SAN LORENZO

NITRATE MANAGEMENT PLAN

PHASE II FINAL REPORT

County of Santa Cruz
Health Services Agency
Environmental Health Service

February 1995

SAN LORENZO NITRATE MANAGEMENT PLAN

(PHASE II FINAL REPORT)

County of Santa Cruz
Health Services Agency
Environmental Health Service

February 1995

Adopted by Santa Cruz County Board of Supervisors, May 2, 1995

Approved by California Regional Water Quality Control Board,
Central Coast Region, Resolution 95-04, April 14, 1995

This report was prepared through Contract No. 0-131-250-0 in the amount of $78,825.00 with the California State Water Resources Control Board.

ABSTRACT: This report presents findings and recommendations resulting from investigations of elevated nitrate levels in surface water and groundwater in the San Lorenzo River Watershed, Santa Cruz County, California. The report includes: water quality data; calculated budgets of nitrate contributions by geographic area and land use; assessment of effect of increased nitrate on biostimulation, algae growth, and beneficial uses; measurement of nitrate levels in the vadose zone beneath shallow and deep septic system leachfields in sandy soils; evaluation of the cost-effectiveness of potential nitrate control measures; and recommendations for a surface water nitrate objective and nitrate management plan.

TABLE OF CONTENTS

TABLES AND FIGURES

SAN LORENZO NITRATE MANAGEMENT PLAN

(PHASE II FINAL REPORT)

February 1995

1 SUMMARY

1.1 Study Purpose

The County of Santa Cruz and the Regional Water Quality Control Board have worked to develop a wastewater management plan for the San Lorenzo River Watershed. As a part of that effort, the agencies have sought to evaluate the impacts of nitrogen release from onsite sewage disposal and other sources and develop recommendations for reduction of nitrate levels in ground water and surface water of the watershed. To further these efforts, the State Water Resources Control Board provided Federal Clean Water Act funds to the County of Santa Cruz to conduct the following activities:

- investigate the extent to which increased nitrate in waters of the San Lorenzo River Watershed is causing water quality degradation and limiting beneficial uses of surface water and groundwater;
- determine the primary sources of increased nitrate;
- identify and evaluate technical measures to control the release of nitrogen; and
- develop a nitrate management plan based on technical issues as well as institutional and financial concerns.

The findings and recommendations of the study will be incorporated into the County's San Lorenzo Wastewater Management Plan, planning policies, and other appropriate programs.

1.2 Study Elements

The study had the following components:

1. Measure growth of algae and other biological activity in the River to determine the extent to which that activity is related to nitrate.
2. Measure current nitrate levels in surface water, shallow groundwater and deep groundwater in critical areas of the Watershed.
3. Conduct field surveys to identify and quantify potential nitrate sources: homes on septic systems, fertilized area, stables, etc.
4. Using monitoring results, and information from other studies develop a nitrogen budget which quantifies the primary sources of nitrate in the Watershed.
6. Identify and evaluate potential nitrate control measures for the sources identified in the San Lorenzo Watershed.
7. Measure the effectiveness of various control measures for nitrogen reduction:
    a. Shallow leachfields for onsite disposal systems in sandy soils.
    b. Intermittent sand filter and recirculating gravel filter for existing onsite disposal systems (funded separately with Basin Planning funds).
    c. Use of litter and other control measures to reduce nitrate discharge from a horse stable in sandy soils (funded separately with Basin Planning funds).

8. Develop a nitrate objective for the San Lorenzo River.
9. Develop a nitrate management plan to achieve that objective, taking into account technical, institutional , and financial considerations.

1.3 Severity of Impacts

1. Summer nitrate concentrations in the San Lorenzo River at Felton have averaged 0.42 mg-N/L from 1976 through 1993. This is almost four times greater than historic levels (from the early 1960's), and seven times greater than the nitrate objective established by the Regional Board which reflects estimated predevelopment levels. Nitrate levels during the summer months are of the greatest concern, as that is the time of greatest potential biostimulation and impact on beneficial uses.

2. The current summer load of nitrate nitrogen in the River at Big Trees is 36 pounds per day. An estimated 85% of this is from non-natural sources and is comparable to the direct discharge of untreated sewage from 500 homes.

3. The City of Santa Cruz, which utilizes the River to provide 60% of the water supply for 85,000 people, has experienced periodic taste and odor problems in drinking water from the River since 1976. The presence of various organic compounds in the water also presents problems for City water treatment, resulting in the formation of disinfection by-products. It is likely that these problems are increased to some extent by elevated nitrate levels which can contribute to increased biological growth (algae, actinomycetes, etc.).

4. Although no conclusive relationship between nitrate concentrations and degree of impact on the City's water supply has been established, City officials are concerned that the discharge of nitrate and other pollutants could jeopardize this primary water supply, and/or require very expensive treatment measures to make it safe to continue to use.

5. At current nitrate concentrations in the River, there do not appear to be any adverse impacts on fishery resources, and impacts on recreation are low.

6. Nitrate levels in the Quail Hollow groundwater basin, part of a designated sole source water supply aquifer in the San Lorenzo Watershed, have increased 4-10 times above natural levels, to 3.6 mg-N/L, which is more than 30% of the drinking water standard. Although levels climbed inexplicably higher in 1986, they declined and have remained generally stable since then. However, water purveyors are concerned that a similar increase in nitrate could occur again, jeopardizing the water supply. To prevent this, water purveyors believe new nitrate sources should be controlled and existing discharges should be reduced.

7. Nitrate concentrations in shallow perched groundwater in close proximity to septic systems in the Boulder Creek area exceed drinking water standards at times. Although this is a potential violation of State policies, it does not seem to present any significant threat to water supplies or to the River. This water cannot be tapped by water supply wells and 95% of the nitrate in the shallow alluvial aquifers is removed by natural processes as

the groundwater migrates to the River during the dry months.

1.4 Primary Nitrate Sources

1. An estimated 84% of the current nitrate load in the River results from human activities in the watershed. Calculations of relative contributions to present summer nitrate levels in the lower River (at Felton) are as follows:

- Septic Systems in sandy areas	38%
- Septic Systems in non-sandy areas	19%
- Natural sources in sandy areas	12%
- Sewer discharge from B.C. Country Club	10%
- Scotts Valley nitrate plume	9%
- Livestock and stables	6%
- Natural sources in non-sandy areas	4%
- Landscaping/fertilizer use	2%

2. Approximately 67% of the nitrate in the River during the summer comes from areas underlain by sandy soils of the Santa Margarita Sandstone. A septic system in sandy soils contributes 10-15 times as much nitrate to the River as a septic system in less permeable soils. Nitrogen reduction efforts will be most effective in sandy areas.

3. Nitrate levels increased significantly during rapid development of the watershed through the 1970's, but subsequent increases have been low to insignificant. This lack of a significant increase is due to lower rates of development and implementation of County growth management programs, land use policies, and wastewater disposal regulations for protection of water quality. Without those policies, it is estimated that increased development in a ten year period would result in 40% increase in current nitrate levels. With current policies in place, that increase would be limited to 5%.

1.5 Potential Control Measures

The cost and effectiveness of potential technical measures to reduce current nitrate levels have been evaluated in this report. Following is a summary of some of the control measures, the amount they would reduce nitrate discharge from that particular source, and the annual cost per pound of nitrate-nitrogen removed from the River during the summer (July - September):

1. Shallow leachfields for septic system repairs: 20% reduction: $231/yr/lb-N.
2. Sand filter for septic system treatment: 50% reduction: $1566.
3. Enhanced septic system denitrification system: 75% reduction: $2506
4. Sewage collection and treatment: 75% reduction: $3284
5. Sewage reclamation at Boulder Creek Country Club: 90% reduction: $122.
6. Improved manure management at stables: 65% reduction: $250

These and other measures are presented in more detail in Tables 8 and 11.

1.6 Nitrate Objective

The current nitrate objective may reflect natural background conditions, and could probably not be attained without eliminating all development and disturbance from the watershed. However, development of a new numeric nitrate objective is not recommended at this time. A single number would not address the wide temporal and spatial fluctuation of nitrate levels in the River and its tributaries. Additionally, there does not appear to be a particular threshold level of nitrate, above which impacts on beneficial uses increase significantly. In place of a numeric nitrate objective, it is recommended that the nitrate management plan be based on an attainable and reasonable objective for nitrogen reduction, with a recommended set of cost-effective measures to attain that reduction.

During the past 10-15 years, the County has already implemented measures that have limited increases in nitrate discharge. It is recommended that further measures be implemented to prevent any increase in existing nitrate levels and to promote a moderate (15-30%) reduction in nitrate levels in the River over the next 10-25 years. This objective represents a balance between costs and benefits. Accomplishing this objective will reduce nitrate to the level that occurred in the early 1970's before taste and odor became a significant problem in the City water supply. This objective will improve the security of surface and groundwater supplies and will probably provide some improvement in recreational use and aesthetics of the River.

Recommended Objective: Implement nitrogen control measures for existing and proposed uses in the San Lorenzo River Watershed to ultimately reduce mean nitrate levels to 30% below 1976-94 levels. Develop and implement cost-effective measures specified in the Nitrate Management Plan which will reduce nitrate delivery by at least 50% for all new and expanded uses in sandy soils and any other large sources of nitrate which release more than 200 pounds of nitrogen per year. Expand the requirement for 50% reduction to all existing septic systems in sandy soils when reduction measures become cost-effective.

1.7 Recommended Nitrate Management Plan

The recommended nitrate management plan provides for implementing the most cost-effective measures to achieve the desired level of nitrate reduction. The plan provides for limiting increased nitrate release from new or expanded development in sandy soils, and gradually reducing nitrate discharge from existing sources as public and private funds become available and reduction technology improves. Table 11 shows some of the potential approaches for reducing nitrate levels. Implementation of the recommended policies will provide for a 15-20% reduction in current nitrate levels over the next 10 years, with a further reduction of 10% in the following 10 years. The following measures are recommended (the schedule for implementation is shown in parentheses):

Wastewater Disposal

1. Maintain the existing requirement of a one acre minimum parcel size for new development served by septic systems in the San Lorenzo Watershed (Ongoing)

2. Implement improved wastewater disposal management through the San Lorenzo Wastewater Management Plan (Ongoing).

3. Complete ongoing efforts to improve treatment procedures at Boulder Creek Country Club Treatment Plant to reduce nitrate discharge by using wastewater reclamation on the golf course. (To be implemented by July, 1995.)

4. Maintain the new requirement for shallow leachfields for new and repaired septic systems (less than 4 feet in sandy areas, and 4-6.5 feet in other areas). (Ongoing)

5. Implement enhanced technology for at least 50% nitrogen removal for septic system in sandy soils:
    a. Require septic systems serving new or expanded uses in sandy soils to install enhanced treatment measures which will reduce nitrogen discharge by at least 50%. (Expected implementation by August, 1995; existing systems to be upgraded at the time of major remodels (projected rate of 1.2% (20 systems) per year).)
    b. Encourage the use of nitrogen removal methods for any onsite disposal system which will use a nonstandard system. (Estimated 20 upgrades per year.)
    c. Continue to evaluate new onsite wastewater disposal technology for nitrogen reduction to identify more cost-effective measures. Require higher levels of nitrogen removal if measures become available that are more cost-effective than sand filters.
    d. Apply for State revolving funds and other funds to develop a funding source to assist property owners in repairing their systems to provide enhanced treatment. (Expected implementation July, 1996, with an estimated 40-100 upgrades per year thereafter.)
    e. When more cost-effective technology and/or funding assistance becomes available, require all onsite system repairs in sandy areas to utilize enhanced treatment for nitrogen removal. (Estimated implementation January 1997, with upgrades of 2.7% (40 systems) per year.)

6. Require all large onsite disposal systems which serve more than 5 residential units or dispose more than an average of 2000 gallons per day to utilize enhanced treatment to reduce nitrate discharge by at least 50%. Installation of such measures for existing systems shall be required at the time of system repair or upgrade. (Estimated 1-2 upgrades involving approximately 5000 gallons per day per year.)

7. Require all new or revised waste discharge permits and all new development projects in the San Lorenzo Watershed to include nitrogen control measures consistent with this Nitrate Management Plan.

Livestock Management

8. Continue to work with stable owners and develop a new ordinance requiring practices to reduce nitrate discharge: cover manure piles, maintain manure piles and paddock areas at least 50-100 ft from streams or drainageways, direct drainage away from paddock areas, and provide other measures as necessary to reduce discharge of nitrate, sediment, and contaminants. (Ongoing, with new ordinance by January, 1996)

Land Use Regulations

9. Maintain current density restrictions requiring 10 acres per parcel for new land divisions and other protective measures for groundwater recharge areas.

10. Maintain current regulations on erosion control, land clearing, and riparian corridor protection.

11. Do not approve new land use projects within the San Lorenzo Watershed which will increase the discharge of nitrate to groundwater or surface water by more than 10 pounds of nitrogen per acre per year from the project area.

Ongoing Monitoring

12. Monitor the Scotts Valley nitrate plume, and identify potential ongoing sources of nitrate. Work with the City of Scotts Valley and property owners for reduction of nitrate discharge from Scotts Valley, if feasible. (Ongoing monitoring, implementation of potential control measures in 2000, if necessary and feasible).

13. Continue to monitor nitrate levels in surface and groundwater. Reevaluate implementation of more stringent control measures if summer nitrate levels in the River have not declined by at least 15% by 2010. (Ongoing monitoring, reevaluation in 2010).

2 INTRODUCTION

The purpose of this study is to develop appropriate recommendations for the management of nitrogen releases in the San Lorenzo River Watershed in order to protect underground water supplies and to maintain dry season concentrations of inorganic nitrogen, primarily nitrate, at levels which will not cause significant adverse impacts on recreation, water supply, aquatic habitat, or other beneficial uses of the River or its tributaries. Nitrate is the primary constituent of concern. Because it can originate from all forms of organic and inorganic nitrogen discharged to the environment, the study addresses the discharge of all forms of nitrogen in the watershed.

2.1 Background

The San Lorenzo River drains a watershed area of 138 square miles (see Figure 5a in Section 5.1.1). The watershed is home to approximately 75,000 people, most of whom utilize onsite wastewater disposal methods. The River is a designated State Protected Waterway, and serves as a major recreation resource for swimming, wading, hiking, and steelhead fishing. The River also provides approximately 60% of the water supply for the City of Santa Cruz water system, with approximately 85,000 customers. This study focuses on the 115 square mile watershed area upstream of the City's water intake. The study area does not include Branciforte Creek, Carbonera Creek, or most of the City of Scotts Valley which does not contribute surface or groundwater flow to Bean Creek.

Since the 1950's, nitrate levels in the San Lorenzo River have risen from below 0.1 mg-N/L to 0.4-0.5 mg-N/L (at the USGS gage at Big Trees, Felton). The major sources of this additional nitrate appear to be wastewater disposal, livestock, residential fertilizers, and other development influences. Portions of the watershed are underlain by very permeable sandy soils, which facilitate the transmission of nitrate to groundwater and surface water.

There has been concern that the elevated nitrate levels in the River are stimulating excessive growth of algae and instream micro-organisms. This increased biological growth could in turn adversely affect coldwater habitat, instream and streamside recreation, and water supply. Since the late 1970's, the City of Santa Cruz Water Department has reported increased taste and odor problems in water drawn from the San Lorenzo, and is now spending over $60,000/year for additional chemical treatment to address that problem. The City has an additional concern that instream biological growth increases the level of organic compounds in the River, which in turn increases the level of trihalomethanes (THM's) and other disinfection by-products in the treated water supply. Under current conditions the City will have to make considerable treatment modifications to meet proposed standards for THM's.

Because of the complexity of the processes of nitrogen cycling in watershed soils and streams, it has been unclear to what extent the stream ecosystem has actually been affected by nitrogen release from development. Preliminary studies during the drought and post-drought period of 1977-78 suggested that algae growth in the River might indicate moderate levels of nutrient enrichment (Butler, 1978). More recently, investigators have suggested that current nitrate levels are not adversely affecting the instream ecosystem, but in fact may be adding to the productivity of the steelhead and salmon fishery

(Gilchrist and Associates, 1984).

Much of the nitrate in the San Lorenzo River originates from a relatively small portion of the watershed: developed streamside corridors underlain by very permeable alluvial soils and developed areas underlain by the extremely permeable Santa Margarita Sandstone. These latter areas include the Quail Hollow area and the Scotts Valley area. In both of these areas, there have also been concerns about nitrate contamination of underlying water supply aquifers.

Some work had been previously conducted to evaluate the extent of nitrogen release from septic systems in the San Lorenzo area. A Section 208 study in 1982 developed substantial data on influences of septic systems on groundwater quality in many areas of the San Lorenzo Valley (<u>San Lorenzo Valley On-Site Wastewater Disposal Management Study</u>, (HEA, 1983)). More recently, in 1986, a 205 (j) report, Scotts Valley Ground-Water Basin Nitrate Pollution Study was completed (Luhdorff and Scalmanini, 1986). The County Planning Department conducted studies of algal growth in 1977-78, and has been monitoring nitrate levels since 1975. Santa Cruz County Health Services Agency has been conducting ongoing monitoring of nitrogen compounds in streams, shallow groundwater, and deeper aquifers since 1986. The Agency has also done regular monitoring of algae growth in various parts of the River since 1987.

There has also been a history of management actions taken to address the issue of nitrates in the San Lorenzo River. Partly in response to the 1977-78 studies and the 1983 208 report, the Central Coast Regional Board, in 1983, lowered the nitrate objective from 1.0 mg-N/L to 0.06 mg-N/L, a level that their staff believed reflected the nitrate levels in the River prior to extensive development in the Watershed. Septic system installation criteria were also modified at that time to provide for more nitrogen removal in the disposal field. At the current time, the established nitrate objective is much lower than prevailing levels in most parts of the Watershed and is probably only attainable at great cost. County staff believes that the current objective is set unnecessarily and unrealistically low and in 1986 requested the Regional Board to modify the objective. The Regional Board has directed their staff to review that objective in conjunction with the efforts by Santa Cruz County.

The San Lorenzo Wastewater Management Program was initiated by the County in 1985. The purpose of this program is to monitor water quality, inspect septic systems, and improve wastewater disposal practices as necessary to protect water quality and public health. In order to properly manage wastewater disposal to prevent impacts from nitrogen discharge, it is necessary to resolve the remaining questions regarding nitrogen impacts and to develop recommendations for appropriate nitrogen control measures. To that end the County applied for and received funding assistance from the State Water Resources Control Board to conduct a water quality planning study under Section 205j of the Federal Clean Water Act.

This nitrate management study commenced in January, 1990, with an initial completion date of November 1991 for the first phase of the work. Midway through the study it became apparent that additional work would be needed to thoroughly resolve the issues of nitrate management. The County applied for and received supplemental 205j grant assistance to conduct Phase 2 of the study from June, 1991 to November 1994. A Phase 1 final report was completed in May 1992, which presented the preliminary findings and interim recommendations from the Phase 1 work. The additional Phase 2 work has generally supported and strengthened the initial Phase 1 findings. The current document summarizes the results of both Phases and presents recommendations for a nitrate management plan for the San Lorenzo Watershed.

2.2 Report Organization

This study was conducted by Santa Cruz County Environmental Health Service staff, with the assistance of two subcontractors for specific tasks. Professor Rhea Williamson of San Jose State University conducted studies of biostimulation (During Phase 1, Dr. Williamson was assisted by Questa Engineering Corporation of Point Richmond, California.) Balance Hydrologics, Inc., of Berkeley, California prepared the watershed nitrogen budget and identified potential technical control measures for reduction of nitrogen discharge during Phase 1. In Phase 2, Balance conducted an investigation of the effectiveness of using shallow leachfields for increased nitrogen removal in sandy soils. The consultants' work is summarized in this report and is presented in detail in separate reports bound under separate cover. This report also presents the detailed work from the subtasks which were conducted by County staff. The final portions of the report represent an integration of findings from all subtasks in order to present a comprehensive recommendation for nitrogen management in the San Lorenzo Watershed.

The organization of this report differs somewhat from the overall organization of the contract workplan. Table 1 shows the report organization in relation to the subtasks of the workplan and the work that was performed by the subcontractors.

Table 1: Organization of Report in Relation to Required Workplan Tasks

REPORT SECTION	PHASE 2 WORKPLAN TASK NO.	BACK-GROUND REPORT
INVESTIGATIONS OF BIOSTIMULATION	5	1,2
NITROGEN SOURCES		
- Water Quality Data	4.4, 4.5	
- Watershed Nitrogen Budget	4.6	3
- Potential Nitrogen Sources	4.6	
- Contributions from Watershed Sources	4.6	
NITROGEN CONTROL MEASURES		
- Investigations of Shallow Leachfield	4.3, 4.5	4
- Technical Control Measures	4.6, 6.1	3
- Inst. and Finan. Considerations	7.1	
NITROGEN MANAGEMENT PLAN	6	

Background Reports (Bound Separately):

1 - Questa Engineering Corporation and San Jose State University, June 30, 1991, San Lorenzo River Nitrate Biostimulation Assessment, Final Report, Prepared for Santa Cruz County Environmental Health Services.

2 - Williamson, Rhea L., et al., June 10, 1993, San Lorenzo River Nitrate Biostimulation Assessment Study Final Report, Prepared for Santa Cruz County Environmental Health Services.

3 - Balance Hydrologics, Inc., July, 1991, A Nitrate Budget-Based Assessment of Potential Nonpoint-Source Control Measures to Reduce Nitrate Delivery to the San Lorenzo Watershed, Santa Cruz County, California, Prepared for Santa Cruz County Environmental Health Services.

4 - Balance Hydrologics, Inc., August, 1994, A Comparative Study of Nitrate Movement Below a Deep and a Shallow Leachfield in Zayante Soils, Glen Arbor, Santa Cruz County, Prepared for Santa Cruz County Environmental Health Services.

3 IMPACTS OF NITROGEN DISCHARGE

Nitrogen discharge in the San Lorenzo River watershed has the potential to adversely impact water supplies, fishery resources, and stream-based recreation activities. Specific findings regarding groundwater supply, fisheries, and recreation are discussed in the following subsections, while the investigations of biostimulation are discussed in Section 4.

3.1 Groundwater Supply

There are two water supply aquifers in the San Lorenzo Watershed which have experienced significant increases in nitrate, with potential to threaten their future utility for water supply. There is also one area in the Watershed with a high density of septic systems where shallow groundwater has nitrate levels periodically in excess of drinking water standards. Although the perched groundwater cannot legally be used for drinking water supply, the high nitrate levels constitute a potential violation of current state policies, and the perched groundwater does contribute water and some nitrate to the San Lorenzo River.

The Quail Hollow basin is a part of the Santa Margarita/Scotts Valley groundwater basin. It is an unconfined sandy aquifer overlain in part by residential development served by onsite sewage disposal systems on lots less than one half acre in size. Groundwater pumping from this basin typically provides 25% of the water supply for the San Lorenzo Valley Water District, which supplies most of the population of the San Lorenzo Valley. Although nitrate concentrations in the groundwater had been increasing gradually over the years, in the fall of 1986, they increased dramatically with a high level of 6.2 mg-N/L (the drinking water standard is 10 mg-N/L). There was great concern that this increasing trend would continue, making the wells unsuitable for water supply.

The Water District commissioned a study to determine the cause of the increase, and the likelihood that the increase would continue. Geohydrologist Nick Johnson (1989) concluded that the nitrate concentrations were directly related to the amount of development surrounding the well fields. However, with the continued implementation of controls on new development in the area already imposed by the County, it was projected that nitrate levels would not increase further. The sharp increase in 1986 was probably related to the flushing out of accumulated nitrate from the unsaturated zone by the heavy rains in early 1986. In subsequent years, nitrate levels in the wells have dropped and stabilized at levels of approximately 3.6 mg-N/L (see Figure 10).

Although long-term nitrate contamination does not currently appear to be a potential threat, any relaxation of development standards or approval of new uses which release significant amounts of inorganic nitrogen could result in new threats to the water supply. Reductions in current nitrate discharge would reduce the likelihood of another unexpected spike in nitrate levels which could temporarily jeopardize the water supply.

In southwestern Scotts Valley, municipal water supply wells experienced nitrate levels in excess of drinking water standards beginning in 1981 (Luhdorf and Scalmanini, 1986). This area was characterized by dense residential development with significant landscaping and onsite sewage disposal systems overlying the highly permeable unconfined aquifer. The area was sewered in 1986 and nitrate concentrations subsequently dropped to 5 mg-N/L by 1990.

A significant underground plume of nitrate remains in the Scotts Valley area, which continues to discharge to Bean Creek, contributing 9% of the summer nitrate load of the San Lorenzo River. This contribution may decline with time as accumulated nitrate is flushed from the system. The contribution had declined significantly by 1990, but then increased by about 50% in 1992 and 1993. This fluctuation may be related to variations in groundwater flow due to the significant pumping depression in the area, or it may be indicative that development, landscaping and golf course fertilization will continue to be source of nitrate in this area. This area should continue to be monitored.

There is potential for excessive nitrate contamination of groundwater in other sandy parts of the Watershed. However, none is known to exist at this time, and it is expected that groundwater supplies should be adequately protected by current standards for development and nitrogen control, as discussed in Sections 7 and 8 of this report.

In one localized area of the Watershed, downtown Boulder Creek, shallow groundwater at times has nitrate in excess of drinking water standards. This is shallow perched groundwater which serves as a zone of mixing, dilution and treatment of plumes of septic system effluent. These zones are typified by impermeable layers at 20-50 feet in depth which would protect any underlying useable drinking water aquifer. The primary concern with nitrate levels in these areas is through their contribution to baseflow and nitrate loads of the River itself. During the summer, this contribution is not particularly significant, as nitrate loads in the River do not change significantly through this reach. Nitrate content is most likely reduced through denitrification and uptake in the riparian corridor through which the perched groundwater seeps into the River.

The elevated nitrate levels in these perched groundwater have been interpreted by State staff as potential violations of the state drinking water policy, which designates all surface and groundwaters as potential drinking water supply, except where they could not yield enough water to support a home. In this case, these perched zones could not be legally tapped for drinking water purposes. With average parcel sizes of 6000 square feet there are no suitable locations for a well that are not within 100 feet of a septic system. Even if a well were installed, the requirement of a 50 foot sanitary seal would prevent tapping the perched zones. Because of these factors, elevated nitrate levels in these perched zones should not be a concern as a direct threat to drinking water supplies. Because these are unusable effluent mixing and treatment zones, County staff believe that the drinking water policy should not be applied as a measure of impact on beneficial use. In addition, the State Water Resources Control Board has already been requested to review the drinking water policy with respect to the unavoidable localized impact of properly functioning septic systems.

3.2 Biostimulation and Instream Beneficial Uses

There has been concern that increased nitrate in the San Lorenzo River has the potential to cause increases in algae growth and other instream biological activity, with resulting impacts on recreation and the aquatic ecosystem. Nitrate and phosphate are the major nutrients necessary for growth of algae, diatoms, fungi, and other organisms of the aquatic ecosystem. Because the River is naturally high in phosphate, nitrate is the limiting nutrient, and an increase in nitrate could thus be expected to result in some increased growth of primary organisms. However, there are also many other factors which affect growth, such as light, substrate, streamflow, temperature, and turbidity. In addition, in flowing water, many types of algae can effectively use nitrate at very low concentrations, and changes in concentration may have limited affect on growth of those organisms.

Increased biological growth has the potential of physically impeding waterways, using up dissolved oxygen necessary for fish and other higher organisms, or creating conditions that are slimy, slippery, smelly, murky, or otherwise unaesthetic and limiting to recreational use of the waterway. Although some of these conditions exist at times on the San Lorenzo River, there has been no reported impact on recreational use of the River (SCCHSA, 1989).

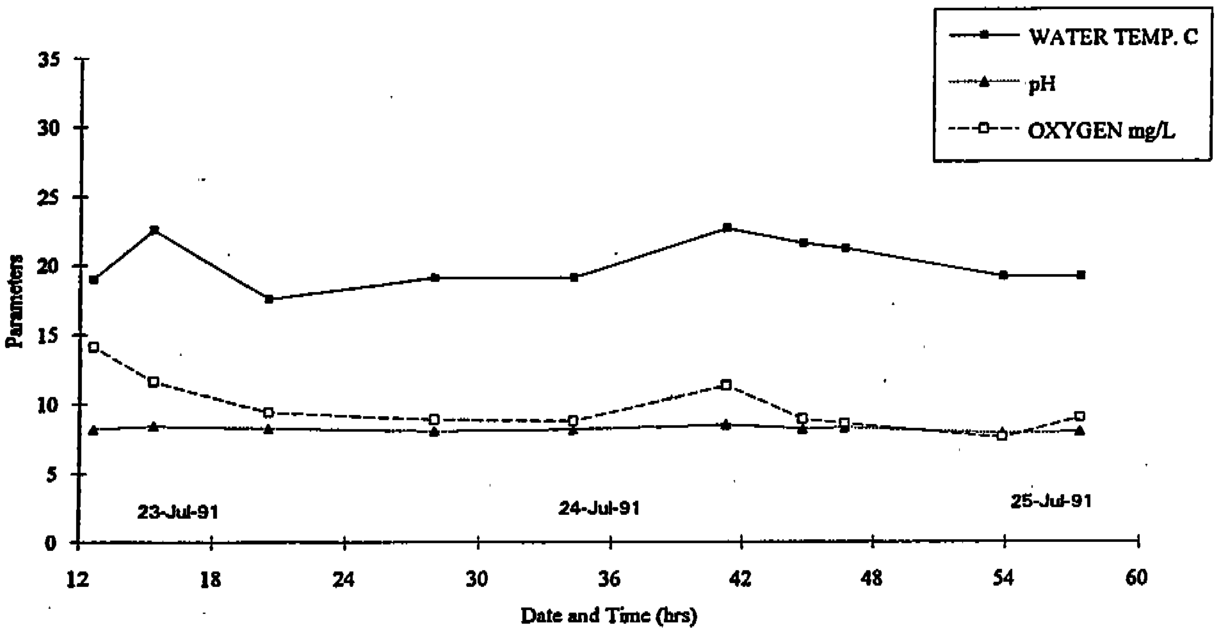
Diurnal dissolved oxygen concentrations have been assessed at several locations in 1975, 1977, and 1991. The lowest recorded oxygen level was 5.5 mg/L in a pool north of Boulder Creek during the end of the 1975-77 drought (Ibid.). During the 1991 studies, the lowest reading was 7.5 mg/L at Sycamore Grove (Williamson et al., 1993) (see Figure 1). Otherwise, oxygen levels have been found to remain quite high, and not threatening to salmonids or other aquatic life.

In 1983, an investigation by a fisheries biologist to assess the impacts of onsite wastewater disposal in the San Lorenzo Valley did not reveal any threats to the fishery (Gilchrist and Associates, 1984). The biologist indicated that increased nitrate and increased algae provided more food and was beneficial to the fishery (Ibid.).

During assessments of algae growth conducted by the County, assessments of potential impact on recreation or aesthetics have been made. There are times when conditions of sliminess, murkiness, or prolific algae growth have been observed, but no complaints, or documentation of actual impact have been received to date.

County staff believe that current levels of nitrate and algae growth do not have any adverse effect on the fishery, and may provide a beneficial effect. Although there may be some adverse impact on recreation or aesthetics, it does not seem to be a major problem at this time. However, the potential effect of a significant increase in algae growth on the fishery and other instream beneficial uses is not known.

Figure 1: Diurnal Fluctuations in Dissolved Oxygen, Temperature, and pH in the San Lorenzo River at Sycamore Grove, July 23-25, 1992



Fluctuations in Oxygen, pH, and Water Temperature at Sycamore Grove in July of 1991.

Summary of Data Collected July 23, 1992 through July 25, 1992 from Several Locations along the San Lorenzo River.

Location	Water Temp. (^{o}C)		pH		Oxygen (mg/l)	
	Min	Max	Min	Max	Min	Max
Sycamore Grove	17.5	22.5	7.8	8.4	7.5	14.1
Big Trees	16.5	23.0	7.5	7.9	7.9	14.1
Gunther	17.5	22.0	7.8	8.3	12.9	14.2
River Street	16.0	20.0	7.7	8.0	7.8	14.2
Waterman Gap	14.0	19.0	7.9	8.2	7.8	10.0

3.3 Surface Water Supply

Water taken from the lower San Lorenzo River at the Santa Cruz City limits provides 60% of the water supply for the City of Santa Cruz and the Live Oak area (approximately 85,000 people). Possible degradation of this surface water supply is by far the most significant potential impact of increased biological growth resulting from increased nitrate in the San Lorenzo River. Increased biological activity could result in the excessive release of compounds that produce obnoxious tastes and odors and compounds which can cause the formation of potentially carcinogenic compounds in the water treatment process.

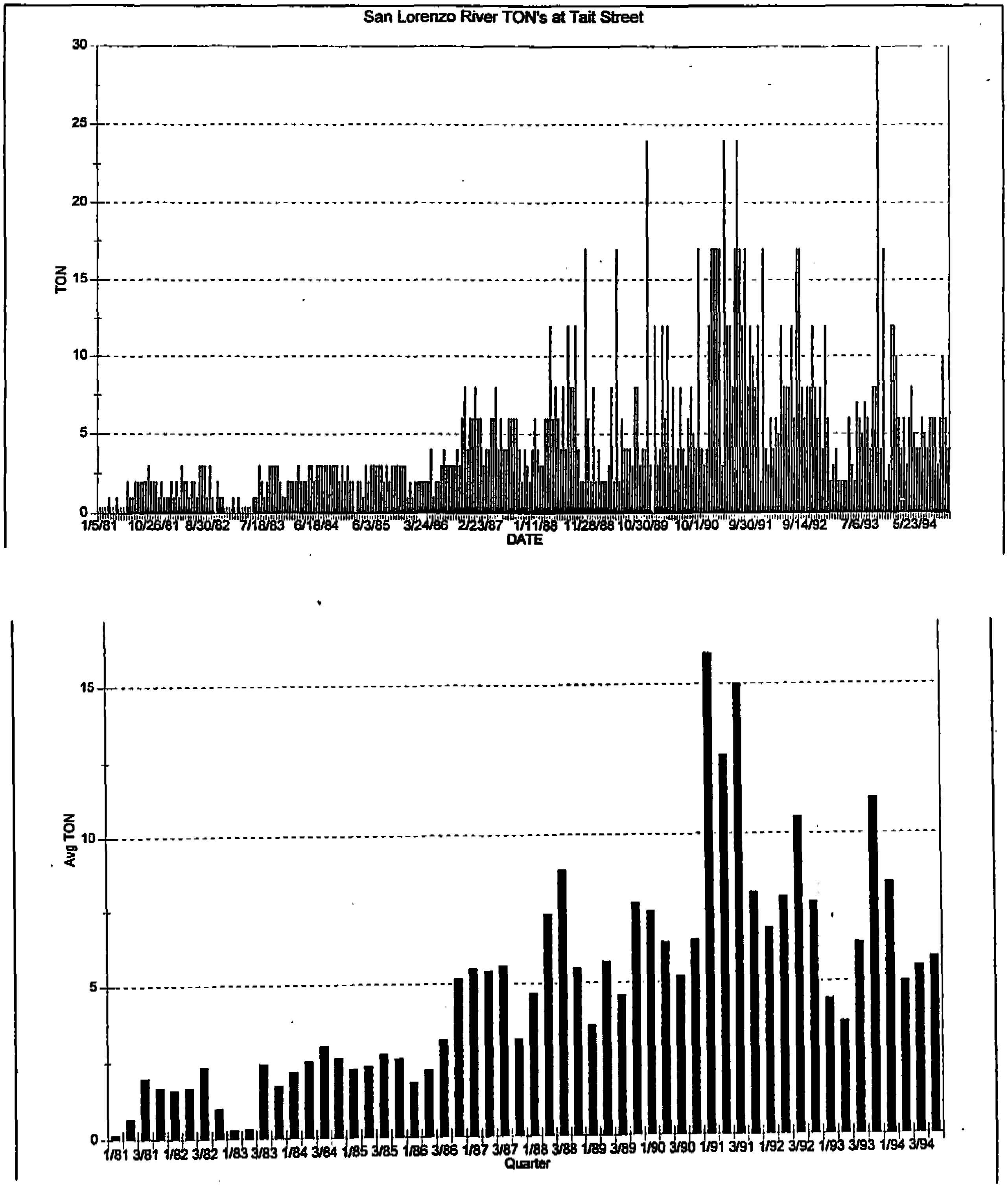
Compounds producing taste and odors are released by a variety of algae, actinomycetes, and other primary organisms that occur in the San Lorenzo River. Although they do not represent a health hazard, the tastes can be quite obnoxious and lead to a public perception that the water is unclean and unsafe to drink. Causative agents often associated with taste and odor problems are the organic compounds, geosmin and 2-methylisoborneol (MIB). The production of geosmin and MIB is limited to actinomycetes and cyanobacteria (blue-green algae).

Increased taste and odor problems have been reported since the late 1970's. The City water treatment plant currently spends $60,000 a year to treat the River water for removal of taste and odor (Terry Tompkins, personal communication). The worst problems typically occur in the fall and may be related to decaying algae or other material. The most severe periods were fall of 1983 and 1986, following relatively wet winters. Wet years generally result in channel erosion and scour, opening up the channel to more sunlight, increased nitrate concentration due to flushing of the watershed, and potential wash-off of soil organisms and organic material into the River. Although results were not available for 1983, nitrate levels were significantly higher in the summer of 1986 compared to subsequent dry years (Section 5.1.3). Figure 2 shows historical values for Threshold Odor Number (TON), a semi-quantitative measure of odor in the water, for water collected from the River at the City's Tait Street diversion. The method for assessing odor changed in 1987, limiting direct comparison of data.

A more significant public health concern results from the formation of carcinogenic disinfection by-products, such as trihalomethanes (THM's), when water containing dissolved organic compounds is treated with chlorine. Treated water from the San Lorenzo River currently meets standards for THM's. However, the State and EPA are considering lowering the standard to a point that would be impossible to meet using current treatment methods. The potential for formation of disinfection by-products may be increased by increased biological activity in the stream, which may in turn be stimulated by increased nitrate levels. The City has much greater problems with water from the San Lorenzo River than from its small coastal streams. This may be related to the much larger size of the River and/or the higher levels of nitrate, both of which would tend to increase biological activity and the load of dissolved organic compounds which can create disinfection by-products.

The effects of biostimulation on taste and odors and production of organic compounds are discussed in more detail in the following section.

Figure 2: **San Lorenzo River Odor (Threshold Odor Number) at Tait Street Intake**
Source: City of Santa Cruz Water Department
Note: The City began testing for Threshold Odor Number units in 1987. Previous odor values are not comparable.



4 INVESTIGATIONS OF BIOSTIMULATION

In order to more thoroughly evaluate the effects of nitrate discharge on drinking water supply and other instream beneficial uses, the Nitrate Management Study included a component to conduct field and laboratory investigations of biostimulation in relation to nitrogen concentrations and other factors. The San Lorenzo River Nitrate Biostimulation Assessment was conducted primarily by Professor Rhea Williamson and her students from San Jose State University, with assistance from County staff (and some assistance during Phase 1 from Questa Engineering Corporation). The primary purpose of the study was to assess instream growth of algae and actinomycetes in relation to nitrate concentration and other factors, and to assess the relationship of biological growth to taste and odor and dissolved organic carbon in the water.

The Phase 1 work included a literature review of historical data and field investigations at six locations along the San Lorenzo River between Sycamore Grove and Waterman Gap (Figures 5a and 5b in Section 5.1.1). These stations represented a variety of field conditions, with mean nitrate concentrations varying from 0.16 to 0.48 mg-N/L. Biological, chemical, and physical parameters were measured six times between July and December of 1990. Phase 2 work included additional monitoring from June 1991 through July 1992, diurnal measurements of dissolved oxygen and other parameters, laboratory assessment of algae growth in response to varied nitrate levels, and an instream assessment of the effect of increased nitrate levels. The findings and conclusions of the work are summarized in the following sections and are presented in detail in two separate reports for each Phase.

4.1 Algae

Algae in the River can be divided into two groups: macroalgae and microalgae. The macroalgae are the large growths of filamentous algae that are obvious to the naked eye. Macroalgae has the most obvious effect on esthetics. It also represents substantial biomass and serves as a substrate for actinomycetes, fungi, invertebrates, and other instream growth. Microalgae are generally microscopic and occur in a thin film attached to rocks, macroalgae or other substrates. Microalgae can also be free-floating as plankton. Diatoms are the predominant type of microalgae. It is the growth of microalgae that causes the slippery feel to rocks. Both types of algae can impart taste and odor to the water and can serve as substrate for actinomycetes and other organisms that can cause taste and odor problems, particularly during the senescence and decay of the algae. Growth of macroalgae and diatoms follows a seasonal pattern with two peaks: late spring to early summer, and fall.

Cladophora is the most visible form of macroalgae in the River. Much of the work focussed on the occurrence of *Cladophora* and the factors affecting it's growth. It was the dominant macro algae collected from all locations in the 1990-92 studies. This is consistent with findings from all studies since the drought of 1977, when *Spirogyra* was found to be dominant at several stations (Butler, 1978). In general, *Cladophora* tended to be found on cobble and boulder substrates. Growth was typically restricted to riffles. At pool sites where *Cladophora* was observed, growth occurred on boulder surfaces, and filaments were short (1-2 cm in length) and of poor condition. Conditions of high flow resulted in the presence of increased *Cladophora* biomass, longer filaments, and fewer epiphytes on *Cladophora* filaments.

These trends are not out of the ordinary. *Cladophora* blooms have been documented throughout the world, particularly in sunlit rivers (Whitton, 1970). The alga proliferates on boulders and bedrock, and has been documented to attain significant filament lengths in a matter of a few days (Wong et al., 1978). In Northern California, filament lengths of several meters in the South Fork of the Eel River (Powers, 1990), and Truckee River (Horne, personal communication) and up to one meter in Mill Creek, California (Williamson, 1987) have been measured in sunlit riffle areas. All three of these systems have inorganic nitrogen concentrations significantly lower than that in the San Lorenzo River (less than 0.05 mg-N/L, less than 0.02 mg-N/L, and less than 0.05 mg-N/L respectively).

Lyngbya, a cyanobacteria (blue-green algae) was found throughout the San Lorenzo River, but was most obvious at Big Trees, where it was present on all cobbles with an earthy odor. It is well documented as a primary cause of taste and odor problems in Southern California (Williamson, et al., 1993). *Anabaena*, another cyanobacteria, was observed with heterocysts that were apparently actively fixing atmospheric nitrogen at one location in the lower River which normally has a moderate inorganic nitrogen concentrations. This type is also known to cause significant taste and odor problems (Terry Tompkins, pers. comm.). Cyanobacterial nitrogen fixation is typically associated with high phosphate and low inorganic nitrogen concentrations in water (Stewart, 1973; Toetz, 1973; Vanderhoef et al, 1974). Nitrogen fixation is thought to cease completely when nitrate levels exceed 0.300 mg-N/L (Horne and Fogg, 1970). The finding of active cyanobacteria suggests that even if nitrate levels in the River were reduced, the cyanobacteria have the potential to increase nitrate concentrations available for all algae growth through their activity.

Algal species identified in this study have, in general, been identified in previous surveys of the San Lorenzo River (Butler, 1978; Ricker and Butler, 1978; SCCHSA, 1989), however biomass descriptions indicate that in previous years, *Cladophora* growth was more prevalent, and that *Lemna* was a major vascular plant in the River, particularly in the summer (SCCHSA, unpublished data, 1987-1989). Algae not found in this study that have been found in previous ones include *Amphora, Chlorococcus, Coleochaete, Cosmarium, Gomphonema, Hydrodictyon, Mougeotia, Nostoc, Tribonema*, and *Vaucheria*.

4.2 Actinomycetes

Actinomycetes are filamentous bacteria that are widely distributed in soil, leaf litter, and to a much lesser extent in stream sediments. They are often responsible for a musty smell or taste in water where they are growing, and are suspected as a major factor causing taste and odor problems in drinking water taken from the San Lorenzo River. Actinomycete growth can be increased by increased presence of nitrogen, organic carbon, and other nutrients in the water (Questa and SJSU, 1991). Actinomycete presence can also be increased by wash off of organisms into the River from soil, where they are much more numerous. This introduction of organisms from the Watershed would be expected to be much greater during wet years (Rhea Williamson, personal communication). Prior to this study, no actinomycete data was available for the San Lorenzo

River.

During this study, isolation of actinomycetes was most successful in the lower three locations in this study, Sycamore Grove, Rincon, and Big Trees. The lower locations were also demonstrated to have the highest levels of *Cladophora* growth and somewhat higher Total Organic Carbon (TOC) concentrations. Use of *Cladophora* as a substrate for growth and the enhancement of actinomycete growth by increased TOC concentrations may explain the greater number of actinomycete isolates at these locations. Interestingly, these lower locations had the lowest levels of coarse organic debris associated with the riffles, with percent cover ranging from 0 percent to less than 5 percent at all three sites, relative to organic cover values of less than 5 percent to 20 percent at Gunther, less than 5 percent to 75 percent at River Street, and less than 5 percent to 65 percent at Waterman Gap. At the lower River stations, *Cladophora* may be a more preferable substrate for the actinomycetes than leaf and twig litter. Although some of the data suggested that actinomycetes were not a significant source of taste and odor problem in the San Lorenzo River, much of the actinomycete investigations were inconclusive due to difficulties with sampling and enumeration procedures (Williamson, et al., 1993).

4.3 Total Organic Carbon

The amount of total organic carbon (TOC) in water is somewhat related to the potential for trihalomethanes and other disinfection by-products to form upon treatment of water for drinking water purposes. The San Lorenzo River was found to have relatively low TOC levels for a river its size. Mean TOC levels were 1.5 mg/L in the headwater areas at Waterman Gap, and 2.6 mg/L at the downstream stations at Big Trees and Sycamore Grove. This represents only a 50% increase in TOC as the River flows the 18 miles from its headwaters to its downstream end. The amount of coarse organic debris in the River decreased significantly in a downstream direction. This is typical of most river systems, where organic material is broken down into a higher proportion of fine and dissolved organic carbon as material is carried downstream. The sources of TOC in the River are mostly from decaying leaves, twigs, and algae and contributions from tributaries along the River. Presence of nitrate and other nutrients facilitates the process of decomposition and release of organic compounds (Williamson, et al., 1993; SCCHSA, 1989; Mendenhall, 1986).

Although TOC in the San Lorenzo River is relatively low, the River has a much higher TOC content and potential for formation of disinfection by-products than the north coast streams used as water supplies by the City of Santa Cruz. This may be related to the much larger watershed size and stream length and greatly increased potential for accumulation of stream borne organic carbon. It may also be related to the much greater algae growth in the River resulting from more sunlight reaching the stream channel. Given the low levels of TOC, and the effect of a variety of other factors, it is unlikely that nitrate has a significant effect on TOC.

4.4 Effect of Nitrogen Concentrations and Other Factors

It is apparent that the San Lorenzo River water quality is enriched with respect to nitrogen. Coupled with high phosphate concentrations, it fits the classic definition of a nitrogen limited system, in which an increase in nitrogen concentration should result in some increase in biological growth. However, in a flowing water environment, even low levels of naturally available nitrate may be more than adequate to support algae growth, particularly if other physical parameters of light, substrate and flow are suitable. These other factors may have much more effect on algae growth than nitrate level.

The River does not appear to have unusually high levels of nitrate. Reid and Wood (1976) cite an average global nitrate value for unpolluted fresh waters (streams, rivers, and lakes) of 0.3 mg N/L, with values up to 1.0 mg-N/L considered typical. A wide range of total inorganic nitrogen (nitrate, nitrite, and ammonia) concentrations can support algal growth, with levels below 0.100 mg-N/L considered limiting for most systems and levels above 0.400 mg-N/L not likely to limit growth (Goldman and Horne, 1983). In eutrophic systems, nitrate levels as low as 0.095 mg N/L can support substantial populations of Oscillatoria (Zevenboom and Mur, 1981). In Castle Lake, California, periphyton grew quite readily at half saturation nitrate concentrations of 0.045 to 0.113 mg-N/L (Priscu, 1982). It thus appears that San Lorenzo nitrate levels are above the level that would affect growth of many types of algae.

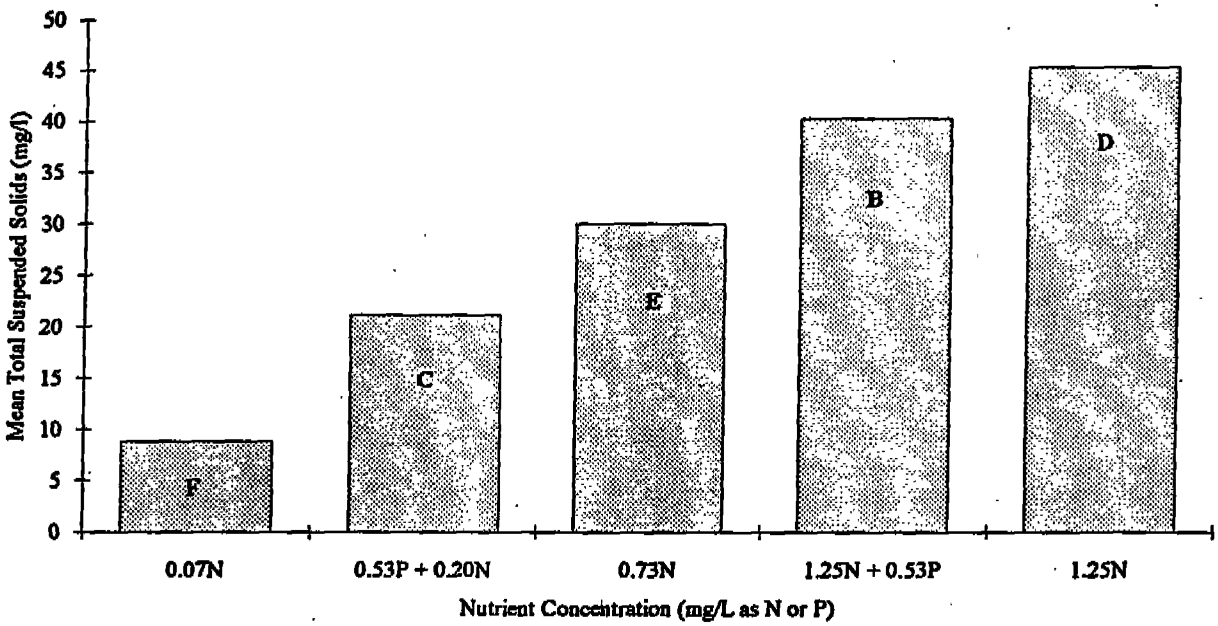
In order to further evaluate the effect of nitrate in the San Lorenzo River, this project included quantitative measurements of macroalgae growth, primarily *Cladophora sp*. Growth of attached microalgae and diatoms was described, but not quantified. The data gathered between June of 1990 and July of 1992 did not indicate any unusual amounts of macroalgae growth in the San Lorenzo River. The data also indicated that there is no one outstanding parameter, biological, chemical or physical, that is particularly responsible for the amount of algae growth at different times of the year or different locations in the San Lorenzo River. A multivariate statistical analysis of factors affecting algae cover during the period was performed, but no significant correlations were identified. However, in looking at changes in algae growth over the period at individual stations, the following factors appeared to have the most effect on algae growth, in the order indicated: flow velocity, water temperature, shading, nitrate, and substrate.

The conclusions above are generally consistent with the finding of the County's 1986-92 studies, which included a multivariate linear analysis comparing factors from station to station. That analysis indicated that variations in nitrate did not significantly affect macroalgae growth. The only significant factor correlating with the average bottom cover by macroalgae was the amount of light reaching the stream bottom. That study also included an analysis of factors affecting the rate of microalgae (diatom) growth on artificial substrates. Comparing stations, there was a significant correlation between nitrate concentration and the rate of diatom growth. No analysis was made of the effect of nitrate on the total biomass of microalgae on natural substrates.

In order to further assess the effect of nitrate, the Phase 2 study included in situ studies and laboratory studies to measure the effects on algae growth of nutrient additions to San Lorenzo River water. The laboratory studies used two types of algae: *Cladophora* collected from the River, and a laboratory culture of single cell microalgae, *Selanastrum capricornutum.* The experiment with the microalgae indicated that a 135% increase in nitrate, from 0.53 to 1.25 mg-N/L, resulted in a doubling of biomass (Figure 3). Increasing phosphate as well had no effect. The data also suggested that significant microalgae growth could occur at concentrations as low as 0.07 mg-N/L. The laboratory studies of *Cladophora* growth showed no significant effect from addition of nitrate and/or phosphate (Figure 4). The insitu experiments were inconclusive, but consistent with other insitu studies, which suggest that nitrate additions do not significantly affect algae growth in streams with nitrate concentrations greater than 0.055 mg-N/L (Williamson, et al., 1993). Other factors such as light, flow, substrate, and grazing are probably more important.

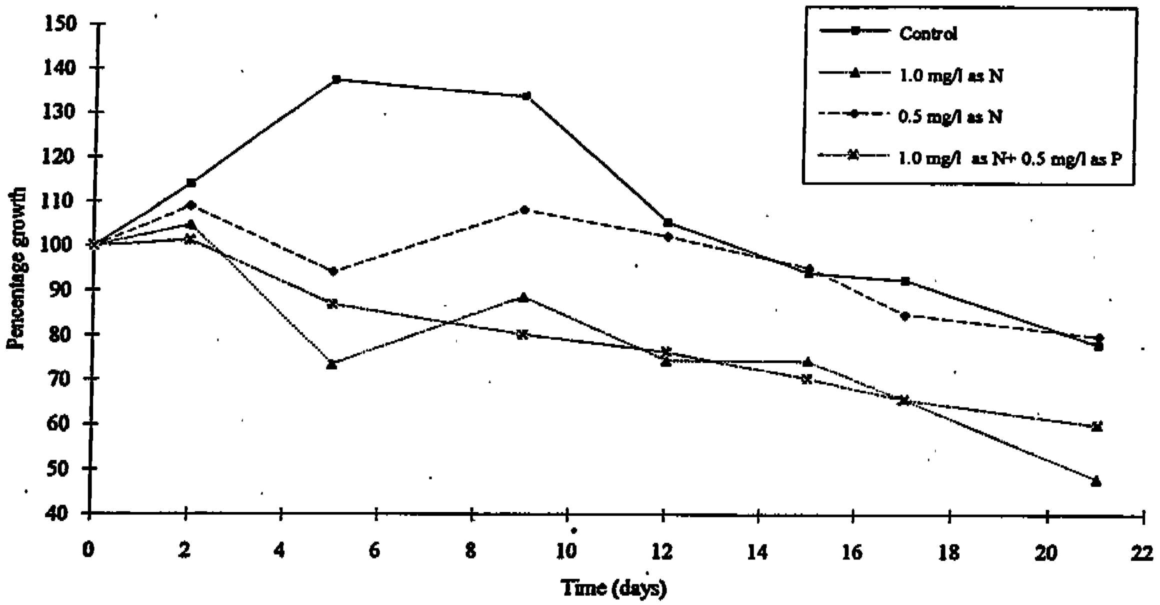
It appears that further increases in nitrate in the River probably will not result in an increase in macroalgae biomass. A reduction to levels of approximately 0.06 mg-N/L or less might result in some reduction in macroalgae (Williamson, et al, 1993). There are indications that nitrate concentrations may have a more direct relationship on the rate of microalgae growth and that reducing nitrate levels could also reduce the amount of microalgae in the River. This could provide potential benefits for recreation, aesthetics, and water supply. Protection of riparian corridors and maintenance of streamside shading would probably have a more significant effect on controlling the overall amount of algae growth in the River.

Figure 3: Laboratory Growth of *Selanastrum* with Nutrient Addition

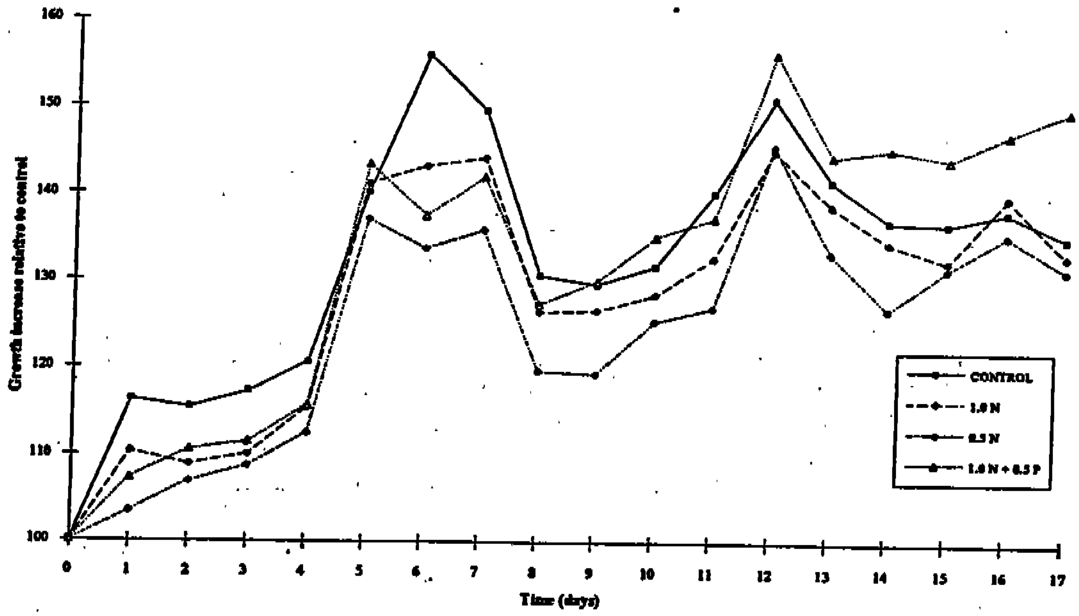


Total Suspended Solids as Determined by Gravimetric Analysis for the Biostimulation Analysis using *Selanastrum capricornutum*.

Figure 4: Laboratory Growth of *Cladophora* with Nutrient Addition



Effect of Nutrient Addition on Growth of *Cladophora*. July 17, 1991



Effect of Nutrient Addition on Growth of *Cladophora*. September 28, 1991.

5 NITROGEN SOURCES

The identification of sources of nitrogen in the watershed is based on water quality data from surface and ground water, development of budgets of nitrate discharge in tributaries and reaches of the River, field assessment and quantification of land uses which release nitrogen, and preparation of area and basin budgets which relate the calculated potential nitrogen release to the observed nitrogen loads in order to determine the proportion of nitrate which originates from the various sources. These elements are discussed in the following sections.

5.1 Water Quality Data

Water quality data was collected and analyzed to augment historic data in order to: measure the movement of nitrate and other nitrogen compounds from different geographic areas of the watershed, measure nitrogen discharges from different land uses, measure the transformations of nitrogen as it moved through the system, and provide data to support the investigations of biostimulation. New and historical data was used to develop and calibrate the budgets of nitrogen movement from various source areas in the watershed.

The study focused on the discharge of nitrate in surface water during the summer months. Nitrate is the nitrogen compound of greatest interest because of its great mobility in moving from watershed sources to the streams, and because of its potential impact on stimulating the growth of biological systems. Summertime is the period of interest when nitrate may have its most significant impacts on biological growth, and when delivery of nitrate from the watershed is not complicated by factors of storm runoff. The summer dry period is typically May through October. For purposes of data analysis in Phase 2, the period was further narrowed to July through September in order to eliminate the effect of June rains in 1993 and September rains during most years.

The following sections describe the monitoring program and the methods of data analysis and discuss the findings of the current work relative to seasonal variations in nitrate discharge and movement.

5.1.1 Monitoring Program

Nitrate data for the River and its tributaries has been collected by various federal, state, and local agencies since the 1950's. Monthly sampling of nitrate at 20 major stations has been maintained by Santa Cruz County Environmental Health since October, 1985. The County also conducted monthly sampling of 5 water supply wells (since October 1986) and 5 shallow groundwater wells in the Boulder Creek area (since January 1988). The results of these sampling programs were published in the September, 1989 Preliminary Report, An Evaluation of Wastewater Disposal and Water Quality in the San Lorenzo River Watershed prepared by Environmental Health. Results of the historical surface water monitoring efforts are summarized in Table 2, taken from the Preliminary Report.

Table 2: Historical Nitrate Levels in Various Parts of the San Lorenzo Watershed, 1952-88

MEAN NITRATE CONCENTRATION (MG/L-N)

STATION NUMBER	LOCATION	1952-62 (DWR)	1963-64 (DWR)	1973-75 (USGS)	1975-79 (SCCPD)	1979-87 (SCCPD)	1981 (JMM)	1986 (SCCHSA)	1987 (SCCHSA)	1988 (SCCHSA)
349	SLR @ Waterman Gap		0.15	0.02	0.17	0.1	0.02	0.17	0.1	0.11
310	Kings Creek		0.13				0.1	0.27	0.22	0.32
289	SLR @ Brimblecom Rd.		0.19	0.02	0.17	0.08	0.04	0.22	0.16	0.14
271	Bear Creek		0.15	0.01	0.21	0.08	0.11	0.15	0.11	0.1
251	Boulder Creek @ SLR		0.15	0.11	0.53	0.31	0.29	0.42	0.58	0.58
245	SLR @ River Street					0.22	0.11	0.31	0.23	0.31
180	SLR @ Ben Lomond					0.08	0.07	0.27	0.2	0.23
140	SLR below Glen Arbor		0.19				0.37	0.46	0.48	0.45
0762	Upper Zayante Creek		0.17	0.14	0.28	0.38	0.09	0.22	0.18	0.21
07528	Lompico Creek		0.2	0.17			0.14	0.32	0.22	0.21
07109	Bean Cr @ Lockhart Gulch		0.48	0.42	0.82	0.78	0.83	0.61	0.93	0.72
070	Zayante Creek @ SLR		0.37	0.42			0.57	0.7	0.6	0.77
060	SLR @ Big Trees	0.07	0.14	0.25	0.34	0.39	0.36	0.48	0.42	0.39
022	SLR @ Sycamore Grove		0.15					0.32	0.27	0.35
0121	Branciforte Creek		0.66	0.64	0.41	0.17		0.43	0.17	
0111	Carbonera Cr @ Santa Cruz		0.44	1	1.42	0.78		1.13	1.13	

SOURCES OF DATA

DWR	California Department of Water Resources, 1966 (10 samples/station)
USGS	U.S. Geological Survey, Sylvester and Covay, 1978 (12 samples/station)
SCCPD	Santa Cruz County Planning Dept., 1979 (24 samples/station)
JMM	James M. Montgomery Engineers, 1982 (4 samples/station)
SCCHSA	Santa Cruz County Health Services Agency (12 samples/station/year)

The monitoring program for this study was developed to verify and to expand on water quality information already available from prior studies, which have identified the geographic areas from which most of the nitrate originates. The efforts for this project focussed on measuring nitrogen release from areas underlain by the highly permeable Santa Margarita Sandstone. Secondarily, work was also done to investigate the increasing nitrate load from Boulder Creek, and to assess the extent of nitrogen release from the heavily developed alluvial areas along the River from Boulder Creek south.

Locations that were sampled for this study are listed in Table 3 and shown in Figures 5a and 5b. The sampling program focussed on measuring inorganic and organic nitrogen levels in surface waters, which are the prime element of management concern. Sampling locations were established at most major tributaries and at the boundaries of critical stream reaches where nitrogen input was expected.

The program also was designed to include shallow and deep groundwater sampling to help assess the movement of nitrogen compounds from their source, through the soil to groundwater, and eventually to surface water. Several deep water supply wells in the Quail Hollow, Olympia, and Scotts Valley areas were made a part of the monitoring network. Several springs, seeps, curtain drain discharge points, and shallow wells were sampled to assess shallow groundwater quality. Additional shallow groundwater monitoring wells were installed in Felton, Glen Arbor, and Ben Lomond. All of these locations continued to be sampled in Phase 2. In addition, vacuum lysimeters were installed below a deep leachfield and a shallow leachfield to directly measure the nitrogen discharge from those sources (see Section 6).

The period of sample collection for Phase 1 was April to December, 1990. Sampling for Phase 2 continued through September of 1993. Sampling has continued at most locations and some more recent data has been used to confirm earlier findings. Six of the surface water stations were sampled approximately biweekly in order to track seasonal variations in nitrate delivery and transformation in the streams. The other stations were generally sampled quarterly, with a greater emphasis on the summer months. Shallow and deep groundwater were sampled approximately monthly. Surface water and shallow groundwater samples were analyzed for nitrate, ammonia, and nitrite. Some of the samples were also analyzed for total Kjeldahl nitrogen. Deep groundwater was only analyzed for nitrate. All surface water samples included the measurement of streamflow, water temperature, pH, electroconductivity, and turbidity. Sampling and analysis was done in conformance with procedures described in the Quality Assurance Project Plan for this project.

Figure 5a: San Lorenzo Watershed Study Area and Major Surface Water Quality Sampling Locations

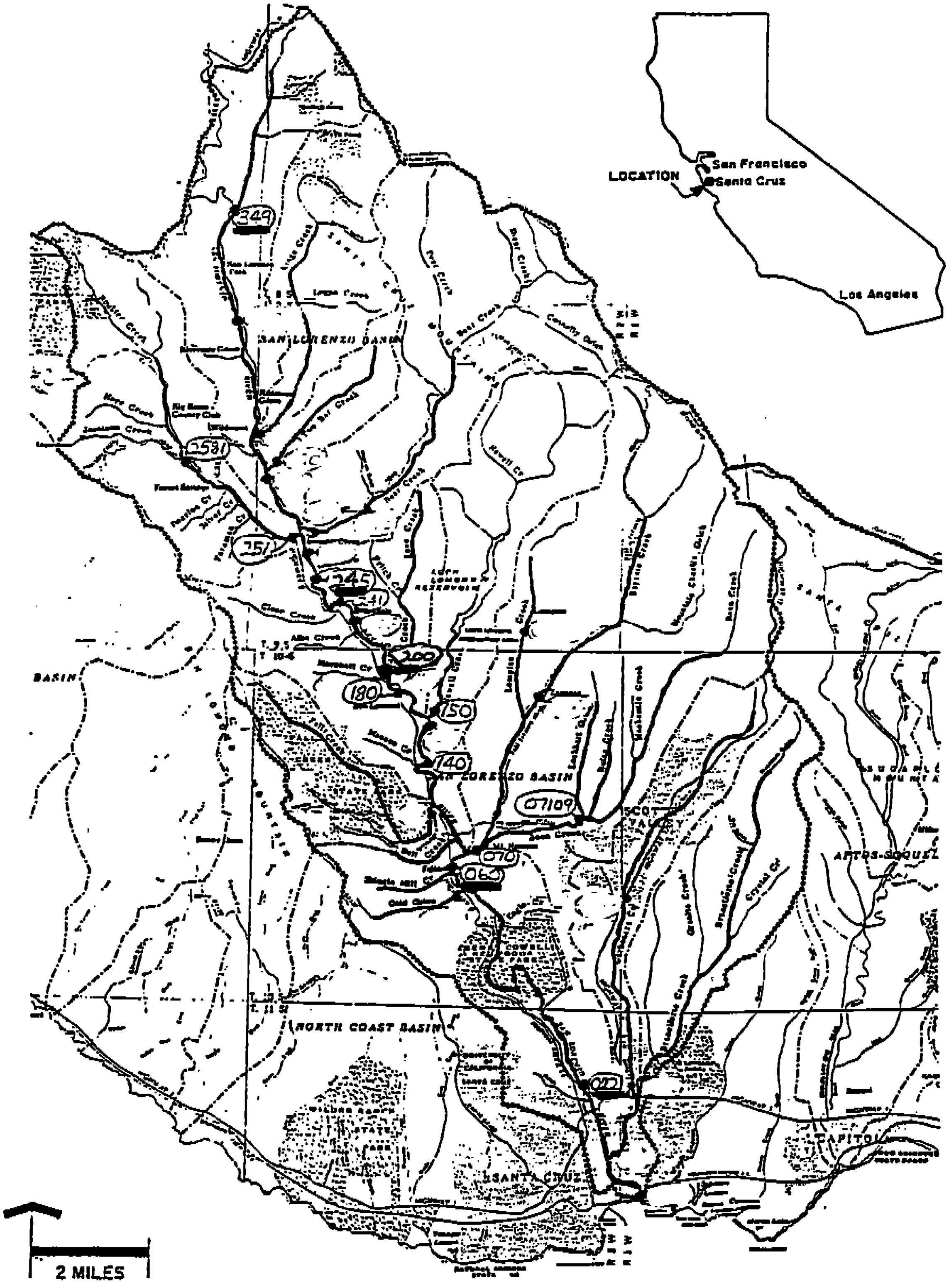


Figure 5b: Water Quality Sampling Locations (See Table 3 for Description)

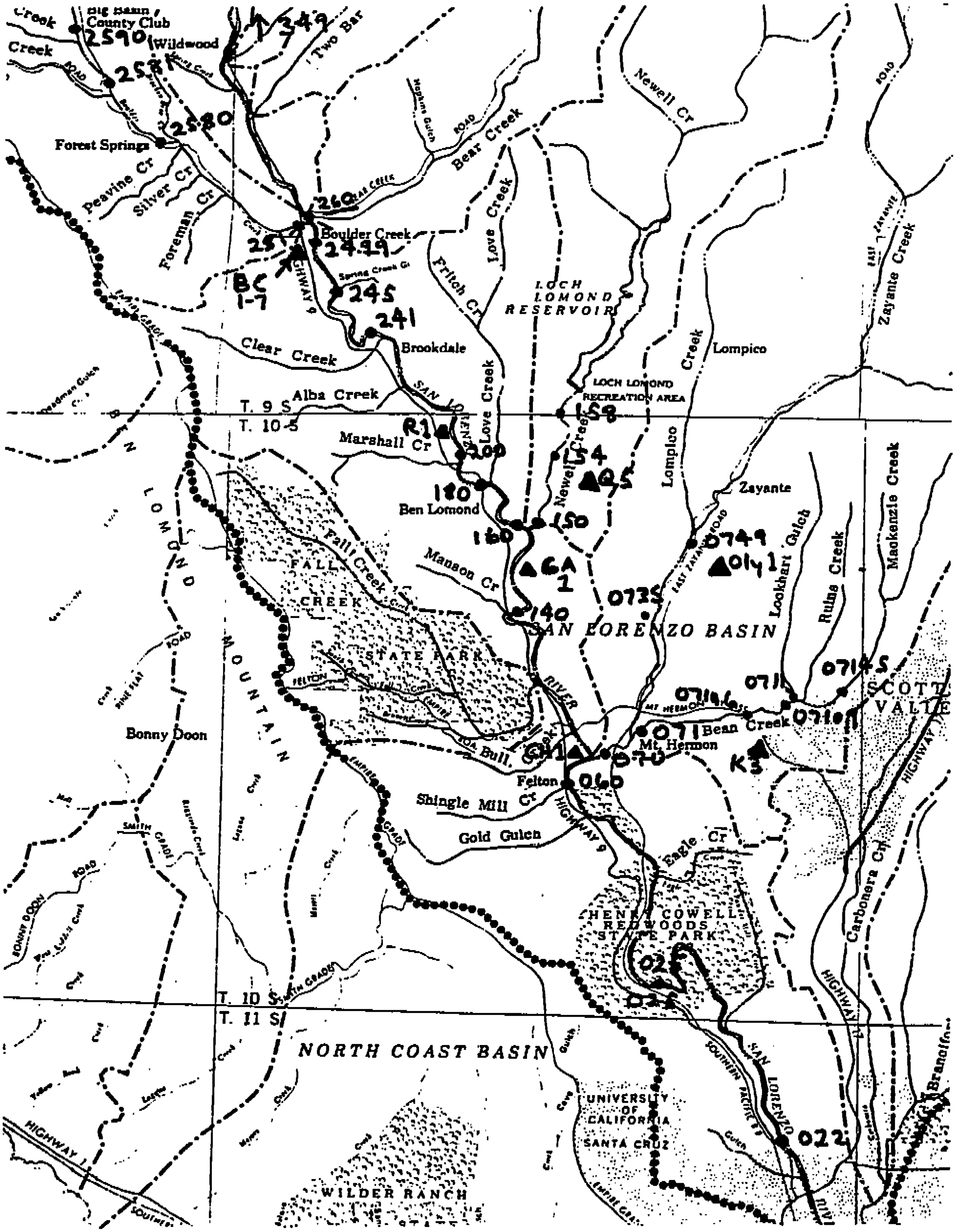


TABLE 3 - WATER QUALITY AND BIOSTIMULATION SAMPLING LOCATIONS

Station Number	Location	Nitrogen		Ground-water	Biostim-ulation
		Investig.	Monthly		
349	SLR @ WATERMAN GAP	X	X		C,J
260	SLR BELOW BEAR CR	X			
2590	BOULDER CR @ MELISSA LN	X			
2581	BOULDER CR @ JAMESON CR	X			
2580	BOULDER CR ABOVE BRACKENBRAE	X			
251	BOULDER CR @ HWY 9	X	X		C
2499	SLR BELOW BOULDER CR	X			
245	SLR @ RIVER ST	X	X		J
241	SLR @ PACIFIC ST., BROOKDALE	X	X		
200	SLR @ GUNTHER	X	X		J
180	SLR ABOVE LOVE CR	X	X		
160	SLR ABOVE NEWELL CR	X			
158	NEWELL CR BELOW DAM	X			
154	NEWELL CR @ RANCHO RIO	X			
150	NEWELL CR @ SLR	X	X		
140	SLR @ MT CROSS BRIDGE	X	X		
0749	ZAYANTE CR BELOW LOMPICO CR	X			
073S	MCENERY RD SPRING	X			
07145	BEAN CR ABOVE GRAZING AREA	X			
0711	LOCKHART GULCH @ BEAN CR	X			
07109	BEAN CR BELOW LOCKHART GULCH	X			
07106	BEAN CR @ MT. HERMON RD	X	X		
071	BEAN CR ABOVE ZAYANTE CR	X			
070	ZAYANTE CR @ SLR	X	X		C
060	SLR @ BIG TREES	X	X		C,J
025	SLR @ RINCON	X			J
022	SLR @ SYCAMORE GROVE	X	X		C,J
Q5	QUAIL HOLLOW WELL 5	X	X	Deep	
OLY 1	OLYMPIA WELL NO. 1	X	X	Deep	
K3	KAISER WELL 3	X	X	Deep	
GA1	SAN LORENZO WAY, GLEN ARBOR	X		Shallow	
CH1	CHAPARRAL CORRAL, FELTON	X		Shallow	
BL2	RIVERSIDE DR, BROOKLOMMOND	X		Shallow	
BC 1	JUNCTION AVE., BOULDER CREEK	X	X	Shallow	
BC 3	OAK ST. / HWY 236, BOULDER CR.	X	X	Shallow	
BC 6	OAK ST/LOMOND ST, BOULDER CR.	X	X	Shallow	
BC 7	LAUREL ST., BOULDER CREEK	X	X	Shallow	
BL3	SUNNYSIDE AVE, BEN LOMOND		X	Shallow	
BL4	FILLMORE AVE, BEN LOMOND		X	Shallow	
BL5	RIVERSIDE DR., BROOKLOMOND		X	Shallow	
BL6	CALIFORNIA DR, BROOKLOMOND		X	Shallow	
GA4	NOTEWARE, GLEN ARBOR	X	X	Shallow	
GA5	HIHN RD, GLEN ARBOR	X	X	Shallow	
F2	VALLEY, FELTON		X	Shallow	
F3	PLATEAU, FELTON		X	Shallow	
F4	LAUREL, FELTON		X	Shallow	
F6	PLATEAU, FELTON		X	Shallow	
F7	PLATEAU, FELTON		X	Shallow	

SAMPLING PROGRAM NOTES

Investigative Sampling: 37 stations quarterly during the study period streamflow, pH, temperature, dissolved oxygen, electro-conductivity, nitrate, nitrite, ammonia, Kjeldahl nitrogen.

Monthly Sampling: 21 stations; streamflow, pH, temperature, dissolved oxygen, electro-conductivity, nitrate; ammonia, nitrite, Kjeldahl nitrogen at 10 stations.

Biostimulation Sampling:

C - County sampling biweekly: algae coverage, enumeration of growth on artificial substrates, odor, sliminess, suitability for recreation.

J - 205j Contract sampling biweekly-monthly: algae coverage, actinomycetes, taste and odor, light, etc.

Groundwater Sampling: Taken from shallow groundwater monitoring wells or water supply wells.

5.1.2 Data Analysis

All data obtained was entered into a spreadsheet program with Symphony 2.2 software. Data summary, statistical analysis, and graphing of both the current and historical data was done using Symphony and SPSS-PC+ software. A summary of the data is presented in Appendix A and is displayed in various graphs.

The analysis of present and historical data focussed on nitrate concentration and nitrate load. Nitrate is by far the most predominant form of inorganic nitrogen in the River and is of greatest concern for inducing biostimulation. Being highly mobile in soil and groundwater, nitrate is also the predominant form of nitrogen delivered from the watershed to the streams. In this document, results for nitrate and all other forms of nitrogen are always reported as their weight in nitrogen (ie. mg-N/L or lb-N/day). This convention facilitates tracking of nitrogen compounds through the watershed systems, regardless of the form of nitrogen.

For each surface water sample, the nitrate load (in pounds per day) was calculated by multiplying the stream discharge times the nitrate and total nitrogen concentrations and applying the appropriate conversion factor (5.39).

Ammonia and nitrite are typically below detection levels in San Lorenzo watershed surface water. Of the 146 samples analyzed for ammonia, 85% of the samples had nondetectable levels of ammonia. (The detection limit was typically 0.1 mg-N/L.) Nitrite (with a typical detection limit of 0.04) was detected in only 2% of the samples analyzed for nitrite.

Total Kjeldahl nitrogen (TKN) is primarily a measure of the dissolved organic nitrogen compounds in the water. These may originate from leaching of material from soil, leaf litter, or instream biological activity. Data from the San Lorenzo Watershed shows great variation in TKN concentrations, with little apparent relationship to any other factors. Organic nitrogen could provide an instream source of nitrate or ammonia, which would be released by the biological breakdown of organic nitrogen compounds. Although levels of TKN can be quite high in relation to nitrate concentrations, it was also quite variable both in time and location, with no apparent pattern. The lack of any kind of correlation to nitrate levels or algae growth indicates that Kjeldahl nitrogen probably has little direct relationship to instream biological growth or nitrogen delivery from the watershed. The nitrogen budgets developed for the study thus focus on nitrate rather than total nitrogen loads.

5.1.3 Geographic and Temporal Variations in Nitrate Levels

A summary of the nitrate load data collected from this study and previous efforts is plotted in Figure 6 to show the seasonal variations in nitrate concentration and load since 1986. Mean summer nitrate concentrations and loading for the River at Big Trees from 1976 to 1993 are shown in Figure 7. Figure 8 shows the contributions of stream discharge and nitrate load in different parts of the Watershed.

Figure 6: Nitrate Concentration and Load by Season, Big Trees

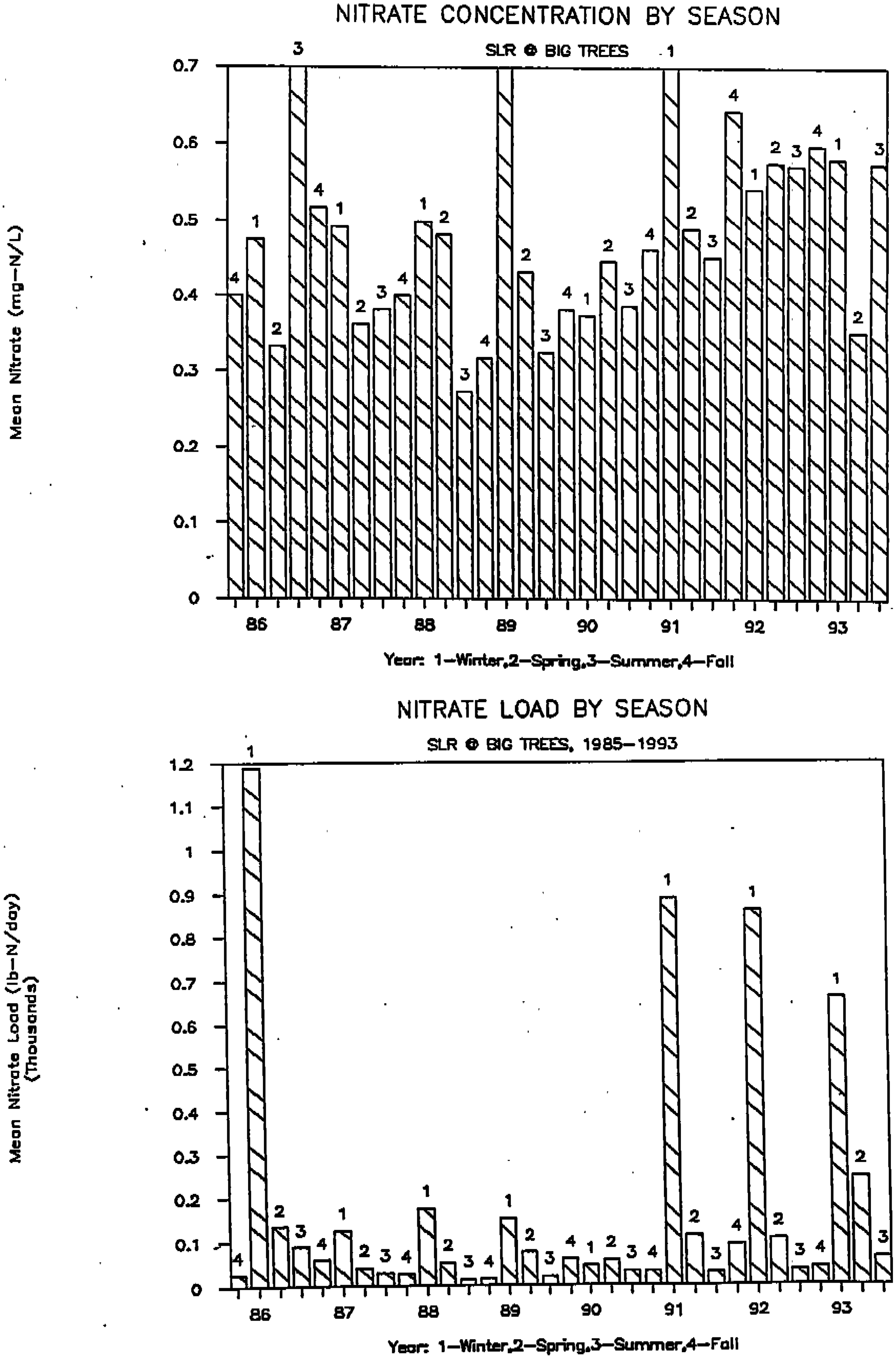


Figure 7: Mean Summer Nitrate Levels at Big Trees, 1976-1993

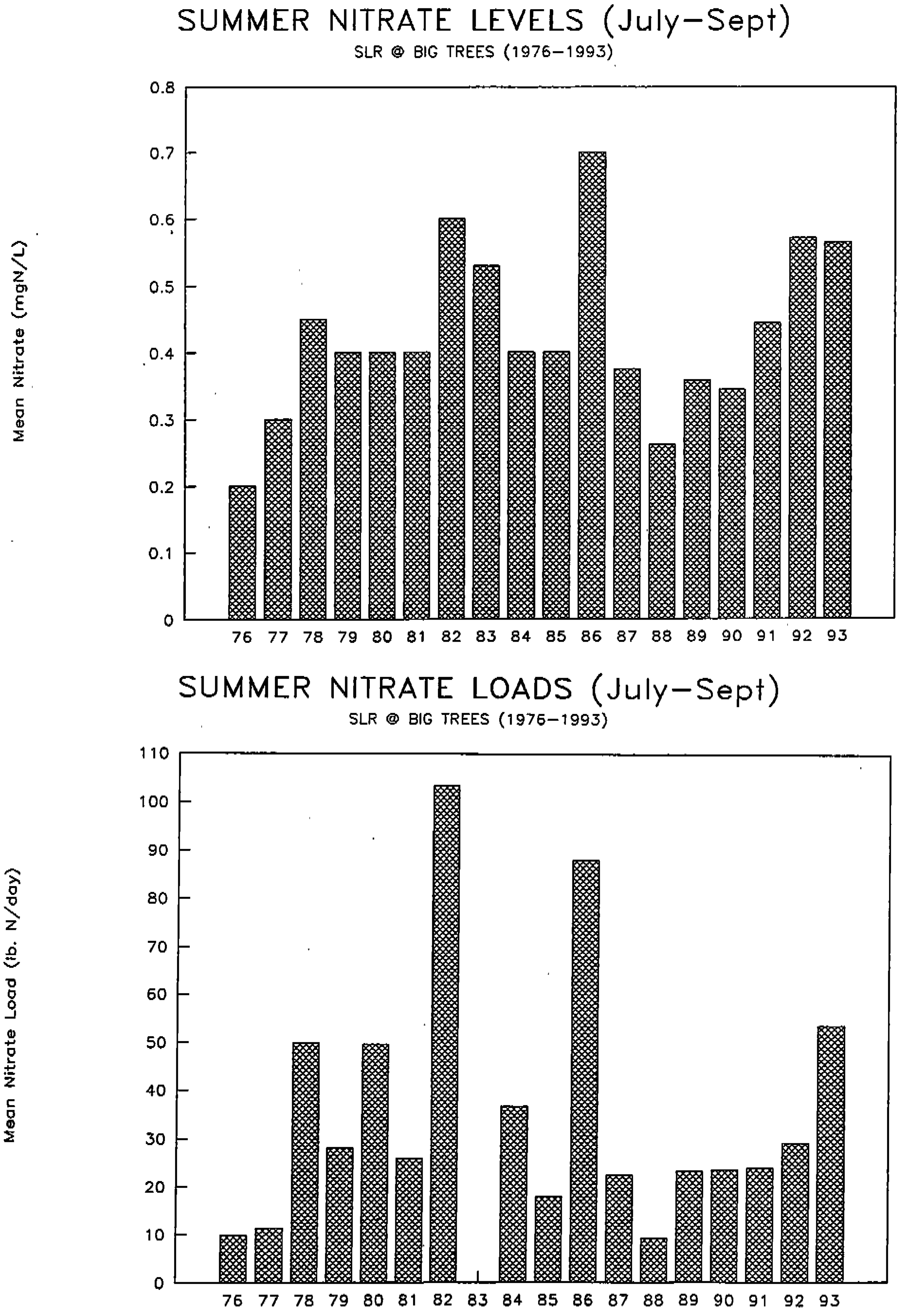
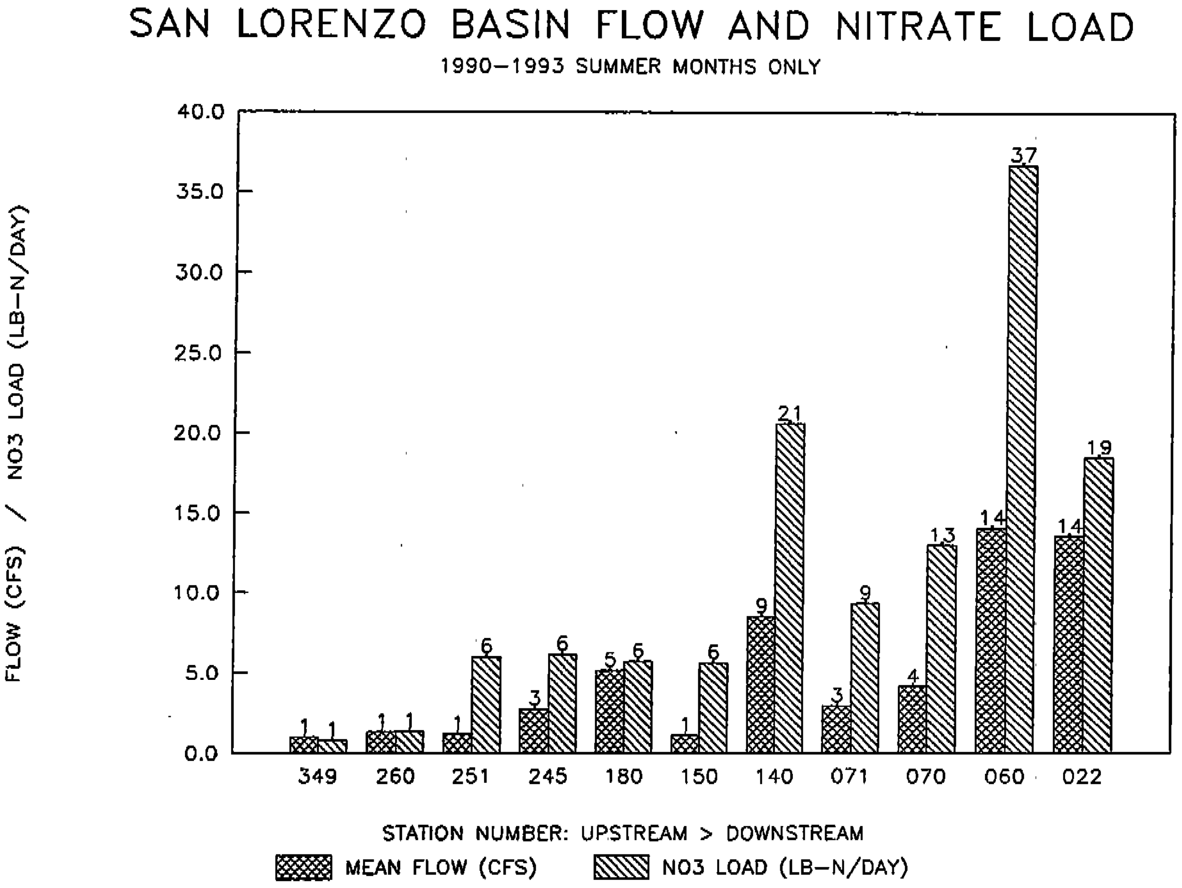


Figure 8: **Summertime Nitrate Contributions at Different Stations on the San Lorenzo River, 1990-1993**

Station Locations (See Figure 5 for map of locations):

349 - San Lorenzo River at Waterman Gap
260 - San Lorenzo River above Boulder Cr.
251 - Boulder Creek at San Lorenzo River
245 - San Lorenzo River at River Street, below Town of Boulder Creek
180 - San Lorenzo River at Love Creek, Ben Lomond
150 - Newell Creek at San Lorenzo River
140 - San Lorenzo River at Mt Cross, below Glen Arbor
071 - Bean Creek at Zayante Creek
070 - Zayante Creek at San Lorenzo River
060 - San Lorenzo River at Big Trees, Felton
022 - San Lorenzo River at Sycamore Grove, above Tait Street, Santa Cruz



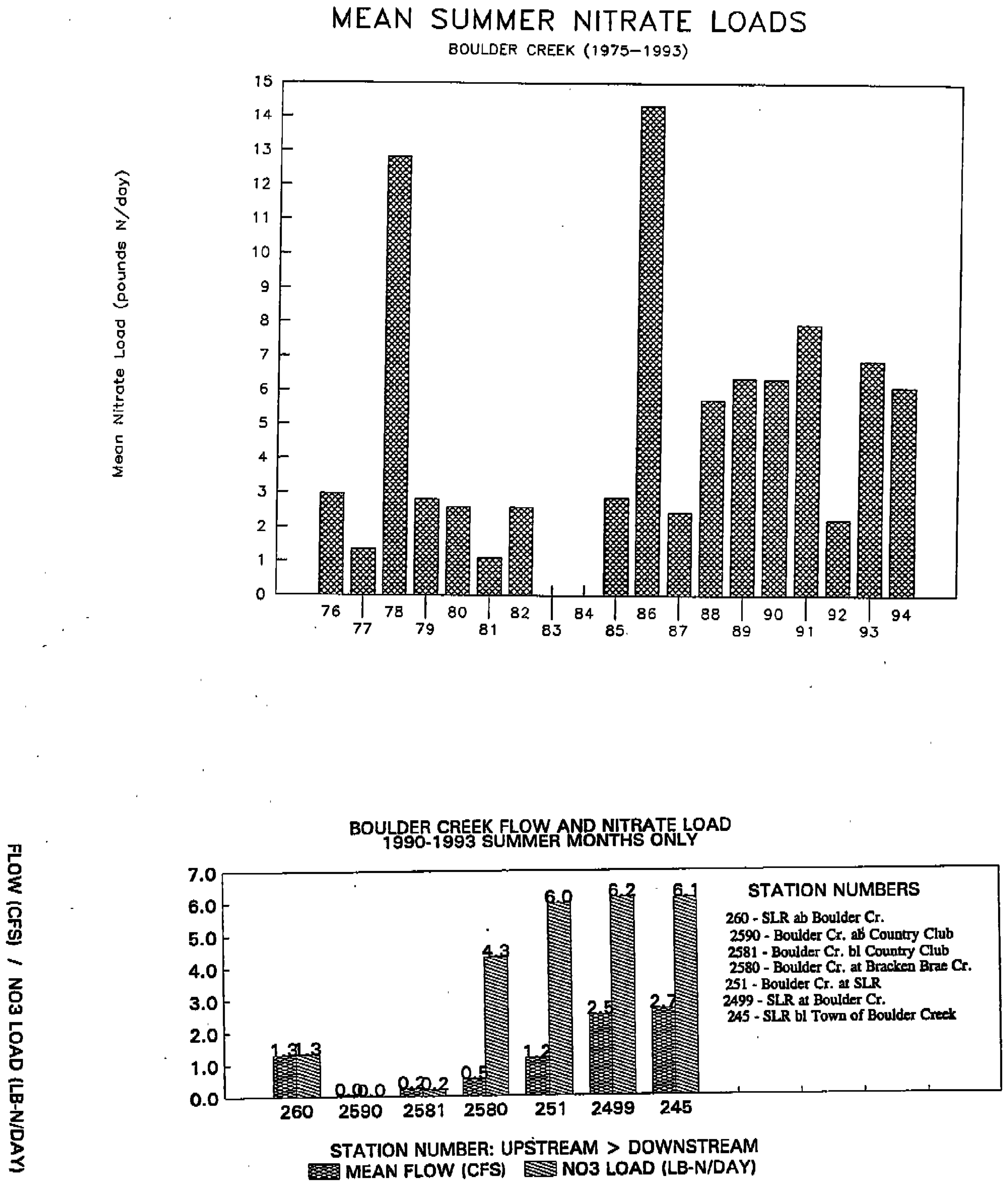
This data shows a clear pattern: 75-80% of the nitrate load at Big Trees enters the River downstream of Ben Lomond, with a very significant part of it entering between Ben Lomond (Station 180) and the lower end of Glen Arbor (Station 140); another large proportion comes from Zayante Creek (Station 070). The large majority of the nitrate load in the River north of Ben Lomond is contributed by Boulder Cr. These figures show some interesting overall temporal patterns. Summer nitrate concentrations in the River at Big Trees tend to be significantly higher during wetter years of 1978, 1982, 1986, and 1993. The overall load tends to be 20-40% higher. With higher levels of rainfall, soil moisture and groundwater, there is greater potential for flushing and delivery of nitrate to the River.

An analysis of variance (ANOVA test) was run on data for each summer from 1986 to 1990 to determine if there were any statistically significant differences from year to year in stream discharge and nitrate concentration. This indicated that nitrate concentrations were significantly higher (by 40%) in 1986 in the San Lorenzo River at Big Trees (Station 060 at Felton) and in Zayante Creek (Station 070). Nitrate concentrations were significantly higher in 1990 in Boulder Creek (Station 250) and in the River downstream from Boulder Creek (Station 245). Other stations did not show significant differences from year to year.

The cause for the nitrate increase in Boulder Creek became apparent through detailed sampling of the creek during Phase 1 of this study. The results are plotted in Figure 9, which shows a very significant increase in the load in Boulder Creek just upstream of Bracken Brae (station 2580). This reach of the stream is downgradient from the sewage disposal area for the sewer facilities which serve 300 homes around the Boulder Creek Country Club. Aerated effluent, in which all the nitrogen has been converted to nitrate, is discharged subsurface to very highly permeable granitic soils several hundred yard upslope from Boulder Creek. The effluent migrates to the creek and is the only potential source for the great increase in nitrate load in that reach. This disposal practice was begun in May, 1987, after irrigation of the golf course with wastewater was discontinued. The increase since that period is also apparent in Figure 9. This nitrate discharge also results in significantly elevated nitrate levels in middle portion of the River between Boulder Creek and Ben Lomond.

A reduction in nitrate concentration and nitrate loading in Newell Creek and Zayante Creek was observed in the dry years of 1990 and 1991, relative to the wet years of 1986 and 1993. This is most likely related drought impacts resulting in increased groundwater pumping from the Santa Margarita sandstone in those basins and reduced flushing of nitrate through the groundwater system. In wet years, such as 1986, the Quail Hollow basin contributes approximately 1.5 cfs. in baseflow to Newell Creek, in addition to the 1 cfs released by the City of Santa Cruz from Loch Lomond. However, in 1990, there was virtually no groundwater discharge from the basin to the creek. Groundwater in Quail Hollow typically has a nitrate concentration of 1-2 mg-N/L (Figure 10). Elimination of this discharge to the creek represents a significant decrease in nitrate load to the River during dry years.

Figure 9: Summer Nitrate Loading in Boulder Creek

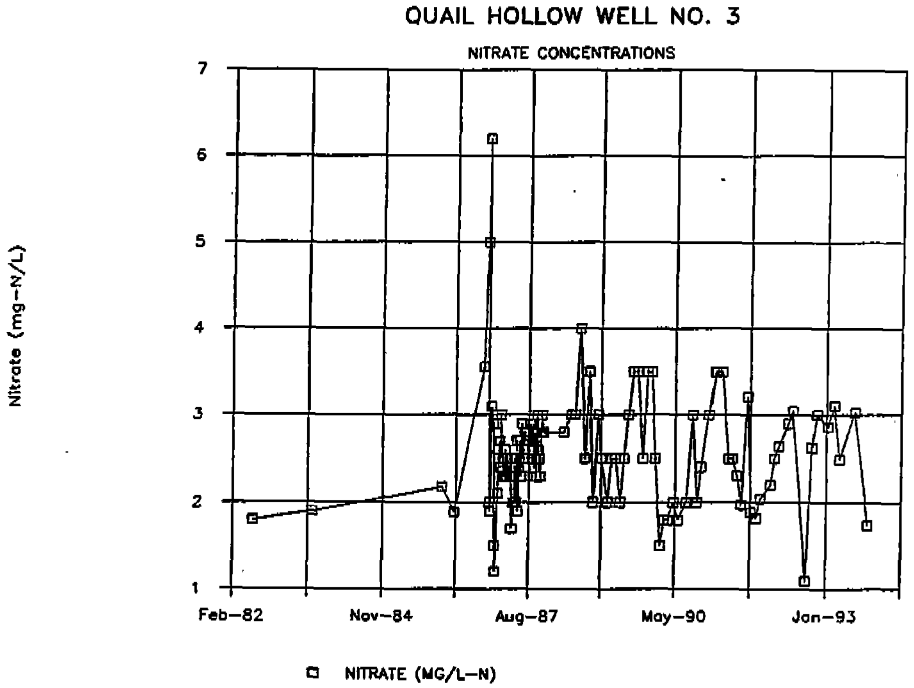


Nitrate levels in deep and shallow groundwater are shown in Figures 10 and 11. Groundwater levels in Quail Hollow have increased since development occurred on the overlying areas in the mid 1970's. There was a sharp increase in 1986 in response to flushing during a wet year, but since that time levels have been relatively stable. Shallow, perched groundwater shows much sharper variations, generally in response to rainfall. Of the roughly 15 shallow groundwater wells monitored in the San Lorenzo Watershed, the wells in Boulder Creek are the only ones that have shown levels above the drinking water standard of 10 mg-N/l.

The variable influence of rainfall on nitrate in soil and groundwater is also indicated in the data from shallow groundwater in Boulder Creek. Well No. 1 showed a positive correlation between nitrate and rainfall, Well No. 6 showed a negative correlation to rainfall, Well No. 2 showed generally low nitrate levels independent of rainfall, and Well No. 3 showed generally moderate nitrate levels independent of rainfall. All these wells are in similar soil conditions within 300 yards of each other in a developed area. None of the wells are closer than 50 feet to the nearest septic system. The high degree of variability among these four wells makes it somewhat problematic to generalize results from a shallow monitoring well to a larger area. Because of that, this study has relied primarily on instream nitrate data to measure nitrate contributions from different areas and different nitrogen sources.

A review of the nitrate data for both surface and groundwater indicates that there is potential for significant loss of nitrate as water moves through the system. Invariably the nitrate concentrations in surface water are one-half to one order of magnitude lower than the nitrate levels in nearby contributing shallow and deep groundwater. There is also significant potential for nitrate loss in the River itself as water flows downstream. This is indicated in Figure 8 by the 50% drop in nitrate as the River flows from Big Trees (Station 060) to Sycamore Grove (Station 022) and by the relatively constant nitrate concentration in the River from Boulder Creek to Ben Lomond, despite the high density of onsite wastewater disposal in that corridor. This nitrate removal is an important factor that was taken into account in the development of nitrogen budgets for large sub-basins of the Watershed and for specific classes of land uses in those basins.

Figure 10: Quail Hollow Groundwater Data



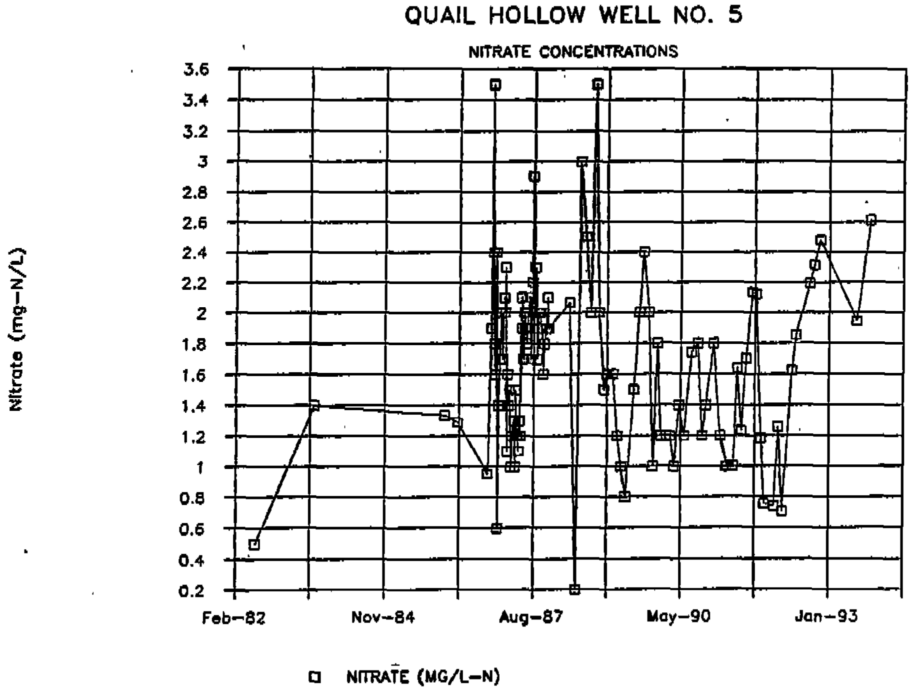
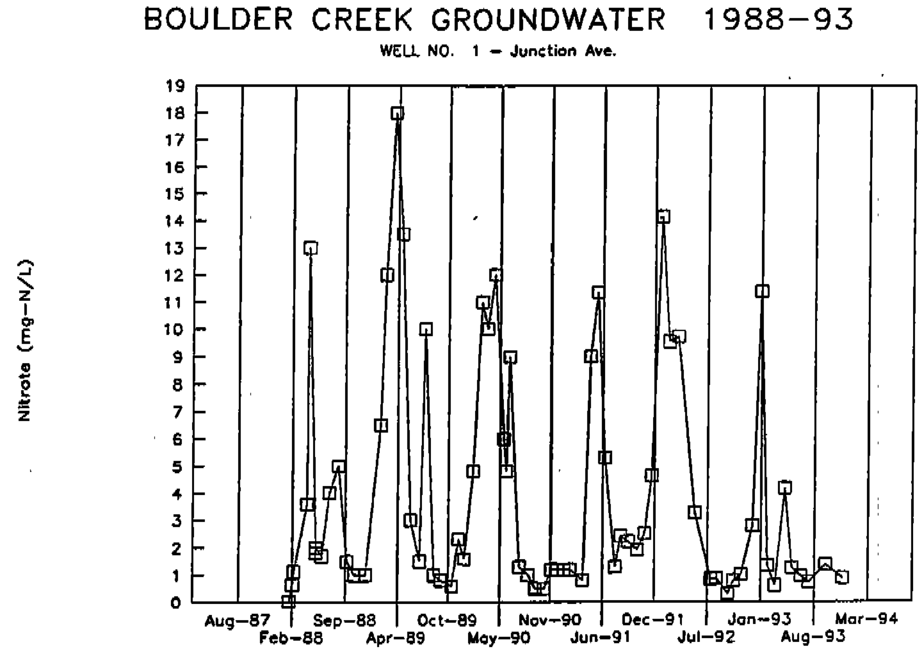
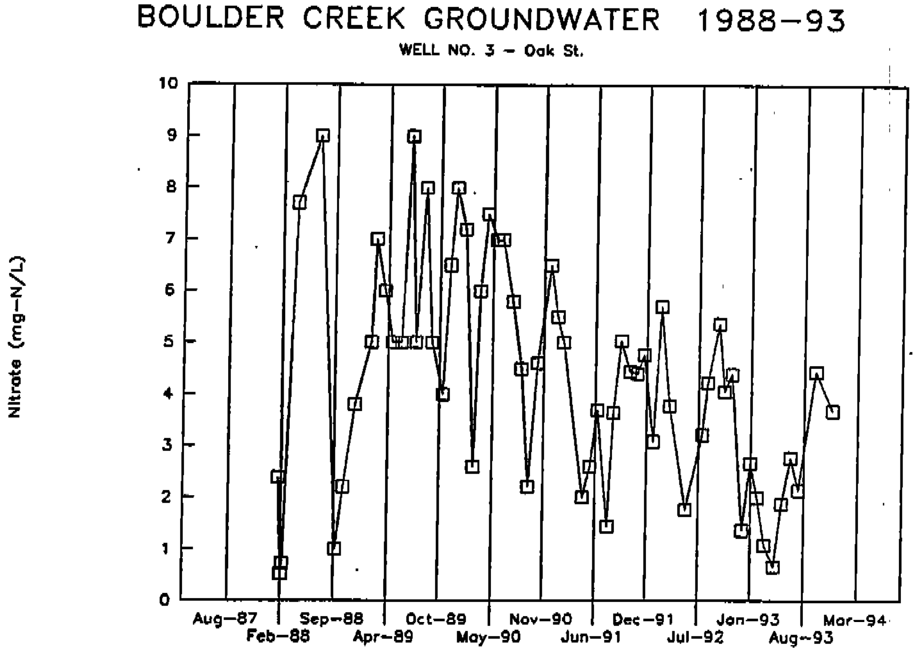


Figure 11: Boulder Creek Shallow Groundwater Data





5.2 Watershed Nitrogen Budget

Nitrogen budgets for the entire San Lorenzo watershed were prepared during Phase 1 by Balance Hydrologics, Inc. Using historical nitrate data from 1975-1990 and measurements or estimates of mean annual runoff at different stations, they developed estimates of the total annual nitrate load at 10 different sampling points in the Watershed. This was further broken down into the summer and winter nitrate contributions. The 110 square mile watershed upstream from Felton yields an average of 56 tons of nitrate nitrogen per year, of which about 6 tons flow in the 5 months from May to September. The summer period is the time of greatest interest for management purposes. The nitrate load of the basin decreases downstream to 46 tons annually and 2.8 tons during the summer months as the River flows into the Santa Cruz city limits. This reduction is due to instream denitrification in the reach downstream of Felton.

Balance also reviewed historical data to determine if there were any inconsistencies or major variations that might result from timing or method of sampling, analytical procedure, or streamflow at the time of sampling. Although nitrate concentrations were at times elevated during storm runoff, there did not seem to be a significant fluctuation in relation to streamflow. Nitrate concentrations did increase significantly from the 1950's and 1960's through the 1970's, but little or no increase has been observed since then (SCCHSA, 1989; Balance, 1991). Balance found that data collected since the mid 1970's was internally consistent and could be treated as a single population. They chose to base the remainder of their analyses on the large volume of available data collected primarily from 1985 through 1991.

Balance prepared a detailed nitrate budget focussing on average summertime nitrate release from areas of alluvial and sandy soil in the central part of the watershed. This area typically contributes 90% of the nitrate passing through the River at Felton. The budget is contained in Appendix B.

During Phase 2, the watershed budget was further refined by County staff to reflect data gathered from 1990 through 1993, and to focus on the core summer months of July through September. This refined budget is shown in Table 4.

In preparing the detailed budget, Balance noted that nitrate is removed from the River system during summer months at a rate of about 7% per mile during both wet and dry years. This amount was consistent with rates of removal measured in other streams (Balance, 1991). The amount of nitrate normally lost from the River from Boulder Creek to Felton (Big Trees) amounts to 900 pounds during the 3 summer months. This is almost one third of the total nitrate load at Big Trees for the same period. The mechanism for removal is most likely denitrification in organic bottom sediments, and perhaps some uptake by riparian and aquatic vegetation. This removal is much diminished to nonexistent during winter months.

Table 4: Summary of Watershed Nitrate Budget for Summer Months, July-September

CONTRIBUTING AREA	MEAN DAILY LOAD (LB-N/DAY)	MEAN TOTAL SUMMER LOAD (LB-N)
Boulder Creek (Station 251)	6	540
Quail Hollow/Glen Arbor (from Station 180 to Station 140, including Newell Creek)	15	1350
Zayante and Bean Creek (Station 070)	13	1170
Other Sources	12	1080
In Channel Losses	-10	-900
Total Discharge at Big Trees (Felton) (Station 060)	36	3240

5.3 Identification of Potential Nitrogen Sources

In order to relate the instream nitrate loads back to specific land uses and other sources in the watershed, County staff undertook a field survey during Phase 1 to identify and quantify all potentially significant sources of nitrogen release. These efforts focussed on the sandy areas of the watershed and assessed the amount of nitrogen release from onsite wastewater disposal systems, fertilizer applications, livestock, and any other potential sources in individual sub-basins. The estimates of nitrogen release for each source were tabulated for each sub-basin of interest and related back to observed water quality data to identify the amount of nitrate which is ultimately released to the streams from each source. This information was then related to the watershed nitrate budget to calculate overall watershed contribution by source.

The field surveys involved the use of maps, aerial photographs, windshield surveys, interviews with property owners, and literature review to estimate the potential nitrate contribution from each source. Individual homes, pastures, stables, and landscaped areas were identified and mapped in order to quantify contributions from each sub-basin. The process is discussed in detail in Appendix C of the Phase 1 Report and summarized in the following paragraphs for each type of nitrate source. A number of assumptions were made in developing these estimates, which were subsequently tested, adjusted and verified during the process of creating specific sub-basin budgets to reflect observed water quality.

Septic Systems - The number of housing units in a sub-basin was determined from either field tabulation of homes or reference to earlier reports. The amount of nitrogen generated by each household was calculated assuming that wastewater has a concentration of 50 mg/L of nitrogen, that 70 gallons of wastewater are produced per person per day, and that in general, the average household consists of 2.8 persons (Johnson, 1988). The resulting figure of 23.88 lb-N/year falls within the ranges generally cited in the literature. Based on literature values it was estimated that in typical soils, 25% of the nitrogen from septic systems is removed in the upper soil layers by uptake or denitrification (Ramlit, 1982). In sandy soils, it was assumed that only 15% of the nitrogen is removed and 85% percolates as nitrate to groundwater (Ibid). This estimate was changed to 75-80% for updated budgets calculated in Phase 2, based on the results of lysimeter sampling below leachfields in sandy soils (see Section 6).

Sewered Areas - Nitrogen release from the one sewered area of concern, Boulder Creek Country Club, was calculated in the same way as the discharge from septic systems, except that the average household size was assumed to be 1.8 persons due to the predominance of condominiums and retired persons in that development. The release of nitrate to deep percolation was assumed to be 90%, due to the discharge of nitrified effluent in a very localized area in extremely permeable gravelly soil.

Landscaping - Landscaped yards in the basin were tabulated and classified as having either significant or moderate landscaping. The average nitrogen application for properties with significant landscaping was estimated assuming the following typical characteristics: one 30 ft. X 30 ft. grass lawn, four 30 ft X 4 ft beds of shrubs and flowers, and one 10 ft X 4 ft vegetable garden. Based on review of fertilizer instructions and interviews with property owners, it was assumed that the lawn had a fertilizer application of 0.5 pound per 100 square feet (0.0008 lb. of nitrogen/sq.ft. with a 16% nitrogen fertilizer) twice a year. It was assumed garden areas had applications of 1 pound per square foot (0.0012 lb. of nitrogen with a 12% nitrogen fertilizer) twice a year. Moderate landscaping was generalized to consist of one 4 ft. X 40 ft. row of plants along the house and one 4 ft. X 15 ft. bed of plants, both receiving fertilizer applications of 0.0012 lb. nitrogen/sq.ft. twice a year. Because fertilizer is applied on the ground surface, specifically to promote plant uptake, it is assumed that 30-50% of the applied nitrogen percolates to groundwater as nitrate in sandy soils.

Livestock - During Phase 2, estimates for nitrogen loading from stables were revised to reflect a more recent analysis done by Balance (1994b). It was assumed that each horse or cow generates 108 pounds of nitrogen per year. It was further estimated that in large stables a significant amount of the manure is hauled away each year. However, prior to 1993, most of the manure was stockpiled in areas where the nitrogen could be readily leached out during the rainy season. Additionally, much of the nitrogen is in the urine, which readily percolates. For these budgets of past nitrogen contribution, it was assumed that all of the nitrogen produced in stable areas is applied to the soil. However, because nitrogen from livestock is released on the ground surface, there is potential for nitrogen removal through ammonia volatilization, vegetation uptake, denitrification and other factors. It was thus assumed that only 25-50% of the nitrogen released may percolate as nitrate to groundwater, depending on soil conditions, with a higher delivery rate for very sandy soils. This is consistent with the 29% delivery estimated by Balance Hydrologics for the Quail Hollow Stables (Balance, 1994b)

Natural Vegetation - It was assumed that natural vegetation releases 4.2 pounds of nitrogen per acre per year, based on prior estimates for scrub vegetation on sandy soil in the Central Coast region (HEA, 1978). Areas of natural vegetation were determined using land cover calculations by sub-basin that were prepared for the San Lorenzo River Watershed Management Plan (Santa Cruz County Planning Department, 1979). The percent percolation was adjusted during the calibration process to obtain calculated groundwater nitrate concentrations similar to those observed in undeveloped areas. The percent percolation was 10% in loam soils in the Boulder Creek basin, and approximately 50% in the very sandy soils of Newell and east Glen Arbor basins.

Scotts Valley Plume - A significant source of nitrate exists in the Scotts Valley area and cannot be easily categorized by any particular land use type. The nitrate probably comes from a combination of past onsite sewage disposal from an area that was sewered in 1986, significant landscape fertilization, golf course fertilization, land disturbance, and historical agricultural activities. Nitrate concentrations in groundwater underlying the area averaged about 5 mg-N/L in spring 1991 (Todd, 1991). This nitrate rich groundwater flows towards Bean Creek and contributes about half of the nitrate load of the creek. Nitrate levels had generally been decreasing, but some locations showed an increase in 1991 and subsequent years. One of the main points of discharge to Bean Creek, Dufour Spring, was quite low in 1990, and then climbed significantly in the following years. These fluctuations could be related to migration of the center of the nitrate plume towards Bean Creek. More complete flushing of the plume may be delayed due to the significant pumping depression that has developed in the same area during the past ten years. There may also be localized sources of additional nitrate input (Todd, 1991). The actual amount of the current contribution to Bean Creek and the River was estimated using the sub-basin budgets, as described in the following section.

5.4 Sub-Basin Nitrogen Budgets

The estimates of nitrate release for each source described above were tabulated by sub-basin and put into a simple budget format which accounts for nitrogen removal in the upper soil layer, dilution by groundwater recharge, nitrogen removal by water extraction from groundwater, and removal of nitrogen as water percolates through the groundwater body to surface water. The budget calculates total nitrate percolation to groundwater, expected nitrate concentration in groundwater, nitrate load discharged to surface water, and expected nitrate concentration in the stream. The budgets were calibrated by comparing the estimates to observed conditions and adjusting the delivery factors until the calculated values matched the observed values.

Sub-basin budgets were prepared for all the areas which contribute significant proportions of nitrate to the River: Boulder Creek, Lower Newell Creek, Glen Arbor, Lower Zayante Creek, and Lower Bean Creek. Budgets for Boulder Creek and Lower Zayante are presented as two examples of the sub-basin nitrogen budgets in Table 5a and 5b. The remainder of the budgets are contained in Appendix C. The procedure for preparation and calibration of the budgets is discussed as follows:

The estimated nitrogen release from the sources found in the basin are calculated in the lower half of the budget (under SOURCES), based on the information described in Section 5.3 relative to specific sources. These estimates are then tabulated in the SUMMARY portion of the budget. The number of units and the total annual release of nitrogen to the ground is tabulated for each source (ANNUAL LBS/YR RELEASE). The relative percentage from each source relative to the total amount released in the basin is presented.

The percentage of percolation (% PERC.) is the estimated percentage of nitrogen release from each source which percolates into groundwater as nitrate. This is based on information described above and calibration of the budget to reflect observed nitrate concentrations in groundwater. Reductions in nitrate percolation result from plant uptake, volatilization, or denitrification. The same percent percolation was generally applied for all sources of nitrate that were at or near the ground surface (fertilizer, and natural vegetation). Higher rates were given for livestock due to the concentrate application of manure and urine in most livestock areas. Percolation rates were higher for areas with very sandy soils (Newell Creek), than areas with better developed soils (Zayante Creek corridor). The percent percolation applied to the total nitrogen release results in the annual nitrate load to groundwater (ANNUAL LOAD TO GW), expressed in pounds of nitrate-nitrogen per year. The proportion of nitrate in groundwater from each source is also shown.

If the basin experiences significant groundwater extraction for export, this was factored in as the percentage remaining AFTER EXPORT. For example, in the Zayante Creek basin, the rate of nitrate export during summer groundwater pumping is 3.1 lb-N/day. This is 8% of the average daily percolation of 38.6 lb-N/day. Thus only 92% of the nitrate released to the groundwater basin remains for possible discharge to the stream. The export of nitrate was determined by multiplying the average nitrate concentration in the Olympia wells by the summer pumpage from the well field which is the major source of extracted water in that sub-basin.

As a final step in the budget, the SUMMER % DELIVERY TO STREAM, was applied to calculate the proportion of the nitrate in groundwater which actually enters the stream during summer baseflow conditions. Annual load was first multiplied by 25% to reflect the three summer months. A further reduction factor was then applied to reflect the significant reduction in nitrate that occurs between groundwater and streamflow, particularly during the summer months. Causes of reduced nitrate discharge to streams include nitrate accumulation in soil and groundwater at distances from streams, denitrification and uptake in the riparian corridor areas, and instream nitrogen uptake or removal in the channels above the outlet to that sub-basin. The amount of nitrate release to the stream was determined primarily through calibration against observed nitrate concentrations and loads in streams, particularly in relation to areas where individual sources predominate. The resulting value is the SUMMER LOAD TO STREAM, from each source type, which is expressed in pounds of nitrogen during the three summer months. The proportion of nitrate load in the stream from each source is also shown.

The final column, OVERALL SUMMER RELEASE is the percentage of nitrogen released from a given source which ultimately appears as nitrate in the stream during summer baseflow conditions. For example in Zayante Creek, only 4.1% of the nitrogen released from septic systems is entering the stream during summer months.

The budget also shows various calculated and observed factors which are used for calibration or summarizing information: average concentration of nitrate in groundwater, average daily nitrate discharge to groundwater, average daily nitrate load in the stream, and the observed values for each parameter, where available.

The various release factors of the budget were adjusted during calibration in order to obtain calculated groundwater nitrogen concentrations, stream concentrations, and stream loading rates that closely approximated observed conditions. Where possible, the budget was calibrated incrementally. Similar assumptions were applied to all sub-basins where appropriate. The budgets were first calibrated for predevelopment conditions to approximate natural background levels of nitrate in groundwater and surface water. The effects of development were then added in, incrementally where possible. For example, the budget for the mid Boulder Creek basin, which primarily contains the sewered country club area, was calibrated to approximate the observed nitrate levels in Boulder Creek before it reaches the area served by septic systems. Nitrate contributions from septic systems were then added in to approximate the nitrate concentrations found at the mouth of Boulder Creek.

As a further test of the budget procedure, the specific data on sources for the Glen Arbor basin was put into the budget for Newell Creek without changing any of the adjustment factors. The budget produced results that were within 5% of observed conditions.

The budgets were calibrated to fit average conditions observed during the summers of 1990-93, which included both wet and dry conditions. The mean summer nitrate load at Big Trees during this period was equivalent to the long-term mean for 1976-1993. For comparative purposes, budgets for Glen Arbor were calculated for the dry year of 1990 and the wet year of 1986. For the wet year, the percent of nitrate released to streams increased threefold.

Although it is clear that total nitrate delivery increases significantly during wet years, it has not been established how wet year conditions affect the actual nitrate delivery from each individual source. It might be expected that delivery rates would increase more for nitrate sources that are dependent on rainfall for carrying the nitrate: natural vegetation, fertilizers and livestock. Even in dry years, a significant portion of the nitrate from wastewater disposal would be carried through the system by the percolating wastewater. Although this delivery would certainly increase in wet years, the proportion of the total nitrate load contributed by wastewater could be lower in wet years.

Table 5a: Sub-Basin Nitrogen Budget

NITROGEN SOURCES BOULDER CREEK BASIN

SUMMARY

ELEMENT	UNITS	ANNUAL LBS/YR RELEASE	%	% PERC.	ANNUAL LOAD TO GW	%	SUMMER % DELIVERY TO STREAM		SUMMER LOAD TO STREAM	%	OVERALL SUMMER DELIVERY
SEPTIC SYSTEMS	380	9075	24%	0.75	6806	50%	25%	5%	85	16%	3.8%
SEWERED AREA	300	4606	12%	0.90	4145	31%	25%	40%	414	78%	36.0%
HIGH LANDSCAPE	300	806	2%	0.20	161	1%	25%	5%	2	0%	1.0%
MOD. LANDSCAPE	0	0	0%								
LIVESTOCK	0	0	0%								
NATURAL VEG	5675	23835	62%	0.10	2384	18%	25%	5%	30	6%	0.5%
TOTAL		38322	lb/yr	0.35	13496	lb/yr		16%	531	lb	5.5%
AVERAGE DAILY (LB/DY)					37.0				5.9	lb/day	

AVG GW CONC. (ANNUAL LOAD / RECHARGE)	1.2MG/L
CALC STREAM CONC: AVG LOAD / OBS. FLOW	1.1MG/L

OBSERVED CONDITIONS - SUMMERS, 1990-93	
GROUNDWATER CONCENTRATION	? MG/L
STREAM NITRATE-N CONCENTRATION	0.9MG/L
STREAM FLOW (CFS)	1.0CFS
STREAM LOAD (LB/DAY)	6.0LB/DAY

SOURCES:

LANDSCAPING	LB/UNIT/YR	UNITS	TOTAL LOAD
SIGNIFICANT	2.68	300	806.4 LB/YR
MODERATE	0.52	0	0

LIVESTOCK	LOAD/YR/ANIMAL LB-N/YR/HD	ANIMALS	% ONSITE DISPOSAL	TOTAL LOAD LB-N/YR
STABLE	108	0	1	0
RANCHETTE	108	0	1	0
TOTAL		0		0

SEPTIC SYSTEMS (2.8 PERSONS/HOUSEHOLD)

LOAD/HOUSE/YR	UNITS	TOTAL LOAD
23.88	380	9075 LB/YR

SEWERED AREA (1.8 PERSONS/HOUSEHOLD)

LOAD/HOUSE/YR	UNITS	TOTAL LOAD
15.35184	300	4606 LB/YR

NATURAL VEGETATION

LOAD(LB/AC/YR)	AREA(ACRES)	TOTAL LOAD
4.2	5675	23835 LB/YR

RECHARGE

RAINFALL (IN.)	% RECHARGE	RECHG(IN)	AREA	RECHARGE AF/YR
55	20%	11	5675	5202

20% FOR FOREST AREAS; 24 INCHES FOR SANTA MARGARITA

11-Jan-95

Table 5b: Sub-Basin Nitrogen Budget

NITROGEN SOURCES

LOWER ZAYANTE

ADJUSTED FOR GROUNDWATER EXPORT

SUMMARY

ELEMENT	UNITS	ANNUAL LBS/YR RELEASE	%	% PERC.	ANNUAL LOAD TO GW	%	AFTER EXPORT	SUMMER % DELIVERY TO STREAM		SUMMER LOAD TO STREAM	%	OVERALL SUMMER DELIVERY
SEPTIC SYSTEMS	380	9075	33%	0.75	6806	48%	92%	25%	6%	94	48%	4.1%
HIGH LANDSCAPE	123	331	1%	0.25	83	1%	92%	25%	6%	1	1%	1.4%
MOD. LANDSCAPE	99	52	0%	0.25	13	0%	92%	25%	6%	0	0%	1.4%
LIVESTOCK	120	12960	47%	0.45	5832	41%	92%	25%	6%	80	41%	2.5%
NATURAL VEG	1274	5351	19%	0.25	1338	10%	92%	25%	6%	18	10%	1.4%
TOTAL		27768	lb/yr	0.51	14071	lb/yr			6%	194	lb	2.8%
AVERAGE DAILY (LB/DY)					38.6		35.5			2.2	lb/dy	
AVG GW CONC. (ANNUAL LOAD / RECHARGE)					2.0	MG/L						
CALC STREAM CONC: AVG LOAD / OBS. FLOW					0.7	MG/L						

OBSERVED CONDITIONS - SUMMERS, 1990-93		ABOVE BASIN	BELOW BASIN	GW EXPORT
GROUNDWATER CONCENTRATION - NATURAL	0.5MG/L			
GROUNDWATER CONCENTRATION - DEVELOPED	3.0MG/L			
STREAM NITRATE-N CONCENTRATION	0.6MG/L	0.5	0.6	0.5
STREAM FLOW (CFS)	0.6CFS	0.6	1.2	1.2
STREAM LOAD (LB NO3-N/DAY)	2.1LB/DY	1.5	3.6	3.1

SOURCES:

LANDSCAPING	LB/UNIT/YR	UNITS	TOTAL LOAD
SIGNIFICANT	2.6	123	330.624LB/YR
MODERATE	0.5	99	52.272

LIVESTOCK	LOAD/YR/ANIMAL LB-N/YR/HD	ANIMALS	% ONSITE DISPOSAL	TOTAL LOAD LB-N/YR
STABLE	108	70	1	7560
RANCHETTE	108	50	1	5400
TOTAL		120		12960

SEPTIC SYSTEMS (2.8 PERSONS/HOUSEHOLD)	LOAD/HOUSE/YR	UNITS	TOTAL LOAD
	23.88	380	9075LB/YR

SEWERED AREA (1.8 PERSONS/HOUSEHOLD)	LOAD/HOUSE/YR	UNITS	TOTAL LOAD
	15.35184	0	0LB/YR

NATURAL VEGETATION	LOAD(LB/AC/YR)	AREA(ACRES)	TOTAL LOAD
	4.2	1274	5351LB/YR

RECHARGE RAINFALL (IN.)	% RECHARGE	RECHG(IN)	AREA	RECHARGE AF/YR
45	53%	24	1621	3242

20% FOR FOREST AREAS; 24 INCHES FOR SANTA MARGARITA

09-Jan-95

5.5 Summary of Watershed Nitrogen Sources

The results from the individual sub-basin budgets were combined with the overall watershed budget to summarize the relative contribution from each type of source to the total watershed nitrate load. The percentage contribution to total sub-basin nitrate load from each source was multiplied by the average load from that sub-basin (Table 5) and added to comparable values from other sub-basins to determine the watershed nitrate contribution from that source. The results of this analysis are shown in Table 6.

===

Table 6: Contributions by Source to Total Summer Nitrate Load in the San Lorenzo River Between Boulder Creek and Felton (July-September).

SOURCE	SUMMER PERCENT CONTRIB.	SUMMER LOAD POUNDS NITROGEN	MEAN DAILY SUMMER LOAD LB-N/DAY	
Septic Systems in Sandy Areas	38%	1573	17.5	7000
Treated Sewage Discharge, Boulder Creek	10%	414	4.6	2000
Natural Vegetation in Sandy Areas	12%	497	5.5	1850
Septic Systems in Non-Sandy Areas	19%	787	8.7	4050
Scotts Valley Nitrate Plume	9%	373	4.1	1100
Livestock and Stables, Sandy Areas	6%	248	2.8	1100
Natural Sources in Non-Sandy Areas	4%	166	1.8	930
Landscaping and Fertilizer, Sandy Areas	2%	83	0.9	370
Instream Nitrate Losses		-900	-10.0	-6200
TOTAL		3240	36.0	12200

The percent contribution and the average summer load represent the amount of nitrate contributed to the River in the reach from Boulder Creek to Felton during the summer. The proportions and loadings are based on measurements for 1990-93, which reflect a range of hydrologic conditions. The mean summer load for that period (36.71 lb-N/day) is practically equal to the mean summer load for the period of 1976-1993 (35.59 lb-N/day).

===

A number of additional observations about discharge of nitrate in the watershed can be made by comparing the estimated results of the sub-basin budgets:

1. During the summers of 1990-93, approximately 4% of the nitrogen released from individual sewage disposal systems in the sandy loam areas within one quarter mile of Boulder Cr. was entering the creek as nitrate. 10-25% of the nitrogen from septic systems in the sandy areas underlain by Santa Margarita Sandstone reached the streams as nitrate. These figures are comparable to those from earlier studies, where nitrate delivery from

septic systems to streams was found to be 12-55% for very sandy soils, and 1-28% for moderately sandy and alluvial areas (HEA, 1983; SCCHSA, 1989). The range indicated for the earlier studies was for dry conditions in early fall, 1981 (the low percentage) and very wet spring conditions in June 1982.

2. In the sandy areas, nitrate delivery rates increased significantly with density of development: nitrate delivery rates from both fertilizer use and wastewater disposal are much greater in Glen Arbor and Newell Creek than Zayante or Bean Creek. The nitrate delivery rate from septic systems in Glen Arbor, where the average lot size is 0.5 acres, is 6 times the rate for Zayante, where the average size of lots served by septic systems is more than 4.3 acres.

3. Nitrate delivery rates are much higher where there is relatively dense development in close proximity to a concentrated discharge such as at McEnery Spring in the Zayante Basin, where delivery rates are almost 8 times greater than in the overall basin. There is little or no opportunity for denitrification in the zone of groundwater discharge in this situation.

4. In sandy areas, wastewater from each household contributes an estimated average of 1.1 pounds of nitrate nitrogen to streams during three months of an average summer. Under previous, limited manure management practices, each horse in sandy areas released an estimated average of about 1 pound of nitrate nitrogen to streams during an average summer (July-September) Practices have begun to be improved since 1993.

5. The watershed budget indicates that 85% of the summer nitrate load in the middle San Lorenzo River is derived from non-natural sources. Under natural, undeveloped conditions nitrate loads could be expected to be 15% of what they are now, resulting in a nitrate concentration of approximately 0.06 mg-N/L. This is the level that is currently set by the Regional Board as the nitrate objective for the San Lorenzo River.

6. The daily summer nitrogen load from non-natural sources in the River at Big Trees is comparable to the load that would be generated by 500 houses discharging untreated sewage directly to the River.

The nitrate budgets represent a good estimate of the contribution to nitrate concentration from non-natural sources in the Watershed. For management purposes, it will be assumed that the sub-basin and watershed budgets represent typical current conditions. It will also be generally assumed that any reduction in the nitrate load which results from reducing nitrogen discharge to the watershed, will result in an equivalent reduction in nitrate concentration in the River. These budgets have been used to assess the effects of reductions in nitrogen discharge brought about by potential nitrogen control measures.

6 INVESTIGATION OF SHALLOW LEACHFIELDS

During Phase 2 of the nitrate management study, nitrate release from leachfields in sandy soils was further investigated. As discussed above, septic systems in sandy soils are the major contributor of nitrate to the River. Most of these systems are deep (10-12 feet), which reduces the potential for nitrogen removal prior to percolation to groundwater. During Phase 1, it was suggested that nitrate discharge could be reduced by as much as 35% for little additional cost if shallow trenches were utilized to replace deeper trenches.

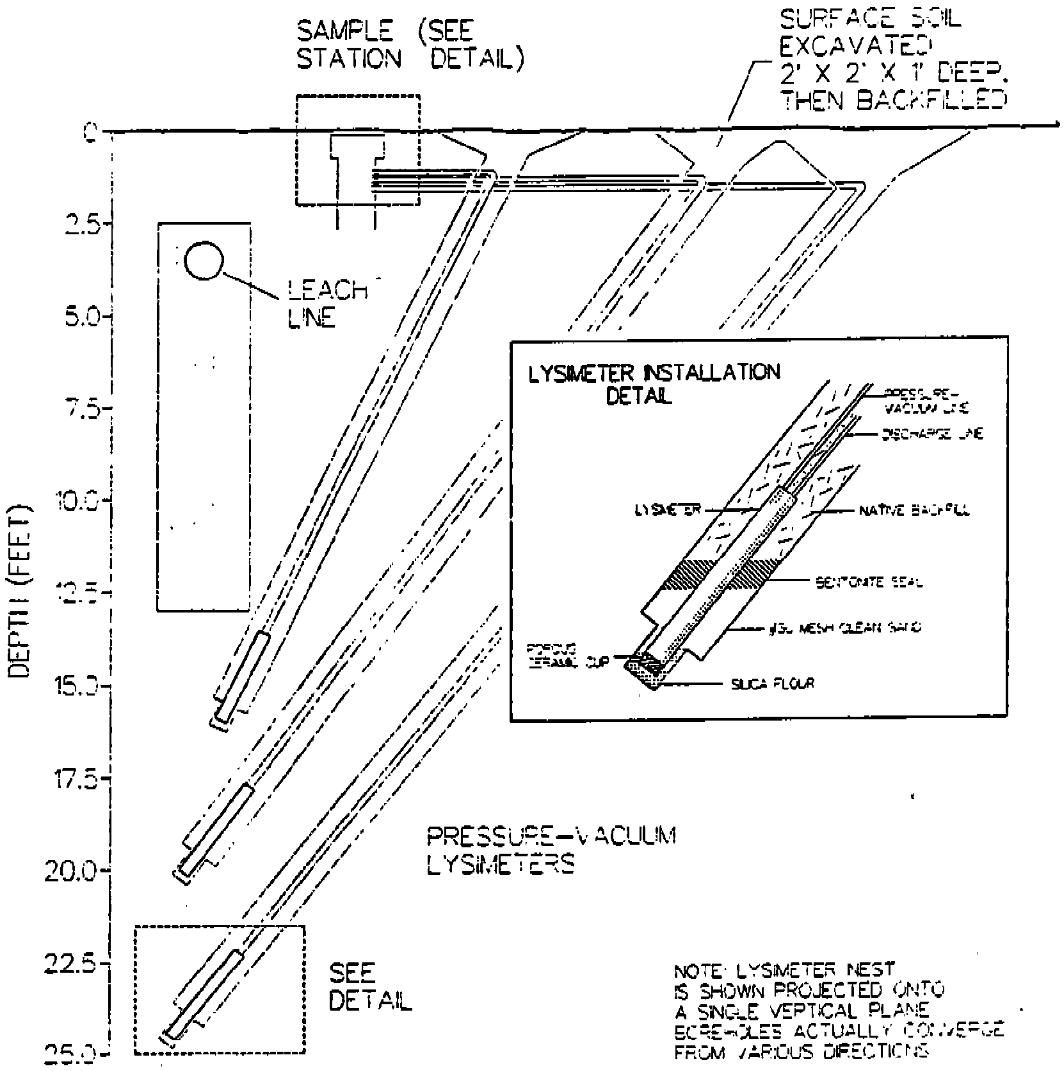
The Phase 2 project included a comparative evaluation of nitrogen discharge beneath a shallow and a deep leachfield in sandy soils. This work was conducted on a single parcel in the sandy area of upper Glen Arbor (Hihn Road) by Balance Hydrologics and County staff. The initial results are presented in Balance's report, <u>A Comparative Study of Nitrate Movement below a Deep and a Shallow Leachfield in Zayante Soils, Glen Arbor, Santa Cruz County</u>, August, 1994. County staff have performed further analysis and updated the results from more recent sampling.

The literature review for the project suggested that the main method of nitrogen removal below a leachfield would be through denitrification. It was not expected that uptake by plants would provide any significant nitrogen removal at depths greater than one foot from the surface. Prior to denitrification, nitrogen in the septic effluent must be oxidized from ammonia and organic nitrogen to nitrate. The literature suggested that this would take place in the first few feet of movement through the unsaturated sands below the leachfield. This was indeed confirmed by the findings of the study. Denitrification is a biological process that requires a source of organic carbon, high soil moisture, and an intermittent anaerobic (oxygen-free) zone.

Although conditions below leachfields may be quite conducive to denitrification, in sandy soils it was expected that denitrification would be limited due to the rapid drainage of the sandy soils. However, some researchers suggested that actual denitrification could be higher than predicted. Most researchers did not expect significantly greater amounts of denitrification from a shallower leachfield in sandy soils, but they recognized that denitrification can be an unpredictable process. The premise of the study was that denitrification would be higher in a shallow leachfield due to greater presence of organic matter, more biological activity, and greater potential for intermittent saturation in the upper soil layers.

The project included installation of 22 vacuum lysimeters below an existing 12 foot deep leachfield (10 ft. flow), below a new 2 foot deep leachfield (1 ft. flow), and in an undisturbed control area on the parcel. The full layout of all the lysimeters is shown in Appendix D; the deep trench is shown in Figure 12. The deep trench is 50 feet long and the shallow trench is 15 feet long. A distribution box was installed to split the effluent flow evenly between the two leachfields. During sample collection, the distribution box was checked and the risers in the ends of the shallow field were checked to confirm that it was receiving half of the effluent flow, and that effluent was being distributed throughout the length of the shallow trench.

Figure 12: Construction of Lysimeters Below Deep Leachfield



Balance
Hydrologics, Inc.

Figure 5. **Construction of a representative lysimeter nest, deep trench leachfield,**

Samples were collected semimonthly from the septic tank and the lysimeters and analyzed for nitrate, ammonia, total nitrogen, total organic carbon, and chloride. Soils on the site are typical of Zayante sands, overlying the loosely consolidated Santa Margarita Sandstone (Balance, 1994a). Water usage at the residence served by the system was 150-200 gallons per day, with monthly nitrogen loadings ranging from 1.66 lb-N/mo in January 1993 to 2.85 lb-N/mo in April 1993.

Mean values from each lysimeter for 1992-1994 are included in Appendix D. Mean values from lysimeters under the shallow trench and lysimeters under the deep trench are plotted in Figure 13. A statistical analysis of the data was done with SPSS-PC+ software using data from October, 1992 through December, 1994. The data was grouped according to sample source (deep trench, shallow trench, septic tank, or control), antecedent rainfall conditions (rainy, dry, or mixed), and point in the duration of the study (prior to January, 1994, or after). Analysis of Variance was performed to determine which groupings showed statistically significant differences for nitrate, ammonia, Kjeldahl nitrogen or total nitrogen.

There were several anomalies in the data that required further evaluation and adjustment. During the summer of 1994, one lysimeter under the shallow leachfield twice showed very high levels of nitrate (80-140 mg-N/L), chloride, and electroconductivity. Although the results for those samples appeared to be accurate, they varied substantially from the other samples and did not seem to reflect the quality of percolating effluent. These samples were dropped from the analysis as outliers. For the same reason, four other samples were also dropped for both shallow and deep leachfields in summer of 1993.

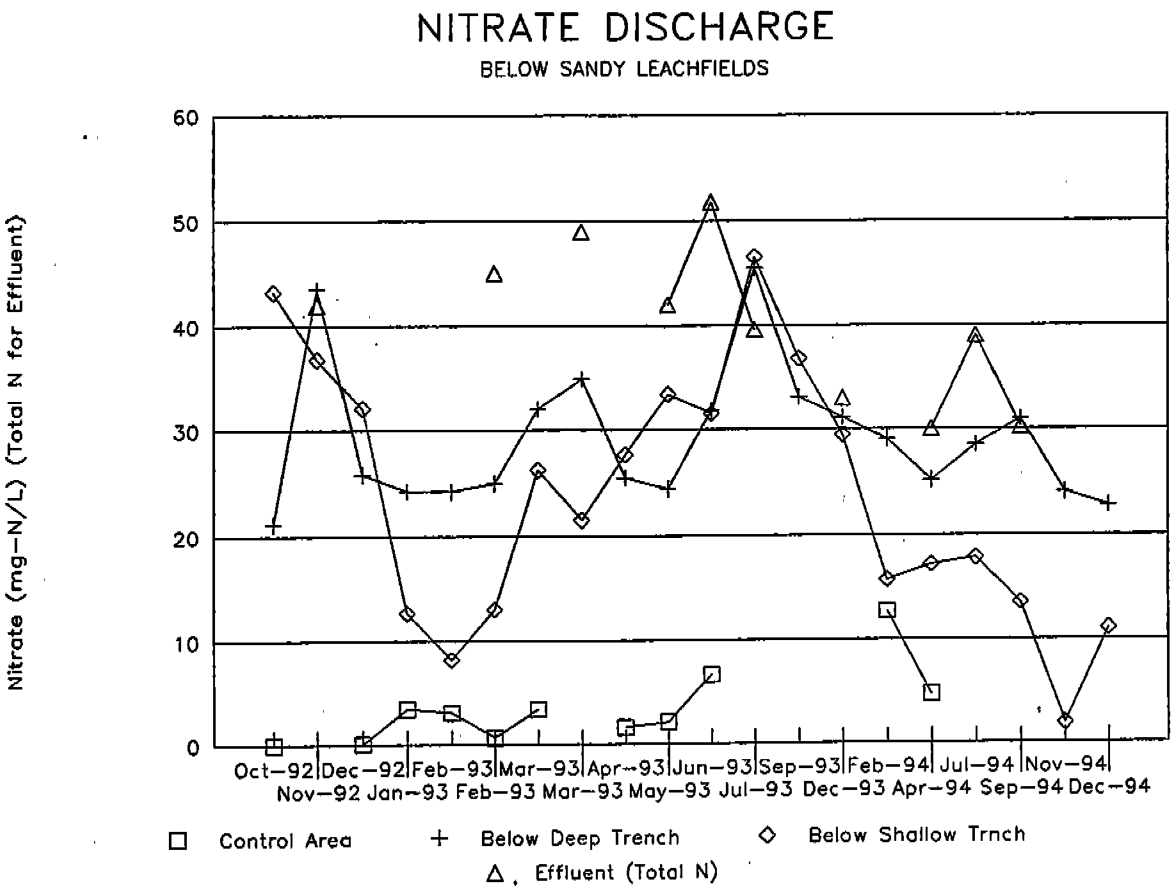
In evaluating the data for each trench, there was no statistically significant difference between individual lysimeters, based on depth or lateral position along the trench. For the remainder of the analyses, data for each trench was grouped together by sampling period. The data showed very significant variation depending on antecedent rainfall conditions with a significance value of 0.0001 (indicating an extremely low probability that the values are not different). Mean nitrate values for samples from beneath both leachfields were 23.48 mg-N/l during rainy conditions, 31.58 mg-N/l during dry conditions, and 29.67 mg-N/l during mixed conditions.

The differences in nitrate values below the deep trench and the shallow trench were much weaker. Over the full duration of the study, the mean nitrate value below the shallow trench was 28.14 mg-N/l, compared to 29.45 mg-N/l below the deep trench. However, the significance value for the difference in means was 0.1387, indicating there was a 14% probability that additional samples would show no difference between the trenches. When the data was aggregated by antecedent rainfall condition, the difference between the trenches became stronger. For rainy conditions, the mean nitrate value was 19.74 mg-N/l below the shallow trench and 26.19 mg-N/l below the deep trench, with a significance value of 0.0055. Under dry conditions, the relationship was reversed, with a mean nitrate value of 34.2 mg-N/l below the shallow trench and 29.8 mg-N/l below the deep trench, with a significance value of 0.1547. However, this relationship was further reversed in 1994.

Table 7: Analysis of Nitrogen Loss Below Deep and Shallow Leachfields in Sandy Soils, Summer, 1994

	Deep Trench	Shallow Trench	Improvement
Septic Effluent Total Nitrogen (mg-N/L)	39.0	39.0	
Mean Lysimeter Nitrate	26.8	17.5	
Mean Lysimeter Kjeldahl Nitrogen	3.7	5.1	
Calculated Lysimeter Total Nitrogen	30.5	22.6	7.9 mg-N/L
Nitrogen Loss	22%	42%	20%

Figure 13: Nitrate Discharge Below Sandy Leachfields



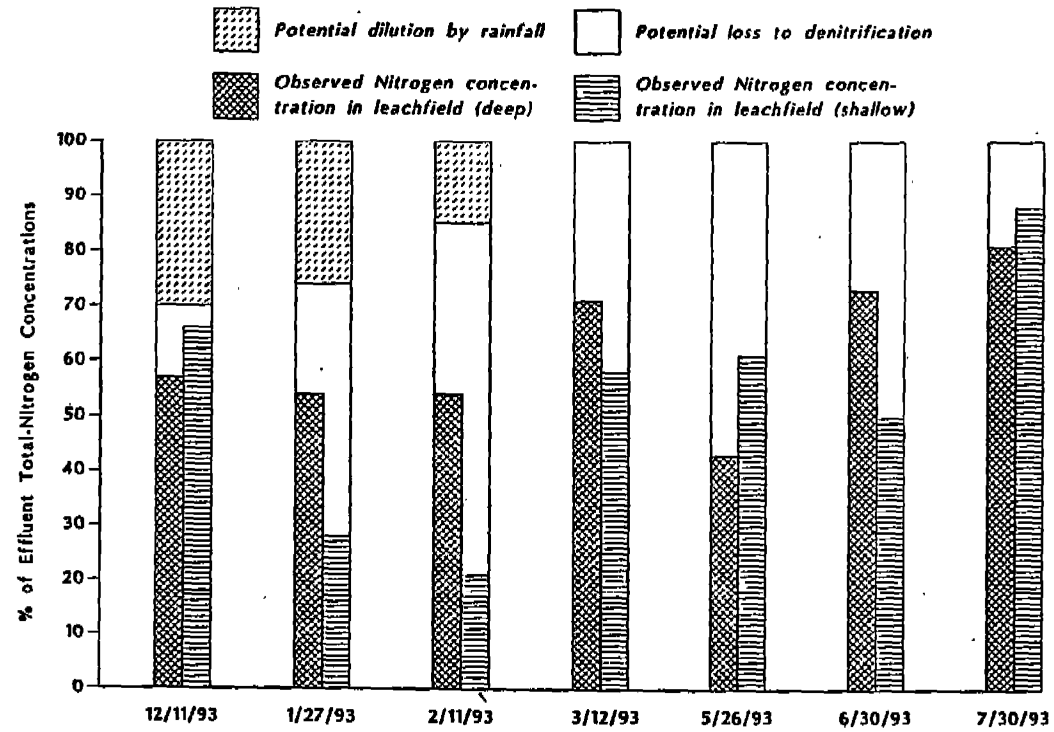
The differences between trenches became more pronounced after 1993, as indicated in Figure 13. Nitrate levels below the shallow trench were significantly lower during both wet and dry conditions. During 1994, the mean nitrate value for the deep trench was 26.87 mg-N/L, and 12.14 mg-N/L for the shallow trench, with a significance value of 0.0000 for the difference between means. It is believed that the significant change in nitrate values below the shallow trench in 1994 is attributable to maturing of the trench with formation of a biological mat and improved treatment capability. This maturation is confirmed by the beginning of ponding for the full length in the bottom of the shallow trench in 1994. Additional sampling is ongoing to confirm that 1994 conditions are indicative of the long-term performance of the shallow trench.

The consultant plotted the percentage reduction in nitrogen in the leachfields relative to nitrogen in effluent (Figure 14) and evaluated probable reasons for the reductions during the early part of the study. During the winter period, significant reductions where attributable to dilution by rainfall. However, during all seasons, a significant amount of loss was probably attributable to denitrification. The occurrence of nitrogen loss is further confirmed by the substantial decline in the proportion of nitrogen to chloride below the leachfields (0.038 under the shallow leachfield) relative to the septic effluent (0.050). If the lower nitrogen levels were due to dilution only, the ratio would be the same. The consultants also observed that there was enough organic carbon in the deepest lysimeters to facilitate additional denitrification at greater depths if other conditions proved suitable.

Looking at data from the summer of 1994, when both trenches were fully functional and no dilution was occurring, the shallow trench had nitrate levels 20% lower than below the deep trench, as indicated in Table 7. It would appear that during summer months, denitrification may remove about 20% of the nitrate percolating below a deep leachfield, and 40% percolating below a shallow leachfield. During the wet season, this loss would be expected to be greater with the higher soil moisture being more conducive to denitrification. This is indeed indicated in this study as shown by Figure 14. The summer 1994 denitrification figures will be utilized in the remainder of this report for nitrogen loss from deep and shallow systems.

The findings of significant denitrification in sandy soils are also supported by a recent study in the Los Osos area which found nitrogen reductions of 10-75% below septic seepage pits (TACCSLO, 1994). The soils in Los Osos have more fines and stratification which would cause localized zones of saturation and reduced oxygen. They would thus be expected to support higher rates of denitrification than the sandy soils of the San Lorenzo Watershed.

Figure 14: Attenuation of Nitrogen Discharge Below Sandy Leachfields



Notes: 1. Effluent Total-N concentrations are assumed to be 45.0 mg N /l for sample dates between December 1993 and March 1994; and 60.0 mg N /l for sample dates between May and July 1994 (see Table 9.)

2. Plant uptake and possible soil release from storage not considered (see text).

Balance Hydrologics, Inc.

Figure 8. Attenuation of nitrogen concentrations beneath deep and shallow leachfields in sandy soils during wet and dry conditions, Year 1.

7 NITROGEN CONTROL MEASURES

Potential control measures have been identified and evaluated for their expected effectiveness in reducing nitrate discharge in the San Lorenzo River. The measures have been evaluated in terms of their technical feasibility and effectiveness, their overall effectiveness in the Watershed (utilizing the budgets already generated), their cost relative to amount of nitrogen removed, their overall cost of implementation, and the institutional framework for implementation. Several scenarios were developed to indicate the effect and cost of implementation of different combinations of control measures. Based upon the degree of nitrogen reduction proposed, the most cost-effective measures have been recommended for inclusion in an overall nitrogen management plan.

7.1 Technical Control Measures

A number of nitrogen control measures potentially applicable to the San Lorenzo Watershed have been identified by county staff and Balance Hydrologics (1991). The majority of measures would reduce nitrate discharge from wastewater disposal in sandy soils, but additional measures for other sources have also been identified. These measures would be applicable to both new and existing land use activities in order to limit the potential increase in nitrogen discharge and to reduce current nitrogen discharges. The majority of these involve use of special technologies to reduce nitrogen discharge from individual sources; others involve improved management practices or general land use regulations.

7.1.1 *General Considerations Regarding Nitrogen Reduction*

The amount of nitrogen discharge which ultimately reaches groundwater or surface water is determined by the action of natural processes which modify the various forms of nitrogen and ultimately remove nitrogen from the hydrologic system. Nitrogen discharged to soil from most sources is in the form of ammonia and organic nitrogen. Organic nitrogen generally remains close to the point of discharge until it is broken down to ammonia or nitrate. Ammonia does not move rapidly through the soil and may be adsorbed by soil particles, fixed by microbes and plant roots, or lost to the atmosphere through volatilization.

In unsaturated, aerobic conditions, particularly typical of sandy soils, the ammonia and organic nitrogen will be rapidly converted to nitrate by soil organisms (nitrification). Although some nitrate may be taken up by plants, it is highly mobile and a large proportion will ultimately be carried downward out of the biological zone by percolating wastewater and/or rainwater. If nitrate reaches a saturated, anaerobic zone, where there is also carbon present from wastewater, soil humus, or other sources, nitrate will be removed from the system as nitrogen gas through action by soil organisms (denitrification). After nitrate percolates to deep groundwater, there is a further occasion for substantial removal through denitrification or uptake by plants as the groundwater passes through the riparian zone and discharges to surface water. Additional denitrification and uptake also takes place in the stream environment.

Nitrogen control measures would reduce the nitrate load in the River by reducing or removing the nitrogen source, treating the source to reduce nitrogen prior to discharge, or modifying the method of discharge to promote increased nitrogen removal by the natural processes. Evaluation of the technical aspects of potential nitrogen control measures takes into account their effectiveness in removing nitrogen, their overall cost in relation to that effectiveness, their history of performance and reliability, and their potential either to provide benefits unrelated to nitrogen removal or to cause adverse impacts.

For many technologies the cost assessment does not reflect the total cost of a measure, but is based on the incremental cost related to nitrogen removal. For example, if a leachfield installation or replacement is required for purposes other than nitrogen removal, the cost of providing for nitrogen removal by installing a shallow system is the difference between the costs of a shallow system and a conventional system, not the total cost of a shallow system. However, if a system replacement is required for purposes of nitrogen reduction alone, then the full system replacement cost must be taken into account in determining cost-effectiveness.

During Phase 1, Balance Hydrologics Inc. prepared tables which describe the applicability, cost and effectiveness of potential technical nitrogen control measures (Appendix E). A more detailed discussion is contained in their final report (1991). County staff has expanded on this information, updated it, and related it back to the overall nitrate budget to better evaluate the cost-effectiveness of each measure. This information is summarized in the Table 8 and discussed in the following sections.

7.1.2 Wastewater Disposal Improvements

The greatest source of nitrate to the San Lorenzo River is in-basin wastewater disposal. Most of this nitrate comes from onsite disposal systems in sandy areas, where nitrogen is not as effectively removed by natural soil treatment. In sandy soils, during an average year, 75-80% of the nitrate from individual conventional septic systems reaches groundwater, and up to 30% may reach surface water. Various technologies are available to reduce this nitrogen discharge through improved disposal techniques, improved treatment technologies, or wastewater reduction. (For more detailed specifications on systems, see SCCHSA, 1995, and references cited in Table 8 or in the narrative.)

<u>Improved disposal techniques</u> promote greater nitrogen removal in the soil by disposing the effluent in a way which promotes greater rates of biological treatment and/or reduces the rate of downward percolation. Use of <u>shallow disposal trenches</u> is probably one of the simplest methods of improved disposal. Not only does this provide for effluent disposal in the biologically active zone of the soil, but it also disperses the effluent over a much greater area and reduces the rate of downward percolation. Analysis of County septic system installation records for sandy areas shows that 65% of the septic systems in sandy areas have disposal trenches that are over 10 feet deep. The investigation conducted as a part of this project indicated that a shallow trench that is less than 2 feet from the ground surface will provide

additional nitrogen reduction of 20% over a conventional deep trench (see Section 6). County regulations were amended in 1993 to require trenches not deeper than 4 feet in sandy soils or 6 feet in nonsandy soils. (The reason for not requiring 2 foot trenches (1 foot flow) is that that would require many linear feet of trench and the use of pumps to get even effluent distribution at significantly increased cost and potentially reduced reliability.) Shallow trenches provide other benefits of overall improved treatment of sewage effluent in the upper, biologically active soil zones.

Other improved disposal methods utilize effluent dosing and/or disposal in imported soil material more conducive to nitrogen removal. Pressure Distribution (P.D.) Systems (with sand-filled trenches) and Mounded Beds utilize a pump and dosing cycles to distribute the effluent evenly throughout the disposal device and provide for alternating unsaturated aerobic and saturated anaerobic conditions. This dosing improves overall treatment and allows for alternating conditions for nitrification and denitrification. Estimated nitrogen reduction is 10-30% greater than a conventional deep disposal system. Removal can probably be increased in mound systems by placing the disposal bed in imported loam or clay loam fill, which would promote treatment by lowering the percolation rate and potentially providing for more denitrification. Balance has proposed further increasing denitrification by installing a "geomembrane" of low permeable soil several feet below the disposal device which would create a perched groundwater lens highly conducive to denitrification. Although this also needs field evaluation, it is estimated to reduce nitrogen discharge by 70%.

Nitrogen Treatment techniques utilize special technologies to reduce the nitrogen concentration prior to effluent disposal. This is typically done in some sort of filter which is designed to promote nitrification and denitrification in the filter prior to discharge: sand filters, RUCK Systems, Upflow Anaerobic Filters, and small package sewage treatment plants using sequencing batch reactors. Although findings are not consistent, intermittent and recirculating sand filters have been found to reduce nitrogen by an average of 55% in a variety of circumstances (DEQ, 1982; EPA, 1993; Regional Board, 1994). Sand filters are being used more extensively for improved wastewater treatment and are relatively simple to construct. The other technologies may provide from 50% to 90% reduction, but are more technical, experimental, and/or not widely used. Use of any of the above treatment technologies has additional benefits of reducing suspending solids, biological oxygen demand, and pathogens. This can allow use of smaller and deeper disposal devices, which can help reduce the overall cost of the system.

Nitrogen treatment devices are more cost-effective when dealing with larger sewage flows, such as camps, resorts, or community systems. The relative cost per gallon of treated sewage is much lower with increasing flows. There are also substantial benefits for reduced disposal area requirements. There are an estimated 20 large disposal systems in the San Lorenzo Watershed which discharge a total of 200,000 gallons per day of sewage. An estimated 25% of these are in sandy areas and contribute 1.4 lb/day of nitrate to the River during the summer.

Another technique under consideration for nitrogen removal from wastewater provides chemical removal of ammonia by passing the effluent through a tank filled with a granulated zeolite. This can provide for removal of 75-90% of the nitrogen, but does not provide any treatment of other sewage constituents. The initial capital cost is low, but there is an ongoing maintenance cost for replacement and reprocessing of spent zeolite (Regional Board, 1994). The actual magnitude of this cost is still unknown, as only a few experimental systems are in operation. Approved methods of disposal and/or reprocessing of spent zeolite have not yet been established.

Wastewater reduction methodologies reduce nitrogen discharge by reducing or eliminating the discharge of wastewater. Methods include: composting toilets, haulaway systems, or sewer systems for export and/or centralized treatment. Although composting toilets have the added benefit of reducing water use, the systems are generally user-intensive and can have adverse health impacts if not properly managed. Centralized treatment methods have the advantage of greater potential reliability, but may concentrate a large volume of wastewater in one location, which may have significant localized impacts. Many wastewater reduction measures have the potential disadvantage of reduction of groundwater recharge which can reduce groundwater supply and streamflow and have other significant environmental impacts, including construction impacts, transmission line leaks or breaks, reduced fishery productivity, and growth inducement (Gilchrist and Associates, 1984).

There is one existing community disposal system, the Boulder Creek Country Club (CSA-7), which currently is a significant source of nitrate to the River. This situation began in 1987 when the system could not meet new State requirements for reclamation of wastewater on the golf course. Reclamation had provided for very effective nitrogen removal, but it was deemed too expensive at the time to upgrade the treatment facilities to meet the new State reclamation requirements. The County, which is the operator of this system, is currently pursuing upgrade of the treatment process to allow reclamation. This will provide for substantial summer nitrogen removal, with the added benefit of reducing groundwater pumping

Due to the high proportion of nitrogen originating from wastewater disposal in sandy soils, the effectiveness of nitrogen control measures in those areas is 10 times greater than in non-sandy areas. For example, a shallow system in sandy soils is estimated to reduce summer nitrate load in the River by 0.2 pounds in a normal year; in non-sandy soils the reduction for a shallow system is estimated to be 0.02 pounds. It is therefore important to clearly define and identify those areas where control measures are most needed and appropriate. This can be done using maps of soil, geology or groundwater recharge areas; or by using field determinations of soil texture or percolation rate. Relatively good mapped information is already available and used by the County, particularly for planning and project review purposes. Percolation test results are required for installation of any new sewage disposal system, but have not been required for system replacements.

Prior studies recommended that consideration be given to limiting wastewater disposal in areas with permeability rates faster than 12 inches per hour (HEA, 1983). Although this is roughly comparable to a percolation rate of 5 minutes per inch, percolation rates and permeability rates are not equivalent. Further assessment of known percolation rates in the sandy areas of the San Lorenzo Watershed is needed in order to develop an appropriate criteria for requirement of specialized nitrogen control measures for wastewater disposal.

TABLE 8
POTENTIAL TECHNICAL MEASURES FOR REDUCTION IN NITROGEN DISCHARGE

CONTROL MEASURE (Notes on following pages.)	REDUCTION OF BASELINE NITROGEN DISCHARGE (SUMMER) (a)	SUMMER NITRATE SAVED PER UNIT (POUNDS) (b)	CAPITAL COST PER UNIT	ANNUALIZED COST PER UNIT (c)	ANNUAL. COST PER POUND NITROGEN REMOVED (d)	TOTAL CAPITAL COST (X$1000) (e)	TOTAL ANNUAL. COST (X$1000) (f)	TOTAL SUMMER NITRATE LOAD REDUCTION (pounds) (g)	(%)
WASTEWATER DISPOSAL, SANDY AREAS		1400 Units (Homes and Businesses) (h)							
Shallow System (<4 ft.)	20% (5-65%) (l)	0.2	$4,500 (J)	$508	$2,311	$6,300	$712	308	7%
Incremental Cost, Repair (m)		0.2	$500	$51	$231	$700	$71	308	7%
Mounded Bed with Loam Fill	20% (0-30%) (n)	0.2	$20,000 (J)	$2,337	$10,623	$28,000	$3,272	308	7%
Incremental Cost, Repair (m)		0.2	$15,500	$1,829	$8,312	$21,700	$2,560	308	7%
Pressure Distribution (sand-filled trench)	15% (0-30%) (i)	0.2	$10,000 (J)	$1,319	$7,991	$14,000	$1,846	231	6%
Incremental Cost, Repair (m)		0.2	$5,500	$810	$4,910	$7,700	$1,134	231	6%
Pressure Dist. with Geomembrane	70% (o)	0.8	$15,000 (o)	$1,828	$2,374	$21,000	$2,559	1078	26%
Incremental Cost, Repair (m)		0.8	$10,500	$1,319	$1,714	$14,700	$1,847	1078	26%
Intermittent Sand Filter	50% (0-70%) (p)	0.6	$8,000 (J)	$1,065	$1,936	$11,200	$1,491	770	19%
Incremental Cost (z)	50%	0.6	$6,000	$861	$1,566	$8,400	$1,206	770	19%
Treatment for Large Systems (aa)	80%	1.3	$1,100	$362	$283	$138	$45	160	4%
Zeolite Filters	85% (q)	0.9	$1,950 (q)	$619	$662	$2,730	$866	1309	32%
RUCK System	50-75% (r)	0.7	$16,000 est	$1,930	$2,699	$22,400	$2,701	1001	24%
Upflow Anaerobic Filt. & Sand Filt.	60-75% (s)	0.8	$16,000 (J)	$1,930	$2,506	$22,400	$2,701	1078	26%
Package Sys (Clearwater, etc.)	90%	1.0	$18,000 (J)	$2,133	$2,155	$25,200	$2,987	1386	33%
Elimination of Blackwater Discharge									
Composting Toilet	80% (i)	0.9	$10,000 (i)	$1,019	$1,157	$14,000	$1,426	1232	30%
Haulaway	100%	1.1	$3,500 (J)	$5,720	$5,200	$4,900	$8,008	1540	37%
Sewage Collection and Export	100%	1.1	$25,000 (k)	$3,218	$2,926	$35,000	$4,506	1540	37%
Collection and Nitrogen Removal	75% (k)	0.8	$20,000 (k)	$2,709	$3,284	$28,000	$3,793	1155	28%
WASTEWATER DISPOSAL, NON-SANDY AREAS		10,500 Units (Homes and Businesses) (t)							
Shallow System in Non-Sandy Areas	20% (5-65%) (l)	0.02	$4,500 (J)	$508	$33,889	$47,250	$5,338	158	4%
Incremental Cost, Repair (m)		0.02	$500	$51	$3,395	$5,250	$535	158	4%
Enhanced Treatment (sand filter, etc.)	50% (l)	0.04	$8,000 (J)	$1,115	$29,728	$84,000	$11,706	394	10%
Incremental Cost, Repair (m)		0.04	$6,000	$861	$22,963	$63,000	$9,042	394	10%
Treatment for Large Systems (aa)	80%	0.1	$1,100	$362	$3,771	$413	$136	36	1%
WASTEWATER DISPOSAL, CSA 7		250 Households (u)							
Treatment for Nitrate Removal	est. 75% (k)	1.2	$800 (k)	$141	$114	$200	$35	311	8%
Treatment for Reclamation	est. 90% (k)	1.5	$1,200 (k)	$182	$122	$300	$46	373	9%
LIVESTOCK / MANURE MANAGEMENT		250 Animals in Stables, Paddocks in Sandy Soils (v)							
Runoff Diversion, Cover Manure	30% (i)	0.3	$24 (i)	$11 (i)	$37	$6	$3	74	2%
Contract to Haul Manure	20% (i)	0.2	$0	$50 (ij)	$252	–	$12.5	50	1%
Use of litter in paddocks	30%	0.3	$0 (i)	$50 (i)	$168	–	$12.5	74	2%
Riparian Corridor Protection	50% (w)	1.0	$200 (x)	$30	$30	$6	$0.9	30	1%
PUBLIC EDUCATION									
Improved Fertilizer, N. Management	25% (y)	0.1			$24	$2	$0.5	21	1%

NOTES, EXPLANATIONS OF ENTRIES IN TABLE 8

a. The percentage reduction in nitrate discharge represents the amount of reduction provided by implementation of the nitrogen control measure beyond what would be coming from that source under current conditions during summer months of July through September. The current baseline for each source is described in the footnote for that source. Percentages indicated are the estimates used for this analysis, with a range of reported values in parentheses. Sources of percentages are as indicated in footnotes.

b. The percentage reduction is applied to the total pounds of nitrate nitrogen currently discharged per unit to the Central River during the summer, to determine the reduction in pounds. Each unit is typically one household or business, but may also be a head of livestock.

c. The annualized cost per unit for all measures (except livestock management) is the capital cost amortized over a 20 year period at a discount rate of 8%, with the addition of any annual operation or maintenance costs.

d. The annualized cost per unit divided by the reduction in summer nitrate load per unit.

e. The total cost of implementation for all units to which the control measure is applicable.

f. The total annualized cost for implementation by all applicable units.

g. The total reduction in summer nitrate load in the River at Felton expected to result if the measure were implemented for all applicable units.

h. An estimated 1400 individual wastewater disposal systems are located in areas underlain by sandy soils, primarily the Santa Margarita Sandstone. With current disposal practices, each of these contributes an estimated 1.1 pounds of nitrate to the River during an average summer (July -September).

i. Estimated by Balance Hydrologics (1991, 1994).

J. Estimates based on Santa Cruz prices for related systems (see also SCCHSA, 1995).

k. Estimate for nitrogen removal derived from figures provided for a possible wastewater disposal project for downtown Boulder Creek (Questa Engineering, 1991, 1994). Estimate for reclamation from County Department o Public Works (Jeff Mill, personal communication, 1995).

l. Range of estimates for improved nitrogen removal for shallow systems is 20% for a 2 ft. deep system (Balance Hydrologics, 1991), to observed removal of 65% from a small sampling of systems less than 6 ft. deep compared to systems 8 feet deep or over in sandy soils of the San Lorenzo Valley (SCCHSA, 1989; HEA, 1983). Recent sampling has shown nitrate reductions of 20% as compared to a deep trench in sandy soils (Section 6).

m. Incremental costs for repair are the difference in price between a conventional repair ($4500 capital cost), and a repair using the nitrogen control measure indicated. This assumes the measure would only be required at the time a system repair was necessary. Systems using dosing (mound, P.D., sand filters) also include extra $250 annually for maintenance, electrical costs, and monitoring.

n. Mound systems have been reported to have a range of values for nitrogen removal from insignificant (EPA, 1980) to 50% (SCCHSA, 1989). An estimate of 40% removal is made if different soil horizons are present belov the distribution (Balance Hydrologics, 1991). This would give an action similar to a sand filter (SCCHSA, 1995). EPA (1993) cites an average total nitrogen removal of 44%, or 16% more than a conventional system.

o. Conceptual system combining effects of shallow pressure distribution for nitrification (SCCHSA, 1995), with installation of underlying impermeable layer for denitrification (Balance Hydrologics, 1991). Costs are estimated to be intermediate between a mound and p.d. system.

p. Measurements of nitrogen removal in intermittent and recirculating sand filters vary from insignificant (EPA, 1980) to consistently above 50%-70% (ODEQ, 1982; EPA, 1993; Stinson Beach Water District, pers. comm.) U of designs and dosing rates that provide at least 50% removal is assumed for this study.

q. Regional Board, 1994. Costs for long-term maintenance of zeolite filters are unknown at this time. Effective filter designs have not yet been perfected, not have procedures for diposition of spent filter media been established. Actual costs may be much greater than indicated.

r. Removal rates for RUCK system are cited in two sources (National Small Flows Clearinghouse, 1991; EPA, 1993). Costs are not available but are estimated compared to other technologies.

s. EPA, 1993.

t. An estimated 10,500 individual wastewater disposal systems are located in areas underlain by non-sandy soils. With current disposal practices, each of these contributes an estimated 0.075 pounds of nitrate to the River during an average summer (July - September).

u. Approximately 250 housing units are served by the sewage treatment system for Boulder Creek Country Club (County Service Area No. 7). With current disposal practices, the entire area contributes an estimated 414 pounds of nitrate to the River during an average summer (July - September), equivalent to an estimated 1.7 pounds per housing unit.

v. An estimated 250 head of livestock, primarily horses, are kept in sandy areas of the watershed (an additional 100 head are kept in other areas, often in close proximity to creeks). Without any manure management, or other nitrogen control measures, each animal in sandy areas could be contributing as much as 1.0 pound of nitrate nitrogen to the River during an average summer, as estimated in the subbasin nitrogen budgets, based on updated figures for nitrate release from livestock (Balance Hydrologics, 1994).

w. Assumes horses in riparian areas contribute twice as much nitrate to River (2 pounds in the summer), due to reduced opportunity for nitrogen removal in riparian corridors; also assumes 10% of all livestock in the watershed (30 head) are currently kept in riparian corridors; if removed, summer nitrogen load will be reduced by 1 pound per head.

x. Assumed cost for fencing livestock out of riparian areas.

y. Ambitious assumption that $2000 public education program for homeowners in sandy areas will cause 50% of th 860 homeowners with landscaping to modify their fertilizer application techniques so as to reduce nitrate percolation from their landscaping by 50%. The program would be repeated every 4 years.

z. Effluent treated by a sand filter requires only half of the standard disposal area, providing capital cost savings of $2000, which partially offsets the cost fo the sand filter.

aa. Incremental cost of adding treatment for nitrogen removal for existing large systems. For estimating purposes, it is assumed that large systems average 10,000 gallons per day, and serve the equivalent of 125 units in sandy areas and 375 units in non-sandy areas. Assumes treatment is provided by recirculating sand filter which can produce effluent with 5 mg/L nitrogen. Estimated capital costs are $75,000 for 10,000 gpd capacity, with annual O&M costs of $250 per unit. (Figures are derived from Questa, 1994) Capital costs are offset by $20,000 savings for reduced disposal area. Each unit assumed to generate 200 gpd. It is also assumed that under untreated conditions, nitrogen delivery from these large systems is 150% greater than for individual systems, due to the high volume of effluent. Actual costs and effectiveness will vary depending on the specific system.

7.1.3 *Livestock Management*

Wastes from stables, paddocks, and other livestock areas contribute an estimated 6% of the summer nitrate load in the San Lorenzo River. Impacts may be more pronounced in individual tributaries or stream reaches where there are concentrations of animals. In lower Zayante Creek, livestock contributions amount to 41% of the estimated nitrate load. One horse or cow discharges almost as much nitrogen to the environment as an average household of three people.

Nitrogen delivery from livestock can be significantly reduced by runoff control, manure management, and siting of paddock areas to reduce percolation and runoff of nitrogenous wastes. Many of these measures have additional benefits of erosion control, dust control, reduction of flies, reduction of pathogen (ie. *Cryptosporidium*) discharge, and improved animal welfare. Although preventing runoff of wastes is always important, in the sandy areas it is also important to prevent percolation of nitrogen containing wastewater from livestock areas.

Specific nitrogen control measures should include:
1. Maintenance of an adequate separation between livestock and watercourses to prevent direct discharge of wastes and to promote the natural filtration and denitrification processes within riparian areas. A separation of 50-100 feet is required for onsite wastewater disposal devices, and is the minimum appropriate for livestock areas, unless other measures are taken to prevent contamination.
2. Stockpiling collected waste material on concrete, baserock, or other impermeable surfaces to prevent percolation.
3. Covering manure stockpile areas with tarps or roofs to prevent percolation and runoff of wastes.
4. Provision of roof gutters, ditches, and runoff control structures to keep clean rainfall and runoff away from paddock and manure stockpile areas, and prevent runoff of wastes to surface water.

Additional measures may also provide significant benefits and should be considered:
5. Surfacing paddock areas with baserock or other low-permeabilitiy surfacing to reduce percolation of nitrate.
6. Regular placement of litter to absorb wastes, with regular removal of litter and wastes to a suitable stockpile area.
7. Roofing stable and paddock areas to reduce runoff and percolation.
8. Operation of programs for regular removal of stockpiled manure for composting, mushroom growing, fertilization, or other uses which will not contribute to nitrogen discharge.

As a result of the Phase 1 study, some of these measures are already being taken by stable owners in the San Lorenzo Watershed. It is estimated that nitrate discharges from those operations will be reduced by 25-50%. There is good potential for substantial reductions of up to 85% if all the measures are implemented by most livestock owners. Because these measures are relatively inexpensive and treat relatively large amounts of nitrogen in one location, they are quite cost-effective, providing for substantial reductions of nitrate discharge at relatively little cost.

Management measures for reduction of nitrogen should be applied wherever animals are kept in stables, paddocks, or any other areas so small that vegetative ground cover is removed by their presence. In pasture areas where the density of animals is low enough to maintain full vegetative ground cover, nitrogen release is much less significant due to the dispersed deposition of wastes and the potential for treatment and uptake of the nitrogen.

7.1.4 *Public Education*

Discharge of nitrate is also related to the practices of individual residents: fertilizer application, land clearing, use of garbage disposals, and water conservation. Because nitrate is leached so readily from sandy soils, it is important that fertilizers be applied at much lower application rates, but more frequent intervals for full effectiveness. Organic or slow release fertilizers should be used as much as possible. Because land clearing can cause a very significant release of the nitrogen that is stored in vegetation and soil, clearing should be minimized, and followed immediately by revegetation and other erosion control measures to minimize leaching of nitrogen. Disposal of organic wastes in garbage disposals increases nitrogen load of wastewater by approximately 5% (Balance, 1991). Eliminating garbage disposals would reduce nitrogen discharge and improve overall septic system performance. Use of water conservation measures will reduce the volume of wastewater flow, slowing and dispersing the downward percolation and allowing higher rates of nitrogen removal (Ibid).

Public education is probably the most effective measure for reducing discharge from these practices by individual residents. Nitrogen reduction could be integrated with education regarding erosion control, runoff control, protection of groundwater recharge, protection of unique biotic communities, and use of drought tolerant native landscaping. All of these subjects are particularly important to minimize impacts of development in sandy areas.

7.1.5 *Land Use Regulations*

Land use regulations to limit the density or location of development can serve to minimize nitrogen delivery to groundwater and surface water. If density is kept low, dilution of nitrate from recharge is maintained and the total potential nitrate load to the basin is reduced. Lower densities also help to ensure that there is adequate room on the site to allow use of shallow wastewater disposal devices for nitrogen reduction.

The Regional Board's Basin Plan requires a one acre minimum lot size for new lots to be served by septic systems. The County has already implemented a one-acre minimum requirement for all new development in the San Lorenzo Watershed, regardless of the date of lot creation. County policies also require a minimum lot size of 10 acres for any new lots created in groundwater recharge areas and prohibit any new nonresidential uses which would allow percolation of pollutants into underlying groundwater. Implementation of these specific density requirements and a general County policy of reducing growth in rural areas are probably the main reason that nitrate levels in the River have not increased significantly since the mid 1970's (Balance, 1991). Continued compliance with these density requirements should serve to prevent nitrate concentrations in groundwater from exceeding drinking water standards (Johnson, 1988). The existing policies are probably adequate to maintain appropriate development density for minimizing nitrogen discharge from new residential development.

The nitrogen budgets prepared as a part of this study have indicated the great significance of nitrogen removal that takes place in riparian corridors. Without that, nitrate loads in the streams could be expected to be five to ten times greater. It is important to maintain this capability by protection of riparian corridors from disturbance. The County already has an ordinance which prevents any new development or clearing within 50 feet of a perennial stream or within a riparian woodland if that extends to a greater distance. Existing development activities are exempt. This ordinance should be maintained and possibly strengthened, particularly in regard to keeping of livestock, as discussed previously. More aggressive enforcement may also be appropriate.

Balance (1991) has also suggested the use of nitrogen minimizing plans for new development in sandy areas. These would be similar to erosion control plans, and include calculations of the potential increase in nitrogen discharge issuing from the project, and the specification of measures to reduce or mitigate the discharge. The plans would take into account wastewater disposal methods, density and number of units, extent and type of landscaping, fertilization practices, number of livestock to be kept, and livestock management practices. The plan would be developed and implemented as a condition of development approval to meet a specified level of nitrogen discharge. Preparation of such plans would probably be more useful and cost-effective for developments larger than individual single family homes.

Any increase in nitrogen discharge from new uses which are not specifically addressed in this report (such as golf courses, playing fields, nurseries, etc.) should be limited to the same extent as the limit for new residential development served by onsite disposal in the Watershed. Residential development is limited to parcels at least one acre in size, and requires measures to reduce nitrate discharge by at least 50%. The average household on a septic system generates about 24 pounds of nitrogen per year. It is thus recommended to limit the increased discharge of nitrate from new projects to no more than 10 pounds of nitrogen per acre per year from the project area. Projects which cannot achieve this goal should not be permitted in sandy areas of the Watershed.

7.1.6 Water Resources Management

Management of water resources has an effect on the nitrogen concentrations and loads in surface and groundwater. This can come about by direct extraction of nitrate from groundwater basins, modification of groundwater flow and delivery to surface water, reduced dilution by extraction of water of low nitrate concentration, or the potential use of reclaimed wastewater for irrigation or other uses. Switching to different water sources or utilizing different water treatment methodologies may also reduce some of the potential impacts of increased nitrate in surface water or groundwater supplies.

During the dry year of 1990, it was apparent that nitrogen loading of Zayante and Newell Creek was reduced by extraction of nitrate from the groundwater basin by municipal supply wells in the basin. During the period of 1987 through 1990, extraction rates in the Quail Hollow Basin were so high relative to recharge, that by 1990 there was little discharge of groundwater or nitrate to Newell Creek from the basin. The location and rate of pumping of individual wells also has an effect on the nitrate concentration in water extracted from those wells. This was clearly demonstrated in the Quail Hollow wells, where the average nitrate concentration was a function of the number of wastewater disposal systems in the vicinity of the individual wells (Johnson, 1988). As pumping rates increased, the cone of depression around the well increased, drawing in nitrate from a wider area and causing the nitrate concentration to increase (Ibid). Extraction of low nitrate groundwater or surface water reduces the amount of water available for dilution and causes the nitrate concentrations to increase.

Balance (1991) suggested that nitrate concentrations in the River could be reduced by extracting more groundwater from beneath the developed areas of Quail Hollow and East Glen Arbor to intercept the flow of nitrate moving to the Newell Creek and the River. The increased groundwater use would allow the diversion of low nitrate surface water from Ben Lomond Mountain to be reduced, further diluting the nitrate in the River. This might reduce nitrate levels by 20-30%. However, the capital cost would be more than $500,000, with a significant incremental annual cost for increased pumping. This would also raise potential issues of reduced water quality in the new water supply wells.

Although a water development project such as the above could not be justified for the purposes of nitrate removal alone, future water development proposals, particularly in the Santa Margarita Sandstone, should be assessed for their impacts on nitrate levels in surface and groundwater. Efforts are currently underway to provide for comprehensive management of the Santa Margarita Sandstone and Scotts Valley groundwater basin. This effort can make use of a groundwater model (prepared with Section 205j funding) to project changes in groundwater flow and streamflow under future water use and development scenarios, and allow some prediction on possible effects on nitrate movement.

Use of reclaimed wastewater has the potential to increase or decrease the nitrate loading in the River. A return to irrigation with wastewater on turf areas with clay soils at the Boulder Creek Country Club has the potential to significantly reduce the nitrate load by 75% in Boulder Creek and by 45% in the River between Boulder Creek and Ben Lomond. However, any potential application of treated wastewater to more permeable soils would require thorough evaluation and management to ensure that significant amounts of nitrate would not be allowed to escape.

As an alternative to reducing nitrogen discharge, the impacts of increased nitrate on water supply could be avoided by developing alternative water sources or treatment methodologies. These mitigation measures can be quite expensive. A new well with pipeline would cost approximately $100,000 to $500,000, depending on the location and depth of the well. Treatment by reverse osmosis to meet drinking water standards for nitrate is considered less cost-effective than developing a new source, provided a new source is available.

Although surface water can always meet drinking water standards for nitrate, the increased nitrate may indirectly result in increased taste and odor and presence of organic compounds which become carcinogenic compounds (trihalomethanes, etc.) upon conventional treatment with chlorine. Water treatment costs to remove taste and odor from the River water for the City of Santa Cruz water supply under current conditions are approximately $60,000 per year (Tompkins, pers. comm.). With new regulations, overall treatment costs could increase to $500,000 to $1,000,000 per year, in addition to a $6,000,000 capital cost for upgrade of treatment facilities. (Not all of this is related to the potential impacts of nitrate.) It is undetermined to what extent, if any, these costs could be reduced if nitrate levels in the River were reduced.

7.2 Institutional and Financial Considerations

The previous section described potential technical measures for management of nitrate in the San Lorenzo Watershed. Potential implementation of these measures is dependent upon various institutional and financial considerations:

- Comparison of the amount of nitrogen reduction required in relation to the incremental costs of implementing control measures.
- Consideration of who pays for implementation as compared to who benefits.
- Identification of regulatory and institutional framework for implementation of various measures.

7.2.1 *Cost-Effectiveness*

Determining the objective for nitrogen reduction should take into account the desired levels of nitrate in the River, and the level of effort and expenditure required to attain that nitrate level. Due to the high costs of complete nitrate removal, County staff believe it is probably not realistic to set as an objective the restoration of nitrate levels to predevelopment conditions. The severity of existing or potential impacts on beneficial uses of the water must be compared to the cost and feasibility of reducing or preventing those impacts.

The severity of any current nitrate impacts also has bearing on the timing and extent to which control measures are required. If the primary objective is to prevent an increase in nitrate levels, measures would primarily be required for new uses only. If a gradual reduction is desired, measures for existing uses can be implemented over time, as septic systems are repaired, homes are remodeled or stable areas are expanded. These methods of implementation have low incremental cost compared to overall project cost. Short term implementation of nitrogen control measures to bring about a rapid decrease in nitrate level would have a very high cost resulting from a high level of effort specifically for nitrogen removal.

The cost-effectiveness of potential nitrogen control measures has been summarized in Table 8. This provides information on the amount of nitrate load reduced by each measure per unit installation, the capital cost, the annual cost, the cost per pound of nitrogen reduction, the total costs if all units (homes) were required to implement the measure, and the percentage reduction in River nitrate load that would result from full implementation.

This information can be used to compute the total cost of implementing nitrogen control measures for comparison to the amount of nitrogen reduction achieved. As an example, construction of sewers and exporting wastewater from the sandy areas of the watershed would provide the greatest amount of nitrogen reduction from a single control measure. This would reduce nitrate levels in the River by 37% at an estimated total capital cost of $35 million, or $4.5 million per year. As a comparison, if existing deep leachfields were replaced with shallow leachfields at the time of normal replacement, the capital cost would be $700,000, or $71,000 per year, and the estimated reduction in River nitrate would be 7%. The latter project is more cost-effective ($231 per pound of nitrogen saved versus $2926/lb-N) and more justifiable, particularly if it can provide the needed amount of nitrogen reduction.

A review of Table 8 reveals another aspect of cost-effectiveness: control of large single sources is generally much more cost-effective than control of numerous diffuse nonpoint sources. The estimated cost per pound of summer nitrate-nitrogen removed by improved treatment at Boulder Creek Country Club is $122 compared to $1556 for installation of intermittent sand filters for all septic systems in sandy soils. Similarly, manure management measures at stable areas are also quite cost-effective.

Several scenarios which compare the cost of implementing a package of nitrate reduction measures to the resulting changes in River nitrate levels are presented in Section 7.3.

7.2.2 Financing

Related to cost-effectiveness is the assessment of how the costs of implementation are paid, particularly in relation to availability of funds, ability of individuals to pay, and potential allocation of costs to beneficiaries of nitrate reduction. Typically, the costs of implementation should be borne by the person or entity that is responsible for the particular nitrogen source, in order to mitigate the impacts of their actions. This approach is well accepted with regard to any new development, although it can have ramifications such as increasing the cost of housing or precluding a particular project or activity.

Requiring the responsible party to pay the cost of nitrogen control becomes more complicated when the nitrogen source is a pre-existing, approved use. In these circumstances an argument can be made for providing assistance to the responsible party that may have unwittingly inherited a problem, particularly if they do not have the financial resources to deal with it. Assistance can come in the form of education, technical assistance, low cost loans, grants, or centralized action by an agency (such as a sewer project) with the cost being spread over a wider base. Ultimately, implementation of nitrogen control measures may be limited by issues of affordability and availability of public and private funds.

One method of financing might have the beneficiaries of nitrate reduction assist with the cost of nitrate control. If for example, there was a direct trade-off between nitrate source control and costs of water treatment or development of a replacement water source, and it was less expensive to reduce nitrate than increase treatment, it could be more cost-effective and expedient for water users to provide some financial assistance for implementation of nitrate control measures. However, many would argue that it is inappropriate for those impacted by a problem to pay for the solution instead of those causing the problem.

With the moderate level of nitrogen control recommended in this plan, direct financing by the responsible parties is probably the most appropriate method of financing. Efforts will also be made to provide broader assistance through low cost loans and development of more cost-effective technologies. If it is ultimately deemed that more expensive nitrogen removal is required, issues of broader financing will have to be further addressed.

7.2.3 Existing Agencies and Institutional Framework

Implementation of nitrogen control measures in the San Lorenzo Watershed will be conducted by a variety of agencies with responsibilities for regulation of wastewater disposal, land use regulation, management of water resources and wastewater, technical assistance, and financial assistance. There are also a variety of agencies that are affected by nitrate management. The existing institutional framework and the roles of the various agencies are presented in Table 9 and discussed below.

Agencies with responsibility for Regulation of Waste Discharge affect nitrogen management through establishment of water quality objectives in receiving waters, establishing standards for nitrogen removal from onsite wastewater disposal and community disposal systems, and establishing standards for large livestock operations. Waste disposal operations must receive permits that are in compliance with established regulations.

Agencies which actually operate Waste Disposal Facilities are responsible for obtaining the technology, establishing the financing, and actually implementing improved nitrogen removal for sewage treatment facilities ranging from the Boulder Creek Country Club to State Park facilities.

Land Use Regulations include zoning and general plan regulations that can limit the density and the type of land use activities that are allowed in areas such as groundwater recharge areas, riparian corridors or water supply watersheds. Individual projects are reviewed for compliance with regulations and goals of environmental protection, and specific conditions may be placed on projects to minimize nitrogen discharge and overall environmental impact. An example is the limitation of the number of horses that can be kept at a stable, and the manure management measures that would be required as conditions for approval of a use permit to operate a stable.

Management Agencies have a direct role in nitrogen control through their operation of wastewater disposal facilities, landfills, or water supply facilities. These agencies are responsible for obtaining the technology, establishing the financing, and actually implementing improved nitrogen removal for the facilities they operate or oversee.

Technical and Financial Assistance is needed to educate responsible parties regarding the need for nitrogen control and the best means to accomplish that objective. Because many of the methodologies are somewhat new and experimental, assistance to evaluate the effects of pilot projects is quite important. Ultimately financial assistance may be needed for implementation.

A number of <u>Affected Agencies</u> have a role in managing resources that are affected by nitrate management. These include the State Department of Fish and Game, State Parks, and the various water purveyors that utilize surface and groundwater in the Watershed. These agencies would have a role in reviewing and commenting on proposed measures for nitrate management and may also have an interest in assisting with implementation.

The existing and potential roles of specific agencies are also discussed in Section 8 as a part of the nitrate management plan.

TABLE 9: AGENCIES INVOLVED WITH NITRATE CONTROL IN THE SAN LORENZO WATERSHED

AGENCY	ROLE IN NITRATE CONTROL *						PROGRAM OR REGULATION
	WASTE REGUL.	LAND USE	MGT. ROLE	TECH. ASSIS.	FINAN. ASSIS.	AFFECTED AGENCY	
U.S. Environmental Protection Agency	X						Clean Water Act
				X			Sole-Source Aquifer Regulations
					X		Small Flows Clearinghouse
							Funding for Studies, Implementation
U.S. Soil Conservation/ Resource Cons. Dist.				X			Advice on land management, livestock management
State Water Resources Control Board	X						Porter Cologne Act
				X	X		Funding for Studies, Implementation
Regional Water Quality Control Board, Central Coast	X	X					Basin Plan
	X			X			Water Quality Objectives
	X						Waste Disposal Permits
					X		Funding Assistance for Investigations
State Parks			X			X	
State Fish and Game	X					X	Fish and Game Code
Santa Cruz County Environmental Health	X			X			Standards for New and Repaired Septic Systems
	X		X				San Lorenzo Wastewater Management Program
		X					Restrictions on Lot Size for Septic Systems
							Requirements for Manure Management
Santa Cruz County Public Works Department			X				Operator of CSA-7 and CSA-10 Sewage Disposal Plants
Santa Cruz County Planning Department		X					General Plan Policies, Zoning Regulations
		X					Environmental Review, Project Approval
San Lorenzo Valley Water District			X				Operator of Bear Creek Disposal Facility
			X			X	Water Pumping and Distribution
City of Santa Cruz Water Department			X			X	Surface Water Diversion
Scotts Valley, Lompico Water Districts, Other Purveyors			X			X	Water Pumping and Distribution
City of Scotts Valley			X				Wastewater Reclamation
		X					General Plan, Zoning, Project Approval

* The different types of roles are explained in the text.

7.3 Potential Management Scenarios

In order to evaluate the potential effect of implementing packages of nitrogen control measures, five different scenarios were developed to show the total cost of each package and to show the summer nitrate loads and nitrate concentrations in the River and representative tributaries that would result after implementation. Data for this analysis was taken from Table 4, Table 6, Table 8 and Appendix C. The results of the analysis are shown in Table 10. The scenarios address mean summer nitrate levels and use a ten year time period, assuming full implementation of upgrades in ten years. This assumption is useful for evaluating the full effect of a policy, but it is not expected that upgrades of all existing septic systems would take place that quickly.

The comparison of scenarios shows that the County has already made significant progress in developing policies that result in sharply reduced nitrate levels in the River. Current policies include the requirement for a minimum lot size of 1 acre for new development, a requirement for 10 acre minimum lot size for new lots created in groundwater recharge areas, and other policies to limit the impacts of new land uses in rural areas of the County. Under these current standards, nitrate levels would only be expected to increase by 5% in the main River over the next 10 years. If the current standards were removed and development rates and practices returned to conditions prior to 1978, nitrate levels would increase on the average by 50% over the next 10 years.

Three scenarios were developed to show the effect of different degrees of nitrogen reduction on dry summer nitrate levels:

- The moderate nitrogen reduction scenario includes:
    1) the requirement of shallow disposal systems for all new development and all existing septic systems;
    2) upgrade of the Boulder Creek Country Club (CSA-7) Treatment Plant to provide adequate effluent quality for golf course irrigation; and,
    3) the requirement of strict manure management for all new livestock operations and encouragement of management for existing operations.

- The higher nitrogen reduction scenario would include similar measures as the moderate scenario, with the additional requirement of:
    1) installation of enhanced treatment devices for all new and existing septic systems in sandy soils; and,
    2) the requirement that all existing and new livestock operations improve manure management.

- The very high nitrogen reduction scenario provides for:
    1) sewage collection and export of sewage from 10,000 parcels in the watershed;
    2) the requirement of shallow disposal for all remaining parcels;
    3) upgrade of the Boulder Creek Country Club (CSA-7) Treatment Plant to provide adequate effluent quality for golf course irrigation; and,
    4) the requirement that all existing and new livestock operations improve manure management.

TABLE 10: EFFECTIVENESS AND COST OF APPROACHES TO NITROGEN REDUCTION

Notes on next page STATION	PRESENT CONDITIONS SUMMER (July-Sept.)			EFFECT OF PROJECTED GROWTH OVER 10 YEARS					
				NEW DEVELOPMENT WITH WITH CURRENT STANDARDS (c)			NEW DEVELOPMENT WITH RELAXED STANDARDS (d)		
CONTRIBUTING SOURCES (a)	LOAD lb.-N	%	CONC. mg-N/l	CHANGE %	LOAD lb.-N	CONC. mg-N/l	CHANGE %	LOAD lb.-N	CONC. mg-N/l
River Above Boulder Creek	120		0.14	19%	143	0.17	47%	176	0.21
Non-Sandy Septic Systems (e)	92	77%		10%	101		40%	129	
Natural Sources	14	12%		0%	14		0%	14	
Stables	14	12%		100%	28		140%	34	
Boulder Cr.	540		0.94	0%	541	0.94	79%	968	1.69
Sewered Areas	414	77%		0%	414		100%	828	
Alluvial Septic Systems (e)	92	17%		5%	97		20%	110	
Natural Sources	30	6%		0%	30		0%	30	
River above Ben Lomond	520		0.22	18%	611	0.26	79%	932	0.39
Upstream Sources (f)	360	69%		23%	444		107%	744	
Alluvial Septic Systems (e)	140	27%		5%	147		20%	168	
Natural Sources	20	4%		0%	20		0%	20	
Zayante Creek above Bean Cr.	320		0.56	7%	342	0.60	53%	490	0.86
Sandy Septic Systems (e)	110	34%		4%	114		40%	154	
Livestock	90	28%		20%	108		140%	216	
Natural & Upstream Sources	120	38%		0%	120		0%	120	
River at Felton	3240		0.42	5%	3397	0.44	40%	4542	0.59
Sandy Septic Systems	1230	38%		4%	1279		40%	1722	
Sewered Areas	320	10%		0%	320		100%	640	
Natural Sources	520	16%		0%	520		0%	520	
Non-Sandy Septic Systems	620	19%		10%	682		30%	806	
Scotts Valley	290	9%		0%	290		0%	290	
Livestock	200	6%		20%	240		140%	480	
Landscaping	60	2%		10%	66		40%	84	

STATION	EFFECT OF NITROGEN CONTROL MEASURES											
	MODERATE REDUCTION (g)				HIGHER REDUCTION (i)				VERY HIGH REDUCTION (j)			
CONTRIBUTING SOURCES (a)	CHANGE % (h) NEW	OLD	LOAD lb.-N	CONC. mg-N/l	CHANGE % (h) NEW	OLD	LOAD lb.-N	CONC. mg-N/l	CHANGE % (h) NEW	OLD	LOAD lb.-N	CONC. mg-N/l
River Above Boulder Creek		-8%	110	0.13		-13%	105	0.12		-55%	54	0.06
Non-Sandy Septic Systems (e)	-20%	-20%	81		-20%	-20%	81		-20%	-75%	30	
Natural Sources	0%	0%	14		0%	0%	14		0%	0%	14	
Stables	-65%	-25%	15		-65%	-65%	10		-65%	-65%	10	
Boulder Creek		-72%	149	0.26		-72%	149	0.26		-84%	84	0.15
Sewered Areas	-90%	-90%	41		-90%	-90%	41		-90%	-90%	41	
Alluvial Septic Systems (e)	-20%	-20%	77		-20%	-20%	77		-20%	-90%	13	
Natural Sources	0%	0%	30		0%	0%	30		0%	0%	30	
River above Ben Lomond		-41%	306	0.13		-42%	302	0.13		-75%	130	0.05
Upstream Sources (f)		-53%	168			-54%	165			-75%	90	
Alluvial Septic Systems (e)	-20%	-20%	118		-20%	-20%	118		-20%	-90%	20	
Natural Sources	0%	0%	20		0%	0%	20		0%	0%	20	
Zayante Creek above Bean Cr.		-11%	285	0.50		-33%	215	0.38		-47%	169	0.30
Sandy Septic Systems (e)	-20%	-20%	92		-50%	-50%	57		-90%	-90%	11	
Livestock	-65%	-25%	74		-65%	-65%	38		-65%	-65%	38	
Natural Sources	0%	0%	120		0%	0%	120		0%	0%	120	
River at Felton		-18%	2641	0.34		-33%	2177	0.28		-62%	1232	0.16
Sandy Septic Systems (e)	-20%	-20%	1023		-50%	-50%	640		-90%	-90%	128	
Sewered Areas	-90%	-90%	32		-90%	-90%	32		-90%	-90%	32	
Natural Sources	0%	0%	520		0%	0%	520		0%	0%	520	
Non-Sandy Septic Systems	-20%	-20%	546		-20%	-20%	546		-20%	-90%	112	
Scotts Valley		0%	290			0%	290			0%	290	
Livestock	-65%	-25%	164		-65%	-65%	84		-65%	-65%	84	
Landscaping	10%		66		10%		66		10%		66	
COST (k)												
Capital	$ 6,914,000				$ 15,544,000				$ 152,934,000			
Annualized	$ 742,210				$ 2,026,000				$ 15,544,250			
Annual Cost per pound of nitrate-nitrogen reduced	$980				$1660				$ 7,180			

NOTES FOR TABLE 10

a. The breakdown of nitrate load from major contributing sources is based on the subbasin nitrate budgets and overall nitrate budget prepared as a part of this study.

b. Nitrate Loads and Concentrations are based on mean summer conditions, as observed and estimated for 1990-93; loads are for 3 month period of July through September. Load contributions are adjusted to reflect channel losses of nitrate. Big Trees nitrate concentration is the mean for 1976-1993.

c. Projections of loading after 10 years under current standards assume current development policies regarding density requirements for new development and current technical standards for septic system installation. Growth rates are estimated based on the actual rates of development in the San Lorenzo Valley for 1983-1990 (SCCPD, 1990):
- New Development in upland areas: 1 % / year.
- New Development in River corridor areas: 0.5 % / year.
- New Development in sandy (recharge) areas: 0.4 % / year.
- Increases in horses and other livestock in upland areas: 100% over 10 years.
- Increases in horses, livestock in sandy areas: 50% over 10 years
- No change in Scotts Valley nitrate discharge.
  - Discharge from landscaping increases at the same rate as development in sandy soils.

d. Relaxed Standards: Projects nitrate loads in 10 years if current policies which include provisions for nitrogen control are removed, as follows:
- Residential growth occurs at an annual rate of 4% throughout upland and sandy areas of the Watershed; this is the growth rate that prevailed in 1973-76, before many of the current controls were enacted. This rate assumes removal of: the restriction on developing parcels less than 1 acre, the 10 acre minimum for new lots in groundwater recharge areas, and the general restrictions on lot splits imposed by growth management policies.
- Growth occurs at a rate of 2% in the alluvial corridor areas, where growth is limited by the lack of undeveloped land.
- Sewage discharge at the Boulder Creek Country Club (CSA-7) doubles to fully utilize capacity of that plant, without installation of nitrogen control.
- Livestock increases by 140% in both sandy and upland areas, due to reduced oversight of potential impacts in groundwater recharge and water supply watershed areas.

e. The estimated mean summer River nitrate load originating from non-sandy septic systems is 0.06 pound nitrate-nitrogen per septic system. Systems located in more permeable alluvial or granitic soils can have a higher delivery rate, approximately 0.2 pound; systems located in sandy soils have an average delivery rate of 0.9 pounds (1.1 pounds before instream nitrate loss is factored in).

f. The contribution from upstream sources is estimated to be 65% of the upstream load, based on an estimated rate of instream nitrogen removal of 7% per mile (Balance Hydrologics, 1991).

g. Moderate nitrate reduction assumes that additional nitrogen control measures are implemented. Growth rates under the current standards scenario are assumed, and the nitrogen reductions are applied to the loads that are projected to result in 10 years under current standards. The following nitrogen control measures and their costs of implementation over a 10 year period are presented as an example in this scenario:
- Shallow disposal trenches to be required for all new and existing septic systems (20% nitrate reduction). Assumes there will be 1310 new systems.
  Capital Cost = $6,605,000 (13,210 units x $500 incremental installation cost); Annualized Cost = $673,710.
- Boulder Creek Country Club (CSA-7) Treatment Plant to be upgraded for wastewater reclamation (90% nitrate reduction).
  Capital Cost = $300,000; Annualized Cost = $46,000.
- New stable, livestock operations to be required to cover manure piles, provide runoff diversion, and regularly haul away manure (estimated 65% nitrate reduction); Existing livestock operations to be encouraged to improve practices through education (estimated 25% reduction).
  Capital Cost = $9000 (200 new livestock units + 100 existing livestock units improved; x $30 / unit); Annualized Cost = $22,500.

h. Different percentages of nitrate reduction for each source are shown for new development and old existing development, due to differential application of requirements for new installations vs. retrofits. The total cumulative percentage change in load at each point on the River is shown in the first row.

i. Higher nitrate reduction assumes that more stringent nitrogen control measures are implemented. Growth rates under current standards are assumed, and the nitrogen reductions are applied to the loads that are projected to result in 10 years under current standards. The following nitrogen control measures and their costs of implementation over a 10 year period are presented as an example in this scenario:

- Shallow disposal trenches to be required for all new and existing septic systems in non-sandy soils (20% nitrate reduction).
  Capital Cost = $5,875,000 (11,750 units x $500 incremental repair cost); Annualized Cost = $599,250.
- Enhanced onsite treatment using sand filters, or similar measures to provide at least 50% nitrogen reduction required for new and existing systems in sandy areas.
  Capital Cost = $9,360,000 (1560 units x $6000 / unit for sand filter); Annualized Cost = $1,343,160.
- Boulder Creek Country Club (CSA-7) Treatment Plant to be upgraded for wastewater reclamation (90% nitrate reduction).
  Capital Cost = $300,000; Annualized Cost = $46,000.
- New and existing stable, livestock operations to be required to cover manure piles, provide runoff diversion, and regularly haul away manure (estimated 65% nitrate reduction).
  Capital Cost = $9000 (500 livestock units x $30 / unit); Annualized Cost = $37,500.

j. Very high nitrate reduction assumes that very stringent nitrogen control measures are implemented. Growth rates under current standards are assumed, and the nitrogen reductions are applied to the loads that would normally result after 10 years under current standards. The following nitrogen control measures and their costs of implementation over a 10 year period are included in this scenario:

- A sewage collection system to be constructed to serve approximately 10,000 parcels in the sandy areas and densely developed alluvial corridors. Sewage would be collected and exported from the watershed, probably for treatment and ocean disposal.
  Capital Cost = $150,000,000 (10,000 units x est. $15,000); Annualized Cost = $15,200,000.
- Shallow disposal trenches to be required for all remaining septic systems and new systems in non-sandy soils (20% nitrate reduction).
  Capital Cost = $2,625,000 (5250 units x $500 incremental repair cost); Annualized Cost = $267,750.
- Boulder Creek Country Club (CSA-7) Treatment Plant to be upgraded for wastewater reclamation (90% nitrate reduction).
  Capital Cost = $300,000; Annualized Cost = $46,000.
- New and existing stable, livestock operations to be required to cover manure piles, provide runoff diversion, and regularly haul away manure (estimated 65% nitrate reduction).
  Capital Cost = $9000 (500 livestock units x $30 / unit); Annualized Cost = $30,500.

k. Costs are calculated from cost figures in Table 8, as described in the notes above for each scenario. The annual cost per pound of nitrate reduced below levels that would occur under current standards is also indicated.

The moderate reduction scenario would result in a 18% reduction in projected nitrate levels in the River, a 72% reduction in nitrate levels in Boulder Creek, and an 11% reduction in nitrate levels in Zayante Creek. The annualized cost for installation and operation of the measures spread over 10 years would be $742,210 per year. The higher reduction scenario would reduce nitrate levels in the River by 33%, in Boulder Creek by 72%, and in Zayante Creek by 33%; at an annualized cost of $2.026 million per year. The very high reduction scenario would reduce nitrate levels throughout the system by 50-80% at an annualized cost of $15.544 million per year. The moderate level of nitrogen reduction is more cost effective and has a cost of $980 per pound of nitrogen removed from the River. The higher reduction and very high reduction scenarios had costs of $1660 and $7180 per pound of nitrogen removal, respectively.

In order to arrive at recommendations for the most suitable management measures, the actions which made up the moderate and higher scenarios were further assessed. More realistic estimates of the timing of implementation were also utilized: nitrogen reduction measures for existing systems were projected to be implemented at the time of system repair or upgrade, which would extend over a 25 year period at the current rate of improvements. Thus, with the actions of the higher reduction scenario, after ten years, mean summer nitrate in the River would decline 22% (to 0.33 mg-N/L).

Potential management actions are each listed in Table 12, generally in order of increasing cost and decreasing cost-effectiveness. If more nitrogen reduction is required measures farther down the list will have to be implemented. Table 12 shows the recommended measures needed to achieve the level of nitrogen reduction discussed in the next section.

Table 11: Timing and Extent of Potential Nitrogen Reduction:

	% Reduction and Mean Nitrate Concentration in the River at Big Trees (mg-N/L) after:		
Scenario:	10 yrs	20 yrs	25 yrs
Moderate Nitrogen Reduction	16%	17%	18%
Including Use of Shallow Systems	0.35	0.35	0.34
Higher Nitrogen Reduction	21%	30%	34%
Including 50% Nitrogen Removal	0.33	0.29	0.28

TABLE 12: POTENTIAL ACTIONS FOR NITROGEN REDUCTION

Effects on Summer Nitrate Levels at Big Trees In the Next Ten Years

APPROACH	In Effect or Recom-mended	EFFECTS ON SUMMER NITRATE LEVELS				ANNUALIZED COST		
		% CHANGE FOR ACTION	CUMM. % CHANGE	MEAN NO3-N CONC. mg-N/L	MEAN NO3-N LOAD lbs-N	PER PARCEL/ UNIT	NUMBER PARCELS/ UNITS	COST PER LB-N REDUCED
BASELINE								
Current Conditions, Policies	Ongoing	-	-	0.42	3240	-	-	
10 Yrs Growth, Current Policies	Ongoing	5%	5%	0.44	3397	-	-	
10 Yrs Growth, Relaxed Policies		40%	40%	0.59	4542	-	-	
REDUCTIONS								
CSA 7 Upgrade to Reclamation	In Progress	-9%	-4%	0.40	3106	$182	250	$122
Improved Manure Management	Recom.	-4%	-8%	0.39	2976	$75	500	$250
ONSITE DISPOSAL IMPROVEMENTS								
Use of Shallower Leachfields *	Ongoing	-5%	-13%	0.36	2814	$51	3000	$231
- Repair Large Systems (80% N red.)*	Recom.	-2%	-15%	0.36	2749	$362	250	$283
Enhanced Treatment (50% N removal)								
- New Systems in Sandy Soils	Recom.	-1%	-15%	0.36	2744	$861	56	$1,566
- Major Remodels in Sandy Soils *	Recom.	-3%	-17%	0.35	2689	$861	175	$1,566
- Repairs in Sandy Soils *	Pend.	-6%	-21%	0.33	2566	$861	375	$1,566
- New Systems in Nonsandy Soils		-1%	-16%	0.35	2707	$861	1050	$22,963
- Major Remodels in Nonsandy Soils *		-2%	-18%	0.34	2655	$861	1310	$22,963
- Repairs in Nonsandy Soils *		-4%	-20%	0.34	2594	$861	2835	$22,963
ALTERNATIVE TREATMENT								
Higher Treatment (75% N removal)								
- New Systems in Sandy Soils		-1%	-14%	0.36	2772	$1,930	56	$2,506
- Major Remodels in Sandy Soils *		-4%	-18%	0.34	2641	$1,930	175	$2,506
- Repairs in Sandy Soils *		-9%	-27%	0.31	2360	$1,930	375	$2,506
- New Systems in Nonsandy Soils		-2%	-29%	0.30	2297	$1,930	1050	$30,000
- Major Remodels in Nonsandy Soils *		-2%	-32%	0.29	2218	$1,930	1310	$30,000
- Repairs in Nonsandy Soils *		-5%	-34%	0.28	2126	$1,930	2835	$30,000
Zeolite Filters for Sandy Soil Systems *		-15%	-23%	0.32	2496	$620	600	$662

NOTES

* For approaches marked with an asterisk, implementation will continue for an additional 25 years, resulting in total nitrate reductions of 250% of the amount indicated.

Projected rates of new development: 0.4% per year in sandy soils, 1% per year in nonsandy soils. Based on actual rates of development, 1983-1990 (SCCPD, 1990).

Projected rates of major remodel (addition of bedroom and/or more than 250 square feet): 1.2% per year. Projected rate is 2 times the observed rate during 1992-94, a time of greatly reduced building activity.

Projected rates of septic system repair are 2.7% per year, based on current repair rates.

Costs and estimates of nitrate reduction are taken from Table 8.

The cummulative percentage reduction takes into account that some measures are not necessarily additive. For example, if enhanced treatment or zeolite filters were used, this reduction would be provided instead of the shallow system reduction.

Zeolite Filters are still an unproven technology. Actual costs may be significantly higher.

8 NITROGEN MANAGEMENT PLAN

This study has produced information on the current levels of nitrate in the San Lorenzo Watershed, the impacts of elevated nitrate levels, the sources of that nitrate, and the cost and effectiveness of potential control measures. This information can now be used to recommend an objective for nitrogen control and identify the most appropriate measures to attain that objective.

8.1 Nitrogen Objective

Implementation of nitrogen control measures must be guided by an overall objective for protecting water quality and water quality dependent uses in the San Lorenzo Watershed. The primary objective must be to prevent any threats to such beneficial uses to the greatest extent feasible. Following is a discussion of the background for establishing a nitrogen objective, and the recommendation for an objective based on the findings of this study.

8.1.1 Background and Relevant Policies

The State Water Code provides for the establishment of water quality objectives which "are necessary for the reasonable protection of beneficial uses and for the prevention of nuisance" (Basin Plan). The State and Regional Boards are empowered to establish such objectives. They are also required to take into account technical and economic feasibility of attaining the objective when they establish it.

The Regional Board's Basin Plan originally set a blanket nitrogen objective of 1.0 mg-N/L for all surface waters in the Central Coast Region. In 1983, the Board began establishing specific objectives for each water body and adopted a nitrate objective for the San Lorenzo River of 0.25 mg/L as nitrate. (This is equivalent to 0.06 mg-N/L as nitrogen.) This objective was set to reflect nitrate measurements taken in the 1950's, and to promote a reduction of perceived impacts on beneficial uses. Santa Cruz County staff had cited instances of potential nuisance algae growth and early signs of possible eutrophication in some reaches of the River near Ben Lomond and Boulder Creek (Butler, 1978). In retrospect, those conditions were probably related to the extreme conditions of the 1975-77 drought, and have not been confirmed since that time.

Since 1986, County staff has expressed concern that the specific numeric objective is unrealistic and unattainable. In 1986, the Regional Board also directed their staff to reevaluate the nitrogen objective for the San Lorenzo River. Regional Board staff have been awaiting the completion of this study. Based on the current work, it is now apparent that the current objective could only be attained if all human influences were removed from the Watershed, or 100% mitigated.

In addition to the specific objective for the San Lorenzo River, the Basin Plan also contains the provision that waters shall not contain biostimulatory substances (including nitrate) in concentrations that promote excessive aquatic growth that would adversely affect beneficial uses.

There are two other State policies which have bearing on setting objectives for nitrogen reduction in the San Lorenzo Watershed:

- The "Anti-Degradation Policy" provides that waters of the State shall be maintained at the highest quality unless it is shown that changes will be consistent with maximum benefit to people of the state and will not unreasonably affect present and future beneficial uses. Regional Board staff has indicated that this policy would preclude allowing nitrate levels in the River to increase or allowing nitrate to continue at its current, elevated level.
- The "Sources of Drinking Water Policy" states that all surface water and ground water must be maintained suitable for municipal or domestic water supply unless the water source could not support a single well producing 200 gallons per day, or the water could not be economically treated for domestic use. Regional Board staff has indicated that perched groundwater in areas such as Boulder Creek should be considered to be drinking water, and that measures should be taken to reduce nitrate levels in those waters to meet drinking water standards. However, County staff does not believe that these waters could be tapped by a well meeting current standards for a 50 foot sanitary seal and 100 ft setback from septic systems.

In developing a new nitrate objective for the San Lorenzo Watershed, there are several approaches that could be taken:

1. Develop new numeric objectives which would be feasibly attainable, which would reflect the varying conditions and different nitrate levels in different parts of the Watershed, and which would also reflect the significant fluctuation in mean values from year to year. This would be a very complicated and problematic task.
2. Develop or expand on the existing narrative objective which calls for general protection of beneficial uses. This is probably too general and difficult to apply to specific projects.
3. Develop a performance based objective which establishes targets for nitrogen control or reduction and which includes specific management measures to achieve that target. This is the recommended approach.

8.1.2 Recommended Objective

The establishment of nitrogen control objective for the San Lorenzo Watershed should be based on the following overall goals:

1. Prevent any long-term increase in nitrate levels in water supply aquifers.
2. Reduce nitrate concentrations in water supply aquifers to less than 3 mg-N/L, if feasible, to provide an adequate cushion of safety.
3. Prevent any long term increase in nitrate load in the River or its tributaries. Require nitrogen control for new uses and reduce nitrogen discharge from existing uses in order to prevent any net increase.
4. Reduce current nitrate levels in the River and its tributaries enough to reduce impacts on recreation and water supply.
5. Obtain nitrogen reduction through economically feasible, cost-effective methods which represent a balance between cost and nitrogen reduction. Efforts must focus on the most significant sources of nitrogen, which can be controlled most cost-effectively.
6. Implement nitrogen reduction measures for existing sources over time, as other improvements are made, in order to keep the incremental cost of nitrogen control as low as possible. There is latitude for a gradual

reduction over time in that levels normally vary by almost 50% from year to year, as a result of changes in hydrologic conditions and other factors unrelated to the nitrate sources.

Two potential sets of nitrogen control measures have been considered, as indicated in Tables 10 and 11. The moderate reduction scenario, which includes the use of shallow leachfields, would be expected to accomplish most of the objectives listed above and would result in lowering nitrate levels in the River by about 18%. This would prevent any further impacts on beneficial uses, and would provide about a 20% reduction in groundwater nitrate levels, but would probably not be expected to eliminate current impacts or threats to beneficial uses of the River.

A higher level of nitrogen reduction should be considered, which would provide for a 50% reduction in all major nitrogen sources. This would reduce nitrate levels in the lower River by 30%, to approximately the levels which occurred in the 1970's, before the River had significant taste and odor problems. This would provide better protection for both surface and ground water supply. It would also be expected to reduce growth of microalgae in the River to some extent, providing benefits to recreation use by limiting sliminess of rocks and water murkiness during the summer.

Unfortunately, existing technology for reducing nitrogen discharge from individual septic systems is relatively costly, at $8000 (over $850 per year), and its performance for individual residences is inconsistent. County staff believes that the significant cost for retrofitting an existing septic system with nitrogen control is too great relative to the amount of benefit provided by the additional reduction of nitrate in the River. It is recommended that 50% nitrate reduction for individual systems be maintained as a goal, but that requirement of this measure be deferred until technology can be developed with greater cost-effectiveness, on the order of $500 per pound of summer nitrate reduced. This deferral is consistent with the requirement that the Regional Board consider cost and technology in developing water quality objectives.

<u>Recommended Objective:</u> Implement nitrogen control measures for existing and proposed uses in the San Lorenzo River Watershed to ultimately reduce mean nitrate levels to 30% below 1976-94 levels. Develop and implement cost-effective measures specified in the Nitrate Management Plan which will reduce nitrate delivery by at least 50% for all new and expanded uses in sandy soils and any other large sources of nitrate which release more than 200 pounds of nitrogen per year. Expand the requirement for 50% reduction to all existing septic systems in sandy soils when reduction measures become cost-effective.

The measures necessary to attain this objective are listed in Table 12 and specified in Section 8.2. They are summarized below:
- Require use of shallow disposal systems wherever possible for upgrade of existing systems throughout the watershed.
- Develop and require use of cost-effective nitrogen control measures that will provide at least 50% nitrogen reduction for all new septic systems and septic system upgrades in sandy soils.
- Improve wastewater treatment at Boulder Creek Country Club (CSA-7) for nitrogen removal or wastewater reclamation on the golf course.
- Require improved manure management practices at stables and other livestock

areas.

- Require improved treatment for at least 50% nitrogen removal during the upgrade of all large sewage disposal systems in the Watershed.

It is expected that full implementation of these recommendations will take place over a 25 year period, with the majority of the reduction to take place in the first ten years (see Table 11). By the end of the implementation period the following reductions in nitrate loading and resulting nitrate concentrations would be expected (ranges are shown for those locations affected by individual septic system in sandy areas to indicate the range between implementation of 20% reduction and 50% reduction for existing systems):

Upper River above Boulder Creek:	13% reduction;	0.12 mg-N/L
Boulder Creek:	72% reduction;	0.26 mg-N/L
River above Ben Lomond:	42% reduction;	0.13 mg-N/L
Lower Zayante Creek:	27-33% reduction;	0.44-0.38 mg-N/L
River at Felton:	18-34% reduction;	0.34-0.28 mg-N/L

Further reductions in summer nitrate in the lower River of up to 9% will occur if nitrate delivery from Scotts Valley diminishes, as expected.

8.2 Management Measures

The recommended nitrate management plan consists of a variety of specific actions organized under the headings of waste management, land use regulation, livestock management, and land use regulation. The plan includes both maintenance of existing, ongoing activities and recommendations for new efforts. For each management action, the following elements are described:

- Specific description of action and implementing mechanisms.
- Expected benefits including nitrate reduction and other benefits.
- Responsible agency and assisting entities.
- Timing for implementation.

8.2.1 Wastewater Disposal

1. Maintain the Requirement of One Acre Minimum Lot Size for New Development Served by Onsite Sewage Disposal - This requirement applies to any new development on existing lots of record in the San Lorenzo Watershed area (with a possible exception only for necessary community uses if impacts are mitigated).
   Benefits - Reduces cumulative impacts of wastewater disposal and new development. Provides for dilution of nitrate and limits total amount of loading possible. Prevents underlying groundwater from exceeding drinking water standards.
   Responsible Agencies - Santa Cruz County Environmental Health (Board of Supervisors).
   Timing - Ongoing since 1983.

2. Implement the San Lorenzo Wastewater Management Plan - This program provides for regular inspection of all onsite disposal systems in the watershed, upgrade of failing systems to meet current repair standards,

and improved maintenance and management of systems.
Benefits -Reduces impacts of wastewater disposal and provides mechanism for implementation of improved nitrate control practices during system repairs.
Responsible Agencies - Santa Cruz County Environmental Health (Board of Supervisors), assisted by the Regional Water Quality Control Board.
Financing - Current annual cost of $463,000 financed by County Service Area service charges on all affected properties (47%), County General Fund (20%), Repair Permit fees (17%), and grants (16%).
Timing - Ongoing since 1986.

3. Resume Wastewater Reclamation at Boulder Creek Country Club (CSA-7) - The County should complete its efforts to make treatment plant improvements to allow reclamation of wastewater on the golf course. This provides for removal of at least 90% of the nitrogen in the Country Club wastewater 8 months of the year.
   Benefits - Will greatly reduce summer nitrate levels in Boulder Creek and River north of Ben Lomond. Reclamation will reduce use of groundwater and surface water for irrigation.
   Responsible Agencies - Santa Cruz County Public Works Department (Board of Supervisors), with oversight by the Regional Water Quality Control Board and the State Department of Health Services.
   Financing - Projected capital cost of $300,000 to be paid by property owners connected to system.
   Timing - Efforts are underway in 1991; implementation expected in 1995.

4. Require Shallow Leachfields for New Development and System Repairs - In 1993 the County's septic ordinance was amended to limit maximum leachfield depth to 4 feet wherever site conditions will allow, particularly in sandy soils. Variances are allowed in non-sandy soils if site conditions are inadequate, but are only allowed in sandy soils if impacts are mitigated in other ways, such as through installation of a sand filter.
   Benefits - Expected nitrate reduction of 20%. Provides for improved wastewater treatment.
   Responsible Agencies - Santa Cruz County Environmental Health (Board of Supervisors).
   Timing - Ongoing implementation since March 1993.

5. Require Enhanced Nitrate Removal in Sandy Soils - The following measures should be taken by the County to provide for the use of enhanced nitrogen removal methods:
   a. Develop a requirement for enhanced treatment providing at least 50% nitrogen removal using sand filters, geomembranes, zeolite filters, or other nitrate removal measures for new and expanded systems in sandy soils (sand, loamy sand, and sandy loams).
   b. Encourage the use of nitrogen removal methods for any onsite disposal system which will use a nonstandard system. (Estimated 20 upgrades per year)
   c. Evaluate new onsite wastewater disposal technology for nitrogen removal to identify more cost-effective methods. Require measures that provide more than 50% reduction if those become more cost-effective.
   d. Seek State Revolving Funds or other funds to develop a funding source

to assist property owners repairing their systems to provide enhanced treatment.

e. When more cost-effective technology and/or funding assistance becomes available, require all onsite system repairs in sandy soils to utilize enhanced treatment for nitrogen removal (estimated 40 systems upgraded per year).

Benefits - Will reduce nitrate discharge from individual systems by 50-75% (30-55% more than shallow systems).
Responsible Agencies - Santa Cruz County Environmental Health (Board of Supervisors).
Timing - Amend ordinance to begin implementing requirements for new systems and upgrades in 1995; expanded implementation expected by 1997, if cost-effective.

6. Require Enhanced Treatment During Upgrade of Large Sewage Disposal Systems - Require all large sewage disposal systems which serve more than 5 residential units, dispose more than an average of 2000 gallons per day, or produce more than 100 pounds of nitrogen per year to utilize enhanced treatment to reduce nitrate discharge by 50% or more. This would be required at the time of system upgrade or repair. For discharges smaller than 4000 gpd this requirement could be waived by the County if site conditions were such that significant nitrate delivery to surface or groundwater was not expected.
Benefits - Will reduce nitrate discharge from large systems by 50-75%. Nitrogen removal is much more cost-effective for large systems. Treatment will also allow the discharger to significantly reduce the amount of disposal area needed.
Responsible Agencies - Santa Cruz County Environmental Health (Board of Supervisors).
Timing - Amend ordinance to begin implementing requirements for new systems and upgrades in 1995.

7. Require Nitrogen Control In the Issuance of New or Revised Waste Discharge Permits - The Regional Water Quality Control Board should limit the discharge of nitrogen consistent with the provisions of this nitrate management plan for waste discharge permits or orders that it revises or issues for discharges within the San Lorenzo Watershed. Such orders should include adequate monitoring requirements to confirm compliance with Plan targets.
Benefits - Will ensure compliance with this Plan by all large dischargers under jurisdiction of the Regional Board.
Responsible Agencies - Central Coast Regional Water Quality Control Board.
Timing - Implement requirements in April, 1995, upon adoption by the Regional Board of the San Lorenzo Wastewater Management Plan and the Nitrate Management Plan.

8.2.2 Livestock Management

8. Require Runoff Control, Manure Management and other Measures to Control Discharge of Nitrate and Fecal Matter for New and Existing Stables or Livestock Operations - The following measures should be implemented through operator education, use permit conditions, and through implementation of new ordinance requirements:

a. Maintenance of a separation of 50-100 feet between watercourses and livestock and manure stockpiles, unless other measures are taken to prevent contamination.
b. Stockpiling collected waste material on concrete, baserock, or other impermeable surfaces to prevent percolation.
c. Covering manure stockpile areas with tarps or roofs to prevent percolation and runoff of wastes.
d. Provision of roof gutters, ditches, and runoff control structures to keep rainfall and runoff away from paddock and manure stockpile areas, and prevent runoff of wastes to surface water.
e. Construction of grass-lined ditches and/or ponds as needed to contain and treat contaminated runoff.

Additional measures should also be considered:

f. Surfacing paddock areas with baserock or other low-permeabilitiy surfacing to reduce percolation of nitrate.
g. Regular placement of litter to absorb wastes, with regular removal of litter and wastes to a suitable stockpile area.
h. Roofing stable and paddock areas to reduce runoff and percolation.
i. Operation of programs for regular removal of stockpiled manure for composting, mushroom growing, fertilization, or other uses which will not contribute to nitrogen discharge.

Since 1992, County staff have worked with large stable owners to implement improved manure management and other measures for water quality protection. Considerable improvement has occurred with a significant investment of County staff time. However, additional problems remain (particularly with smaller operations) and County authority to require specific measures is unclear. An ordinance should be prepared with the participation of local livestock organizations which will incorporate the recommendations listed above under 8 and 9 for livestock management and water quality protection. In the meantime, County staff should continue efforts for education of livestock owners and enforcement of water quality protection through the Health and Safety Code.

Benefits - Reduces nitrate discharge by 70%. Reduces sedimentation and contamination by *Cryptosporidium* and other pathogens.
Responsible Agencies - Santa Cruz County Environmental Health, Planning Department, Zoning Administrator, Planning Commission, Board of Supervisors, City of Scotts Valley.
Timing - Ongoing implementation through education and permit review for new operations. Ordinance requirements to be developed in 1995, with adoption in 1996.

8.2.3 Land Use Regulation

9. Maintain Minimum Parcel Size Requirement and Other Protective Measures for Groundwater Recharge Areas. The County General Plan currently requires a ten acre minimum parcel size for any new lots created in designated groundwater recharge areas. Policies also prohibit approval of any new land use in recharge areas which could cause significant water quality degradation of the underlying aquifers.
Benefits - This reduces nitrate discharge from new development and provides protection of water supply aquifers, particularly where existing

development densities are so high that severe degradation would result if past development trends continued. Also promotes groundwater recharge, reduces land disturbance and erosion, and protects unique biotic resources.
Responsible Agencies - Planning Department, Planning Commission, Board of Supervisors, City of Scotts Valley.
Timing - Ongoing since 1978.

10. Maintain Measures to Prevent Excessive Land Clearing, Require Erosion Control, and Protect Riparian Corridors. - The County's erosion control ordinance restricts clearing of areas over 1 acre and requires mulching, revegetation and erosion control for all land disturbing projects. The County also requires protection of all areas within 50 feet of a perennial stream, within 30 feet of an intermittent stream or wetland, and within any riparian woodland.
Benefits - This reduces nitrate discharge from new development and clearing activities and protects the capability of riparian corridors to very significantly reduce nitrate in groundwater entering the streams. Undisturbed riparian corridors reduce nitrate discharge to streams by up to 90%. Also reduces land disturbance and erosion, and protects unique biotic resources.
Responsible Agencies - Planning Department, Planning Commission, Board of Supervisors.
Timing - Ongoing since 1980.

11. Review All New Large Development Applications to Ensure Substantial New Nitrate Discharges are Not Approved. - Environmental Review and discretionary review of new development proposals, particularly those located in sandy areas, should assess projected nitrate discharge from proposed projects and ensure incorporation of suitable mitigation measures to prevent any increase in nitrate discharge to groundwater or surface water of more than 10 pounds of nitrogen per acre per year from the project area.
Benefits - Prevents significant increase in nitrate discharge, and allows other proposed control measures to bring about an overall reduction in current nitrate loads.
Responsible Agencies - Planning Department, with consultation from Environmental Health, Zoning Administrator, Planning Commission, Board of Supervisors, City of Scotts Valley.
Timing - Ongoing.

8.2.4 Ongoing Monitoring

12. **Monitor Nitrate Plume Originating from Scotts Valley and Seek Additional Nitrate Control Measures if Necessary** - Monitor the occurrence of elevated nitrate levels in the Camp Evers area and determine if nitrate levels will continue to be elevated after the area has been sewered. If levels continue high, identify sources and work with the City and property owners to reduce nitrate discharge if feasible.
Benefits - Complete elimination of nitrate discharge from Scotts Valley would reduce nitrate levels in the River by 9%.
Responsible Agencies - County Environmental Health (monitoring) and City of Scotts Valley (if action is needed).
Timing - Ongoing monitoring, implementation of control measures in 2000,

if necessary and feasible.

13. Monitor Effectiveness of Nitrate Management Plan - Continue to monitor nitrate levels in surface and groundwater to measure the overall effectiveness of the Plan. Measure nitrogen discharge from specific control measures to determine the effectiveness of individual measures. Consider implementation of more stringent control measures if mean summer nitrate levels in the River at Felton have not declined by at least 15% by 2010.
    Benefits - Will measure success of programs and provide information to support more stringent controls if necessary.
    Responsible Agencies - County Environmental Health .
    Timing - Ongoing monitoring, reevaluation by 2010, if necessary.

REFERENCES

Aston, Robert, 1979, "Water Quality Technical Section", San Lorenzo River Watershed Management Plan, Santa Cruz County Planning Department.

Balance Hydrologics, Inc., July, 1991, A Nitrate Budget-Based Assessment of Potential Nonpoint-Source Control Measures to Reduce Nitrate Delivery to the San Lorenzo Watershed, Santa Cruz County, California, Prepared for Santa Cruz County Environmental Health Services.

Balance Hydrologics, Inc., August, 1994(a), A Comparative Study of Nitrate Movement Below a Deep and a Shallow Leachfield in Zayante Soils, Glen Arbor, Santa Cruz County, Prepared for Santa Cruz County Environmental Health Services.

Balance Hydrologics, Inc., August, 1994(b), San Lorenzo River Nitrogen Control Measure Project: Quail Hollow Ranch Regional Park Stables, Prepared for Santa Cruz County Environmental Health Services.

Butler, Terry, 1978, "An Assessment of Algal Growth and Eutrophication in the San Lorenzo River", Santa Cruz County Office of Watershed Management (Planning Department).

California Department of Water Resources, 1966, San Lorenzo River Watershed Water Quality Investigation.

Environmental Protection Agency, 1980, Design Manual, Onsite Wastewater Treatment and Disposal Systems.

Environmental Protection Agency, 1993, Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters.

Gilchrist, John and Associates, 1984, Focused Supplemental Environmental Impact Report, Proposed San Lorenzo Valley Class I Wastewater Treatment Facilities, Prepared for San Lorenzo Valley Water District.

Goldman, C.R., and A.J. Horne. 1983. Limnology. McGraw Hill, Inc., New York. 464 pp.

Harvey and Stanley Associates, 1984, "San Lorenzo Valleywide Wastewater Management Project: Fishery Impact Analysis and Mitigation Development".

Hynes, H. B. N., 1970, The Ecology of Running Waters, University of Toronto Press.

H. Esmaili and Associates (HEA), 1983, San Lorenzo Valley Onsite Wastewater Disposal Management Study.

H. Esmaili and Associates (HEA), 1978, Nonpoint Sources of Groundwater Pollution in Santa Cruz and Monterey Counties, California, for the Association of Monterey Bay Area Governments.

Jagger, Paul and Van Voris, Bert, 1981, "A Review of Water Quality Standards for the San Lorenzo and Salinas Rivers", Regional Water Quality Control Board, Central Coast Region.

Johnson, Nicholas M., 1988, Evaluation of Elevated Nitrate Concentrations in the Quail Hollow Well Field with the Use of a Groundwater Flow Model.

Laak, R., 1982, "A Passive Denitrification System for Onsite Systems", Proceedings of the Third National Symposium on Individual and Small Community Sewage Treatment, ASAE Pub 1-32.

Larry Walker Associates, 1984, San Lorenzo Valley Septic Management Project, for San Lorenzo Valley Water District.

Luhdorff and Scalmanini, 1986, Final Report - Scotts Valley Ground-Water Basin Nitrate Pollution Study, Submitted to the Association of Monterey Bay Area Governments.

Mendenhall, Ross, 1986, "Literature Review: Nitrogen Cycling in the San Lorenzo Valley", UCSC Senior Thesis.

National Small Flows Clearinghouse, 1991, "RUCK System: Denitrification Process for Onsite Sewage Disposal", Small Flows, April, 1991.

Oregon Department of Environmental Quality (ODEQ), 1982, Oregon On-Site Experimental Systems Program.

Questa Engineering Corporation and San Jose State University, June 30, 1991, San Lorenzo River Nitrate Biostimulation Assessment, Final Report, Prepared for Santa Cruz County Environmental Health Services.

Questa Engineering, Inc., 1991, Boulder Creek Wastewater Feasibility Study, for Santa Cruz County Environmental Health Service.

Ragone, S.E., Katz, B.G., Kimmel G.E., and Linder, J.B., 1981, "Nitrogen in Groundwater and Surface Water from Sewered and Unsewered Areas, Nassau County, Long Island, New York", USGS Water Resource Investigation.

Ramlit Associates, 1982, Assessment of Cumulative Impacts of Individual Waste Treatment and Disposal Systems, Berkeley, Ca.

Regional Water Quality Control Board, Central Coast Region (Regional Board), 1982, "Staff Report for Consideration of Amendments to the Water Quality Control Plan for the Central Coastal Basin - Concerning Water Quality Standards for the San Lorenzo River, Santa Cruz County".

Regional Water Quality Control Board, Central Coast Region #3 (Regional Board), 1994, Draft Report: Evaluation of Several Alternative Onsite Treatment Systems for the Removal of Nitrogen from Wastewater.

Reid, G.K., and R.D. Wood, 1976. Ecology of Inland Waters and Estuaries. Second Edition. Van Nostrand Co., New York. 485 pp.

Robertson, W.D., J.A. Cherry, and E.A. Sudicky, 1991, "Ground-Water Contamination from Two Small Septic Systems on Sand Aquifers", Ground Water, Vol. 29, No. 1.

Santa Cruz County Health Services Agency, 1989, Preliminary Report, An Evaluation of Wastewater Disposal and Water Quality in the San Lorenzo River Watershed.

Santa Cruz County Health Services Agency, 1991, "Quality Assurance Plan, Nitrogen Sampling in the San Lorenzo River Watershed 205(j)".

Santa Cruz County Health Services Agency, 1995, Wastewater Management Plan for the San Lorenzo River Watershed.

Santa Cruz County Planning Department, 1979, San Lorenzo River Watershed Management Plan.

Santa Cruz County Planning Department, 1984, "Staff Report on Surface Water Quality Monitoring Program in Santa Cruz County, 1976-1982".

Santa Cruz County Planning Department, 1986, Santa Cruz County Growth Management System, Growth Trends Report.

Santa Cruz County Planning Department, 1990, Preliminary Rural Resources Assessment.

Stewart, W.D.P. 1973. Nitrogen Fixation. In N.G. Carr and B.A. Whitton (Eds.). The Biology of Blue-Green Algae, Univ. Calif. Press. Berkeley. 260 pp.

Sylvester Marc, and Covay Ken, 1978, Stream Quality in the San Lorenzo River Basin, U.S. Geological Survey.

Technical Advisory Committee to the County of San Luis Obispo, August 10, 1994)Los Osos/Baywood Park Nitrogen Study.

Todd, David Keith, 1990, 1991, Scotts Valley Water Resources Management Plan, for the Scotts Valley Water District.

Toetz, D. 1973. The limnology of nitrogen in an Oklahoma reservoir: Nitrogenase activity and related limnological factors. The American Midland Naturalist. 89:379-380.

Vanderhoef, L.N., C.-Y Huang, R. Musil, and J. Williams. 1974. Nitrogen fixation (acetylene reduction) by phytoplankton in Green Bay, Lake Michigan, in relation to nutrient concentration. Limnol. Oceanogr. 19:119-125.

Whitton, B.A. 1970. Biology of *Cladophora* in freshwaters. Wat. Res. 4:457-476.

Williamson, Rhea L., Naresh Channaveerappa, and Leopoldo Sanchez, 1993, San Lorenzo River Nitrate Biostimulation Assessment Study Final Report, Prepared for Santa Cruz County Environmental Health, San Jose State University Department of Civil Engineering and Applied Mechanics.

Wong, S.L., B. Clark. M. Kirby, and R.F. Kosciuw. 1978. Water temperature fluctuations and seasonal periodicity of *Cladophora* and Potamogeton in shallow rivers. J. Fish. Res. Board Can. 35:866-870.

APPENDIX A: Summary of Water Quality Data, April, 1990 to September, 1993

See Section 5.1 for discussion of monitoring program and data analysis procedures.

SUMMARY OF SUMMER NITROGEN LEVELS BY STATION, 1990-1993

STATION NUMBER	LOCATION	DISCHARGE MEAN (CFS) /NUMBER /NITRATE-N LOAD (LB/DAY)	NITRATE-N MEAN(mgN/L) /NO. DETECTS /MAXIMUM /MINIMUM	KJELDAHL-N MEAN(mgN/L) NO. DETECTS /NO. NOT DETECT	AMMONIA-N MEAN(mgN/L) NO. DETECTS /NO. NOT DETECT
R1	R1	. 0 .	. 0 . .	. 0 0	. 0 0
Q5	Q5	3.63 2 0.00	1.76 9 2.19 1.20	. 0 0	. 0 0
O1	O1	1.06 5 0.00	.49 17 .70 .22	. 0 0	. 0 0
K3	K3	. 0 0.00	2.07 14 4.73 .29	. 0 0	. 0 0
GA3	GA3	. 0 .	. 0 . .	. 0 0	. 0 0
GA1	GA1	. 0 .	5.68 3 10.08 .85	. 0 0	. 0 0
F7	F7	. 0 .	7.09 2 8.93 5.25	. 0 0	. 0 0
F3	F3	. 0 .	3.38 2 6.40 .35	. 0 0	. 0 0
F2	F2	. 0 .	.07 2 .09 .05	. 0 0	. 0 0
CH1	CH1	. 0 .	. 0 . .	. 0 0	. 0 0

SUMMARY OF SUMMER NITROGEN LEVELS BY STATION, 1990-1993

STATION NUMBER	LOCATION	DISCHARGE MEAN (CFS) /NUMBER /NITRATE-N LOAD (LB/DAY)	NITRATE-N MEAN(mgN/L) /NO. DETECTS /MAXIMUM /MINIMUM	KJELDAHL-N MEAN(mgN/L) NO. DETECTS /NO. NOT DETECT	AMMONIA-N MEAN(mgN/L) NO. DETECTS /NO. NOT DETECT
BL4	BL4	. 0 .	1.33 1 1.33 1.33	. 0 0	. 0 0
BC6	BC6	. 0 .	7.69 12 22.60 .84	. 0 0	. 0 0
BC3	BC3	. 0 .	4.05 13 7.00 1.44	. 0 0	. 0 0
BC1	BC1	. 0 0.00	2.09 16 9.00 .29	1.92 2 0	.07 2 0
349	SLR @ Waterman Gap	.98 16 .77	.16 15 .52 .07	1.10 2 1	. 0 3
260	SLR ab Boulder Cr	1.31 3 1.33	.14 4 .20 .03	. 0 2	. 0 4
2590	Boulder Cr ab Country Club	.05 2 .01	.08 4 .19 .01	.50 1 1	. 0 4
2581	Boulder Cr ab Jamison Cr	.24 4 .21	.34 4 .91 .10	. 0 2	. 0 4
2580	Boulder Cr ab Bracken Brae	.54 4 4.32	1.38 4 2.75 .47	.60 1 1	. 0 3
251	Boulder Cr. @ Hy 9	1.18 15 5.99	.94 16 1.40 .12	.80 1 1	. 0 3

STATION NUMBER	LOCATION	DISCHARGE MEAN (CFS) /NUMBER /NITRATE-N LOAD (LB/DAY)	NITRATE-N MEAN(mgN/L) /NO. DETECTS /MAXIMUM /MINIMUM	KJELDAHL-N MEAN(mgN/L) NO. DETECTS /NO. NOT DETECT	AMMONIA-N MEAN(mgN/L) NO. DETECTS /NO. NOT DETECT
2499	SLR bl Boulder Cr.	2.51	.46	1.45	.20
		4	4	2	1
		6.17	.63	0	3
			.30		
245	SLR @ River St	2.69	.45	1.23	.10
		16	72	4	1
		6.14	.85	3	8
			.20		
180	SLR @ Ben Lomond	5.19	.22	1.10	.10
		16	19	3	1
		5.74	.40	4	8
			.03		
158	Newell Cr bl Dam	1.12	.17	.	.
		3	2	0	0
		.95	.17	0	3
			.17		
154	Newell Cr @ Rancho Rio	.82	.33	.60	.
		4	4	1	0
		1.37	.60	1	4
			.15		
150	Newell Cr @ SLR	1.09	.87	.70	.
		12	16	1	0
		5.64	1.55	1	4
			.50		
140	SLR @ Mt Cross	6.27	.58	.60	.
		12	16	1	0
		20.58	.89	1	3
			.05		
0749	Zayante Cr bl Lompico Cr	.61	.49	.	.20
		4	4	0	1
		1.46	.90	2	3
			.27		
073S	McEnery Rd Spring	.13	1.85	1.43	.
		11	13	4	0
		1.25	2.70	0	4
			.19		
07142	Bean Cr ab Green Valley	.17	.50	.50	.
		5	5	1	0
		.48	.70	1	2
			.12		

```
                                         DISCHARGE     NITRATE-N
                                         MEAN (CFS)    MEAN(mgN/L)     KJELDAHL-N       AMMONIA-N
                                          /NUMBER      /NO. DETECTS    MEAN(mgN/L)      MEAN(mgN/L)
STATION                                  /NITRATE-N     /MAXIMUM       NO. DETECTS      NO. DETECTS
NUMBER    LOCATION                       LOAD (LB/DAY)  /MINIMUM      /NO. NOT DETECT  /NO. NOT DETECT
_______   ___________________________   ___________    __________     ____________     ____________


07109     Bean Cr bl LockhartG                  .78           .59           2.80               .
                                                  5             9              1               0
                                               2.64           .80              1               4
                                                              .39

071083P   Dufour Spring                         .20          1.83              .               .
                                                 12            12              0               0
                                               2.01          2.36              0               0
                                                             1.20

07106     Bean Cr @ Mt.Hermon Rd               1.97           .57              .               .
                                                 13            13              0               0
                                               6.23           .87              2               3
                                                              .38

071       Bean Cr @ Zayante Cr                 2.90           .65              .               .
                                                  4             4              0               0
                                               9.34           .87              2               4
                                                              .40

070       Zayante Cr @ SLR                     4.11           .58            .77             .15
                                                 18            20              3               2
                                              12.94           .97              4               7
                                                              .35

060       SLR @ Big Trees                     14.08           .48           2.20             .10
                                                 84            78              4               1
                                              36.71           .90              4               9
                                                              .20

022       SLR @ Sycamore Grove                13.55           .33            .79             .10
                                                 16            33              4               1
                                              18.52           .75              3               7
                                                              .09
REPORT problem required an additional 1960 bytes of memory.
```

APPENDIX B: Watershed Nitrate Budget

Prepared by Balance Hydrologics, Inc., in: A Nitrate Budget-Based Assessment of Potential Nonpoint-Source Control Measures to Reduce Nitrate Delivery to the San Lorenzo Watershed, Santa Cruz County, California, Prepared for Santa Cruz County Environmental Health Services, July, 1991.

Table 6. Estimated summer nitrate budget for the central San Lorenzo River (1)

Code	Watershed and Station	Drainage Area (sq. mi.)	Estimated Mean Annual Discharge	Estimated Percent, Summer Discharge (2)	Summer Discharge (ac. ft.)	Mean Nitrate Concentration (mg/l NO3-N)(3)	Nitrate Discharge (tons, NO3-N)
349	San Lorenzo River above Waterman Switch	6.17	4416	12	530	0.12	0.09
310	Kings Creek at gaging station	7.56	6078	10	608	0.27	0.22
271	Bear Creek above Boulder Creek	16	14688	14	2056	0.12	0.34
251	Boulder Creek	11.3	12385	14	1734	0.55	1.3
	Surface runoff, other areas above River Street	9.9	10395	12	1247	0.2	0.34
					Subtotal:		2.29
	Assumed alluvial recharge and other (4)						0.56 (4)
	Assumed channel losses, 1.5 miles (10%)						-0.26(5)
245	San Lorenzo River at River Street	51	48000	12	5760	0.33	2.59
	Tributaries: River Street to Ben Lomond	6	6540	12	785	0.15	0.16
					Subtotal:		2.75
	Assumed alluvial recharge and other						-0.01
	Assumed channel losses (5), 4 miles (25%)						-0.59

180	San Lorenzo River at Ben Lomond	56.9	54600	12	6552	0.23	2.05
171	Love Creek	3	2400	10	240	0.2	0.07
150	Newell Creek at San Lorenzo River		3353		571 (6)	0.75	0.58
	Tributaries: Ben Lomond to Brackney	4.0 (7)	2914	12	350	0.2	0.1
	Ground water inflow to San Lorenzo River		550 (8)	40	220	3.2	0.96
					Subtotal:		3.76
	Assumed alluvial recharge and other (4)						2.08
	Assumed channel losses, 2.3 miles (15%)						-0.86
140	San Lorenzo River at Brackney	74	63267		7933	0.46	4.97
110	Fall Creek	4.3	4707	20.9	984	0.13	0.17
70	Zayante Creek at San Lorenzo River	26.3	23756		3084	0.63	2.64
	Tributaries: Brackney to Big Trees	1.5	1635	12	196	0.15	0.04
					Subtotal:		7.82
	Assumed alluvial recharge and other (4)						-0.30 (4)
	Assumed channel loss, 2.7 miles (18%)						-1.41
60	San Lorenzo River at Big Trees	106	93365	11.2	10457	0.43	6.11

1) Based on data or computations in Johnson 1983, 1984; Aston and Ricker, 1979; Ricker, 1979; Ricker, 1991.
2) Estimated percentage of mean annual runoff that occurs from May 1 through Oct. 31. Determined based on monthly discharges reported in prior work (see above). For other basins, estimated from nearby, similar watersheds analyzed in previous work.
3) Average of all samples in database for summers 1985-90. Some stations include limited data for 1975-85.
4) Difference between computed sum of inflows and observed outflow.
5) Losses to uptake or denitrification estimated as approximately 7% per mile of channel (see text); losses from multiple inflows are weighed by nitrate loadings and distance along channel.
6) Sum of release from reservoir and estimated ground water inflow. See separate budget below.
7) Tributary area between the Ben Lomond and Brackney stations is estimated as 8.1 square miles, of which 3.0 sq. mi. is the Love Creek watershed, 4.0 sq. mi. are other watersheds, and an estimated 1.1 sq. mi. in the Hihn Rd. area is considered to contribute minimal surface runoff during summer.
8) Based on Johnson (1988)
9) Based on Johnson's (1989) seasonal partitioning of aquifer outflows to Bean Creek and Zayante Creek.
10) See Table 2.

Table 7. Estimated summer nitrate budget for Zayante Creek

Code	Watershed and Station	Drainage Area (sq. mi.)	Estimated Mean Annual Discharge	Estimated Percent, Summer Discharge (2)	Summer Discharge (ac. ft.)	Mean Nitrate Concentration (mg/l NO3-N)(3)	Nitrate Discharge (tons, NO3-N)
726	Zayante Creek at Zayante	11.1	8059	7.5	604	0.26	0.21
7528	Lompico above Zayante Creek	2.8	2033	7.5	152	0.21	0.04
7109	Bean at Mt. Hermon	9.0	7020	7.5	527	9.71	0.51
	Other areas above mouth	3.4	2519	7.5	189	0.25	0.06
	Ground water inflow to Bean Creek		2637	40	1017	1.2	1.66
	Ground water inflow to Zayante Creek		1488	40	595	1.2	0.97
					Subtotal:		3.45
	Assumed alluvial recharge and other (4)						-0.21
	Assumed channel losses (5)		1.5 miles (10%)				-0.35
70	Zayante Creek at San Lorenzo River		23756		3084	0.69	2.9

1) Based on data or computations in Johnson 1983, 1984; Aston and Ricker, 1979; Ricker, 1979; Ricker, 1991.
2) Estimated percentage of mean annual runoff that occurs from May 1 through Oct. 31. Determined based on monthly discharges reported in prior work (see above). For other basins, estimated from nearby, similar watersheds analyzed in previous work.
3) Average of all samples in database for summers 1985-90. Some stations include limited data for 1975-85.
4) Difference between computed sum of inflows and observed outflow.
5) Losses to uptake or denitrification estimated as approximately 7% per mile of channel (see text); losses from multiple flows are weighed by nitrate loadings and distance along channel.

Table 8. Estimated summer nitrate budget for lower Newell Creek

Code	Watershed and Station	Drainage Area (sq. mi.)	Estimated Mean Annual Discharge	Estimated Percent, Summer Discharge (2)	Summer Discharge (ac. ft.)	Mean Nitrate Concentration (mg/l NO3-N)(3)	Nitrate Discharge (tons, NO3-N)
	Releases from Loch Lomond (6)	8.9			303	0.4	0.16
	Ground water inflow to Newell Creek		670	40	268	1.6	0.58
					Subtotal:		0.74
	Assumed alluvial contribution (4)						0.06
	Assumed channel losses (5), 1mile (7%)						-0.05
150	Newell Creek at San Lorenzo River						0.75

1) Based on data or computations in Johnson 1983, 1984; Aston and Ricker, 1979; Ricker, 1979; Ricker, 1991.
2) Estimated percentage of mean annual runoff that occurs from May 1 through Oct. 31. Determined based on monthly discharges reported in prior work (see above). For other basins, estimated from nearby, similar watersheds analyzed in previous work.
3) Average of all samples in database for summers 1985-90. Some stations include limited data for 1975-85.
4) Difference between computed sum of inflows and observed outflow.
5) Losses to uptake or denitrification estimated as approximately 7% per mile of channel (see text); losses from multiple flows are weighed by nitrate loadings and distance along channel.
6) Assumed 1 cfs summer releases from Loch Lomond.

APPENDIX C: Sub-Basin Nitrogen Budgets

See Section 5.4 for explanation of methodology for preparing the budgets.

NITROGEN SOURCES BOULDER CREEK BASIN

SUMMARY

ELEMENT	UNITS	ANNUAL LBS/YR RELEASE	%	% PERC.	ANNUAL LOAD TO GW	%	SUMMER % DELIVERY TO STREAM		SUMMER LOAD TO STREAM	%	OVERALL SUMMER DELIVERY
SEPTIC SYSTEMS	380	9075	24%	0.75	6806	50%	25%	5%	85	16%	3.8%
SEWERED AREA	300	4606	12%	0.90	4145	31%	25%	40%	414	78%	36.0%
HIGH LANDSCAPE	300	806	2%	0.20	161	1%	25%	5%	2	0%	1.0%
MOD. LANDSCAPE	0	0	0%								
LIVESTOCK	0	0	0%								
NATURAL VEG	5675	23835	62%	0.10	2384	18%	25%	5%	30	6%	0.5%
TOTAL		38322 lb/yr		0.35	13496 lb/yr			16%	531 lb		5.5%
AVERAGE DAILY (LB/DY)					37.0				5.9 lb/day		

AVG GW CONC. (ANNUAL LOAD / RECHARGE)	1.2 MG/L
CALC STREAM CONC: AVG LOAD / OBS. FLOW	1.1 MG/L

OBSERVED CONDITIONS - SUMMERS, 1990-93	
GROUNDWATER CONCENTRATION	? MG/L
STREAM NITRATE-N CONCENTRATION	0.9 MG/L
STREAM FLOW (CFS)	1.0 CFS
STREAM LOAD (LB/DAY)	6.0 LB/DAY

SOURCES:

LANDSCAPING	LB/UNIT/YR	UNITS	TOTAL LOAD
SIGNIFICANT	2.68	300	806.4 LB/YR
MODERATE	0.52	0	0

LIVESTOCK	LOAD/YR/ANIMAL LB-N/YR/HD	ANIMALS	% ONSITE DISPOSAL	TOTAL LOAD LB-N/YR
STABLE	108	0	1	0
RANCHETTE	108	0	1	0
TOTAL		0		0

SEPTIC SYSTEMS (2.8 PERSONS/HOUSEHOLD)

LOAD/HOUSE/YR	UNITS	TOTAL LOAD
23.88	380	9075 LB/YR

SEWERED AREA (1.8 PERSONS/HOUSEHOLD)

LOAD/HOUSE/YR	UNITS	TOTAL LOAD
15.35184	300	4606 LB/YR

NATURAL VEGETATION

LOAD(LB/AC/YR)	AREA(ACRES)	TOTAL LOAD
4.2	5675	23835 LB/YR

RECHARGE

RAINFALL (IN.)	% RECHARGE	RECHG(IN)	AREA	RECHARGE AF/YR
55	20%	11	5675	5202

20% FOR FOREST AREAS; 24 INCHES FOR SANTA MARGARITA

11-Jan-95

NITROGEN SOURCES

LOWER NEWELL

ADJUSTED FOR GROUNDWATER EXPORT

SUMMARY

ELEMENT	UNITS	ANNUAL LBS/YR RELEASE	%	% PERC.	ANNUAL LOAD TO GW	%	AFTER EXPORT	SUMMER %DELIVERY TO STREAM		SUMMER LOAD TO STREAM	%	OVERALL SUMMER DELIVERY
SEPTIC SYSTEMS	245	5851	58%	0.80	4681	74%	83%	25%	32%	311	74%	21.3%
HIGH LANDSCAPE	96	285	3%	0.40	114	2%	83%	25%	32%	8	2%	10.6%
MOD. LANDSCAPE	52	27	0%	0.40	11	0%	83%	25%	32%	1	0%	10.6%
LIVESTOCK	0	0	0%	0.50	0	0%	83%	25%	32%	0	0%	0.0%
NATURAL VEG	930	3906	39%	0.40	1562	25%	83%	25%	32%	104	25%	10.6%
TOTAL		10069	lb/yr	0.63	6368	lb/yr			32%	423	lb	16.8%
AVERAGE DAILY (LB/DY)					17.4		14.5			4.7	lb/dy	
AVG GW CONC. (ANNUAL LOAD / RECHARGE)					1.4MG/L							
CALC STREAM CONC: AVG LOAD / OBS. FLOW					0.8MG/L							

OBSERVED CONDITIONS - SUMMERS, 1990-93		ABOVE BASIN	BELOW BASIN	GW EXPORT
GROUNDWATER CONCENTRATION - NATURAL	0.5MG/L			
GROUNDWATER CONCENTRATION - DEVELOPED	1.8MG/L			
STREAM NITRATE-N CONCENTRATION	0.9MG/L	0.2	0.9	1.1
STREAM FLOW (CFS)	1.1CFS	1.0	1.1	0.5
STREAM LOAD (LB NO3-N/DAY)	4.6LB/DY	1.0	5.6	3.0

SOURCES:

LANDSCAPING	LB/UNIT/YR	UNITS	TOTAL LOAD
SIGNIFICANT	2.6	96	258.04LB/YR
MODERATE	0.5	52	27.456
SCHOOL			26.7

LIVESTOCK	LOAD/YR/ANIMAL LB-N/YR/HD	ANIMALS	% ONSITE DISPOSAL	TOTAL LOAD LB-N/YR
STABLE	108	0	1	0
RANCHETTE	108	0	1	0
TOTAL		0		0

SEPTIC SYSTEMS (2.8 PERSONS/HOUSEHOLD)

LOAD/HOUSE/YR	UNITS	TOTAL LOAD
23.88	245	5851LB/YR

NATURAL VEGETATION

LOAD(LB/AC/YR)	AREA(ACRES)	TOTAL LOAD
4.2	930	3906LB/YR

RECHARGE

RAINFALL (IN.)	% RECHARGE	RECHG(IN)	AREA	RECHARGE AF/YR
45	53%	24	1085	2170

20% FOR FOREST AREAS; 24 INCHES FOR SANTA MARGARITA

12-Jan-95

NITROGEN SOURCES GLEN ARBOR

SUMMARY

ELEMENT	UNITS	ANNUAL LBS/YR RELEASE	%	% PERC.	ANNUAL LOAD TO GW	%	SUMMER % DELIVERY TO STREAM		SUMMER LOAD TO STREAM	%	OVERALL SUMMER DELIVERY
SEPTIC SYSTEMS	454	10842	82%	0.80	8673	89%	25%	32%	694	89%	25.6%
HIGH LANDSCAPE	159	427	3%	0.40	171	2%	25%	32%	14	2%	12.8%
MOD. LANDSCAPE	194	102	1%	0.40	41	0%	25%	32%	3	0%	12.8%
LIVESTOCK	12	1296	10%	0.50	648	7%	25%	32%	52	7%	16.0%
NATURAL VEG	143	601	5%	0.40	240	2%	25%	32%	19	2%	12.8%
TOTAL		13268	lb/yr	0.74	9774	lb/yr		32%	782	lb.	23.6%
AVERAGE DAILY (LB/DY)					26.8	lb/dy			8.7	lb/dy	

AVG GW CONC. (ANNUAL LOAD / RECHARGE)	9.5MG/L
CALC STREAM CONC: AVG LOAD / OBS. FLOW	0.7MG/L

OBSERVED CONDITIONS - SUMMERS 1990-93		ABOVE BASIN	BELOW BASIN
GROUNDWATER CONCENTRATION - NATURAL	0.3MG/L		
GROUNDWATER CONCENTRATION - DEVELOPED	5.7MG/L		
STREAM NITRATE-N CONCENTRATION	0.7MG/L		
STREAM FLOW (CFS)	2.3CFS	6.2	8.5
STREAM LOAD (LB NO3-N/DAY)	9.2LB/DY	11.4	20.6

SOURCES:

LANDSCAPING	LB/UNIT/YR	UNITS	TOTAL LOAD
SIGNIFICANT	2.6	159	427.39LB/YR
MODERATE	0.5	194	102.43

LIVESTOCK	LOAD/YR/ANIMAL LB-N/YR/HD	ANIMALS	% ONSITE DISPOSAL	TOTAL LOAD LB-N/YR
STABLE	108	0	1	0
RANCHETTE	108	12	1	1296
TOTAL		12		1296

SEPTIC SYSTEMS (2.8 PERSONS/HOUSEHOLD)

LOAD/HOUSE/YR	UNITS	TOTAL LOAD
23.88	454	10842LB/YR

NATURAL VEGETATION

LOAD(LB/AC/YR)	AREA(ACRES)	TOTAL LOAD
4.2	143	601 LB/YR

RECHARGE

RAINFALL (IN.)	% RECHARGE	RECHG(IN)	AREA	RECHARGE AF/YR
45	53%	24	236	472

20% FOR FOREST AREAS; 24 INCHES FOR SANTA MARGARITA

12-Jan-95

NITROGEN SOURCES GLEN ARBOR 1986

SUMMARY

ELEMENT	UNITS	ANNUAL LBS/YR RELEASE	%	% PERC.	ANNUAL LOAD TO GW	%	SUMMER % DELIVERY TO STREAM		SUMMER LOAD TO STREAM	%	OVERALL SUMMER DELIVERY
SEPTIC SYSTEMS	454	10842	77%	0.85	9216	88%	25%	42%	968	88%	35.7%
HIGH LANDSCAPE	159	427	3%	0.40	171	2%	25%	42%	18	2%	16.8%
MOD. LANDSCAPE	194	102	1%	0.40	41	0%	25%	42%	4	0%	16.8%
LIVESTOCK	12	2100	15%	0.40	840	8%	25%	42%	88	8%	16.8%
NATURAL VEG	143	601	4%	0.40	240	2%	25%	42%	25	2%	16.8%
TOTAL		14072	lb/yr	0.75	10508	lb/yr		42%	1103	lb	31.4%
AVERAGE DAILY (LB/DY)					28.8				12.3	lb/dy	
AVG GW CONC. (ANNUAL LOAD / RECHARGE)					5.1	MG/L					
CALC STREAM CONC: AVG LOAD / OBS. FLOW						MG/L					

OBSERVED CONDITIONS - SUMMER 1986			ABOVE BASIN	BELOW BASIN
GROUNDWATER CONCENTRATION - NATURAL	0.3	MG/L		
GROUNDWATER CONCENTRATION - DEVELOPED		MG/L		
STREAM NITRATE-N CONCENTRATION		MG/L		
STREAM FLOW (CFS)		CFS		
STREAM LOAD (LB NO3-N/DAY)	12.7	LB/DY	35.9	48.6

SOURCES:

LANDSCAPING	LB/UNIT/YR	UNITS	TOTAL LOAD	
SIGNIFICANT	2.6	159	427.39	LB/YR
MODERATE	0.5	194	102.43	

LIVESTOCK	LOAD/YR/ANIMAL LB-N/YR/HD	ANIMALS	% ONSITE DISPOSAL	TOTAL LOAD LB-N/YR
STABLE	175	0	0.75	0
RANCHETTE	175	12	1	2100
TOTAL		12		2100

SEPTIC SYSTEMS (2.8 PERSONS/HOUSEHOLD)	LOAD/HOUSE/YR	UNITS	TOTAL LOAD	
	23.88	454	10842	LB/YR

NATURAL VEGETATION	LOAD(LB/AC/YR)	AREA(ACRES)	TOTAL LOAD	
	4.2	143	601	LB/YR

RECHARGE RAINFALL (IN.)	% RECHARGE	RECHG(IN)	AREA	RECHARGE AF/YR
45	107%	48	236	944
	20% FOR FOREST AREAS;		24 INCHES FOR SANTA MARGARITA	

12-Jan-95

NITROGEN SOURCES LOWER ZAYANTE

ADJUSTED FOR GROUNDWATER EXPORT

SUMMARY

ELEMENT	UNITS	ANNUAL LBS/YR RELEASE	%	% PERC.	ANNUAL LOAD TO GW	%	AFTER EXPORT	SUMMER % DELIVERY TO STREAM		SUMMER LOAD TO STREAM	%	OVERALL SUMMER DELIVERY
SEPTIC SYSTEMS	380	9075	33%	0.75	6806	48%	92%	25%	6%	94	48%	4.1%
HIGH LANDSCAPE	123	331	1%	0.25	83	1%	92%	25%	6%	1	1%	1.4%
MOD. LANDSCAPE	99	52	0%	0.25	13	0%	92%	25%	6%	0	0%	1.4%
LIVESTOCK	120	12960	47%	0.45	5832	41%	92%	25%	6%	80	41%	2.5%
NATURAL VEG	1274	5351	19%	0.25	1338	10%	92%	25%	6%	18	10%	1.4%
TOTAL		27768	lb/yr	0.51	14071	lb/yr			6%	194	lb	2.8%
AVERAGE DAILY (LB/DY)					38.6		35.5			2.2	lb/dy	

AVG GW CONC. (ANNUAL LOAD / RECHARGE)	2.0MG/L
CALC STREAM CONC: AVG LOAD / OBS. FLOW	0.7MG/L

OBSERVED CONDITIONS - SUMMERS, 1990-93		ABOVE BASIN	BELOW BASIN	GW EXPORT
GROUNDWATER CONCENTRATION - NATURAL	0.5MG/L			
GROUNDWATER CONCENTRATION - DEVELOPED	3.0MG/L			
STREAM NITRATE-N CONCENTRATION	0.6MG/L	0.5	0.6	0.5
STREAM FLOW (CFS)	0.6CFS	0.6	1.2	1.2
STREAM LOAD (LB NO3-N/DAY)	2.1LB/DY	1.5	3.6	3.1

SOURCES:

LANDSCAPING	LB/UNIT/YR	UNITS	TOTAL LOAD
SIGNIFICANT	2.6	123	330.624LB/YR
MODERATE	0.5	99	52.272

LIVESTOCK	LOAD/YR/ANIMAL LB-N/YR/HD	ANIMALS	% ONSITE DISPOSAL	TOTAL LOAD LB-N/YR
STABLE	108	70	1	7560
RANCHETTE	108	50	1	5400
TOTAL		120		12960

SEPTIC SYSTEMS	(2.8 PERSONS/HOUSEHOLD)		
	LOAD/HOUSE/YR	UNITS	TOTAL LOAD
	23.88	380	9075LB/YR

SEWERED AREA	(1.8 PERSONS/HOUSEHOLD)		
	LOAD/HOUSE/YR	UNITS	TOTAL LOAD
	15.35184	0	0LB/YR

NATURAL VEGETATION			
	LOAD(LB/AC/YR)	AREA(ACRES)	TOTAL LOAD
	4.2	1274	5351LB/YR

RECHARGE				
RAINFALL (IN.)	% RECHARGE	RECHG(IN)	AREA	RECHARGE AF/YR
45	53%	24	1621	3242
	20% FOR FOREST AREAS;		24 INCHES FOR SANTA MARGARITA	

09-Jan-95

NITROGEN SOURCES MCENERY SPRING

SUMMARY

ELEMENT	UNITS	ANNUAL LBS/YR RELEASE	%	% PERC.	ANNUAL LOAD TO GW	%	SUMMER % DELIVERY TO STREAM		SUMMER LOAD TO STREAM	%	OVERALL SUMMER DELIVERY
SEPTIC SYSTEMS	46	1099	51%	0.80	879	66%	25%	40%	88	66%	32.0%
HIGH LANDSCAPE	15	40	2%	0.40	16	1%	25%	40%	2	1%	16.0%
MOD. LANDSCAPE	10	5	0%	0.40	2	0%	25%	40%	0	0%	16.0%
LIVESTOCK	2	350	16%	0.50	175	13%	25%	40%	18	13%	20.0%
NATURAL VEG	160	672	31%	0.40	269	20%	25%	40%	27	20%	16.0%
TOTAL		2166	lb/yr	0.62	1341	lb/yr		40%	134	lb	24.8%
AVERAGE DAILY (LB/DY)					3.7	lb/dy			1.5	lb/dy	
AVG GW CONC. (ANNUAL LOAD / RECHARGE)					1.9MG/L						
CALC STREAM CONC: AVG LOAD / OBS. FLOW					1.8MG/L						

OBSERVED CONDITIONS - SUMMERS 1990-93	
GROUNDWATER CONCENTRATION - NATURAL	0.5MG/L
GROUNDWATER CONCENTRATION - DEVELOPED	2.5MG/L
STREAM NITRATE-N CONCENTRATION	1.8MG/L
STREAM FLOW (CFS)	0.2CFS
STREAM LOAD (LB NO3-N/DAY)	1.5LB/DY

SOURCES:

LANDSCAPING	LB/UNIT/YR	UNITS	TOTAL LOAD
SIGNIFICANT	2.68	15	40.32LB/YR
MODERATE	0.52	10	5.28

LIVESTOCK	LOAD/YR/ANIMAL LB-N/YR/HD	ANIMALS	% ONSITE DISPOSAL	TOTAL LOAD LB-N/YR
STABLE	175	0	0.75	0
RANCHETTE	175	2	1	350
TOTAL		2		350

SEPTIC SYSTEMS (2.8 PERSONS/HOUSEHOLD)

LOAD/HOUSE/YR	UNITS	TOTAL LOAD
23.88	46	1099LB/YR

SEWERED AREA (1.8 PERSONS/HOUSEHOLD)

LOAD/HOUSE/YR	UNITS	TOTAL LOAD
15.35184	0	0LB/YR

NATURAL VEGETATION

LOAD(LB/AC/YR)	AREA(ACRES)	TOTAL LOAD
4.2	160	672LB/YR

RECHARGE

RAINFALL (IN.)	% RECHARGE	RECHG(IN)	AREA	RECHARGE AF/YR
45	53%	24	160	320

20% FOR FOREST AREAS; 24 INCHES FOR SANTA MARGARITA

12-Jan-95

NITROGEN SOURCES LOWER BEAN

SUMMARY

ELEMENT	UNITS	ANNUAL LBS/YR RELEASE	%	% PERC.	ANNUAL LOAD TO GW	%	SUMMER % DELIVERY TO STREAM		SUMMER LOAD TO STREAM	%	OVERALL SUMMER DELIVERY
SEPTIC SYSTEMS	424	10668	37%	0.75	8001	57%	25%	12%	240	57%	9.0%
HIGH LANDSCAPE	64	510	2%	0.30	153	1%	25%	12%	5	1%	3.6%
MOD. LANDSCAPE	156	82	0%	0.30	25	0%	25%	12%	1	0%	3.6%
LIVESTOCK	25	2650	9%	0.50	1325	9%	25%	12%	40	9%	6.0%
NATURAL VEG	3625	15225	52%	0.30	4568	32%	25%	12%	137	32%	3.6%
TOTAL		29136	lb/yr	0.48	14071	lb/yr		12%	422	lb	5.8%
AVERAGE DAILY (LB/DY)					38.6				4.7	53%	
SCOTTS VALLEY CONTRIBUTION		NITRATE LB/DAY							4.1	47%	
TOTAL CALC LOAD									8.8	lb/dy	
AVG GW CONC. (ANNUAL LOAD / RECHARGE)					1.0MG/L						
CALC STREAM CONC: AVG LOAD / OBS. FLOW					0.6MG/L						

OBSERVED CONDITIONS - SUMMER 1990-93	
GROUNDWATER CONCENTRATION - NATURAL	0.3MG/L
GROUNDWATER CONCENTRATION - KAISER WELL	2.0MG/L
STREAM NO3-N CONCENTRATION	0.6MG/L
STREAM FLOW (CFS)	2.9CFS
STREAM LOAD (LB. NO3-N/DAY)	8.8LB/DY

SOURCES:

LANDSCAPING	LB/UNIT/YR	UNITS	TOTAL LOAD
SIGNIFICANT	2.68	64	172.03LB/YR
MODERATE	0.52	156	82.368

LIVESTOCK	LOAD/YR/ANIMAL LB-N/YR/HD	ANIMALS	% ONSITE DISPOSAL	TOTAL LOAD LB-N/YR
STABLE	106	0	1	0
RANCHETTE	106	25	1	2650
TOTAL		25		2650

SEPTIC SYSTEMS(2.8 PERSONS/HOUSEHOLD)	LOAD/HOUSE/YR	UNITS	TOTAL LOAD
	23.88	424	10125LB/YR

OTHER (NOT INCLUDED)		TOTAL LOAD	
MT HERMON FERTILIZER		338LB/YR	= 126 SIG. LANDSCAP.
MT HERMON CAMPERS	23600PERS-DY/YR	543LB/YR	= 23 SEPTIC SYSTEMS

NATURAL VEGETATION	LOAD(LB/AC/YR)	AREA(ACRES)	TOTAL LOAD
	4.2	3625	15225LB/YR

RECHARGE				
RAINFALL (IN.)	% RECHARGE	RECHG(IN)	AREA	RECHARGE AF/YR
45	53%	24	3625	7250
	20% FOR FOREST AREAS;		24 INCHES FOR SANTA MARGARITA	

APPENDIX D: Results of Lysimeter Sampling Below Sandy Leachfields

See Section 6 for a Discussion of Methods and Analysis of Data

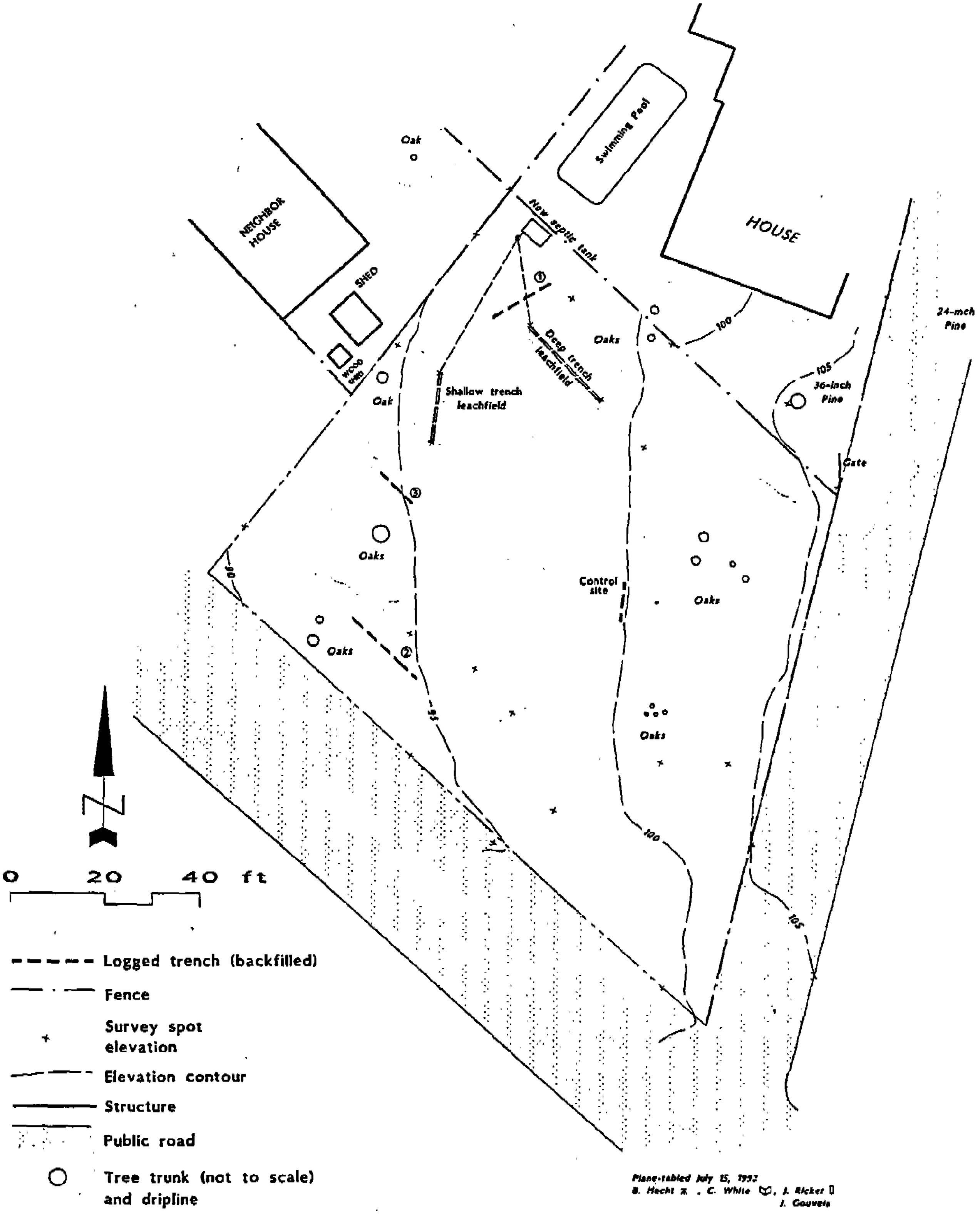
Appendix D: Results of Lysimeter Sampling Below Sandy Leachfields

Sample Location	Lateral Distance /Depth Below Leachfield (in feet)	Nitrate (mg-N/L)	Ammonia mg-N/L	Total Kjeldahl Nitrogen (mg-N/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Electo-Conduc-tivity
Control	. 3.0						
	Mean	.42	.08	2.1	27.0	2.3	224.8
	Number	8	5	2	2	6	4
	StdDev	.87	.02	.6	19.8	1.4	210.2
	. 8.0						
	Mean	2.08	.07	2.5	10.0	45.3	500.0
	Number	10	8	2	3	7	6
	StdDev	2.48	.03	.4	9.5	12.4	0.0
	. 13.0						
	Mean	9.00	.09	.	.	132.5	.
	Number	6	4	0	0	4	0
	StdDev	3.20	0.00	.	.	72.4	.
Mean		3.26	.08	2.3	16.8	50.6	389.9
Number		24	17	4	5	17	10
StdDev		4.11	.02	.5	15.2	60.0	186.9
Deep Trench	0.0 3.0						
	Mean	33.23	.07	3.2	14.3	401.2	522.0
	Number	21	16	4	7	12	20
	StdDev	10.11	.04	2.3	8.9	202.3	737.1
	0.0 8.0						
	Mean	34.90	.07	3.0	.	454.7	868.8
	Number	15	8	1	0	8	15
	StdDev	9.18	.03	.	.	127.5	879.0
	0.0 13.0						
	Mean	33.52	.12	4.2	9.4	401.7	750.3
	Number	22	15	5	7	14	20
	StdDev	11.71	.22	3.1	10.5	117.0	764.5

Sample Location	Lateral Distance /Depth Below Leachfield (in feet)	Nitrate (mg-N/L)	Ammonia mg-N/L	Total Kjeldahl Nitrogen (mg-N/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Electo-Conduc-tivity
Deep Trench	4.0						
	3.0						
	Mean	27.07	.08	.	.	530.5	1026.7
	Number	13	6	0	0	7	12
	StdDev	7.62	.04	.	.	157.9	952.6
	4.0						
	8.0						
	Mean	26.08	.08	.	.	640.7	1477.2
	Number	12	6	0	0	7	10
	StdDev	9.04	.04	.	.	319.9	991.8
	4.0						
	13.0						
	Mean	25.06	.08	.	.	588.2	1147.0
	Number	14	7	0	0	8	14
	StdDev	9.80	.03	.	.	284.1	1239.9
	4.5						
	13.0						
	Mean	32.76	.08	.	.	480.0	871.7
	Number	14	7	0	0	8	14
	StdDev	12.51	.03	.	.	201.6	547.5
	9.0						
	3.0						
	Mean	19.99	.08	.	.	1508.4	1895.1
	Number	11	7	0	0	8	13
	StdDev	8.94	.03	.	.	1682.9	1967.6
	9.0						
	8.0						
	Mean	22.92	.10	.	.	536.2	1161.7
	Number	11	6	0	0	7	12
	StdDev	9.02	.03	.	.	343.1	1722.3

Sample Location	Lateral Distance /Depth Below Leachfield (in feet)	Nitrate (mg-N/L)	Ammonia mg-N/L	Total Kjeldahl Nitrogen (mg-N/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Electo-Conduc-tivity
Deep Trench	9.0						
	13.0						
	Mean	31.96	5.79	.	.	.	.
	Number	5	1	0	0	0	0
	StdDev	21.30	.	.	.	.	.
Mean		29.45	.16	3.7	11.9	590.4	1018.5
Number		138	79	10	14	79	130
StdDev		11.35	.65	2.5	9.7	629.0	1160.1
Septic Effluent	.						
	.						
	Mean	1.02	28.62	41.6	122.2	732.4	2063.3
	Number	17	18	5	6	12	15
	StdDev	2.45	13.87	7.1	58.4	444.0	836.9
Mean		1.02	28.62	41.6	122.2	732.4	2063.3
Number		17	18	5	6	12	15
StdDev		2.45	13.87	7.1	58.4	444.0	836.9
Shallow	0.0						
	3.0						
	Mean	22.64	.58	6.8	7.6	415.4	430.5
	Number	7	5	2	1	3	4
	StdDev	20.45	1.14	4.6	.	162.9	262.5
	0.0						
	8.0						
	Mean	21.03	.11	5.8	7.0	982.6	1043.6
	Number	12	8	1	1	7	14
	StdDev	16.23	.09	.	.	705.1	878.6
	0.0						
	13.0						
	Mean	34.89	.20	8.6	19.5	683.8	928.3
	Number	15	10	2	2	9	13
	StdDev	14.38	.42	6.3	7.8	528.6	1008.8

Sample Location	Lateral Distance /Depth Below Leachfield (in feet)	Nitrate (mg-N/L)	Ammonia mg-N/L	Total Kjeldahl Nitrogen (mg-N/L)	Total Organic Carbon (mg/L)	Chloride (mg/L)	Electo-Conduc-tivity
Shallow	4.0						
	2.0						
	Mean	26.36	.06	2.2	9.5	844.0	1172.5
	Number	20	13	2	6	11	20
	StdDev	16.66	.03	1.3	2.1	556.2	1308.9
	4.0						
	8.0						
	Mean	40.05	.08	.	.	743.8	813.6
	Number	12	7	0	0	6	12
	StdDev	15.59	.03	.	.	327.3	836.1
	4.0						
	13.0						
	Mean	25.90	.07	2.8	4.5	317.2	500.7
	Number	11	7	2	3	4	11
	StdDev	13.59	.03	.4	.8	78.5	778.1
	9.0						
	3.0						
	Mean	51.42	.	.	.	.	.
	Number	1	0	0	0	0	0
	StdDev	.	.	.	.	.	.
	9.0						
	8.0						
	Mean	23.50	.09	.	.	930.2	1076.8
	Number	12	6	0	0	7	13
	StdDev	12.21	0.00	.	.	638.5	883.1
	9.0						
	13.0						
	Mean	26.03	.08	4.9	8.8	549.5	828.5
	Number	13	7	1	1	7	13
	StdDev	20.13	.03	.	.	306.5	753.5
Mean		28.14	.14	5.1	9.5	734.3	918.9
Number		103	63	10	14	54	100
StdDev		16.80	.36	3.6	5.3	514.4	952.8

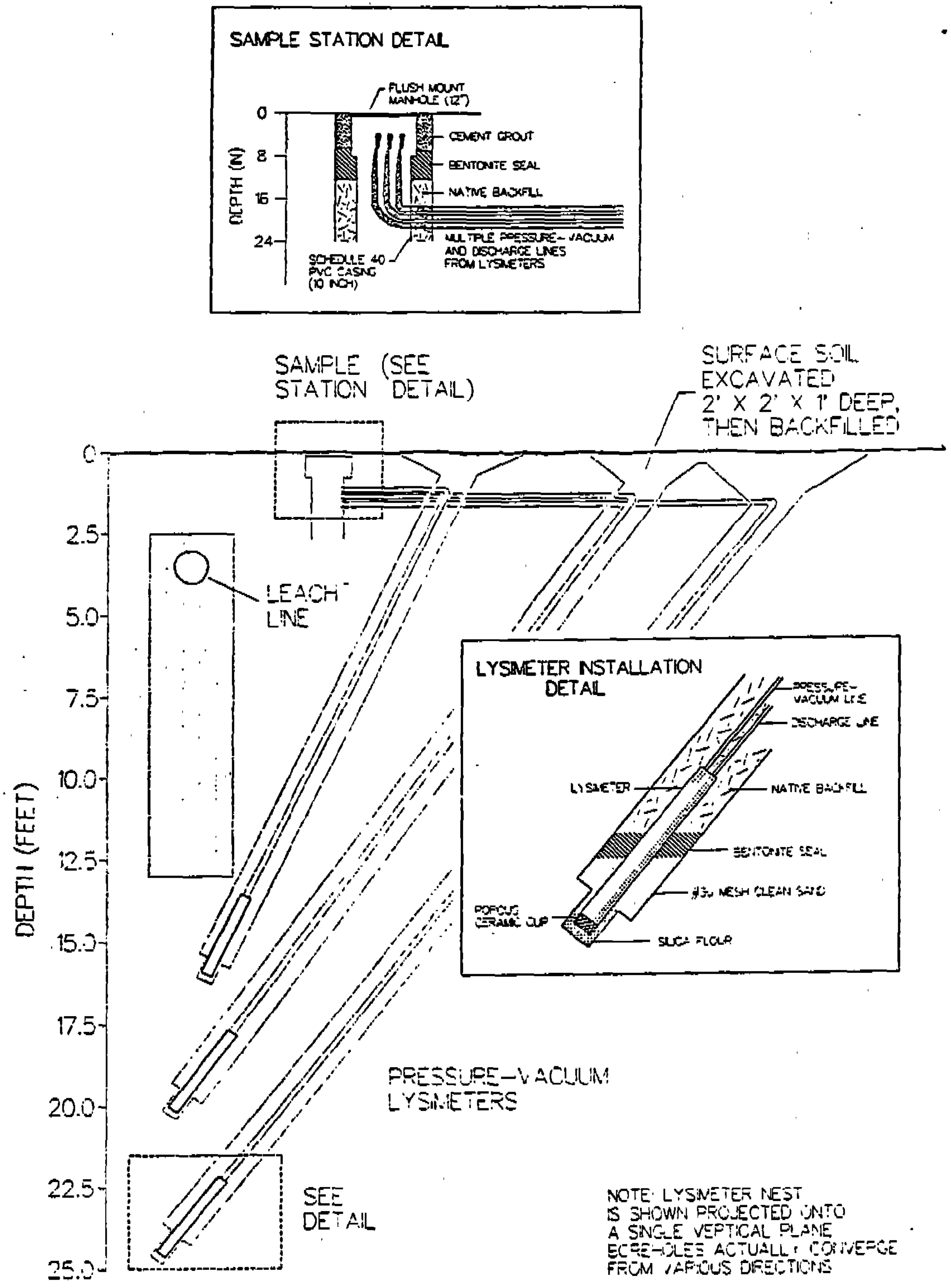


Plane-tabled July 15, 1992
B. Hecht, C. White, J. Ricker
J. Gouveia

Arbitrary local datum of 100.00 feet

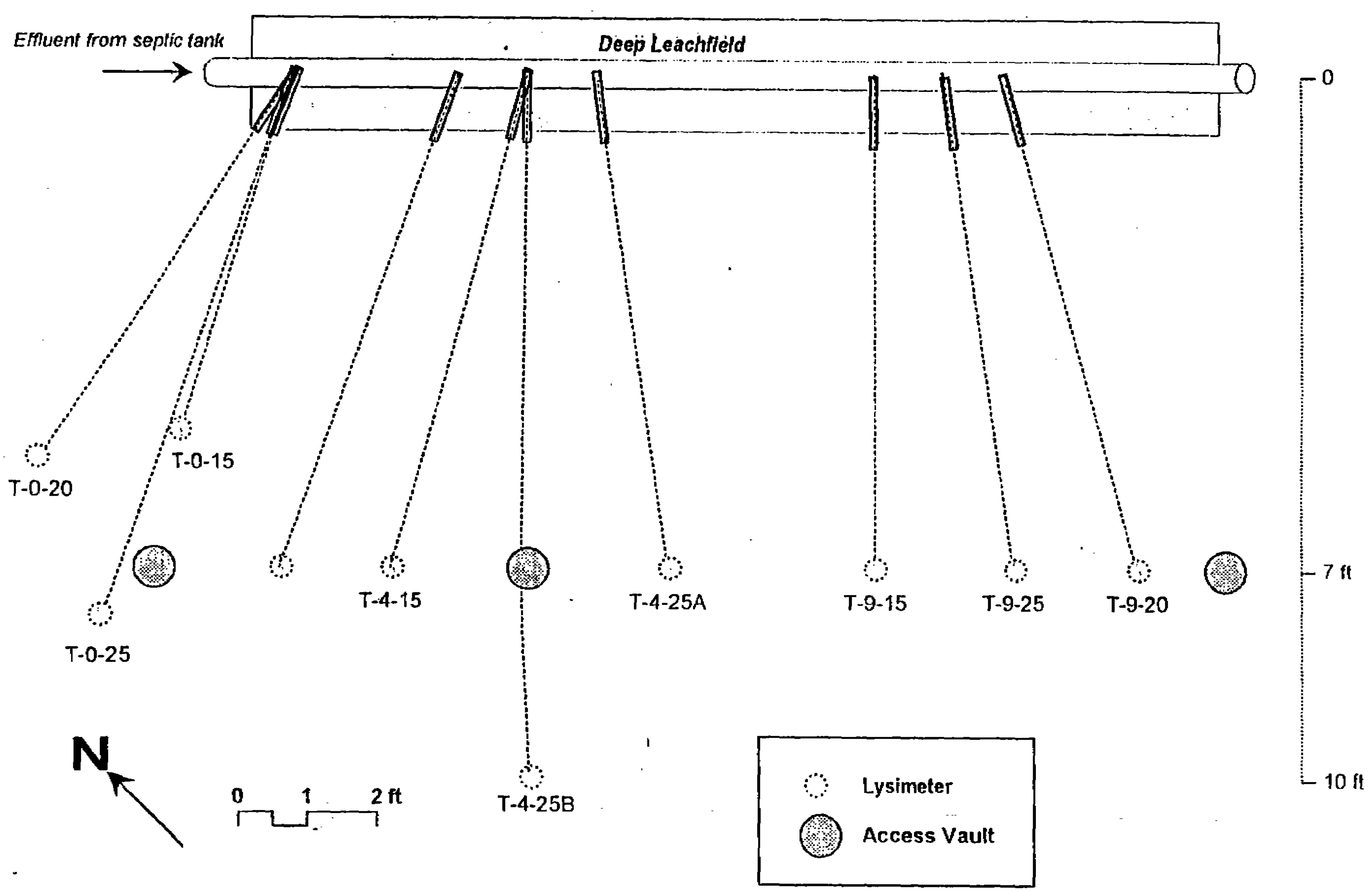
Balance Hydrologics, Inc.

Figure 4. Plot plan of the residence, Glen Arbor area, Santa Cruz County.



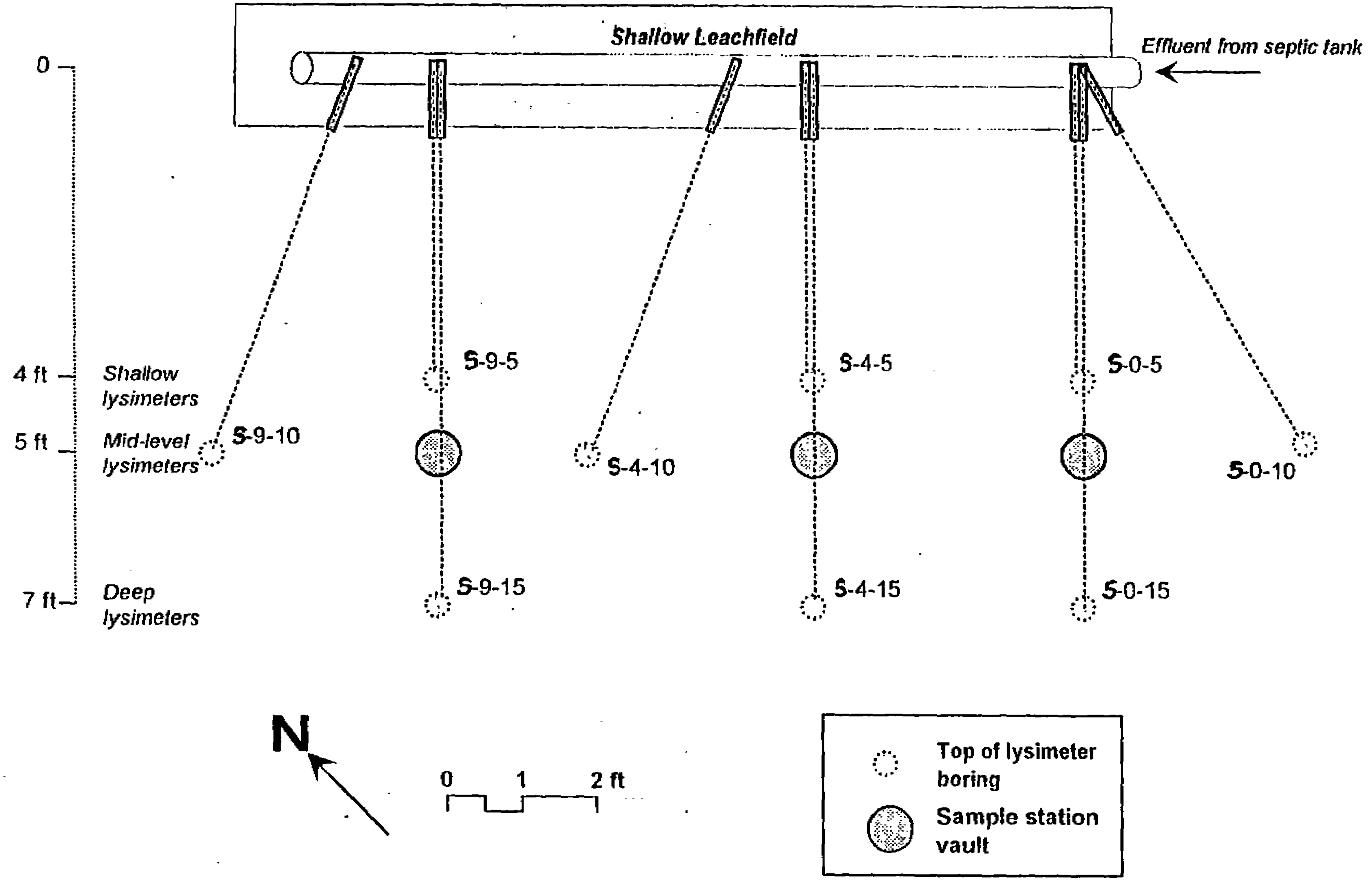
Balance Hydrologics, Inc.

Figure 5. Construction of a representative lysimeter nest, deep trench leachfield,



Balance Hydrologics, Inc.

Figure 6. Plan view of lysimeter array at the deep trench leachfield,



Balance
Hydrologics, Inc.

Figure 7. Plan view of lysimeter array at the shallow leachfield,

APPENDIX E: Nitrate Control Measures

Prepared by Balance Hydrologics, Inc., in: A Nitrate Budget-Based Assessment of Potential Nonpoint-Source Control Measures to Reduce Nitrate Delivery to the San Lorenzo Watershed, Santa Cruz County, California, Prepared for Santa Cruz County Environmental Health Services, July, 1991.

Appendix F: Approaches, Means and Costs Considered for Reducing Nitrate and Ammonia Delivery to the San Lorenzo River

Approach	Means	NO3 + NH3 Reduction Realizable Sandy Soils	NO3 + NH3 Reduction Realizable Non-Sandy Soils	Costs	Additional Considerations
Minimize nitrogen delivery to septic systems	Installation of non-water carriage toilets				
	1) Composting toilets	80% (65-90%)	80% (65-90%)	Initial: $5,000-$10,000 for each toilet fixture. Additional cost for installation is site-specific. Maintenance: $50-$100 per year for bulking agent. Uses a small amount of electricity to power a fan and for supplemental heating (optional).	Moderately resistent to homeowner neglect: Bulking agent added weekly and pile raked monthly. Produces a small amount of stable organic matter yearly, suitable for disposal onsite or offsite. Larger units accept kitchen wastes. Installation requires basement excavation, slope or second-story location.
	2) Incinerator toilets	80% (65-90%)	80% (65-90%)	Initial: Unknown Maintenance: cost of electricity or gas. Semi-annual cleaning and adjustment of burning assembly and/or heating components.	Relatively energy-inefficient and noisy. Evaporates liquids and volatizes organic components, leaving ash as a residual, which may be disposed of onsite or offsite. Toilet wastes only.
	3) Mineral oil flush toilets	80% (65-90%)	80% (65-90%)	Initial: Unknown Maintenance: removal of yearly excreta and disposal at suitable landfill is costly. Yearly maintenance of oil purification system requires a skilled technician. Flushing and oil purification requires power.	Residuals disposal not possible onsite. Oil coating may render offsite disposal problematic. Possible health risk due to risk of spills and contamination during pumping, transport and disposal.

Appendix F: Approaches, Means and Costs Considered for Reducing Nitrate and Ammonia Delivery to the San Lorenzo River (continued)

Approach	Means	NO3 + NH3 Reduction Realizable Sandy Soils	Non-Sandy Soils	Costs	Additional Considerations
	Haulaway systems (year-round)	80% (65-90%)	80% (65-90%)	Maintenance: Variable depending on the frequency of pumping. Typically at least $200 per load for pumping, transport and disposal in a sanitary landfill.	Possible health risk due to (increased) risk of spills and contamination during pumping, transport and disposal.
	Prohibit garbage disposal units	very small	5% (2-8%)	Variable depending on whether voluntary compliance or removal of unit is required.	Kitchen wastes can be routed to solid waste bins for offsite disposal or composted onsite. User education improves voluntary compliance. Kitchen wastes may be an important source or carbon for microbes important in both nitrification and denitrification in sandy soils.
Minimize nitrate and ammonia delivery from on-site systems to ground and surface water	Modify existing septic systems				
	1) Replace tank and crib systems with conventional or shallower leachfield	NA	25% (40%)	Initial: Installation of conventional septic tank and leachfield @ $4,000 - $5,000.	Location, number and proximity to surface waters are not known. Assumed present only in non-sandy areas.
	2) Replace deep leachfields with conventional shallow leachfields	15% (35%)	25% (50%)	Initial: Installation of new leachfield @ $3,000	

Appendix F: Approaches, Means and Costs Considered for Reducing Nitrate and Ammonia Delivery to the San Lorenzo River (continued)

		NO3 + NH3 Reduction Realizable			
Approach	Means	Sandy Soils	Non-Sandy Soils	Costs	Additional Considerations
	3) Replace conventional leachfields with mounded bed systems			Initial: Construction of mounded beds, installation of wet well and pump with timer @ $10,000-$15,000. Maintenance: Electricity required for intermittent pumping. Requires occasional pump maintenance.	Appropriate in areas of high groundwater.
	a) Horizons similar in texture	No data for very permeable soils (>20 in/hr) were found.	20%		
	b) Horizons differ in texture or density	40%	60%		
	4) Replace conventional leachfields with pressure distribution systems	50% (estimated)	65% (estimated)	Initial: Construction of very shallow leachfield, installation of wet well and pump with timer @ $10,000 - $15,000. Maintenance: Electricity required for intermittent pumping. Requires occasional pump maintenance.	No data available. Nitrogen savings are estimated.

Appendix F: Approaches, Means and Costs Considered for Reducing Nitrate and Ammonia Delivery to the San Lorenzo River (continued)

Approach	Means	NO3 + NH3 Reduction Realizable Sandy Soils	 Non-Sandy Soils	Costs	Additional Considerations
	5) Replace conventional leachfields with geomembrane systems	10% (estimated)	NA	Initial: Construction of a leachfield, depth to be determined, incorporating alternating layers of soils having different porosities. Estimated @ $5,000.	A conceptual approach which rationalizes the effect, noted above in the mound systems (3B), where changes in soil texture/density promote increased dentrification. Experimental system installation would require monitoring.
	Supplementary Treatment Systems	Sand filters are discussed below. At present costs, installation of aerobic or anaerobic package treatment plants for individuals is prohibitive.			
	a) Ion exchange	85%	85%	Initial: Installation of filtration tank with zeolite media between septic tank and leachfield @ $2,000. Maintenance: Removal and replacement of zeolite after 5 - 7 years @ $1300.	
	Segregated Greywater Treatment				
	a) Sand filter only	Minimal N loss; simply enhances conversion of NH3 and organic N to nitrate.	Minimal N loss; simply enhances conversion of NH3 and organic N to nitrate.	Initial: Construction of sand filter and installation @ $3,000-$4,000. Maintenance: Periodic removal, replacement and disposal of uppermost layer of sand; backflushing of filter, and occasional pump maintenance.	Vulnerable to homeowner neglect. Installation should improve septic system performance.

Appendix F: Approaches, Means and Costs Considered for Reducing Nitrate and Ammonia Delivery to the San Lorenzo River (continued)

Approach	Means	NO3 + NH3 Reduction Realizable		Costs	Additional Considerations
		Sandy Soils	Non-Sandy Soils		
	b) Sump only	Minimal N loss; simply enhances conversion of NH3 and organic N to nitrate.	Minimal N loss; simply enhances conversion of NH3 and organic N to nitrate.	Initial: Construction of 4 x 4 x 4 foot sump filled with drain rock @ $1,000.	Vulnerable to homeowner neglect. Installation should improve septic system performance.
	c) Sand filter or sump, with dedicated shallow leachfield	5%	5%	Initial: Construction of sand filter or sump, with leachfield @ $2,000-$4,000.	Requires additional area for second, smaller leachfield. Vulnerable to homeowner neglect. Installation should improve septic system performance.
	d) Evaporation/ absorption and evapotranspiration systems	5%	5%	Initial: Construction of beds similar to leachfields. Costs will vary with specific designs.	Performance will vary according to season and location. Installation should improve septic system performance.

Appendix G: Estimated Annualized Cost of Nitrate Plus Ammonia Reduction Measures

Means	Est. Useful Lifespan (a)	Estimated Installed Cost	Annual Maintenance Cost	Annualized Cost (b)	Remarks
Installation of non-water-carriage toilets					
1) Composting toilets (large size)	20 yr.	$10,000	$250	$1,740	Based on new construction; cost of retrofit will be moderately larger.
2) Incinerator (c)					
3) Mineral Oil Flush (c)					
Haulaway					
1) Winter only	Indefinite	N/A	$1,800	$1,800	Assumes no tank replacement/ alarm system installation. ALL wastewater removed.
2) Year-round	Indefinite	N/A	$5,000	$5,000	Assumes no tank replacement/ alarm system installation. ALL wastewater removed.
Modify existing septic systems					
1) Replace tank and crib systems with conventional or shallower leachfield	20 yr.	$4,000	$100	$700	Assumes septic tank is pumped out once every four years.
2) Replace deep leachfields with conventional or shallower leachfields	20 yr.	$3,000	$100	$550	Assumes septic tank is pumped out once every four years.

Appendix G: Estimated Annualized Cost of Nitrate Plus Ammonia Reduction Measures (continued)

Means	Est. Useful Lifespan (a)	Estimated Installed Cost	Annual Maintenance Cost	Annualized Cost (b)	Remarks
3) Replace conventional leachfields with mounded bed systems	20 yr.	$12,500	$250	$2,100	Assumes septic tank is pumped out once every four years.
4) Replace conventional leachfields with pressure distribution systems	20 yr.	$12,500	$250	$2,100	Assumes septic tank is pumped out once every four years.
5) Replace conventional leachfields with conceptual "geomembrane" system	20 yr.	$5,000 to $7,500	$250	$1,000-$1370	Assumes septic tank is pumped out once every four years.
Supplementary treatment facilities	Sand filters are discussed below. At present costs, installation of aerobic or anaerobic package plants is not considered to be a viable option for on-site wastewater treatment at individual residences.				
1) Install filtration tank with zeolite media	Indefinite	$2,000	$250	$550	
Segregated greywater treatment					
1) Sump only	20 yr.	$1,000	$150	$300	
Sump with dedicated shallow leachfield	20 yr.	$2,000	$150	$450	
2) Sand filter only	20 yr.	$3,000	$150	$600	
Sand filter with dedicated shallow leachfield	20 yr.	$4,000	$150	$750	

Appendix G: Estimated Annualized Cost of Nitrate Plus Ammonia Reduction Measures (continued)

Means	Est. Useful Lifespan (a)	Estimated Installed Cost	Annual Maintenance Cost	Annualized Cost (b)	Remarks
3) Evapotranspiration or evapotransporation/ absorption system (d)	20 yr.	$3,000	$150	$600	
Animal waste management at organized stables					
1) Runoff diversion	Indefinite	$5,000	$1,000	$1,750	
2) Cover manure pile	Indefinite	$1,000	$300	$450	Replace tarps every 3 to 4 years
3) Contract haul manure	Indefinite	NA	$18,000	$18,000	Assumes aerobically composted wastes are exported monthly at $50 per ton, for transport and disposal, from a 60-horse stable
Intensified Water Development	Indefinite	> $500,000	(e)	(e)	

(a) Although actual lifetimes of properly maintained septic systems are about twenty years, all are depreciated over a ten-year period (EPA, 1979) to reflect uncertainties with respect to future institutional and technological factors bearing on waste disposal.

(b) Capital costs, installation costs, and operating expense amortized over ten years assuming an interest rate of 8%.

(c) Not considered to be a viable option, based on current technology and regulatory environment.

(d) Costs and nitrogen removal rates of evapotranspiration and evapotranspiration/absorption systems are highly site-specific.

(e) Costs based on a highly-managed and - monitored array of 4 or 5 wells, with controls, mains, pumps and appurtenances. Seasonal nitrate control would be an important, but subordinate objective. Distribution of costs between water development and nitrate control to be determined by operator. Note needs for further feasibility analyses and for offsets for instream flows described in text.

Appendix H: Comparative Unit Costs of Nitrate Plus Ammonia Control

Means	Amount of nitrogen saved annually (a) (lb-N)	Annualized cost per pound nitrogen saved (b)
1) On-site systems		
Composting toilets	5.8	$300
Haulaway		
Winter only	5.8	$860
Year-round	2.1	$860
Modified systems		
Tank/crib replacement (c)		
Conventional leachfield	1.2	$580
Shallow leachfield	2.9	$290
Deep leachfield replacement		
Conventional leachfield	1.1	$510
Shallow leachfield	2.8	$225
Mounded bed installation		
Horizons same texture	0.7 (d)	$3,000
Horizons alternate texture	2	$1,050
Pressure distribution system installation	2.9 (e)	$725
Geomembrane	0.7 (f)	$1,430
Filtration tank with zeolite media	5.2	$110

Appendix H: Comparative Unit Costs of Nitrate Plus Ammonia Control (continued)

Means	Amount of nitrogen saved annually (a) (lb-N)	Annualized cost per pound nitrogen saved (b)
Sand filter installation with leachfield	0.3	$2,500
Sump installation with leachfield	0.3	$1,500
Evapotranspiration or evapotranspiration/absorption systems	0.3	$2,000
2) Other measures		
Animal waste management at organized stables		
Runoff diversion	2500	$4
Cover manure piles	700	$3
Contract. haul manure	1200	$75
Intensified water development	1,200 to 4,000	(g)

(a) Nitrogen savings are calculated based on delivery to the river from sandy soils. In many non-sandy soils of the San Lorenzo Valley, the amount saved would be 10-50% greater.

(b) Capital costs, installation costs, and operating expenses amortized over ten years (EPA, 1979), assuming an interest rate of 8%.

(c) These systems are assumed to be present only in non-sandy areas.

(d) No data available for mounded beds on very sandy soils. Data presented is from systems on non-sandy soils where nitrate losses are proportionately lower.

(e) No data available. Value is an estimate of nitrogen savings.

(f) No data available. Value is an estimate of nitrogen savings from a conceptual system. Features can possibly be combined with other leachfield measures to promote additional nitrate control at favorable costs.

(g) Allocation of costs between wastewater management and water development to be determined by operator.

APPENDIX I

CALCULATIONS OF NITROGEN RELEASE

Estimated release at present from conventional septic systems on:

<u>Sandy soils</u>: 24 lb N/yr x 0.85 x 0.30 = 6.1 lb N/yr entering the river

<u>Non-sandy soils</u>: 24 lb N/yr x 0.75 x 0.20 = 3.6 lb N/yr entering the river

---

1) Non-water carriage toilets (and year-round haulaway):

Assumes 80% (19.2 lb N/yr) of the N entering the septic tank is from human wastes which these fixtures exclude.

24 lb N/yr x 0.20 = 4.8 lb N/yr entering the septic tank

<u>Sandy soils</u>: 4.8 x 0.85 x 0.30 = 1.2 lb N/yr

<u>Non-sandy soils</u>: 4.8 x 0.75 x 0.20 = 0.7 lb N/yr

2) Tank/crib replacement

Assumes 100% of N enters ground water, rather than 85%, and that these systems are <u>only on non-sandy soils</u>. N input is then 4.8 lb N/yr rather than 3.6 lb N/yr.

Replace with conventional leachfield: 24 lb N/yr x 0.75 x 0.20 = 3.6 lb N/yr

Replace with shallower leachfield: 24 lb N/yr x 0.50 x 0.20 = 2.4 lb N/yr

3) Deep leachfield replacement

Assumes 100% of N enters ground water, rather than 85%, Therefore, N input is then 4.8 lb N/yr instead of than 3.6 lb N/yr.

<u>Sandy soils</u>:

Replace with conventional leachfield: 24 lb N/yr x 0.85 x 0.30 = 6.1 lb N/yr

Replace with shallower leachfield: 24 lb N/yr x 0.65 x 0.30 = 4.6 lb N/yr

<u>Non-sandy soils</u>:

Replace with conventional leachfield: 24 lb N/yr x 0.75 x 0.20 = 3.6 lb N/yr

Replace with shallower leachfield: 24 lb N/yr x 0.50 x 0.20 = 2.4 lb N/yr

4) Mounded bed installation

Sandy soils:

Horizons same texture: No data for very sandy soils

Horizons alternate texture: 24 lb N/yr x 0.65 x 0.65 x 0.30 = 3.0 lb N/yr

Non-sandy soils:

Horizons same texture: 24 lb N/yr x 0.60 x 0.20 = 2.9 lb N/yr

Horizons alternate texture: 24 lb N/yr x 0.50 x 0.50 x 0.20 = 1.2 lb N/yr

5) Pressure distribution system with very shallow leachfield

Sandy soils: 24 lb N/yr x 0.45 x 0.30 = 3.2 lb N/yr

Non-sandy soils: 24 lb N/yr x 0.25 x 0.20 = 1.2 lb N/yr

6) Geomembrane systems-a conceptual design specifically for sandy soils.

Sandy soils: 24 lb N/yr x 0.75 x 0.30 = 5.4 lb N/yr

7) Filtration tank with zeolite media

Assumes 85% of the nitrogen in the septic tank effluent is adsorbed by the zeolite for later disposal off-site.

Sandy soils: 24 lb N/yr x 0.15 x 0.85 x 0.30 = 0.9 lb N/yr

Non-sandy soils: 24 lb N/yr x 0.15 x 0.75 x 0.20 = 0.5 lb N/yr

8) Sumps/sand filters/evapotranspiration-absorption beds

Proposed solely for greywater treatment. Greywater contains about 20% of the total N entering the septic tank (4.8 lb N/yr). In the conventional septic tank-leachfield system, this 4.8 lb N/yr results in a release of:

Sandy soils: 4.8 lb N/yr x 0.85 x 0.30 = 1.2 lb N/yr

Non-sandy soils: 4.8 lb N/yr x 0.75 x 0.30 = 0.7 lb N/yr

N release after greywater treatment system installed:

Sandy soils: 4.8 lb N/yr x 0.65 x 0.30 = 0.9 lb N/yr

Non-sandy soils: 4.8 lb N/yr x 0.75 x 0.20 = 0.5 lb N/yr

9) Large animal wastes at organized stables

Assumes that approximately 300 horses are kept in organized stables. Total nitrogen production is calculated based on:

300 horses x 175 lb N/yr per horse = 26 tons N/yr

26 tons x 75% (urine; N not removed with dung and exported) = 20 tons entering the soil

20 tons x 50% = 10 tons entering ground water

10 tons x 33% = 3.3 tons entering surface water

Reductions from implementation of best management practices:

1) Runoff diversion and covering manure piles:

26 tons x 0.40 (a 35% decrease in soil loading) = 10.4 tons

10.4 tons x 50% x 33% = 1.7 tons

2) Contract-haul manure

26 tons x 0.25 (a further 15% decrease in soil loading) = 6.5 tons

6.5 tons x 50% x 33% = 1.1 tons

Total nitrogen savings: 1.6 + 0.6 = 2.2 tons