	0.44
Aug 12	"	1	.	-
	"	2	0.72	0.25
	"	3	0.68	0.30
	"	4	0.65	0.30
	"	5	0.60	0.26
	"	6	0.79	0.37
	"	7	1.52	1.03
	"	8	1.77	1.27
Aug 13	"	1		-
	"	2	3.20	0.62
	"	3	3.02	0.72
	"	4	2.65	0.78
	"	5	3.07	0.71
	"	6	2.64	0.64
	"	7	4.26	2.24
	"	8	4.70[a]	2.56[a]
Aug 14	"	1	-	-
	"	2	2.71	0.82
	"	3	2.72	0.93
	"	4	2.91	1.15
	"	5	2.56	0.78
	"	6	2.94	1.01
	"	7	4.92	2.92
	"	8	4.09	1.86
Aug 15	"	1	-	
	"	2	2.69	1.07
	"	3	2.74	1.10
	"	4	2.85	1.32
	"	5	2.57	0.77
	"	6	2.78	1.09
	"	7	5.13	3.08
	"	8	4.13	2.67

TABLE C-5 (Continued)

Date 1968	Assay No. (0)	Pond No.	Suspended Solids mg/ℓ	Volatile Suspended Solids mg/ℓ
Aug 21	5	1		-
	(3 days)	2	2.94	1.64
[Assay	"	3	3.55	2.23
Started	"	4	2.93	1.56
Aug 16]	"	5	2.55	1.25
	"	6	2.64	1.39
	"	7	2.62	1.47
	"	8	2.95	1.44
Aug 23	"	1	-	
	"	2	2.29	1.48
	"	3	3.23	2.21
	"	4	2.34	1.46
	"	5	1.67	0.77
	"	6	1.60	0.79
	"	7	1.96	1.20
	"	8	1.93	0.97
Aug 26	"	1	-	-
	"	2	1.48	0.78
	"	3	3.60	2.60
	"	4	3.23	2.37
	"	5	1.09	0.51
	"	6	1.05	0.46
	"	7	2.35	1.49
	"	8	2.18	1.19
Aug 27	"	1		-
	"	2	1.87	0.90
	"	3	4.25	3.02
	"	4	3.77	2.55
	"	5	1.54	0.59
	"	6	1.08	0.62
	"	7	2.49	1.53
	"	8	2.23	1.33
Aug 28	"	1		-
	"	2	1.51	0.83
	"	3	3.79	3.33
	"	4	3.43	2.71
	"	5	1.21	0.60
	"	6	1.27	0.61
	"	7	1.98	1.48
	"	8	1.95	1.42
Aug 29	5	1	-	-
	(3 days)	2	1.47	0.74
	"	3	3.89	2.84
	"	4	3.40	2.35
	"	5	1.20	0.46
	"	6	1.27	0.51
	"	7	1.90	1.26
	"	8	1.93	1.22
Aug 30	"	1	.	-
	"	2	1.38	0.84
	"	3	3.64	3.23
	"	4	2.93	2.29
	"	5	1.12	0.58
	"	6	1.15	0.62
	"	7	1.93	1.58
	"	8	1.94	1.53
Sept 6	6	1	0.55	0.33
	(10 days	2	0.95	0.47
[Assay	"	3	0.88	0.47
Started	"	4	0.89	0.46
Sept 1]	"	5	0.77	0.37
	"	6	0.87	0.44
	"	7	0.82	0.44
	"	8	0.79	0.46
Sept 9	"	1	0.39	0.30
	"	2	0.59	0.40
	"	3	0.54	0.39
	"	4	0.57	0.40
	"	5	0.49	0.33
	"	6	0.61	0.38
	"	7	0.61	0.43
	"	8	0.63	0.48
Sept 11	"	1	0.72	0.44
	"	2	0.94	0.50
	"	3	0.99	0.63
	"	4	0.95	0.60
	"	5	0.76	0.46
	"	6	0.97	0.61
	"	7	1.69	1.30
	"	8	1.56	1.28

TABLE C-5 (Continued)

Date 1968	Assay No. (0)	Pond No.	Suspended Solids mg/ℓ	Volatile Suspended Solids mg/ℓ
Sept 13	6	1	0.88	0.58
	(10 days)	2	0.95	0.47
	"	3	1.12	0.76
	"	4	1.03	0.66
	"	5	0.72	0.39
	"	6	0.86	0.61
	"	7	4.22	3.30
	"	8	3.36	3.10
Sept 16	"	1	1.70	1.27
	"	2	0.84	0.41
	"	3	1.00	0.96
	"	4	1.47	0.77
	"	5	0.70	0.36
	"	6	1.58	1.01
	"	7	8.22	6.47
	"	8	6.00	5.34
Sept 18	"	1	2.04	1.91
	"	2	1.06	0.51
	"	3	1.51	1.01
	"	4	1.43	0.87
	"	5	0.90	0.48
	"	6	1.74	1.33
	"	7	7.46	5.96
	"	8	4.84	4.40
Sept 20	"	1	3.13	2.04
	"	2	1.39	0.62
	"	3	2.08	1.27
	"	4	1.79	1.12
	"	5	1.38	0.51
	"	6	2.44	1.64
	"	7	6.36	4.56
	"	8	4.68	3.84
Sept 23	"	1	2.75	2.29
	"	2	1.46	0.63
	"	3	1.72	0.96
	"	4	1.52	0.79
	"	5	1.16	0.35
	"	6	1.98	1.27
	"	7	4.10	2.74
	"	8	3.53	2.65
Sept 25	6	1	2.04	2.06
	(10 days)	2	1.47	0.69
	"	3	1.85	1.16
	"	4	1.68	1.07
	"	5	1.30	0.57
	"	6	2.14	1.62
	"	7	4.63	3.44
	"	8	4.03	3.36
Sept 27	"	1	2.48	2.14
	"	2	1.28	0.56
	"	3	1.52	0.97
	"	4	1.70	1.00
	"	5	1.19	0.51
	"	6	2.00	1.29
	"	7	4.69	3.42
	"	8	3.64	3.06
Sept 30	"	1	2.70	
	"	2	1.30	
	"	3	1.70	
	"	4	1.63	
	"	5	1.23	
	"	6	1.81	
	"	7	4.50	
	"	8	3.55	
Oct 1	"	1	2.14	1.81
	"	2	0.99	0.39
	"	3	1.32	0.83
	"	4	1.23	0.76
	"	5	0.94	0.30
	"	6	1.36	0.81
	"	7	3.52	2.36
	"	8	2.48	1.99
Oct 2	"	1	2.59	2.13
	"	2	1.18	0.47
	"	3	1.61	1.04
	"	4	1.40	0.95
	"	5	1.10	0.46
	"	6	1.66	0.97
	"	7	4.20	2.79
	"	8	3.22	2.45

TABLE C-5 (Continued)

Date 1968	Assay No. (θ)	Pond No.	Suspended Solids mg/ℓ	Volatile Suspended Solids mg/ℓ
Oct 3	6 (10 days)	1	2.56	2.34
		2	1.16	0.60
	"	3	1.77	1.16
	"	4	1.61	1.02
	"	5	1.15	0.59
	"	6	1.77	1.15
	"	7	3.91	2.76
	"	8	3.36	2.45
Oct 4	"	1	2.84	2.52
	"	2	0.93	0.46
	"	3	1.61	1.12
	"	4	1.30	0.96
	"	5	0.96	0.42
	"	6	1.57	0.95
	"	7	3.76	2.70
	"	8	3.34	2.54
Oct 9	7 (5 days)	1	0.52	0.35
		2	0.88	0.42
[Assay Started	"	3	1.17	0.72
Oct 4]	"	4	0.93	0.62
	"	5	0.76	0.33
	"	6	0.86	0.27
	"	7	2.15	1.75
	"	8	4.45	2.76
Oct 11	"	1	0.60	0.23
	"	2	0.93	0.36
	"	3	1.20	0.64
	"	4	1.06	0.47
	"	5	0.93	0.32
	"	6	1.29	0.57
	"	7	4.02	2.24
	"	8	4.28	2.52
Oct 15	"	1	3.61	1.16
	"	2	3.77	0.99
	"	3	4.89	1.25
	"	4	4.14	1.11
	"	5	4.13	0.94
	"	6	4.17	1.21
	"	7	4.72	2.92
	"	8	6.01	2.90
Oct 18	7 (5 days)	1	2.71	0.67
		2	2.63	0.73
	"	3	3.07	0.98
	"	4	2.71	0.91
	"	5	2.57	0.71
	"	6	2.61	0.76
	"	7	5.39	2.81
	"	8	5.39	2.88
Oct 21	"	1	2.47	0.72
	"	2	2.41	0.73
	"	3	2.50	0.78
	"	4	2.12	0.75
	"	5	2.20	0.57
	"	6	2.36	0.78
	"	7	6.43	3.23
	"	8	7.29	3.77
Oct 23	"	1	2.14	0.54
	"	2	2.20	0.65
	"	3	2.12	0.67
	"	4	1.84	0.63
	"	5	1.90	0.46
	"	6	2.10	0.78
	"	7	7.82	3.80
	"	8	9.91[a]	5.06[a]
Oct 25	"	1	1.69	0.50
	"	2	1.79	0.63
	"	3	1.76	0.72
	"	4	1.34	0.59
	"	5	1.48	0.47
	"	6	1.68	0.73
	"	7	8.21	4.48
	"	8	11.03	5.75
Oct 28	"	1	1.44	0.48
	"	2	1.64	0.64
	"	3	1.45	0.65
	"	4	1.04	0.55
	"	5	0.98	0.39
	"	6	1.69	0.69
	"	7	7.32	4.33
	"	8	10.00	5.38

TABLE C-5 (Continued)

Date 1968	Assay No. (θ)	Pond No.	Suspended Solids mg/ℓ	Volatile Suspended Solids mg/ℓ
Oct 29	7 (5 days)	1	1.92	0.47
		2	2.16	0.70
	"	3	1.87	0.74
	"	4	1.53	0.68
	"	5	1.53	0.45
	"	6	1.81	0.67
	"	7	9.22	3.64
	"	8	11.11	5.44
Oct 31	"	1	2.42	0.72
	"	2	2.71	0.92
	"	3	2.18	0.92
	"	4	1.90	0.79
	"	5	1.78	0.52
	"	6	2.15	0.81
	"	7	9.99	4.92
	"	8	10.26	5.19
Nov 1	"	1	2.07	0.56
	"	2	2.37	0.78
	"	3	2.00	0.85
	"	4	1.66	0.78
	"	5	1.64[a]	0.49[a]
	"	6	1.99	0.76
	"	7	8.70	4.31
	"	8	11.00[a]	5.09[a]

[a] Mean value of two or more samples

TABLE C-6

SIMULTATED SECONDARY EFFLUENT FEED FOR PILOT PONDS

MACRONUTRIENTS	CONCENTRATION IN FEED (mg/ℓ)
NH_4 Cl	76.4
K_2 HPO_4	56.0
Fe SO_4 $7H_2O$	2.48
Mg SO_4 $7H_2O$	53.2
MICRONUTRIENTS	
$Co(NO_3)_2$ $6H_2O$	0.012
$(NH_4)_5$ Mo_7O_{24} $4H_2O$	0.122
Cu SO_4 $5H_2O$	0.200
Zn Acetate	0.280
Mn Cl_2 $4H_2O$	0.500
H_3BO_3	5.000

IRON AND TRACE ELEMENTS SUPPLEMENT FOR
TERTIARY EFFLUENT FEED FOR PILOT PONDS

MACRONUTRIENTS	CONCENTRATION IN FEED (mg/ℓ)
Fe SO_4 $7H_2O$	2.48
MICRONUTRIENTS	
$Co(NO_3)_2$ $6H_2O$	0.012
$(NH_4)_6$ Mo_7O_{24} $4H_2O$	0.122
Cu SO_4 $5H_2O$	0.200
Zn Acetate	0.280
Mn Cl_2 $4H_2O$	0.500
H_3BO_3	5.000

TABLE D-1

CHEMICAL ANALYSES OF SHORE AND MID-LAKE TAHOE

Date	Sample Location	Unfiltered Samples			0.45 μ Millipore Filtered Samples											
		Susp. Solids	Vol. Susp. Solids	COD	Nitrogen as N					Phosphorus as P		Ca	Cl	pH	Alk. as $CaCO_3$	Cond. (10^{-6})
					Organic	NH_3	NO_2	NO_3	Total	PO_4	Total					
		mg/l	mg/l	mg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	mg/l	mg/l		mg/l	mhos
1967																
6- 4	MLT[a]				20	<5	3	4	30	<5	29		1.7	7.8	39.2	70
8-23	MLT				107	15	1	2	125	3			2.5	7.7	-	-
1968																
7-15	MLT				95	60	1	5	161	<5	<10		0.2	7.8	40.6	83
9-13	MLT				61	63	<1	<1	124	<1	<2		1.1	7.7	41.8	82
9-13	SLT[b]		-		29	45	<1	1	75	<1	3		0.5	7.7	-	81
10- 4	MLT				175	48	<1	4	227	<1	<2		2.0	7.7	41.8	83
10- 4	SLT				125	29	<1	2	156	<1	2		1.7	7.7	42.6	83
11- 8	MLT				225	34	<1	4	263	<1	3		2.3	7.5	41.6	83
11- 8	SLT				325	41	<1	4	370	<1	5		2.3	7.5	41.4	84
12-12	MLT				150	20	2	4	176	<1	11		1.2	7.7	31.6	89
12-12	SLT				200	<5	3	5	208	4	8		1.5	7.7	35.8	88
1969																
1- 3	MLT				<5	20	6	1	30	<1	1		1.8	7.7	41.3	75
1- 4	SLT			-	75	50	5	1	131	<1	<1		1.8	7.6	40.7	77
2- 4	MLT			<1	<5	9	6	15	32	5	5		1.5	7.9	42.0	75
2- 4	SLT			<1	56	20	5	12	93	9	18	-	2.3	8.0	43.3	83
3- 6	SLT			<1	87	13	<1	10	110	1	5	10.0	2.6	8.1	43.2	83
3-15	MLT			<1	86	32	<1	8	126	<1	<1	11.9	1.4	7.7	40.8	78
4- 1	SLT			<1	82	62	8	17	169	3	6	11.9	3.8	7.5	40.2	85
5- 6	MLT			14[c]	40	16	3	2	61	4	5	10.0	1.8	7.6	41.8	70
5- 6	SLT			11[c]	75	<5	3	4	84	5	6	8.4	1.7	7.3	36.5	63
6- 4	SLT			-	60	<5	3	7	72	<1	22	7.8	1.3	7.6	41.0	90
6- 9	MLT				75	<5	6	<1	84	2	4	9.5	1.8	7.5	39.9	76
7- 1	MLT				34	10	6	1	51	2	7	9.0	1.4	7.6	40.3	84
7- 1	SLT			-	30	15	5	6	56	4	9	9.3	1.5	7.4	40.3	84
8- 5	MLT			21	162	25	2	3	192	2	9	9.8	1.4	7.7	38.6	86
8- 5	SLT			<1	198	30	1	4	233	3	9	10.3	1.4	7.7	37.9	81
9-10	MLT				130	36	2	10	178	4	9	7.9	1.5	7.9	41.6	82
9-10	SLT			-	165	30	2	15	212	3	6	7.0	1.5	8.0	42.0	80
10- 6	MLT			6	125	5	2	17	149	6	12	8.6	1.3	7.8	41.8	77
10- 6	SLT			4	132	26	3	20	181	6	8	9.5	1.4	7.9	40.6	80
11- 4	MLT				98	16	6	2	122	7	7	8.7	1.2	7.7	42.3	86
11- 6	SLT				244	30	6	2	282	4	7	8.7	1.4	7.6	41.8	88
12-12	SLT				84	10	4	<1	98	5	9	9.5	0.8	7.7	42.4	72
12-14	MLT				<5	40	3	<1	44	37	38	7.5	1.0	7.5	35.9	76
1970																
1- 6	SLT				74	8	2	7	91	6	13	9.1	2.2	7.6	42.8	114
1-12	MLT	-			34	20	11	2	67	9	10	10.5	0.6	-	-	-
1-16	SLT	33.06	4.72		457	201	3	177	838	6	16	10.2	2.7	7.3	-	-
2- 4	SLT	-	-		192	32	1	7	232	4	7	9.4	1.2	7.5	40.6	88
2- 6	MLT				118	118	4	5	245	2	9	9.5	1.2	7.2	39.2	82
2- 9	SLT	-			58	42	3	6	109	2	12	9.6	1.5	7.3	40.2	84
3- 9	SLT	3.37			98	30	1	5	134	6	14	9.5	2.3	7.7	42.2	89
3-12	SLT	0.31	0.31		106	16	<1	5	128	4	7	11.6	1.7	-	-	-
3-12	MLT	-	-		82	22	1	6	111	4	6	10.3	1.0	7.7	40.4	84
3-25	SLT	1.20	0.40		38	9	1	1	49	3	3	9.8	0.5	7.5	39.4	90
3-30	SLT	1.41	0.50		82	23	1	3	109	1	3	9.5	1.1	7.4	38.2	95
4- 9	SLT	0.62	0.46		50	25	3	4	82	4	7	9.2	1.3	7.4	39.2	91
4-17	MLT	-	-		22	6	6	<1	34	3	4	9.3	1.0	7.5	44.1	93
4-20	SLT	0.74	0.51		106	12	7	12	137	3	7	8.9	1.2	7.4	42.9	90
4-22	SLT	-	-		14	34	2	8	58	3	6	-	1.0	7.1	37.8	110
5- 6	SLT	0.80	0.58		142	40	4	6	192	5	13	8.5	1.2	7.4	39.4	94
5- 6	MLT		-		79	19	3	17	118	3	12	8.9	1.5	7.3	38.5	100
5-11	SLT	14.78	2.20		110	10	3	10	133	3	44	8.2	2.2	7.2	38.2	87
5-14	SLT	2.83	0.66		50	4	2	3	59	3	14	9.0	1.5	7.2	36.8	89
5-21	SLT	0.53	0.45		91	30	5	8	134	10	13	8.4	1.5	-	-	97
6- 1	SLT	-			187	41	2	12	242	4	7	9.0	1.2	7.5	38.0	75
6- 1	MLT		-		94	49	3	22	168	1	4	9.5	1.2	7.4	37.2	75
6- 2	SLT	0.53	0.42		130	44	2	8	184	3	7	8.6	1.3	7.5	38.0	95
6-10	SLT	1.31	0.39		77	22	2	13	114	4	5	8.9	1.3	7.5	39.1	81
6-19	SLT	0.60	0.36		142	58	7	12	226	2	6	9.2	1.2	7.1	38.2	81
6-23	SLT	0.98	0.64		211	44	<1	9	264	1	7	8.5	1.9	7.5	39.5	89
6-29	MLT	0.14	0.11		67	86	4	<1	158	1	7	9.4	0.8	7.2	38.0	91
6-29	SLT	-	-		82	61	2	5	150	2	7	8.7	2.0	7.2	37.6	88
7- 7	SLT	0.74	0.65		89	6	2	1	98	4	10	9.0	0.7	7.6	39.7	86
7-20	SLT	0.88	0.70		41	106	2	3	152	2	5	9.5	1.2	7.5	38.6	97
7-21	SLT	5.53	1.09	-	100	20	<1	4	124	4	11	8.5	1.1	7.7	38.4	86
8- 4	SLT	1.07	0.51	0.7	192	58	<1	<1	250	2	4	8.7	1.5	7.4	38.4	99
8- 4	MLT	0.10	0.10		112	68	4	4	188	7	10	9.5	0.8	7.5	45.0	99
8-26	MLT	0.29	0.20	4.8	103	62	3	2	170	3	4	9.3	0.9	7.6	42.5	90
8-26	SLT	0.61	0.22	2.8	38	52	2	1	93	<1	4	9.7	1.0	7.6	42.7	91
9-29	MLT	0.18	0.18	0.4	121	51	3	5	180	2	10	9.3	0.8	7.6	41.4	91
9-29	SLT	0.37	0.30	4.5	111	42	2	4	159	<1	7	9.5	1.3	7.6	41.8	97
10-15	MLT	-	-	-	50	35	6	1	92	<1	6	10.3	1.4	7.4	47.8	95
11- 2	MLT	0.24	0.21	2.0	434	34	<1	2	470	2	6	10.7	1.5	7.4	41.7	90
11- 2	SLT	0.40	0.26	-	35	35	1	<1	72	1	7	10.3	1.7	7.4	42.5	92
11-23	MLT	0.21	0.21	0.4	68	62	2	2	134	3	10	11.3	1.6	7.4	43.9	93
11-23	SLT	2.76	0.76	9.1	25	67	2	8	102	4	13	10.9	1.4	7.3	45.8	95

[a] Mid-Lake Tahoe.

[b] Shore Lake Tahoe - samples from U. S. Coast Guard Pier.

[c] Malfunctioning equipment.

TABLE D-2

MAXIMUM GROWTH RATES AND MAXIMUM CELL CONCENTRATIONS ATTAINED AT THE END OF FIVE DAYS IN FLASK CULTURE OF LAKE TAHOE WATER

Sampling Date	Maximum Growth Rate ($\hat{\mu}_b$, day^{-1})		Maximum Growth Rate ($\hat{\mu}_{b\ell}$, day^{-1})		Maximum Cell Concentration ($\hat{X}_S$, $cells/mm^3$)	
	Mid-Lake Sample	Near Shore Sample	Mid-Lake Sample	Near Shore Sample	Mid-Lake Sample	Near Shore Sample
6- 6-67[a]		0.05[a]				
10-16-67		0.17				128
10-31-67		0.22				108
11-14-67		0.17				79
12-11-67		0.21				48
12-12-67		0.38				73
1-23-68		0.22				13
2- 6-68		0.27				95
2- 7-68		0.35				96
2-19-68		0.24				80
3- 5-68		0.26				199
3-30-68		0.32				201
4- 1-68		0.46				161
4- 2-68		0.46				294
4- 4-68		0.43				259
4- 5-68		0.42				206
4-13-68		0.41				210
4-17-68		0.56				304
4-18-68		0.47				271
6-15-68	0.428	0.454	0.278	0.255	274.8	255.4
7-15-68	0.510	0.302	0.293	0.223	194.2	151.6
8- 9-68	0.550		0.293		168.2	
9-13-68	0.512	0.324	0.378	0.336	230.4	195.6
10- 4-68	0.330	0.634	0.049	0.247	62.4	126.0
11- 8-68	0.350	0.562	0.199		119.8	144.2
12- 3-68	0.796	0.368	0.548	0.207	168.6	37.8
1- 3-69	0.270	0.372	0.140	0.231	69.0	104.0
2- 4-69	0.203	0.633	0.149	0.360	54.4	147.6
2- 6-69		0.379		0.318		162.6
3-15-69	0.470		0.361		185.2	
4- 1-69		0.517		0.349	-	181.8
5- 6-69	0.227	0.640	0.119	0.350	96.4	223.0
6- 4-69		0.444		0.220		102.6
6- 9-69	0.205		0.070		69.2	
7- 1-69	0.406	0.446	0.279	0.290	129.4	133.7
7- 1-69[b]	0.069	0.135	0.046	0.116	65.8	90.0
8- 5-69	0.055	0.209	0.043	0.110	61.5	97.5
9-10-69	0.386	0.363	0.262	0.153	219.3	136.1
10- 6-69[c]	0.348	0.249	0.192	0.175	99.5	102.3
11- 6-69	0.579	0.571	0.310	0.349	203.4	263.9
12-12-69	-	0.236		0.160		201.1
12-14-69	0.217	0.242	0.168	0.168	133.4	139.7
1-12-70	0.188	0.224	0.130	0.169	121.0	129.0
2- 6-70	0.329		0.305		178.0	
2- 9-70		0.337		0.283		149.7
3- 9-70	0.356		0.227		157.3	
3-12-70		0.328		0.214		156.2
5- 5-70	0.053				65.9	
5-21-70		0.136		0.114		120.1
6- 1-70	0.304	0.177	0.264	0.066	164.5	79.5
6- 2-70		0.151		0.087		79.1
6-29-70	0.285	0.323	0.216	0.221	177.1	150.9
7- 7-70		0.211		0.140		92.3
8- 4-70	0.068	0.289	0.053	0.201	70.0	144.5
8-26-70	0.256	0.260	0.192	0.165	126.5	112.9
9-29-70	0.147	0.152	0.106	0.121	104.5	136.9
10-15-70	0.165		0.052		57.2	
11- 2-70	0.265	0.127	0.152	0.085	126.0	90.5
11-23-70	0.171	0.246	0.006	0.017	56.7	59.6

[a] *Selenastrum gracile* used as test organism.

[b] *Selenastrum capricornutum* substituted for *S. gracile* at this sampling date.

[c] Sample date 10-6-69 cultures were seeded with *Chlorella* contaminated *S. capricornutum.*

TABLE D-3

CREEK WATER ANALYSES

Date	Creek Name	Unfiltered Samples			0.45 µ Millipore Filtered Samples												
		Susp. Solids	Vol. Susp. Solids	COD	Nitrogen as N					Phosphorus as P		Ca	Cl	Fe	pH	Alk. as $CaCO_3$	Cond. (10^{-6})
					Organic	NH_3	NO_2	NO_3	Total	PO_4	Total						
		mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	mg/l	mg/l	µg/l		mg/l	mhos
1967 5-20	Ward[a]			10	350	20	5	62	437	<5	9		0.9	-	7.5	19.0	42
	Incline			15	400	110	5	6	521	<5	43		0.5	150	7.6	29.0	42
6-17	Ward			10	30	60	2	21	113	12	27		0.7	<100	6.6	12.0	32
	Incline			23	70	5	3	54	132	20	45		0.7	200	7.3	17.0	38
7-19	Ward				110	40	3	10	163	<5	103		0.7	200	7.4	24.0	40
8-27	Ward			10	130	20	<1	<1	151	<5	28		0.3	400	7.6	28.2	44
	Incline			15	400	110	5	6	521	<5	43		0.5	2400	7.6	29.0	42
12-12	Incline				200	90	2	13	305	30	60		9.9	180	7.6	28.4	47
1968 1-20	Tr. Tr.[a]			45	120	200	4	90	414	40	80	-	3.0	150	7.0	23.0	53
2-24	Tr. Tr.			52	220	70	6	99	395	50	73		2.4	10	6.6	12.0	32
6-19	Tr. Tr.			1	220	330	18	180	748	360	710		1.9	225	7.3	17.7	45
6-24	Ward			8	150	142	<1	15	307	10	30		0.7	10	7.6	18.2	38
	Incline			20	60	55	<1	25	140	20	50		2.4	370	7.7	26.0	50
8-23	Tr. Tr.			4	800	192	<1	7	999	5	28		1.5	25	7.6	34.0	45
9- 3	Ward			<1	150	114	<1	16	264	8	37		0.3	10	7.5	36.2	63
9- 4	Incline			<1	100	153	3	27	283	23	88		0.5	380	7.6	38.0	60
10- 3	Ward				120	<5	<1	3	123	20	23		0.4	10	7.8	40.0	73
	Incline			·	170	138	4	7	319	34	42		0.9	380	7.6	36.0	79
	Tr. Tr.			5	175	27	<1	4	206	17	31		3.7	50	7.5	33.0	73
11- 4	Ward				387	48	1	25	461	24	110		2.3	310	7.3	35.0	70
	Incline				500	40	1	47	688	12	170		4.4	90	7.3	28.0	60
	Tr. Tr.				270	42	<1	110	422	10	21		1.4	10	7.2	24.0	55
12- 3	Ward				200	22	2	53	277	11	18		0.5	126	7.6	22.4	64
	Incline				225	30	3	64	322	3	12		0.9	50	8.2	24.1	62
	Tr. Tr.				125	22	2	4	153	7	24		3.3	9	7.5	15.7	64
1969 1- 3	Ward[a]				20	25	6	29	80	5	9		0.2	<1	7.4	27.4	40
	Incline				110	55	8	51	224	4	10		0.8	168	7.4	31.9	39
	Tr. Tr.[b]				155	95	8	54	312	37	44		2.9	125	7.3	23.1	44
2- 4	Ward			<1	33	9	5	26	73	8	12		0.5	15	7.6	26.6	44
	Incline			<1	310	650	73	427	1460	900	980		6.8	154	7.8	35.3	95
	Tr. Tr.[b]			1	55	47	9	79	190	15	40		3.9	170	7.3	22.2	47
3- 4	Ward			<1	82	8	<1	13	104	8	18	7.5	0.3	<1	7.9	27.4	46
	Incline			<1	125	31	<1	78	234	24	33	8.4	1.8	140	8.0	35.8	70
	Tr. Tr.[b]			<1	135	31	3	111	280	10	23	8.4	4.8	154	7.9	33.1	70
4- 1	Ward			<1	30	70	7	39	146	3	4	7.5	0.4	<1	7.4	23.6	43
	Incline			<1	400	520	35	277	1232	148	154	8.4	3.8	106	7.4	27.4	45
	Tr. Tr.			<1	150	134	11	31	326	4	7	6.5	3.2	76	7.2	15.4	46
5- 6	Ward			[f]	75	<5	3	21	102	7	8	6.2	1.0		7.1	21.0	39
	Incline			16[c]	140	31	4	74	249	22	28	5.2	1.2		7.2	20.1	36
	Tr. Tr.			2[c]	135	10	4	34	183	5	9	3.8	2.9		7.2	14.2	33
6- 4	Ward			35[c]	105	<5	4	20	132	3	17	3.6	0.2	5	7.2	15.0	33
	Incline			78[c]	33	30	4	29	96	9	25	3.3	0.4	47	7.2	17.6	37
	Tr. Tr.			91[c]	112	41	4	5	162	2	11	2.0	0.8	20	6.9	9.0	24
7- 1	Ward			-	24	9	5	10	48	3	35	5.0	0.4	<1	7.0	17.7	41
	Incline			7	24	<5	5	23	54	15	26	5.0	0.6	73	7.0	20.2	41
	Tr. Tr.			28	50	14	3	11	78	3	13	2.6	0.9	8	6.8	11.9	30
8- 5	Ward			<1	115	30	2	7	154	9	24	5.8	0.4	<1	7.4	23.0	44
	Incline			13	182	19	3	97	301	26	43	5.0	0.6	54	7.4	24.3	50
	Tr. Tr.[d]			5	261	45	2	40	348	9	22	12.6	1.8	14	7.2	18.1	43
8- 8	Incline A[e]	1.62	0.85	3	231	75	3	41	350	6	35	4.9	0.8	103	7.5	19.5	39
	Incline B	72.05	14.34	4	181	64	3	43	291	16	48	9.9	0.6	47	7.8	43.1	70
	Incline C	46.85	9.60	4	184	79	3	25	289	21	74	5.9	0.4	140	7.6	27.8	44
9-10	Ward	0.68	0.64		60	36	2	18	116	12	16	6.6	0.3	<1	7.8	35.2	54
	Incline	34.04	10.23		256	162	3	181	602	15	75	4.9	1.8	170	7.7	30.0	58
	Tr. Tr.	2.22	1.50		856	59	3	51	969	4	140	4.4	3.2	48	7.5	27.0	48
10- 2	Ward	0.42	0.42	<1	146	19	2	7	174	14	22	8.5	1.6	5	7.9	37.6	75
	Incline	21.85	4.50	<1	548	37	3	21	609	7	15	6.3	1.2	137	7.7	30.9	61
	Tr. Tr.	2.04	1.26	11	222	10	3	61	296	5	7	6.5	2.9	70	7.8	29.6	70
11- 4	Ward	0.66	0.53		149	30	3	17	199	24	29	7.8	0.8	30	7.6	34.4	70
	Incline	7.55	1.87		237	13	1	17	268	12	22	6.6	1.0	177	7.5	31.2	62
	Tr. Tr.	2.66	2.11		252	21	4	58	335	6	17	7.0	2.3	77	7.5	30.1	66
12- 4	Ward	-	-	15	179	14	<1	4	197	13	18	8.5	0.5	2	7.5		63
	Incline	18.06	5.13	10	118	40	<1	25	184	13	18	5.8	0.4	126	7.0		50
	Tr. Tr.	13.40	4.79	<1	208	60	2	93	363	7	13	5.5	3.2	45	6.9		57

TABLE D-3 (Continued)

Date	Creek Name	Unfiltered Samples			0.45 µ Millipore Filtered Samples												
		Susp. Solids	Vol. Susp. Solids	COD	Nitrogen as N					Phosphorus as P		Ca	Cl	Fe	pH	Alk. as $CaCO_3$	Cond. (10^{-6})
					Organic	NH_3	NO_2	NO_3	Total	PO_4	Total						
		mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	mg/l	mg/l	µg/l		mg/l	mhos
1970 1-5	Ward	0.37	0.23		45	100	3	32	180	10	15	6.0	0.6	<1	7.3	24.0	48
	Incline	26.34	5.05		352	75	4	87	518	17	25	7.0	1.6	32	7.3	31.7	64
	Tr. Tr.	2.21	0.88		57	59	3	97	216	7	13	5.0	3.8	76	7.2	20.7	54
1-28	Ward				162	46	4	22	234	15	19	5.5	0.2		7.0	19.0	39
	Incline				448	83	7	3	541	25	29	7.5	1.1		7.1	29.4	52
	Tr. Tr.				364	101	5	67	537	10	14	3.5	2.6		6.7	12.3	28
2-10	Ward				94	17	4	10	125	12	33	5.2	0.3	2	7.2	21.0	46
	Incline				386	119	6	92	603	19	51	7.7	0.5	191	7.2	31.6	67
	Tr. Tr.				380	33	5	80	498	12	28	4.4	2.6	35	7.1	17.3	46
2-23	Ward				53	46	1	5	105	12	21	6.7	0.3		7.3	22.4	40
	Incline				500	83	8	130	721	44	101	7.9	0.9		7.0	31.9	54
	Tr. Tr.				211	101	3	78	393	9	25	5.4	2.1		6.9	19.2	42
4-29	Ward	1.91	1.02		25	33	1	30	89	8	12	6.2	0.4	9	7.0	21.4	53
	Incline	11.44	2.77		170	536	8	34	748	10	30	5.6	1.2	41	7.0	28.9	46
	Tr. Tr.	2.12	0.63		125	61	3	59	248	4	9	4.6	2.5	203	6.9	15.2	55
5-14	Incline A				139	36	2	54	231	6	19	3.5	0.4	55	6.7	15.8	41
	Incline B				151	48	3	53	255	7	24	3.7	0.3	157	6.7	16.0	43
	Incline C				177	48	3	42	270	8	22	5.5	0.6	157	6.8	22.8	45
5-25	Ward	4.46	1.23		139	25	2	22	188	2	4	4.5	0.2	21	7.3	14.6	29
	Incline	8.20	2.32		208	12	3	27	250	9	15	3.9	0.7	23	7.0	16.6	40
	Tr. Tr.	5.22	1.41		194	24	3	21	242	2	6	2.2	0.5	95	7.1	8.2	21
6-4	Ward	2.62	0.95		118	32	8	16	174	7	13	3.8	0.4	17	7.0	13.6	34
	Incline	18.11	3.32		390	78	9	28	505	21	29	4.0	0.4	79	7.1	16.4	42
	Tr. Tr.	3.17	0.90		304	64	5	11	384	10	15	1.9	0.4	19	6.7	7.8	24
6-16	Ward	1.62	0.53	2.3	156	65	2	10	233	4	9	3.5	0.6	11	6.9	14.2	37
	Incline	6.79	1.42	2.4	184	50	2	6	242	7	16	4.1	0.4	125	7.0	18.1	38
	Tr. Tr.	3.49	1.13	23.2	211	46	1	14	272	2	7	2.6	0.5	27	6.7	10.6	38
6-23	Ward	1.55	0.57	4.3	74	2	3	4	83	6	16	3.9	0.4	11	7.0	15.9	46
	Incline	7.18	2.23	5.8	34	17	5	12	68	15	27	4.2	0.3	163	7.1	20.4	63
	Tr. Tr.	3.29	1.46	<0.1	130	20	4	11	165	2	14	2.0	0.7	25	6.8	9.4	25
7-1	Ward	1.15	0.49	1.6	56	86	<1	2	144	8	25	4.8	0.4	9	6.9	19.0	43
	Incline	91.32	25.28	8.4	323	174	3	47	547	36	54	4.7	0.7	143	7.1	21.2	54
	Tr. Tr.	5.03	1.26	2.8	142	64	<1	8	214	5	14	2.9	0.7	30	6.9	12.6	40
7-14	Ward	0.64	0.36	8.5	33	29	<1	<1	62	10	29	5.6	0.2	7	7.2	20.0	55
	Incline	26.71	7.64	5.4	70	64	<1	8	142	13	17	5.0	0.4	160	7.2	23.4	54
	Tr. Tr.	3.88	2.07	20.8	130	48	<1	8	186	9	20	3.5	1.1	89	7.1	15.4	51
	General[a]	0.35	0.32	0.8	70	20	<1	6	96	11	25	5.2	0.3	20	7.2	19.2	47
7-30	Ward	0.36	0.18	5.8	84	88	<1	12	184	14	21	7.0	0.3	9	7.3	26.8	77
	Incline	58.30	15.00	22.7	258	44	3	11	316	21	31	5.5	0.3	127	7.2	24.0	63
	Tr. Tr.	2.49	0.91	4.0	178	73	<1	22	274	10	17	4.8	1.1	61	7.1	19.0	58
	General	0.53	0.28	7.9	53	31	<1	4	88	13	17	6.3	0.2	19	7.2	23.6	57
8-7	Ward	2.33	0.55	3.9	100	49	6	8	163	6	25	7.5	0.4	7	7.4	28.2	88
	Incline	16.30	3.67	2.8	134	38	6	23	201	7	21	6.3	0.7	142	7.4	26.8	63
	Tr. Tr.	3.01	1.51	3.2	160	58	6	6	230	2	11	5.3	1.6	42	7.2	22.2	69
	General	1.70	0.85	2.5	89	44	5	2	140	5	20	6.1	0.4	27	7.4	24.4	56
8-14	Ward	0.80	0.40	5.6	62	13	<1	9	84	14	20	7.8	0.2	4	7.4	34.1	81
	Incline	26.97	4.17	6.9	280	58	3	20	361	19	35	6.2	0.4	163	7.4	31.9	85
	Tr. Tr.	4.28	2.09	10.1	218	43	2	6	269	10	19	4.3	1.4	88	7.1	23.0	59
	General	0.38	0.36	4.9	17	16	<1	<1	34	12	17	6.6	0.2	17	7.3	29.3	97
8-27	Ward	0.55	0.25	5.4	<1	26	4	6	36	13	25	8.5	0.8	21	7.4	37.3	68
	Incline	21.57	4.46	6.8	175	46	4	14	239	20	106	5.9	0.4	215	7.3	30.7	56
	Tr. Tr.	4.34	1.57	7.8	151	53	4	10	218	6	15	5.4	2.7	82	7.1	27.5	59
	General	0.34	0.24	5.4	12	34	3	5	54	13	35	6.9	0.6	31	7.2	29.6	56
9-2	Ward	0.75	0.32	5.5	344	30	<1	3	378	15	56	8.5	0.1	12	7.2	34.9	92
	Incline	21.65	4.49	2.1	136	12	6	14	168	15	32	6.1	0.5	192	6.9	29.5	65
	Tr. Tr.	4.76	1.63	5.8	412	25	6	23	466	6	9	5.8	1.6	79	7.0	21.9	72
	General	0.61	0.43	3.1	43	<1	<1	<1	44	14	23	6.5	0.4	24	7.0	28.1	61
9-17	Ward	0.51	0.31	<0.1	20	38	5	7	70	14	23	9.5	0.1	3	7.4	38.9	81
	Incline	27.76	5.46	7.8	258	66	5	21	350	22	88	7.5	2.0	54	7.3	31.6	79
	Tr. Tr.	2.22	0.73	4.2	348	77	5	11	441	15	15	6.6	0.5	123	7.3	30.5	66
	General	0.28	0.19	5.5	5	44	5	2	56	14	15	7.4	0.3	12	7.2	30.5	62
9-23	Ward	1.02	0.53	<0.1	76	36	6	1	119	13	32	9.2	0.2		7.6	42.2	78
	Incline	9.17	2.44	7.3	217	73	4	7	301	16	44	6.7	0.4		7.4	31.3	67
	Tr. Tr.	1.69	1.00	3.6	150	64	3	34	251	4	13	6.9	2.5		7.4	31.3	76
	General	0.44	0.34	<0.1	68	64	3	2	137	14	29	7.3	0.3		7.3	29.8	60
10-1	Ward	0.43	0.35	3.2	33	50	2	3	88	10	24	9.1	0.3		7.6	38.6	77
	Incline	10.96	2.98	6.9	146	58	2	2	208	10	38	7.5	0.2		7.1	41.4	67
	Tr. Tr.	1.52	0.62	4.9	92	53	1	39	185	<1	22	7.4	3.3		7.0	32.7	75
	General	0.29	0.24	5.7	5	54	1	1	61	10	26	7.1	0.3		7.0	35.5	59
10-7	Ward	1.02	0.43	0.8	-	36	1	1		10	24	9.5	0.1		7.3	39.2	86
	Incline	10.78	2.27	3.7	91	14	3	2	110	6	34	7.2	0.3		7.2	33.5	67
	Tr. Tr.	1.85	0.56	1.6	-	18	3	58		<1	7	7.7	4.0		7.3	12.7	84
	General	0.49	0.31	1.6		28	<1	<1		12	23	7.3	0.2		7.1	30.5	64

TABLE D-3 (Continued)

Date	Creek Name	Unfiltered Samples			0.45 μ Millipore Filtered Samples												
		Susp. Solids	Vol. Susp. Solids	COD	Nitrogen as N					Phosphorus as P		Ca	Cl	Fe	pH	Alk. as $CaCO_3$	Cond. (10^{-6})
					Organic	NH_3	NO_2	NO_3	Total	PO_4	Total						
		mg/l	mg/l	mg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	mg/l	mg/l	μg/l		mg/l	mhos
10-14	Ward	0.30	0.30	1.2	76	42	9	10	137	13	34	9.4	0.1		7.4	41.0	72
	Incline	5.68	1.52	4.9	129	59	4	13	205	6	21	7.5	0.5		7.3	35.5	71
	Tr. Tr.	2.50	0.76	4.9	91	72	4	53	220	<1	13	7.5	3.9		7.2	31.6	73
	General	0.27	0.27	2.9	94	58	3	8	163	11	24	7.2	0.3		7.1	29.3	55
10-22	Ward	0.64	0.29	3.2	56	52	5	6	119	22	42	9.3	0.3		7.2	36.3	77
	Incline	3.89	1.04	3.2	63	20	5	5	93	10	15	7.0	0.8		7.2	30.9	66
	Tr. Tr.	2.21	0.80	4.8	76	23	5	33	137	6	11	7.2	4.0		7.0	28.3	73
	General	0.35	0.22	3.6	76	28	6	7	117	14	20	8.2	0.9		7.0	28.8	72
10-28	Ward	3.43	1.35	2.4	46	38	<1	<1	84	18	51	9.6	0.7		7.0	36.1	80
	Incline	16.75	3.72	6.4	84	37	<1	<1	122	8	30	7.0	1.0		6.8	28.1	81
	Tr. Tr.	1.35	0.52	11.1	112	42	<1	34	188	6	29	8.2	8.0		6.8	24.0	84
	General	0.24	0.23	3.2	50	58	<1	<1	108	15	41	8.2	0.9		6.9	28.4	66
11- 3	Ward	0.37	0.30	2.0	326	46	4	5	381	16	18	9.4	0.3		6.8	30.1	64
	Incline	4.27	1.13	6.4	68	32	7	10	117	10	10	6.9	0.5		7.1	30.3	55
	Tr. Tr.	1.32	0.52	3.2	194	28	5	40	267	8	10	7.3	5.1		7.0	30.5	61
	General	1.40	0.97	4.0	354	16	3	6	379	15	19	8.1	0.6		6.6	24.1	51
11-11	Ward	0.51	0.35	<0.1	44	28	11	33	116	16	34	8.2	0.5		7.4	28.0	62
	Incline	8.42	1.04	0.8	82	15	3	7	107	17	27	7.3	1.2		7.4	32.9	65
	Tr. Tr.	4.71	1.16	5.3	82	23	4	57	166	6	14	6.5	3.5		7.3	25.0	66
	General	0.35	0.31	1.9	64	22	3	4	93	13	21	8.1	0.3		7.2	29.0	61
11-18	Ward	0.46	0.40	4.0	127	53	4	7	191	15	25	7.8	0.5		7.1	28.3	60
	Incline	4.17	1.28	4.4	84	50	5	22	161	12	27	7.1	0.6		7.0	31.1	61
	Tr. Tr.	2.11	0.80	4.0	116	56	4	57	233	8	25	7.0	3.3		6.8	27.9	68
	General	0.54	0.49	4.4	80	44	5	2	131	16	24	7.0	0.5		7.0	27.6	53
11-24	Ward	0.61	0.54	2.7	18	9	4	4	35	16	33	7.4	0.5		7.1	29.5	60
	Incline	18.91	4.50	5.8	168	37	5	20	230	14	38	6.9	0.9		7.1	33.2	64
	Tr. Tr.	4.62	2.60	6.6	180	28	3	52	263	12	29	6.7	3.2		7.1	28.1	66
	General	0.63	0.63	3.4	30	40	3	5	78	13	30	7.0	0.4		7.1	28.4	57
12-15	Ward	0.31		2.3	50	24	9	16	98	15	15	7.4	0.7		7.1	28.3	60
	Incline	4.64	1.19	3.8	82	43	6	53	184	14	15	7.9	0.7		7.4	35.2	68
	Tr. Tr.	4.83	1.65	10.2	157	50	5	66	278	14	14	5.9	2.3		7.1	23.6	58
	General			11.0	88	<1	8	10	106	11	11	4.5	0.5		6.9	17.3	37

[a]Sampling point location: Ward — Ward Creek — upstream side of bridge on Highway 89.
Incline — Incline Creek — approximately 150 ft upstream from bridge on Lakeshore Boulevard (old Highway 28).
Tr. Tr. — Upper Truckee-Trout River — downstream from the confluence of the Upper Truckee River and Trout Creek across from the Marina of the Tahoe Keys Development.
General — upstream side of bridge on Highway 89.

[b]Marina frozen.

[c]Results questionable due to equipment malfunctioning.

[d]New earth movement operations opened up a new channel for the Marina and also constructed a dike separating the Marina from the sampling point. Therefore, the samples now not influenced by the Marina.

[e]Sampling point location: A — above Incline Village in an undeveloped and undisturbed area.
B — below an area under construction at the time the sample was collected.
C — regular sampling point.

TABLE D-4

MAXIMUM GROWTH RATES, $\hat{\mu}_b$, $\hat{\mu}_{b\ell}$, AND MAXIMUM CELL CONCENTRATIONS, $\hat{X}_5$, FLASK ASSAY OF CREEK WATERS

Sampling Date	Source of Sample											
	Ward Creek			Incline Creek			Truckee-Trout Creek			General Creek		
	$\hat{\mu}_b$ day^{-1}	$\hat{\mu}_{b\ell}$ day^{-1}	$\hat{X}_5$ $cells/mm^3$	$\hat{\mu}_b$ day^{-1}	$\hat{\mu}_{b\ell}$ day^{-1}	$\hat{X}_5$ $cells/mm^3$	$\hat{\mu}_b$ day^{-1}	$\hat{\mu}_{b\ell}$ day^{-1}	$\hat{X}_5$ $cells/mm^3$	$\hat{\mu}_b$ day^{-1}	$\hat{\mu}_{b\ell}$ day^{-1}	$\hat{X}_5$ $cells/mm^3$
1968												
6-19[a]		-	..	-	-		0.520	0.322	330.2			
6-24	0.318	0.166	155.4	0.508	0.307	294.6						
8-23	-		-				0.450	0.432	433.6			
9- 3	0.512	0.329	209.8			-						
9- 4	-			0.758	0.495	448.4				-		
10- 3	0.192	0.039	57.2	0.590	0.307	191.6	0.738	0.336	200.0			
11- 4	0.926	0.432	290.6	0.842	0.438	325.6	0.824	0.432	334.2			
12- 3	0.536	0.336	92.0	0.628	0.495	216.6	0.694	0.519	153.2	-		
1969												
1- 3	0.395	0.289	155.0	0.528	0.250	155.4	0.653	0.451	365.2			
2- 4	0.649	0.463	181.2	1.168	0.962	1812.8	0.769	0.683	1072.0			
3- 4	0.701	0.335	189.6	0.654	0.368	395.2	0.548	0.343	264.6			
4- 1	0.606	0.377	162.0	0.880	0.769	974.0	0.432	0.264	140.4		-	
5- 6	0.470	0.254	185.8	0.677	0.423	382.8	0.433	0.277	249.8		-	-
6- 4	0.513	0.246	107.8	0.639	0.364	129.6	0.569	0.447	242.2			
7- 1	0.451	0.255	127.0	0.550	0.331	171.8	0.488	0.299	156.2			
8- 5[b]	0.567	0.292	236.5	0.585	0.327	272.2	0.219	0.107	103.0			
8- 8[c]				0.379	0.276	213.6						
8- 8[d]				0.705	0.445	502.6						
8- 8[e]				0.519	0.307	396.2						
9-10	0.635	0.371	315.9	0.694	0.509	1092.0	0.601	0.377	524.8			
10- 2	0.736	0.451	282.4	0.598	0.323	177.4	0.910	0.495	411.4			
11- 6	0.468	0.410	273.7	0.473	0.325	263.0	0.540	0.337	220.8			
12-14	0.280	0.190	154.9				0.340	0.162	155.0			
1970												
1-28	0.332	0.221	159.5				0.340	0.162	155.0			-
2- 6	0.606	0.413	247.3	0.431	0.338	208.8	0.495	0.305	204.2			
2-23	0.302	0.222	169.5	1.033	0.663	2134.8	0.453	0.286	364.2		-	
4-29	0.131	0.084	100.6	0.166	0.087	125.2	0.093	0.049	108.6			-
5-25	0.350	0.228	141.6	0.711	0.405	288.1	0.333	0.222	143.1	-		
6- 4	0.450	0.255	179.5	0.552	0.387	625.6	0.316	0.246	185.1			-
7- 1	0.173	0.081	115.7	0.496	0.347	283.7	0.378	0.250	262.9			
7-14	0.285	0.213	131.3	0.526	0.290	171.1	0.433	0.366	234.0	0.417	0.274	154.1
7-30	0.361	0.247	171.9	0.490	0.318	207.9	0.420	0.242	148.9	0.261	0.178	115.6
8- 7		-		0.224	0.174	129.1	0.237	0.175	110.9	0.407	0.257	144.4
8-14	0.381	0.302	179.2	0.363	0.241	130.0	0.356	0.233	129.3	0.394	0.250	159.6
8-27	0.224	0.103	69.3	0.344	0.187	130.0	0.355	0.128	162.3	0.165	0.114	74.4
9- 2	0.328	0.168	77.2	0.361	0.157	74.1	0.247	0.135	72.7	0.563	0.276	110.4
9-23	0.224	0.148	135.2	0.181	0.133	130.5	[illegible]	0.102	147.2	0.263	0.231	164.3
10- 1	0.177	0.102	102.0	0.195	0.064	63.7	0.187	0.085	69.7	0.194	0.102	81.1
10- 7	0.201	0.117	97.5	0.218	0.150	107.6	0.104	0.058	93.1	0.140	0.087	79.2
10-14	0.186	0.079	108.5	0.263	0.146	128.4	0.113	0.061	103.7	0.258	0.103	110.5
10-22	0.424	0.288	161.7	0.272	0.255	115.1	0.470	0.303	146.0	0.589	0.367	202.9
10-28	0.312	0.222	156.5	0.197	0.113	155.9	0.179	0.144	82.9	0.385	0.292	155.7
11- 3	0.450	0.238	174.0	0.187	0.129	120.1	0.440	0.233	178.7	0.240	0.136	128.3
11-11	0.370	0.205	119.1	0.408	0.236	158.7	0.327	0.150	119.2	0.394	0.198	119.9
11-18	0.159	0.126	97.5	0.044	0.014	57.3	0.384	0.161	107.3	0.402	0.176	108.9
11-23	0.194	0.172	110.0	0.177	0.055	72.8	0.169	0.075	72.1	0.164	0.123	87.6
12- 9				0.234	0.227	112.8						
12-15	0.134	0.110	154.3	0.478	0.284	307.7	0.614	0.348	403.5	0.493	0.286	171.9

[a] Selenastrum gracile used as a test organism

[b] Selenastrum capricornutum substituted for S. gracile at this sampling point

[c] Sample collected above Incline Village in undisturbed area

[d] Sample collected below construction zone in Incline Village

[e] Sample collected below golf course (50 yd above Highway 28)

TABLE E-1

BURTON CREEK ANALYSES

Date	Unfiltered Samples				0.45 μ Millipore Filtered Samples									
	Temp °C	DO	Susp. Solids	Volit. SS	Nitrogen as N: Org. N	NH_3	$NO_3 + NO_2$	Tot. N	Phosphorus as P: PO_4	Tot. P	Cl^-	pH	Alk. as $CaCO_3$	Cond. (10^{-6})
		mg/ℓ	mg/ℓ	mg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	mg/ℓ		mg/ℓ	mhos
1/7/70	4.	9.8			98	14	69	181	61	84		8.0		96.
1/28	5.	10.0			175	66	56	297	55	59		7.2		78.
2/10	4.	10.7			8	18	13	39	10	58		7.2		59.
2/23	4.5	9.6			94	38	7	139	10	20		7.0		47.
4/29	4.	11.9			130	62	34	226	12	13		6.9		44.
5/25	11.	8.5			184	75	11	270	7	18		7.2		60.
6/30	13.5	7.6			91	19	11	121	7	15		7.1		80.
7/14	16.5		.89	.56	94	32	19	145	12	27	.28	7.6	36.8	83.
9/2	12.5		2.98	1.06	<1	29	14	44	9	62	.17			99.
10/7	9.		2.36	.88	296	40	6	342	3	19	.24	7.5	65.2	121.
11/3	8.5		.62	.46	331	54	9	394	16	16	.54	6.8	42.2	104.
2/2/71	2.0		.61	.56	25	46	22	93	17	24	.43	6.9	41.5	90.0
Average					127.2	41.1	22.6	191	18.3	34.6	.33			80.1

DOLLAR CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCO_3$	Cond.
11/4/69	6.0	10.8			161	5	12	178	9	19		7.4		76
12/4	2.0	10.2			84	27	6	117	9	12		7.3		72
1/9/70	1.0	10.9				28	37		14	27		7.6		60
1/28	1.0	11.4			160	50	18	228	13	18		7.6		39
2/10	3.0	8.2			86	28	27	141	10	33		7.2		53
2/23	3.0	10.7			122	30	33	185	10	22		7.0		51
4/29	6.5	9.8			218	32	23	273	7	125		7.1		59
5/25	14.0	8.2			136	31	14	181	6	13		6.9		48
6/30	17.0	7.5			142	14	9	165	6	14		7.6		64
7/14	16.0		2.06	1.21	115	44	29	188	8	13	.49	7.6	43.5	91
9/2	12.8		6.79	3.01	36	10	22	68	17	83	.15			87
10/7	7.5		11.58	5.05	68	10	2	80	4	42	.09	7.4	47.8	98
11/3			2.80	1.25	50	52	17	119	10	10	.51	7.2	46.2	88
Average					114.8	27.8	19.2	160.3	9.5	33.2	.31			68.2

WATSON CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCO_3$	Cond.
11/4/69	4.0	11.2			156	17	10	183	6	39		7.4		71
12/4	~0	11.2			136	37	27	200	10	15		7.4		63
1/7/70	0.5	10.9			222	30	75	327	5	23		7.4		58
1/28	0.5	11.5			170	98	82	350	6	16		7.6		47
2/10	4.5	10.6			106	32	59	197	7	19		7.3		56
2/23	2.0	11.2			103	42	52	197	7	12		7.2		51
4/29	5.0	10.1			354	57	25	436	5	42		7.2		65
5/25	13.0	8.6			218	34	15	267	2	10		7.3		35
6/30	16.4	8.1			98	12	9	119	3	21		7.9		127
7/14	14.5		3.24	1.20		64	37		6	10	.49	7.4	32.3	67
9/2	10.3		10.39	2.42	34	<1	89	124	54	98	.23			75
10/7	5.0		3.48	1.22	33	11	2	46	<1	25	.03	7.3	38.2	75
11/3	3.0		26.96	3.18	88	60	17	165	4	5	.68	6.9	34.4	70
Average					143.2	38.0	38.4	217.6	8.9	25.8	.36			66.2

TAHOE VISTA CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCO_3$	Cond.
11/4/69	9.0	10.8			445	31	300	776	92	140		7.4		186
12/4	1.0	11.4			419	66	141	626	45	61		7.2		171
1/7/70	0.5	9.8			520	82	280	882	32	39		7.8		150
1/28	1.0	10.0			400	217	236	853	83	104		7.5		150
2/10	5.5	9.6			407	300	336	1043	141	168		7.2		150
2/23	6.0	9.4			505	287	476	1268	223	242		7.2		142
4/29	12.0	9.3			596	510	180	1286	132	164		7.1		76
5/25	19.0	8.7			386	88	33	507	38	49		7.3		71
6/30	23.0	8.1			264	24	8	296	17	48		7.7		55
Average					438.0	178.3	221.1	837.4	89.2	112.8				127.9

BLACKWOOD CREEK ANALYSES

Date	Temp °C	Unfiltered Samples: DO mg/ℓ	Unfiltered Samples: Susp. Solids mg/ℓ	Unfiltered Samples: Volit. SS mg/ℓ	0.45 µ Millipore Filtered Samples: Nitrogen as N: Org. N µg/ℓ	Nitrogen as N: NH_3 µg/ℓ	Nitrogen as N: $NO_3 + NO_2$ µg/ℓ	Nitrogen as N: Tot. N µg/ℓ	Phosphorus as P: PO_4 µg/ℓ	Phosphorus as P: Tot. P µg/ℓ	Cl^- mg/ℓ	pH	Alk. as $CaCo_3$ mg/ℓ	Cond. (10^{-6}) mhos
11/4/69	5.0	11.5			242	44	52	338	11	55		7.4		67
12/4	~.0	11.1			165	26	3	194	6	9		7.5		63
1/7/70	2.0	11.0			166	34	110	310	8	19				
1/28	1.0	11.0			134	38	80	252	10			7.5		40
2/10	4.0	10.6			106	12	4	122	7	38		7.2		50
2/23	2.5	11.3			38	45	32	115	7	25		7.2		44
4/29	4.0	11.5			96	47	55	198	6	10		7.0		46
5/25	7.8	9.2			86	66	33	185	7	20		7.3		29
6/30	11.0	9.3			36	<1	14	50	3	8		7.4		44
7/14	17.8		.84	.56	50	31	1	82	5	12	.37	7.2	21.0	58
9/2	9.5		.78	.45	109	28	5	142	9	17	.27			89
10/7	5.5		1.32	.42	240	41	<1	281	6	17	.06	7.4	39.4	84
11/3	5.0		.80	.45	300	40	13	353	9	15	.29	6.8	34.6	70
2/2	3.0		.34	.12	8	47	83	138	8	20	.35	6.8	26.8	54
Average					127	35.7	34.7	197	7.2	20.4	.27			56.8

WARD CREEK ANALYSES

Date	Temp °C	DO mg/ℓ	Susp. Solids mg/ℓ	Volit. SS mg/ℓ	Org. N µg/ℓ	NH_3 µg/ℓ	$NO_3 + NO_2$ µg/ℓ	Tot. N µg/ℓ	PO_4 µg/ℓ	Tot. P µg/ℓ	Cl^- mg/ℓ	pH	Alk. as $CaCo_3$ mg/ℓ	Cond. (10^{-6}) mhos
11/4/69	4.0	12.7			149	30	20	199	24	30		7.2		66
12/4	~.0	11.3			179	14	4	197	13	19		7.5		63
1/5/70	1.5				45	100	35	180	10	15		7.3		48
1/28	1.0	10.9			161	46	26	233	15	19		7.6		39
2/10	3.0	10.86			94	17	14	125	12	33		7.2		46
2/23	3.0	10.80			53	40	6	99	12	21		7.3		40
4/29	3.0	13.3			26	33	31	90	8	12		7.0		53
5/25	8.0	13.4			139	25	24	188	2	4		7.3		29
6/23	11.0	8.50			74	2	7	83	6	16		7.4		46
7/14	18.2		0.64	0.36	33	29	4	62	10	29		7.2		20
9/2	12.8		0.75	0.32	344	30	3	377	15	56	.11			92
10/7	7.0		1.02	0.43	215	36	1	252	10	24	.12			86
11/3	4.5		0.37	0.30	326	46	9	381	16	18	.32	6.8	30.1	64
2/2	2.5		1.49	0.85	< 1	<1	16	16	12	42	.25	6.7	26.0	49
Average					131.1	32.0	14.1	177.3	11.8	24.1	.20		28.1	53

LOWER TRUCKEE RIVER ANALYSES

Date	Temp °C	DO mg/ℓ	Susp. Solids mg/ℓ	Volit. SS mg/ℓ	Org. N µg/ℓ	NH_3 µg/ℓ	$NO_3 + NO_2$ µg/ℓ	Tot. N µg/ℓ	PO_4 µg/ℓ	Tot. P µg/ℓ	Cl^- mg/ℓ	pH	Alk. as $CaCo_3$ mg/ℓ	Cond. (10^{-6}) mhos
11/4/69	10.0	10.7			230	12	8	250	10	50		7.4		84
12/4	7.0	9.5			184	19	2	205	4	6		7.5		83
1/7/70	4.5	10.7			103	6	12	121	10	20		8.0		71
1/28	5.0	8.8			72	42	13	127	10	13		7.6		69
2/10	6.0	10.1			98	17	26	141	7	47		7.2		96
2/23	7.0	9.1			132	46	9	187	6	12		7.1		67
4/29	6.0	12.1			261	44	40	345	4	7		7.0		66
5/25	12.0	9.6			146	72	8	226	5	12		7.3		75
6/23	16.0	8.1			74	24	8	106	3	7		7.4		88
7/14	17.8		0.76	0.48	77	24	<1	102	4	12		7.5	37.6	
9/2	18.0		0.85	0.38	452	15	<1	468	5	13	.51			101
10/7	11.2		13.48	2.90	132	38	3	173	2	14	.20	7.4	43.2	97
11/3	10.5		0.39	0.35	187	44	10	241	4	4	1.59	6.8	38.2	84
2/2	5.5		0.49		57	48	16	121	12	21	1.56	7.2	44.5	85
Average					157.5	32.2	11.3	200.9	6.1	17.1	.97		40.9	82.0

TABLE E-1 (Continued)

INCLINE CREEK ANALYSES

Date	Temp °C	Unfiltered Samples: DO	Susp. Solids	Volit. SS	0.45 µ Millipore Filtered Samples — Nitrogen as N: Org. N	NH_3	$NO_3 + NO_2$	Tot. N	Phosphorus as P: PO_4	Tot. P	Cl^-	pH	Alk. as $CaCo_3$	Cond. (10^{-6})
		mg/ℓ	mg/ℓ	mg/ℓ	µg/ℓ	µg/ℓ	µg/ℓ	µg/ℓ	µg/ℓ	µg/ℓ	mg/ℓ		mg/ℓ	mhos
11/4/69	8.0	10.5			237	73	78	268	12	18		7.3		57
12/4	3.0	10.4			118	40	25	183	13	18		7.0		50
1/7/70	0.5				352	75	91	518	17	25		7.3		64
1/28	1.5	11.4			448	83	10	541	25	29		7.5		52
2/10	6.0	9.9			386	119	98	603	19	51		7.2		67
2/23	8.0	10.4			500	64	138	702	44	101		7.0		54
4/29	14.0	9.7			170	536	45	751	10	30		7.0		46
5/25	18.0	8.6			208	12	30	250	9	14		7.0		40
6/30	17.5	8.1			34	17	17	68	15	27		7.4		63
7/14	14.8		26.71	7.64	70	64	8	142	13	17	0.43	7.2	23.4	54
9/2	6.5		21.65	4.49	136	12	20	168	15	32	0.52			65
10/7	6.2		10.78	2.27	91	14	5	110	6	34	0.30	7.2	53.5	67
11/3	4.0		4.27	1.13	68	32	17	117						
2/2			9.57	2.02	175	28	100	303	26	65	2.46	7.1	37.1	28
Average					213.8	79.2	44.4	337.4	17.2	35.5				54.4

MILL CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCo_3$	Cond.
11/4/69														
12/4														
1/7/70														
1/28	0.5	11.2			871	352	348	1571	37	37'		7.4		74
2/10														
2/23					1432	172	187	1791	62	103		7.0		56
4/29					826	248	104	1178	19	32		7.1		55
Average					1.043	257.3	213.	1513.3	39.3	57.3				61.7

TUNNEL CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCo_3$	Cond.
11/4/69	7.0	10.6			228	33	22	283	13	21		7.3		62
12/4	3.0	10.7			118	47	28	193	14	17		7.0		157
1/7/70	3.0	10.6			478	34	49	561	16	26		7.6		53
1/28	1.0	11.0			450	56	39	545	15	18		7.3		46
2/10	5.0	9.9			53	16	33	102	17	38		7.1		59
2/23	4.0	10.9			89	26	36	151	14	29		7.0		49
4/29	5.0	10.0			148	30	36	214	11	21		7.1		67
5/25	10.0	9.3			232	24	23	279	5	13		7.0		52
6/30	14.1	8.7			151	10	12	173	10	13		7.5		65
7/14	12.6		4.02	2.56	77	55	11	143	13	17	0.52	7.4	29.3	72
9/2	9.0		4.03	2.66	106	3	22	131	17	25	0.25			71
10/7	5.0		5.30	3.38	78	19	4	101	9	52	.07	7.2	36.1	75
11/3	5.5		3.72	2.13	144	43	16	203	9	12	.47	7.1	34.6	67
2/2	4.0		4.72	2.82	86	16	45	147	21	54	.48	7.0	36.7	66
Average					174.1	29.4	26.9	230.4	13.1	25.4	.36			68.6

MARLETTE CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCo_3$	Cond.
11/4/69	7.0	10.6			194	28	53	275	10	189		7.4		75
12/4	2.0	10.2			154	117	37	308	15	18		7.3		67
1/7/70	3.0	10.6			225	51	30	306	5	14		7.6		42
1/28	1.5	11.1			239	93	24	356	8	11		7.6		35
2/10	4.0	10.5			204	27	25	256	9	21		7.0		49
2/23	5.0	10.8			201	22	30	253	10	13		7.1		40
4/29	4.5	9.6			297	40	42	379	13	13		7.1		56
5/25	10.0	9.8			290	37	48	375	4	7		6.7		46
6/30	18.0	8.0			189	19	84	292	9	13		7.5		89
7/14	15.5		2.95	1.51	208	34	78	320	10	15	.28	7.1	23.4	59
9/2	14.5		1.96	0.89	151	3	73	227	20	29	.48			93
10/7	7.0		1.62	0.78	88	15	39	142	17	29	.20	7.2	44.0	86
11/3	5.5		2.86	1.52	197	18	32	247	6	8	.50	7.0	25.8	51
2/2	3.0		16.56	3.44	232	44	30	306	14	17	.78	6.9	25.5	44
Average					204.9	39.1	44.60	288.7	10.7	28.4	.45			59.4

FIRST CREEK ANALYSES

Date	Temp °C	Unfiltered Samples			0.45 μ Millipore Filtered Samples									
					Nitrogen as N				Phosphorus as P		Cl^-	pH	Alk. as $CaCO_3$	Cond. (10^{-6})
		DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P				
		mg/ℓ	mg/ℓ	mg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	mg/ℓ		mg/ℓ	mhos
11/7/70	2.0	10.8			199	28	31	258	13	23		7.7		66
1/28	1.0	11.4			344	66	39	449	9	13		7.5		51
2/10	4.5	10.2			218	36	31	285	13	38		7.1		65
2/23	5.0	11.2			304	57	28	389	16	27		7.1		55
4/29	7.5													
5/25	14.5	8.9			156	42	48	246	4	10		7.0		39
6/30	16.0	8.2			134	9	70	213	6	28		7.5		51
7/14	14.0		10.07	2.68	77	56	34	167	11	18	.29	7.5	31.8	69
9/2	13.0		24.35	4.58	60	<1	16	76	31	65	.28			83
10/7	7.0		7.78	1.94	48	12	1	61	5	6	.01	7.4	43.4	85
11/3	7.5		45.74	6.28	144	57	19	220	15	21	.47	7.1	47.2	88
2/2	3.0		74.12	22.90	430	48	65	543	24	50	1.47	6.9	36.0	63
Average					192.2	37.4	34.7	264.3	13.4	27.2	.50			65.0

SECOND CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCO_3$	Cond.
11/4/69	8.0	10.2			182	47	20	249	22	29		7.3		71
12/4	3.0	10.5			208	27	29	324	17	25		7.2		62
1/7/70	1.5	10.9			237	22	59	318	12	21		7.7		75
1/28	~.0	11.6			517	72	65	654	12	21		7.5		48
2/10	5.0	10.4			764	99	56	919	22	62		7.2		72
2/23					2487	361	81	2929	25	89		7.1		51
4/29	15.0	9.4												
5/25	22.0	8.6			356	40	48	444	17	22		7.0		40
6/30	17.5	6.9			213	12	3	228	20	32		7.6		48
7/14	15.5		94.94	16.82	151	65	9	225	18	26	0.34	7.3	29.6	66
9/2	6.0		14.60	3.22	213	26	11	250	12	34	0.28			74
10/7	8.0		6.22	1.62	74	16	3	93	15	100	0.02	7.3	38.0	73
11/3			2.62	0.76	98	28	17	143	16	16	0.23	6.8	35.7	72
Average					463.3	67.9	33.4	564.7	17.3	39.8	.22			62.7

ROSE KNOB (WOOD) CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCO_3$	Cond.
11/4/69	8.0	11.4			381	67	35	483	26	35		7.4		58
12/4	3.0	10.7			321	22	88	431	23	32		6.9		53
1/7/70	0.5	11.1			238	22	152	412	19	31		7.6		44
1/28	~.0	11.6			297	54	133	484	17	20		7.5		46
2/10	5.0	10.4			261	28	105	394	14	31		7.2		57
2/23	5.5	10.7			170	55	468	693	18	23		7.4		49
4/29	7.0	7.5					81		17	33		7.1		55
5/25	15.5	8.3			258	17	106	381	6	21		7.0		36
/30	19.5	7.6			328	10	5	343	11	22		7.5		45
7/14	18.0		7.56	1.70	65	40	14	119	17	22	0.21	7.3	26	56
9/2	15.8		27.89	4.27	94	32	18	144	20	43	0.26			64
10/7	7.0		4.99	1.25	156	19	4	179	6	40	0.11	7.2	31.5	63
11/3	6.5		29.80	2.88	84	30	25	139	12	15	0.26	6.9	30.8	65
2/2	3.0		6.74	1.79	185	15	116	316	23	52	.55	6.9	30.5	62
Average					219.3	32.6	96.4	348.5	16.4	30.0	.28			53.8

THIRD CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCO_3$	Cond.
11/4/69	4.0	10.3			998	161	78	1237	20	47		7.4		65
12/4	3.0	10.8			1146	91	19	1256	25	25		7.0		55
1/7/70	1.0	10.9			404	56	54	514	14	22		7.3		48
1/28	0.5	11.8			536	81	80	697	19	26		7.5		48
2/10	5.5	9.9			380	26	42	448	20	65		7.1		68
2/23	5.0	9.9			335	37	37	409	17	22		7.2		60
4/29	9.0	8.1			410	92	39	541	14	32		7.1		50
5/25	13.0	9.0			304	12	45	361	4	11		6.9		27
6/30	19.5	7.5			309	31	28	368	9	14		7.4		54
7/14	20.5		9.53	2.14	172	42	420	634	17	17	.43	7.2	26.2	63
9/2	17.5		12.40	2.56	158	320	84	562	54	69	.41			79
10/7	7.0		6.08	1.38	101	12	8	121	7	39	.15	7.2	36.1	73
11/3	6.2		5.19	1.29	139	32	22	193	16	16	.63	7.1	32.1	60
2/2	4.5		16.36	3.01	170	40	50	260	16	46	1.57	7.0	34.0	59
Average					397.3	73.8	71.7	542.9	19.4	32.2	.64			57.8

LOGAN HOUSE CREEK ANALYSES

Date	Temp °C	Unfiltered Samples			0.45 μ Millipore Filtered Samples									
		DO	Susp. Solids	Volit. SS	Nitrogen as N				Phosphorus as P		Cl^-	pH	Alk. as $CaCO_3$	Cond.
					Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P				(10^{-6})
		mg/ℓ	mg/ℓ	mg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	mg/ℓ		mg/ℓ	mhos
11/4/69	7.0	11.4			139	32	30	201	8	42		7.3		114
12/4	~.0	11.3			132	54	23	209	4	9		7.2		176
1/7/70	0.5	11.4			325	26	49	400	9	29		7.8		102
1/28	~.5	11.4			46	58	47	151	6	9		7.7		96
2/10	4.0	10.6			189	9	29	227	6	34		7.1		114
2/23	4.0	9.7			163	42	35	240	5	20		7.3		90
4/29	4.0	11.5			182	36	38	256	6	10		7.0		68
5/25	11.5	8.5			242	37	107	386	6	22		7.3		73
6/30	14.0	8.5			166	22	13	201	4	46		7.4		129
7/14	13.8		1.94	1.01	166	38	23	227	10	21	.31	7.9	70.5	150
9/2	10.0		2.23	1.25	< 1	2	19	22	11	54	.59			127
10/7	5.0		2.96	1.31	56	20	4	80	4	69	.39	7.8	73.5	137
11/3	5.0		1.13	0.65	354	10	12	376	6	10	.86	7.5	68.1	109
2/2	2.5		4.72	1.90	122	398	39	559	11	18	1.96	7.4	70.9	110
Average					163.0	56.0	33.4	252.5	6.8	28.1	.82			113.9

McFAUL CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCO_3$	Cond.
11/4/69	7.0	10.8			246	38	52	336	18	40		7.5		92
12/4	1.0	10.9			134	74	33	241	12	19		7.2		89
1/7/70	0.5	11.2			386	17	52	455	13	27		7.7		72
1/28	0.5	11.4			261	90	35	386	12	18		7.6		68
2/10	3.5	10.8			189	16	37	242	9	36		7.4		103
2/23	4.0	10.1			129	42	42	213	10	35		7.1		68
4/29	8.0	9.5			201	25	21	247	4	9		7.1		68
5/25	16.8	7.4			316	37	12	365	8	25		7.2		64
6/30	18.8	7.5			192	36	13	241	7	14		7.7		94
Average					228.2	41.7	33.0	302.9	10.3	24.8				79.8

EDGEWOOD CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCO_3$	Cond.
11/4/69	7.0	10.2			316	60	41	417	27	39		7.4		78
12/4	3.0	10.5			187	67	34	288	15	19		7.0		71
1/7/70	3.0	10.3			325	24	49	398	18	40		7.6		67
1/28	2.5	11.1			328	110	84	522	21	26		7.4		64
2/10	5.0	9.9			189	31	75	295	14	37		7.2		94
2/23	5.0	10.8			118	43	93	254	14	22		7.1		69
4/29	7.0	10.9			146	54	65	265	12	16		7.0		62
5/25	14.0	8.9			380	86	43	509	16	35		7.1		69
6/30	14.0	8.4			201	36	36	273	18	23		7.5		97
7/14	16.0		3.82	1.44	106	58	31	195	20	31	.72	7.7	46.0	98
9/2	12.0		2.88	1.10	14	< 1	57	72	18	44	.75			92
10/7	6.5		3.48	1.12	263	38	18	319	10	100	.63	7.6	47.0	98
11/3	6.0		2.15	0.82	104	22	32	158	15	18	.96	7.2	42.8	75
2/2	4.0		21.51	3.73	122	92	75	289	17	24	5.91	7.1	50.6	77
Average					199.9	51.5	52.4	303.9	16.8	33.9	1.79			79.4

TRUCKEE – TROUT CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCO_3$	Cond.
11/4/69	7.0	10.2			252	21	62	335	6	17		7.1		60
12/4	1.0	10.8			208	60	95	363	7	13		6.9		57
1/7/70	0.5				57	59	100	216	7	13		7.2		54
1/28	~.0	11.0			364	101	72	537	10	14		7.2		28
2/10	3.0	10.4			380	33	85	498	12	28		7.1		46
2/23	4.0	10.96			211	54	81	346	9	25		6.9		42
4/29	4.5	11.3			124	61	62	247	4	9		6.9		55
5/25	10.0	9.4			194	24	23	241	2	5		7.1		21
6/23	14.5	8.08			130	20	15	165	2	14		7.1		25
7/14	21.6		3.88	2.07	130	48	8	186	9	20		7.1		15
9/2	17.5		4.76	1.63	412	25	29	466	6	9	1.57			72
10/7	9.0		1.85	0.56	252	18	61	331	4	7	4.02	7.3	12.7	84
11/3	6.5		1.32	0.52	194	28	45	267	8	10	5.11	7.0	30.5	61
2/2	2.8		2.86	1.55	130	8	68	206	14	43	2.59	6.8	25.1	48
Average					217.0	40.0	57.6	314.6	6.9	16.2	3.3		22.8	47.7

TAYLOR CREEK ANALYSES

Date	Temp °C	Unfiltered Samples: DO	Unfiltered Samples: Susp. Solids	Unfiltered Samples: Volit. SS	0.45 μ Millipore Filtered Samples: Nitrogen as N: Org. N	Nitrogen as N: NH_3	Nitrogen as N: $NO_3 + NO_2$	Nitrogen as N: Tot. N	Phosphorus as P: PO_4	Phosphorus as P: Tot. P	Cl^-	pH	Alk. as $CaCo_3$	Cond. (10^{-F})
		mg/ℓ	mg/ℓ	mg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	mg/ℓ		mg/ℓ	mhos
11/4/69	9.0	11.1			172	28	38	238	8	10		7.2		29
12/4	5.0	8.7			153	15	57	225	9	12		6.8		24
1/7/70	5.0	9.9			204	51	23	278	10	19		7.4		22
1/28	2.0	10.8			206	42	16	264	7	10		7.1		20
2/10	4.5	10.2			198	17	26	241	4	23		6.9		24
2/23	5.0	10.3			175	43	13	231	3	12		6.8		21
4/29	7.0	9.8			175	32	18	225	2	2		6.9		26
5/25	12.2	8.7			117	26	12	155	3	12		7.0		26
6/30	18.2	7.7			108	30	12	150	1	6		7.0		23
7/14	18.0		1.22	0.72	156	49	16	221	5	11	.34	6.6	6.8	26
9/2	17.0		0.51	0.39	5	<1	12	18	2	18	.45			27
10/7	10.0		0.26	0.37	233	20	7	260	< 1	2	.27	6.6	8.8	26
11/3	4.5		0.88	0.54	111	74	46	231	4	8	.41	6.6	9.6	45
2/2	4.0		0.66	0.66	79	101	22	202	10	12	.79	6.5	9.8	24
Average					149.4	37.8	22.7	209.9	4.9	11.8	.45			25.9

TALLAC CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCo_3$	Cond.
11/4/69	5.0	11.4			112	24	38	174	10	19		7.2		50
12/4	0.5	11.0			103	23	55	181	6	11		7.3		53
1/7/70	1.0	10.9			166	22	18	206	8	22		7.3		45
1/28	1.0	11.4			211	63	36	310	9	11		7.1		29
2/10	4.0	10.8			168	12	36	216	6	33		6.8		47
2/23	7.0	11.2			126	46	22	194	6	12		6.9		38
4/29	5.0	11.1			124	40	32	196	4	9		7.0		34
5/25	9.8	9.4			178	30	26	234	3	18		7.1		30
6/30	12.5	8.7			91	24	18	133	2	6		7.0		28
7/14	15.5		29.19	5.39	256	42	14	312	9	21	.60	6.8	15.1	51
9/2	9.0		1.69	0.94	< 1	<1	21	22	12	36	.23			61
10/7	4.0		1.76	0.55	230	103	5	338	2	12	.05	7.3	30.5	67
11/3	5.0		0.30	0.23	341	22	16	379	6	18	.51	6.6	24.3	53
2/2			.77	.68	53	30	79	162	10	17	.47	7.0	28.8	49
Average					154.3	34.4	29.7	218.4	6.6	17.5	.37			45.4

CASCADE CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCo_3$	Cond.
11/4/69	9.0	10.1			132	35	12	179	11	12				
12/4	4.0	10.0			142	16	1	159	4	10		6.6		13
1/7/70	4.5	10.3			273	24	89	386	6	11		7.0		13
1/28	2.0	10.6			285	60	11	356	8	8		7.0		11
2/10	4.0	10.4			237	16	16	269	6	10		6.7		14
2/23	3.0	10.6			234	52	8	294	7	7		6.8		11
4/29	7.0	9.6			204	40	42	286	5	6		6.8		10
5/25	14.5	9.7			125	31	7	163	4	6		7.0		15
6/30	19.0	7.4			130	62	7	199	2	6		6.8		16
7/14	22.5		1.02	.70	82	12	<1	94	3	10	.15	6.2	3.2	13
9/2	13.0		1.01	.66	17	<1	17	34	3	6	.27			17
10/7														
11/3														
2/2			.65		88	40	33	161	8	11	.69	6.2	6.3	14.1
Average					162.4	32.4	20.3	215	5.6	8.6	.37			13.4

EAGLE CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCo_3$	Cond.
11/4/69	7.0	10.8			136	39	49	224	4	7		6.8		16
12/4	1.0	11.0			38	21	25	84	4	6		6.6		14
1/7/70	1.5	11.8			237	14	31	282	6	11		7.0		11
1/28	~.0	11.1			154	29	23	206	9	13		7.1		9
2/10	2.5	11.1			106	27	34	167	7	22		6.7		16
2/23	2.5	10.9			118	48	31	197	5	9		6.9		11
4/29	3.0	10.9			158	48	64	270	4	7		6.9		10
5/25	8.0	8.2			118	66	24	208	9	9		7.1		14
6/30	14.0	8.2			118	24	14	156	2	6		6.8		12
7/14	18.5		.95	.65	189	28	11	228	2	6	.24	6.1	2.4	13
9/2	13.4		.36	.29	16	<1	92	108	5	10	.24			16
10/7	6.5		16.11	3.21	240	36	92	368	<1	4	.18	6.6	7.6	28
11/3	6.0		.52	.39	74	24	23	121	8	12	.25	5.8	3.6	45
2/2	1.5		.48		70	33	38	141	7	15	.67	6.1	5.9	16
Average					126.6	31.3	39.4	198.1	5.3	9.8	.32			16.5

TABLE E-1 (Continued)

MEEKS CREEK ANALYSES

Date	Temp °C	Unfiltered Samples			0.45 μ Millipore Filtered Samples									
					Nitrogen as N				Phosphorus as P					
		DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCO_3$	Cond. (10^{-6})
		mg/ℓ	mg/ℓ	mg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	mg/ℓ		mg/ℓ	mhos
11/4/69	5.0	11.4			185	39	4	228	10	12		7.3		35
12/4	~.0	10.4			132	28	18	178	7	9		7.0		30
1/7/70	1.0	10.8			237	9	42	288	7	18		7.0		22
1/28	1.0	9.4			335	62	13	410	7	13		7.2		18
2/10	2.0	10.4			132	29	26	187	6	19		6.9		23
2/23	2.0	11.0			194	49	17	260	5	16		7.0		20
4/29	2.0	11.4			103	44	41	188	2	5		6.9		18
5/25	8.2	8.6			156	92	6	254	2	13		7.1		13
6/30	14.3	7.5			118	46	8	172	2	6		7.1		18
7/14	17.0		.81	.56	58	22	16	96	5	12	.28	6.7	8.8	25
9/2	12.0		7.93	2.67	122	<1	8	130	32	52	.23			92
10/7														
11/3	4.5		3.16	1.80	394	39	13	446	24	33	.38	6.8	32.0	73
2/2	1.5		.56		98	42	28	168	10	12	.59	6.5	12.4	26
Average					174.2	38.6	18.5	231.0	9.2	16.5	.37			31.8

GENERAL CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCO_3$	Cond.
11/4/69	4.0	11.9			70	34	25	129	22	22		7.3		52
12/4	~.0	10.8			146	22	10	178	14	18		7.3		47
1/7/70	0.5	10.8			154	18	38	210	9	26		7.3		22
1/28	1.0	11.0			189	50	13	252	9	10		7.3		17
2/10	3.0	10.80			170	38	17	225	6	18		7.0		23
2/23	2.5	10.92			237	46	8	291	7	14		7.0		22
4/29	3.0	11.0			148	46	29	223	5	9		6.9		14
5/25	7.0	11.8			156	64	4	224	3	10		7.1		14
6/23	14.0	8.06			48	30	9	87	4	7		7.2		35
7/14	17.0		0.35	0.32	70	20	6	96	11	25		7.2		19
9/2	9.8		0.61	0.43	43	<1	<1	44	14	23	0.35			61
10/7	5.5		0.49	0.31	228	28	21	257	12	23	0.16	7.1	30.5	64
11/3	5.0		1.40	0.97	354	16	9	379	15	19	0.63	6.6	24.1	51
2/2	2.0		0.22	0.22	44	6	13	63	11	28	0.51	6.6	13.9	68
	Average				146.9	29.9	13.0	191.1	10.1	18.0	0.41			36.4

McKINNEY CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCO_3$	Cond.
11/4/69	4.0	11.8			192	76	13	281	4	14		7.2		49
12/4	0.5	10.7			146	24	48	218	8	8		7.3		47
1/7/70	0.5	11.3			335	17	107	459	6	17		7.5		30
1/28	0.5	11.1			242	63	39	344	9	12		7.4		21
2/10	2.5	11.0			178	14	43	235	4	26		7.0		30
2/23	2.0	11.4			277	42	38	357	5	19		7.1		25
4/29	2.5	12.0			151	57	67	275	3	4		6.8		23
5/25	10.0	9.6			156	94	18	268	4	7		7.2		18
6/30	15.8	7.7			74	20	21	115	3	6		7.1		34
7/14	19.0		.74	.48	67	34	74	175	4	10	.24	7.2	17.0	50
9/2	10.0		.72	.42	46	15	50	111	5	254	.51			55
10/7	5.0		.68	.42	263	42	6	311	<1	6	.31	7.1	32.9	70
11/3	4.0		.36	.36	308	30	14	352	5	11	.51	6.6	25.2	55
2/2	2.0		.90	.58	173	49	63	285	7	13	.48	6.7	17.9	35
Average					186.1	41.2	42.9	270.4	4.8	29.1	.41			38.7

MADDEN CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P	Cl^-	pH	Alk. as $CaCO_3$	Cond.
11/4/69	4.0	12.5			156	25	48	229	24	80		7.2		47
12/4	0.5	11.3			136	15	84	235	<1	6		7.2		43
1/7/70	0.5	11.3			189	20	68	277	9	15		7.6		40
1/28	1.0	10.9			146	43	24	213	9	15		7.5		27
2/10	4.0	10.9			94	12	13	119	7	26		7.2		50
2/23	2.0	11.4			97	43	9	149	7	25		7.1		37
4/29	2.0	11.4			158	52	41	251	6	16		7.0		46
5/25	7.8	10.2			122	138	15	275	7	13		7.2		30
6/30	11.2	8.7			65	<1	13	78	3	7		7.2		30
7/14	15.0		.55	.45	142	25	11	178	3	13	.15	7.0	17.0	49
9/2	11.6		1.81	.70	98	22	47	167	6	28	.39			58
10/7														
11/3	3.5		.43	.40	132	50	13	195	3	7	.54	6.4	20.5	51
2/2	2.5		2.85	0.82	63	45	93	201	14	14	.58	7.0	26.8	52
Average					123	37.7	36.8	197.5	7.6	20.4	.42			43.1

TABLE E-1 (Continued)

SECRET HARBOR CREEK ANALYSES

Date	Temp °C	DO	Susp. Solids	Volit. SS	0.45 μ Millipore Filtered Samples									
					Nitrogen as N				Phosphorus as P		Cl^-	pH	Alk. as $CaCo_3$	Cond. (10^{-6})
					Org. N	NH_3	$NO_3 + NO_2$	Tot. N	PO_4	Tot. P				
		mg/ℓ	mg/ℓ	mg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	μg/ℓ	mg/ℓ		mg/ℓ	mhos
11/4/69	11.0	10.0			365	90	93	548	75	49		7.3		74
12/4	1.5	10.3			332	58	166	556	8	12		7.1		74
1/7/70	2.0	9.9			457	52	131	690	4	18		7.6		58
1/28	0.5	10.8			445	330	261	1036	10	14		7.6		53
2/10	4.0	9.7			244	30	74	348	7	37		7.2		70
2/23	4.0	10.3			192	26	140	358	7	18		7.2		54
4/29	5.5	10.9			175	24			4	18		7.1		54
5/25	14.5	8.0			266	40	48	354	6	13		7.5		66
6/30	16.0	7.5			242	32	46	320	6	49		7.6		101.0
7/14	14.5		6.38	3.27	204	22	97	323	11	34	0.52	7.4	36.7	81
9/2	10.2		13.78	6.88	170	<1	175	346	5	18	1.00			85
10/7	5.0		4.74	2.39	132	20	104	256	6	14	0.20	7.2	40.0	85
11/3	5.5		2.22	1.27	126	10	48	184	4	7	0.89	7.2	43.7	57
Average						56.6	119.4	443.3	9.8	26.0	.65			70.2

BLISS CREEK ANALYSES

11/4/69		6.8			926	103	35	1064	10	22		7.4		118
12/4	5.0	2.4			984	144	12	1140	8	15		7.3		112
1/7/70														
1/28	1.0	4.1			950	124	20	1094	12	28		7.6		67
2/10	3.0	3.1			624	96	22	742	13	40		7.1		88
2/23	4.0	3.2			321	48	18	387	<1	49		7.3		76
4/29	8.0	8.4			538	56	42	636	7	18		6.9		68
5/25	17.0	6.0			600	50	27	677	4	12		7.6		78
6/30	21.7	4.0			644	50	17	711	6	16		7.6		102
Average					698.4	83.9	24.1	806.4	7.6	32.0				88.6

SLAUGHTER CREEK ANALYSES

11/4/69	10.0	10.5			292	79	110	481	13	18		7.5		82
12/4	2.0	10.9			285	93	128	506	7	12		7.1		82
1/7/70	1.0	10.4			522	27	215	764	13	23		7.6		90
1/28	~.0	9.8			529	328	111	968	14	20		7.6		82
2/10	5.0	9.6			512	263	160	935	12	32		7.2		100
2/23	8.0	10.9			326	286	174	786	< 1	35		7.3		84
4/29	21.0	9.0			550	88	97	735	5	9		7.3		68
5/25	22.5	6.6			600	92	63	755	21	40		7.5		78
6/30	22.5	7.5			304	20	7	331	4	11		7.7		232
7/14	17.3		6.45	2.18	142	49	3	194	7	20	0.44	7.5	42.3	96.3
9/2	8.0		2.76	1.05	316	17	58	391	5	14	2.58			132.0
10/7	6.5		4.79	1.52	136	17	43	196	4	6	0.36	7.5	52.4	136
11/3			6.02	2.02	134	11	55	200	12	14	0.46	7.1	36.5	68.2
Average					357.5	105.4	94.2	557.1	9.0	19.5	.96			102.3

GLENBROOK CREEK ANALYSES

11/4/69	6.0	10.8			288	130	31	449	18	71		7.5		240
12/4	1.0	11.0			84	52	27	163	13	15		7.1		236
1/7/70														
1/28														
2/10														
2/23														
4/29	5.0	10.6			242	40	214	496	12	18		7.1		210
5/25	12.0	9.5			208	30	113	351	14	32		7.5		138
6/30	14.0	8.0			163	17	84	264	16	19		7.7		123
7/14			10.29	3.21	182	23	< 1	205	4	55				324
9/2														
10/7	6.5		8.24	2.28	88	16	22	126	1	9	3.91	7.7	116.5	330
11/3	6.5		6.02	2.02	134	11	55	200	12	14	.46	7.1	36.5	68
Average					173.6	39.9	68.3	281.7	11.3	29.1	2.19			208.6

TABLE E-2

NUTRIENT INVENTORY OF STREAMS DISCHARGING INTO LAKE TAHOE

Sub-Basin		Runoff[a]	Nitrogen[b]								Phosphorus				Chloride		Conductivity (10^{-6}) $(x\ 10^3)$[c]	
			Organic-N		NH_3-N		$(NO_2 + NO_3)$-N		Total		PO_4-P		Total					
No.	Name	ac-ft	µg/l	kg	µg/l	kg	µg/l	kg	µg/l	kg	µg/l	kg	µg/l	kg	mg/l	kg	mhos	kg
1	Tahoe State Park Ck.[f]	900	127	140	41	45	23	25	191	211	18	20	35	39	0.33	364	80	62
2	Burton Ck.	3,600	127	560	41	181	23	101	191	844	18	80	35	155	0.33	1,458	80	247
3	Barton Ck.[f]	1,100	123	166	36	49	21	28	180	243	16	22	34	46	0.32	432	76	72
4	Lake Forest Ck.[f]	400	119	58	32	16	20	10	171	84	13	6	34	17	0.32	157	72	25
5	Dollar Ck.	1,000	115	141	28	34	19	23	160	196	10	12	33	40	0.31	380	68	58
6	Cedar Flats[f]	1,300	129	206	33	53	29	46	191	305	10	16	30	48	0.33	527	67	75
7	Watson Ck.	1,900	143	333	38	88	38	88	218	508	9	21	26	61	0.36	840	66	108
8	Carnelian Bay Ck.[f]	1,100	143	193	38	51	38	51	218	294	9	12	26	35	0.36	486	66	62
9	Carnelian Canyon Ck.[f]	2,700	143	474	38	126	38	126	218	722	9	30	26	86	0.36	1,191	66	218
10	Tahoe Vista	3,800	438	2,040	178	830	221	1,030	837	3,900	89	415	113	527	1.00	4,660	128	418
11	Griff Creek[f]	3,800	162	755	38	177	37	172	237	1,105	11	51	26	121	0.39	1,818	66	215
12	Kings Beach[f]	800	162	159	38	37	37	36	237	233	11	11	26	25	0.42	412	66	45
13	East State Line Point[f]	600	162	119	38	28	37	27	237	174	11	8	26	19	0.46	339	66	34
14	First Creek	1,300	192	306	37	59	35	56	264	421	13	21	27	43	0.50	797	65	73
15	Second Creek	1,300	463	723	68	108	33	53	565	900	17	27	40	64	0.22	351	63	70
16	Unnamed Creek No. 1[f]	500	341	209	50	31	65	40	456	280	17	10	35	21	0.25	153	59	25
17	Rose Knob (Wood) Creek	1,900	219	511	33	77	96	224	348	811	16	37	30	70	0.28	653	54	88
18	Third Creek	5,600	397	2,730	74	508	72	495	543	3,730	19	131	32	220	0.64	4,400	58	279
19	Incline Creek	4,400	199	1,073	87	470	54	292	340	1,837	18	97	40	216	1.05	5,670	59	223
20	Mill Creek	1,600	1,043	2,045	257	505	213	418	1,513	2,970	39	76	57	112	1.05	2,060	62	85
21	Tunnel Creek	1,200	174	256	29	43	27	40	230	338	13	19	25	37	0.36	530	69	71
22	Unnamed Creek No. 2[f]	900	174	192	29	32	27	30	230	254	13	14	25	28	0.36	397	69	53
23	Sand Harbor[f]	1,600	174	341	29	57	27	53	230	451	13	26	25	49	0.36	707	69	95
24	Marlette Creek	3,600	205	905	39	172	45	198	289	1,275	11	48	28	124	0.45	1,985	59	182
25	Secret Harbor Creek[d]	3,900	308	1,474	81	388	107	512	500	2,390	9	43	23	110	0.80	3,830	86	288
26	Bliss Creek	100	698	86	84	10	24	3	806	99	8	1	32	4	0.80	98	89	8
27	Deadman Point[f]	100	698	86	84	10	24	3	806	99	8	1	32	4	0.80	98	89	8
28	Slaughter House Creek	(Included with Sub-Basin No. 25)																
29	Glenbrook Creek	1,500	174	320	40	74	68	125	282	519	11	20	29	53	2.19	4,030	209	270
30	North Logan House Ck.[f]	200	163	40	56	14	33	8	253	62	7	2	28	7	0.82	201	114	20
31	Logan House Creek	800	163	160	56	55	33	32	253	248	7	7	28	27	0.82	805	114	78
32	Cave Rock[f]	100	172	21	54	7	33	4	259	32	7	1	28	3	0.82	100	110	14
33	Linclon Creek[f]	900	182	201	52	57	33	36	267	295	8	9	27	30	0.81	895	105	81
34	Skyland[f]	100	191	23	50	6	33	4	274	34	8	1	27	3	0.81	99	100	9
35	North Zephyr Creek[f]	1,100	201	271	48	65	33	45	282	380	9	12	26	35	0.80	1,080	95	90
36	Zephyr Creek[f]	600	210	155	46	34	33	24	289	212	9	7	26	19	0.79	58	90	46
37	South Zephyr Creek[f]	100	219	27	44	5	33	4	296	36	10	1	25	3	0.78	96	85	7
38	McFaul Creek	1,700	228	475	42	88	33	69	303	632	10	21	25	52	0.78	1,625	80	117
39	Burke Creek[f]	2,000	214	525	47	115	42	103	303	743	14	34	30	74	0.77	1,885	79	136
40	Edgewood Creek	3,000	200	735	52	191	52	191	304	1,120	17	63	34	125	1.79	6,590	79	203
41	Bijou Park[f]	1,500	202	372	54	99	51	94	307	565	14	26	29	53	2.04	3,750	70	90
42	Bijou[f]	700	204	175	56	48	49	42	309	265	11	9	25	21	2.29	1,965	62	37
43	Trout Creek[e]	22,000	207	5,640	58	1,565	48	1,295	314	8,473	8	216	21	567	2.54	68,542	54	1,020
44	Upper Truckee River[e]	71,500	207	18,154	58	5,087	48	4,210	314	27,538	8	702	21	1,841	2.54	222,763	54	3,315
45	Camp Richardson[f]	1,100	178	240	48	65	36	49	262	354	7	9	16	22	0.45	608	26	25
46	Taylor Creek	33,400	149	6,104	38	1,557	23	942	210	8,603	5	205	12	492	0.45	18,436	26	746
47	Tallac	5,400	154	1,020	34	225	30	199	218	1,444	7	46	18	119	0.37	2,451	45	209
48	Cascade	7,800	162	1,550	32	306	20	191	215	2,057	6	57	9	86	0.37	3,540	13	87
49	Eagle Creek	17,000	127	2,648	31	646	39	813	198	4,129	5	104	10	209	0.32	6,673	17	248
50	Bliss State Park[f]	3,200	137	538	32	126	34	133	203	797	6	24	12	47	0.33	1,295	20	55
51	Rubicon Creek[f]	(Included with Sub-Basin No. 50)																
52	Paradise Flat[f]	1,000	146	179	34	29	31	38	211	249	7	9	13	16	0.34	417	23	20
53	Lonely Gulch Creek[f]	1,300	156	249	36	57	27	42	219	350	7	11	15	24	0.35	558	26	29
54	Sierra Creek[f]	1,200	165	243	38	56	23	34	226	333	8	12	16	24	0.36	530	29	30
55	Meek's Creek	13,400	174	2,860	39	641	19	312	231	3,797	9	148	17	279	0.37	6,081	32	368
56	General Creek	8,500	147	1,533	30	313	13	136	191	1,991	10	104	18	188	0.41	4,275	36	263
57	McKinney Creek	10,500	186	2,395	41	528	43	554	270	3,477	5	64	29	373	0.41	5,280	39	352
58	Quail Creek[f]	1,700	165	344	40	83	41	85	246	512	6	13	26	54	0.41	855	40	58
59	Homewood Creek[f]	1,900	144	346	39	91	39	91	222	517	7	16	23	54	0.42	980	42	68
60	Madden Creek	2,400	123	362	38	112	37	109	198	583	8	24	20	59	0.42	1,237	43	89
61	Eagle Rock[f]	700	125	107	37	32	36	31	198	170	8	7	20	17	0.35	301	50	30
62	Blackwood Creek	23,300	127	3,630	36	1,029	35	1,000	197	5,630	7	200	20	572	0.27	7,717	57	1,140
63	Ward Creek	18,300	99	2,222	38	852	17	382	154	3,457	11	247	23	516	0.46	10,326	58	911
Total		310,900		70,145		18,466		15,626		104,278		3,686		8,385		420,837		13,448
Average			184		48		41		273		10		22		1.10		50	

[a] Based on 30 in. of precipitation at Tahoe City, California

[b] Nitrogen values have been rounded-off to the nearest whole number, therefore, the value for total nitrogen may not be the apparent summation total. Also individual values are missing, thus, altering the total.

[c] Based on the assumption that 1.0 micro ohm equals 0.7 mg/l

[d] Values presented are the average of Secret Harbor Creek (25) and Slaughter House Creek (28)

[e] Sampling location is at the confluence of Trout Creek and the Upper Truckee River, therefore, both streams are represented by the same constituent values

[f] Samples not collected due to lack of permanent streams or in some cases difficult access areas – values assigned are prorated and/or estimated

TABLE E-3

ANALYSES OF PRECIPITATION IN THE TAHOE BASIN

Date	Type of Prec.	Sta.	0.45 μ Filtered Samples												
			Nitrogen as N					Phosphorus		Fe	Ca	Alk.	Cond. (10^{-6})	pH	Cl
			Organic μg/ℓ	NH_3 μg/ℓ	NO_2 + NO_3 μg/ℓ	Tot. Ino. μg/ℓ	Total μg/ℓ	PO_4-P μg/ℓ	Total μg/ℓ	μg/ℓ	mg/ℓ	mg/ℓ	mhos		mg/ℓ
1970															
1- 6	S[b]	1[a]	132	16	19	35	167	4	7	<1	<1	1.0	7.8	5.9	1.20
	S	2	180	51	23	73	254	9	18	<1	<1	0.8	7.8	5.9	0.80
	S	3	194	40	22	62	256	18	25	<1	<1	1.8	6.3	6.3	0.58
1-13	S	1	168	80	60	140	308	4	15	-	-	-	5.6	6.5	0.29
	S	2	220	78	61	139	359	13	14	-	-	-	5.6	6.4	0.16
	S	3	355	150	56	206	561	13	18	-	-	-	8.0	6.5	-
1-20	S	1	252	90	24	114	366	9	11	-	-	-	-	-	0.31
	S	2	166	83	13	96	262	7	13	-	-	-	-	-	T
	S	3	314	96	19	115	429	12	17	-	-	-	-	-	0.15
1-24	S	1	264	115	29	144	408	7	25	<1	-	<1	4.4	5.9	-
	S	2	44	61	29	90	134	3	7	<1	-	<1	4.0	5.9	-
	S	3	237	93	39	132	369	18	24	<1	-	<1	5.3	5.7	-
2-24	S	1	285	126	92	218	503	4	4	-	-	<1	6.6	5.4	-
	S	2	402	107	72	181	581	2	3	-	-	<1	4.0	5.4	-
3- 1	S	1	-	144	86	230	-	12	17	7	-	<1	23	6.2	2.50
	S	2	184	177	59	236	420	12	21	1	-	<1	23.7	7.4	3.35
	S	3	280	106	47	153	433	8	10	<1	-	1.0	5.9	5.9	0.50
11- 4	R/S	1	159	212	157	369	528	15	20	-	<1	<1	10.8	4.8	0.51
11-17	R/S	1	152	85	69	154	306	10	17	-	1.0	<1	10.1	5.1	0.37
11-30	R/S	1	94	60	45	105	199	8	14	-	<1	<1	8.4	5.0	0.88
12- 1	S	1	150	67	36	103	253	10	16	-	<1	<1	14.9	5.1	2.72
12- 3	S	1	60	48	17	65	125	4	9	-	<1	<1	6.6	5.1	0.48
12- 9	S	1	-	280	55	335	-	16	18	-	<1	<1	29.6	5.2	0.21
12-17	S	1	102	86	77	163	265	7	10	-	-	-	6.2	5.2	-
12-29	S	1	108	120	64	184	292	9	16	-	-	8.2	19.1	6.4	3.53
1971															
2-18	S	1	92	479	220	699	791	9	17	-	-	<1	14.1	6.0	7.21
Average			191.4	117.3	56	174.6	357.0	9.3	14.8	-	0.88	1.07	10.34		1.43

[a]Station 1 - Lake Tahoe Area Council Laboratory near Tahoe City
Station 2 - Near North Ridge Dr. and Muletail Streets - approximately two miles Northwest of Carnelian Bay
Station 3 - Chambers Lodge - approximately six miles South of Tahoe City on Highway 89

[b]S - Snow: R - Rain

TABLE E-4

CONTINUOUSLY RECORDED STREAMS IN THE LAKE TAHOE BASIN

Stream	Water Year	Monthly Flow and Percentage of Yearly Total																								Total
		October		November		December		January		February		March		April		May		June		July		August		September		
		ac-ft	%	ac-ft	%	ac-ft	%	ac-ft	%	ac-ft	%	ac-ft	%	ac-ft	%	ac-ft	%	ac-ft	%	ac-ft	%	ac-ft	%	ac-ft	%	ac-ft
Blackwood	1958-59	109	0.9	195	1.5	211	1.6	663	5.2	1,045	8.2	1,220	9.5	3,245	25.3	3,751	29.3	2,032	15.9	210	1.6	54	0.4	83	0.6	12,818
	59-60	89	0.5	79	0.5	110	0.6	129	0.7	562	3.2	2,039	11.7	5,143	29.6	5,068	29.2	3,636	21.0	342	2.0	109	0.6	48	0.3	17,354
	60-61	112	0.8	257	1.8	242	1.7	188	1.3	487	3.5	698	5.0	2,941	21.0	5,155	36.8	3,390	24.2	360	2.6	96	0.7	78	0.6	14,004
	61-62	168	0.7	169	0.8	245	1.1	293	1.3	679	3.0	736	3.3	5,630	25.1	7,030	31.3	5,980	26.6	1,230	5.5	208	0.9	94	0.4	22,462
	62-63	1,730	6.7	775	3.0	1,690	6.6	2,650	10.3	3,920	15.3	1,420	5.5	2,000	7.8	6,200	24.2	4,010	15.6	887	3.5	244	1.0	143	0.6	25,670
	63-64	210	1.0	1,450	7.2	653	3.2	549	2.7	449	2.2	734	3.6	3,500	17.4	7,380	36.6	4,330	21.5	649	3.2	168	0.8	86	0.4	20,160
	64-65	156	0.4	264	0.7	9,670	24.6	2,230	5.7	1,090	2.8	1,460	3.7	4,960	12.6	9,230	23.5	7,450	19.0	1,900	4.8	604	1.5	274	0.7	39,290
	65-66	246	1.5	370	2.3	303	1.8	356	2.2	350	2.1	1,280	7.8	5,020	30.5	6,280	38.2	1,640	10.0	365	2.2	146	0.9	87	0.5	16,440
	66-67	262	0.7	664	1.8	908	2.5	835	2.3	986	2.7	4,510	12.4	1,100	3.0	8,040	22.1	12,860	35.3	5,430	14.9	600	1.6	180	0.5	36,380
	67-68	293	1.5	242	1.3	229	1.2	376	1.9	2,200	11.4	2,400	12.4	4,110	21.3	5,950	30.8	2,610	13.5	477	2.5	300	1.6	100	0.5	19,290
	68-69	162	0.3	736	1.6	558	1.2	1,780	3.8	1,350	2.9	1,240	2.6	4,770	10.2	19,190	40.8	13,820	29.4	2,590	5.5	598	1.3	190	0.4	46,990
	69-70	346	0.9	234	0.6	4,400	11.6	10,230	27.0	1,680	4.4	1,710	4.5	3,090	8.1	8,750	23.1	5,870	15.5	1,150	3.0	341	0.9	132	0.3	37,930
	Average %		1.3		1.8		6.2		6.6		4.8		6.3		14.7		29.8		21.9		5.0		1.1		0.5	
Trout	1958-59	1,053	7.6	1,144	8.3	1,041	7.5	1,218	8.8	1,275	9.2	1,599	11.5	1,985	14.3	1,894	13.7	1,273	9.2	449	3.2	381	2.7	543	3.9	13,855
	59-60	469	4.6	797	7.7	728	7.1	768	7.5	1,089	10.6	1,387	13.5	1,763	17.1	1,464	14.2	925	9.0	370	3.6	264	2.6	289	2.8	10,307
	60-61	489	4.9	684	6.9	690	6.9	696	7.0	811	8.2	916	9.2	1,355	13.6	1,567	15.8	1,496	15.1	490	4.9	391	3.9	355	3.6	9,940
	61-62	560	3.1	625	3.4	694	3.8	612	3.3	893	4.9	867	4.7	2,900	15.8	3,460	18.9	4,400	24.0	1,960	10.7	795	4.3	553	3.0	18,320
	62-63	1,020	3.5	922	3.2	922	3.2	1,350	4.7	3,440	12.0	2,000	7.0	2,140	7.4	5,400	18.8	6,400	22.3	2,760	9.6	1,410	4.9	994	3.5	28,760
	63-64	1,020	6.4	1,360	8.5	1,230	7.7	1,090	6.8	871	5.4	1,040	6.5	1,980	12.3	3,000	18.7	2,440	15.2	938	5.8	554	3.4	514	3.2	16,040
	64-65	634	1.6	932	2.3	3,790	9.3	2,700	6.6	1,810	4.4	2,110	5.2	3,450	8.4	6,760	16.5	8,900	21.7	4,770	11.7	3,010	7.4	2,020	4.9	40,890
	65-66	1,620	8.4	1,750	9.1	1,580	8.2	1,390	7.2	1,180	6.2	1,700	8.9	2,840	14.8	3,570	18.6	1,790	9.3	859	4.5	460	2.4	438	2.3	19,180
	66-67	623	1.5	1,050	2.6	1,380	3.4	1,160	2.9	1,150	2.9	2,400	6.0	1,730	4.3	7,120	17.7	10,620	26.4	8,270	20.6	2,910	7.2	1,830	4.5	40,240
	67-68	1,610	8.3	1,370	7.1	1,110	5.7	1,220	6.3	1,810	9.3	1,890	9.8	2,320	12.0	3,200	16.5	2,470	12.8	1,090	5.6	706	3.6	560	2.9	19,360
	68-69	833	1.9	1,060	2.4	768	1.7	1,750	3.9	1,330	3.0	1,550	3.5	4,340	9.7	11,290	25.2	12,080	26.9	5,690	12.7	2,550	5.7	1,610	3.6	44,840
	69-70	1,750	5.4	1,480	4.6	1,830	5.6	3,710	11.5	2,260	7.0	2,260	7.0	2,530	7.8	4,940	15.3	5,960	18.4	3,000	9.3	1,450	4.5	1,230	3.8	32,390
	Average %		4.0		4.5		5.4		6.0		6.1		6.7		10.0		18.2		20.0		10.4		5.1		3.7	
Upper Truckee	1958-59	466	1.9	515	2.1	459	1.9	1,098	4.6	944	3.9	1,985	8.2	6,135	25.5	7,144	29.7	4,058	16.9	688	2.9	255	1.1	333	1.4	24,080
	59-60	252	1.1	233	1.0	230	1.0	294	1.3	719	3.2	1,846	8.2	5,952	26.5	7,624	34.0	4,274	19.1	604	2.7	220	1.0	172	0.8	22,426
	60-61	209	1.1	273	1.4	339	1.8	289	1.5	545	2.9	823	4.3	4,013	21.1	7,474	39.4	3,850	20.3	703	3.7	261	1.4	207	1.1	18,990
	61-62	280	0.7	264	0.6	414	1.0	407	0.9	849	2.0	926	2.2	7,720	17.9	13,140	30.5	15,240	35.4	2,820	6.6	673	1.6	300	0.7	43,030
	62-63	973	1.5	624	1.0	1,050	1.7	2,460	3.9	7,820	12.3	2,310	3.6	3,150	5.0	20,250	31.8	19,510	30.7	3,930	6.2	973	1.5	581	0.9	63,630
	63-64	603	2.0	2,140	7.0	1,280	4.2	1,020	3.4	762	2.5	1,180	3.9	4,480	14.7	11,000	36.2	6,000	19.7	1,280	4.2	397	1.3	278	0.9	30,420
	64-65	285	0.4	420	0.6	11,050	15.1	3,990	5.4	2,410	3.3	2,590	3.5	7,320	10.0	17,070	23.3	17,210	23.5	6,350	8.7	3,530	4.8	1,150	1.6	73,380
	65-66	811	2.7	1,010	3.4	954	3.2	988	3.3	857	2.9	2,110	7.1	7,760	26.0	11,020	37.0	2,950	9.9	793	2.7	335	1.1	212	0.7	29,800
	66-67	229	0.3	574	0.8	1,410	2.0	1,190	1.7	1,330	1.9	2,980	4.3	1,990	2.9	15,220	21.9	27,330	39.4	13,780	19.9	2,360	3.4	1,000	1.4	69,390
	67-68	875	2.9	581	1.9	516	1.7	770	2.6	2,360	7.9	2,880	9.6	5,850	19.5	10,050	33.5	4,490	14.9	926	3.1	434	1.4	309	1.0	30,040
	68-69	340	0.5	1,090	1.4	651	0.9	2,230	3.0	978	1.3	1,580	2.1	7,190	9.6	28,380	37.7	23,100	30.7	7,520	10.0	1,450	1.9	729	1.0	75,240
	69-70	951	1.7	887	1.6	2,340	4.2	8,240	14.9	3,250	5.9	3,380	6.1	4,680	8.5	14,900	27.0	12,580	22.8	2,750	5.0	754	1.4	402	0.7	55,120
	Average %		1.2		1.6		3.9		4.3		4.3		4.6		12.4		30.5		26.3		7.9		2.2		1.1	
Taylor	1968-69	638	1.3	2,660	5.3	2,360	4.7	3,730	7.5	2,430	4.9	1,640	3.3	4,710	9.4	14,610	29.2	10,630	21.2	4,950	10.0	1,610	3.2	72	0.1	50,040
	69-70*	238	0.6	601	1.5	4,260	10.4	10,340	25.3	3,170	7.7	1,840	4.5	2,250	5.5	6,640	16.2	8,990	22.0	1,900	4.6	462	1.1	233	0.6	40,924
	Average %		1.0		3.6		7.3		15.5		6.2		3.8		7.7		23.4		21.6		7.5		2.3		0.3	
Incline	1969-70	341	5.0	312	4.6	330	4.8	709	10.4	483	7.1	679	9.9	710	10.4	1,170	17.1	980	14.3	499	7.3	346	5.1	280	4.1	6,840
Third	1969-70	202	3.1	238	3.6	339	5.2	535	8.1	345	5.3	491	7.5	530	8.1	1,360	20.7	1,850	28.2	403	6.1	150	2.3	131	2.0	6,570

*Provisional data

TABLE E-5

RAINFALL-RUNOFF COEFFICIENTS FOR CONTINUOUSLY GAGED STREAMS IN THE LAKE TAHOE BASIN

Water Year	Precipitation Factor	Calculated Precipitation		Runoff		Rf-Ro. Coeff.
		Inches	Acre Feet	Inches	Acre Feet	
TROUT CREEK						
60-61	0.81	27	51,900	5	9,940	0.19
61-62	1.00	33	64,100	10	18,320	0.29
62-63	1.52	50	97,400	15	28,760	0.30
63-64	0.84	28	53,800	8	16,040	0.30
64-65	1.71	57	109,600	21	40,890	0.37
65-66	0.79	26	50,600	10	19,180	0.38
66-67	1.50	50	96,100	21	40,240	0.42
67-68	0.82	27	52,600	10	19,360	0.37
68-69	1.75	58	112,200	23	44,840	0.40
69-70	1.22	40	78,200	16	32,390	0.41
			Average			0.35
UPPER TRUCKEE						
60-61	0.81	41	70,700	11	18,980	0.27
61-62	1.00	50	87,400	25	43,030	0.49
62-63	1.52	77	132,800	37	63,630	0.48
63-64	0.84	42	73,400	17	30,420	0.41
64-65	1.71	86	149,300	42	73,380	0.49
65-66	0.79	40	69,000	17	29,800	0.43
66-67	1.50	76	131,000	40	69,360	0.53
67-68	0.82	41	71,600	17	30,040	0.42
68-69	1.75	88	153,000	43	75,240	0.49
69-70	1.22	61	106,600	37	55,120	0.52
			Average			0.47
BLACKWOOD CREEK						
60-61	0.81	52	32,000	23	14,010	0.44
61-62	1.00	64	39,600	37	22,460	0.57
62-63	1.52	97	60,100	42	25,670	0.43
63-64	0.84	53	33,200	32	20,160	0.61
64-65	1.71	109	67,600	63	39,290	0.58
65-66	0.79	50	31,300	27	16,440	0.53
66-67	1.50	96	59,300	58	36,380	0.61
67-68	0.82	52	32,400	31	19,290	0.60
68-69	1.75	111	69,200	76	46,990	0.68
69-70	1.22	78	48,300	62	37,930	0.79
			Average			0.59
TAYLOR CREEK						
68-69	1.75	110	99,600	55	50,040	0.50
69-70	1.22	77	69,400	45	40,924	0.59
			Average			0.54
INCLINE CREEK						
69-70	1.22	43	15,500	19	6,840	0.44
THIRD CREEK						
69-70	1.22	50	16,400	20	6,570	0.40

1 Accession Number	2 Subject Field & Group	
W	05C	**SELECTED WATER RESOURCES ABSTRACTS** INPUT TRANSACTION FORM

5 *Organization*

Lake Tahoe Area Council
South Lake Tahoe, California

6 *Title*

EUTROPHICATION OF SURFACE WATERS — LAKE TAHOE

10 *Author(s)*

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16 *Project Designation*

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21 *Note*

22 *Citation*

23 *Descriptors (Starred First)*

*Eutrophication, *Aquatic Productivity, *Growth Rates, *Bioassay, Water Quality, Limnology, Water Pollution Sources, Cycling Nutrients

25 *Identifiers (Starred First)*

*Lake Tahoe, *Pilot Pond Bioassays, *Land Use, Nutrient Yield Relationships, Lake Tahoe Area Council

27 *Abstract* A study of the factors leading to the eutrophication of surface waters, with special emphasis on Lake Tahoe, was conducted over a 5-year period (1966-'71). A survey of the nutrients and other chemical constituents was made of surface waters from developed and undeveloped land areas, sewage effluents, seepage from septic tank percolation systems and refuse fills, drainage from swamps, precipitation, and Lake Tahoe water. Also, the algal growth stimulating potential of these sources was made by flask bioassay, utilizing the alga S. gracile as a test organism. Continuous flow assays of the biomass of indigenous Lake organisms produced by various concentrations of sewage effluent were made in ponds simulating the shallow portions of the Lake. Other sources of nutrients proved too dilute to justify pond assays, but flask assays and chemical analyses were made for over 2 years on 3 major creeks. On 28 other creeks quality was monitored by chemical analysis. It was concluded that Lake Tahoe is nitrogen sensitive. Creeks draining developed land carried twice as much nitrogen as those draining undisturbed watersheds. During active development periods this ratio rose as high as 10:1. The surface streams plus precipitation contained twice the concentration of N in Lake Tahoe. Exporting all sewage in the basin would probably remove 70% total N. However, the 30% over present lake concentration contributed by streams and precipitation on the lake surface is equivalent to the secondary sewage effluent of more than 33,000 people, when the concentration of N in the lake is taken as a baseline value. Recommendations are made for protection of the shallows and for evaluating the effect of influent sediments.

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