Canada and Scandinavia. Operating and maintenance procedures and histories are available from a variety of installations with years of satisfactory experience. Those now considering pressure collection systems for the first time can benefit from the collective experience of many fellow system managers, operators and engineers. Pressure collection systems can be planned which will operate reliably into the foreseeable future, within budget, and with few surprises.

REFERENCES

Carcich, Italo G., Hetling, Leo J. and Farrell, R. Paul, (1972), "A Pressure Sewer System Demonstration", US EPA-R2-72-091.

Eblen, Jessie E. and Clark, Lloyd K., (1978), "Pressure and Vacuum Sewer Demonstration Project Bend, Oregon", US EPA-600/2-78-166.

Fair, G. M., (1968), "Converted Sewer System", United States Patent 3,366,339. Filed Nov. 26, 1965, and assigned by the inventor to the public.

Farrell, R. Paul, Jr., (1972), "Pressure Sewers and the Grinder Pump Which Makes them Possible", Journal of the New England Water Pollution Control Association, Vol. 6, No. 2.

Gray, Donald D., (1991), "TN Community's Grinder Pumps Provide Positive O&M Statistics"; in "Small Flows", published by Small Flows Clearing House, West Virginia University.

Palmer, Lynn H. (1993), "Preserving the Antietam Battlefield at Affordable Cost", in Proceedings Collection Systems Operation and Maintenance, Water Environment Federation, Tucson, AZ.

Weibel, S. R., Bendixen, T. W. and Coulter, J. B., (1949-1954), "Studies on Household Sewage Disposal Systems"-- Parts I-III, U. S. Public Health Service, Cincinnati, OH.

Weston, Roy F., Inc. (1983), "Interim Report, I/A Technology Assessment, Post-Construction Evaluation of Cuyler, New York Grinder Pump-Pressure Sewer and Community Soil Absorption System", EPA Contract 68-03-3055.

1774

AREA-WIDE WASTEWATER MANAGEMENT FOR THE SAN LORENZO RIVER WATERSHED, CALIFORNIA

J. Ricker* N. Hantzsche* B. Hecht* H. Kolb*

ABSTRACT

The San Lorenzo River Watershed, California, is an area served predominantly by on-site septic systems which have contributed to localized health hazards and elevated nitrate levels. In some areas of the basin the nitrate levels have increased to the point of exceeding water quality standards and adversely affecting beneficial uses. The San Lorenzo River Wastewater Management Plan provides for the improvement of wastewater disposal practices to protect public health and beneficial uses of surface and groundwater in the San Lorenzo River Watershed. The Plan represents a refinement and strengthening of the wastewater management programs that have been implemented by the County of Santa Cruz Health Services Agency, Environmental Health Service, since 1985. The main elements of the Plan include: (a) financing of studies and improvements through formation of a county-wide service area covering all properties served by on-site systems; (b) a ten-year program to complete lot-by-lot inspections and evaluation of all existing on-site systems; (c) routine and special water quality monitoring studies of surface and groundwaters; (d) watershed loading analysis of all significant nitrogen sources affecting the river and groundwaters; (e) design, installation, and monitoring of demonstration nitrogen removal systems for retrofit and new on-site system applications; and, (f) development of community sewerage systems for selected problem areas in the basin.

KEYWORDS: on-site systems, watershed management, nitrate loading analysis, nitrogen removal, financing, inspection program.

BACKGROUND

The San Lorenzo River, located in the coastal mountains immediately south of the San Francisco Bay Area, drains a watershed area of 138 square miles (see **Figure 1**). The watershed is home to approximately 75,000 people, most of whom utilize on-site 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 percent of the water supply for the City of Santa Cruz, serving approximately 85,000 customers. Groundwater in the unconfined sandy aquifers provides water supply to most of the local population in the basin.

Since 1960 the basin has changed from primarily a summer tourist destination to a more permanent, year-round population. With this change there has been a marked increase in septic system failures and nitrate concentrations in local groundwaters and in the San Lorenzo River, largely attributable to septic systems. The septic system problems and water quality effects have been documented as described below.

---

* J. Ricker, Program Manager, Santa Cruz County Environmental Health Service; N. Hantzsche, Managing Engineer, Questa Engineering Corporation; B. Hecht, President, Balance Hydrologics, Inc.; and H. Kolb, Water Resources Control Engineer, Central Coast Regional Water Quality Control Board.

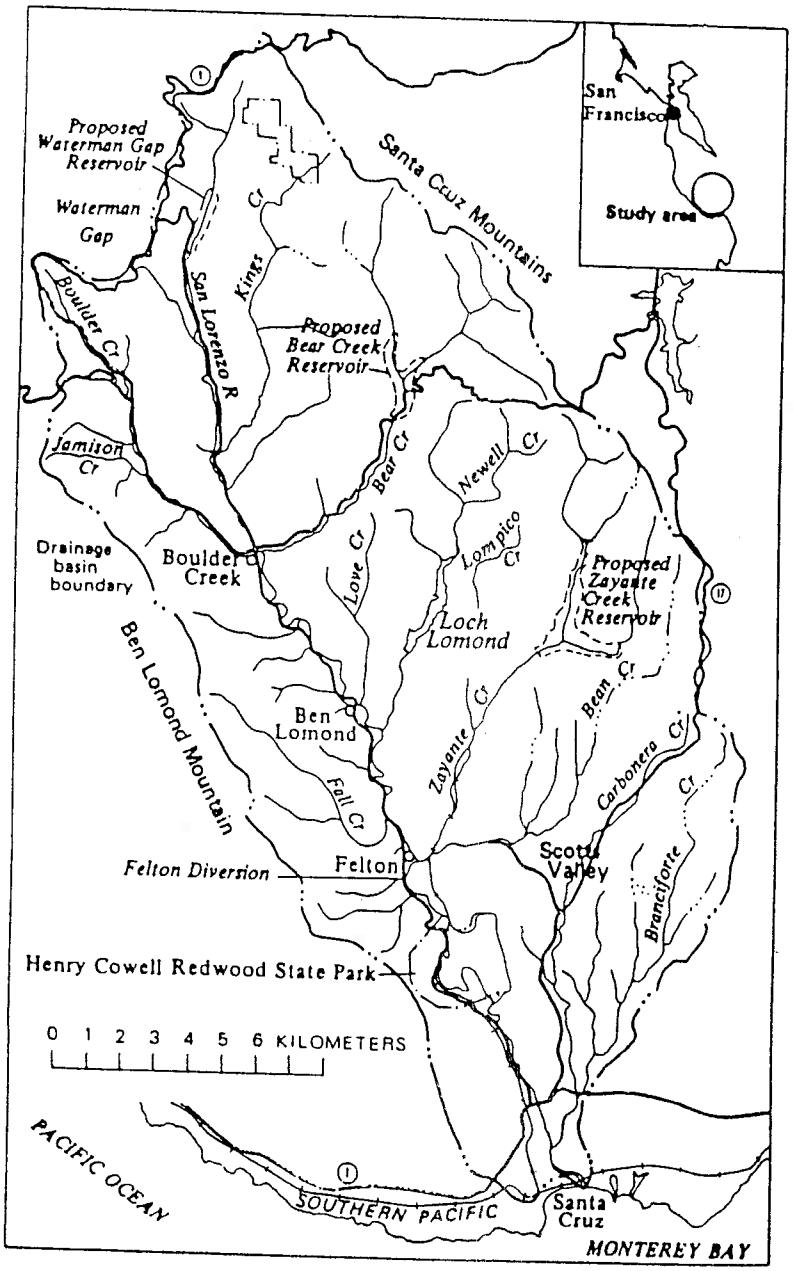

Figure 1. San Lorenzo River Watershed, California

SEPTIC SYSTEM CHARACTERISTICS

Surveys by the Santa Cruz County Health Department have determined septic system usage in the watershed to be characterized by the following types of problems and constraints.

Limited Disposal Area. Approximately 55% of the developed parcels are less than 15,000 square feet and 11% are less than 6,000 square feet in size.

System Size. Two-thirds of the systems are substandard in size, and do not meet minimum repair septic system standards.

System Age. Approximately 40% of the systems are over 20 years old, reaching the end of their expected service life.

Proximity to Streams. About 14% of the existing systems are located less than 100 feet from a stream.

High Groundwater Conditions. Between 30 and 50% of the systems are located where winter groundwater levels are less than 10 feet from the ground surface; and 3 to 6% of the systems experience groundwater less than 3 feet from the surface for at least 30 days of the year. High groundwater can cause systems to back up, untreated sewage to come to the surface, and/or groundwater to be contaminated.

Coarse Soil Texture. Many systems are located in areas of very sandy soils with low organic matter content and virtually no clays.

SEPTIC SYSTEM IMPACTS

Sanitary surveys and monitoring efforts by the Santa Cruz County Health Department have documented the following impacts of septic system usage in the San Lorenzo Valley watershed.

Bacterial Contamination of Surface Waters:

- Episodes of bacterial contamination have occurred occasionally at locations throughout the watershed, but no stations have persistently high levels in excess of standards as a result of on-site wastewater disposal.
- An estimated 6 to 12% of the samples collected from the river and its tributaries during 1986-89 showed evidence of wastewater contamination.
- Approximately 25% of the episodes of contamination in excess of bathing standards are estimated to have resulted from wastewater contamination. The majority of high bacteria levels result from waterfowl, domestic animals, and cumulative urban non-point contamination unrelated to wastewater disposal.

Surface Failures of Septic Systems:

- During area surveys, 3 to 6% of the systems were found to be failing, discharging untreated sewage to the ground surface; another 7 to 9% were illegally discharging greywater, which also has a high bacteria and pathogen level.
- Failing systems have been observed in areas throughout the watershed, discharging

of public contact.

- Although there are some areas with greater concentrations of problems, sewage failures have been observed throughout the study area.

Elevated Nitrate Concentrations in Surface and Groundwater:

- Many systems appearing to be functioning properly are releasing significant amounts of nitrate into groundwater and surface water, contributing to potentially adverse impacts on water supplies.

- Primarily as a result of wastewater disposal, nitrate levels in groundwater aquifers have increased four to ten times, threatening the primary groundwater supply in the watershed.

- Nitrate levels in the San Lorenzo River have increased two to three times since the mid-1960s, potentially resulting in increased biological growth which may be adversely affecting the quality of the water supply for the City of Santa Cruz.

In response to these documented sewage disposal problems, and following unsuccessful efforts to implement area-wide sewerage, the California Regional Water Quality Control Board (Central Coast Region) and the Santa Cruz County Health Department have developed a comprehensive Wastewater Management Plan for the watershed. The Plan deals with: (a) the provision and maintenance of adequate sewage disposal facilities for the residents of the watershed; and, (b) the control of nitrogen releases for the protection of water supplies. The overall approach and specific efforts toward nitrogen control are both described in this paper.

WASTEWATER MANAGEMENT PLAN

Following is a description of the key elements and the implementation steps that have been developed by the County of Santa Cruz and the Regional Board to address the existing and long-term sewage disposal management needs for the San Lorenzo River Watershed.

INSPECTION AND EVALUATION OF EXISTING ON-SITE DISPOSAL SYSTEMS

During the first ten years of the Plan implementation (1985-1995), the 12,900 developed parcels in the San Lorenzo River Watershed will be inspected by County Environmental Health staff to identify any current disposal system malfunctions; and all areas will be evaluated to determine what upgrades are likely to be needed on a long-term basis to meet the watershed objectives. The management area includes all parcels within the entire watershed.

DISPOSAL SYSTEM IMPROVEMENTS

All disposal systems that are found to be malfunctioning will be required to be upgraded in conformance with specific repair standards adopted for the San Lorenzo River Watershed. The repair standards are also applied to the large number of system upgrades which are voluntarily initiated by property owners. Although less stringent in some cases than standards for new development, the repair standards provide for substantial improvement to existing systems and are designed to eliminate the uncontrolled release of pathogens, reduce cumulative discharge of nitrate, and provide satisfactory long-term system

performance for the property owners. Included in these provisions are requirements for closer system management and inspection of systems which cannot fully meet standards. At the current rate of system upgrades, it is expected that by the year 2000, improvements will have been made to all of the currently failing systems which may be contributing to public health problems or water quality degradation. Upgrades of the remaining systems will continue to take place for an additional 10 to 20 years.

ON-GOING SYSTEM INSPECTION AND MAINTENANCE

After the initial inspection, systems will be inspected at regular intervals to ensure satisfactory long-term system performance. Annual inspections will be conducted for pump-up, nonconforming, alternative, and haul-away systems. Inspections will be made every one to three years for existing substandard, non-failing systems and systems in close proximity (i.e., within 150 feet) to creeks. Systems which meet standards will be inspected, on average, once every six years. Proper disposal system maintenance will be promoted through property owner education, monitoring of septic tank pumping, and regular inspections.

DEVELOPMENT OF COMMUNITY DISPOSAL SYSTEMS

Feasibility studies are being conducted to identify and evaluate alternatives for community wastewater disposal systems to serve areas with concentrations of developed properties that do not meet repair standards for continued use of conventional on-site disposal methods. Community disposal systems will be developed where they are found to be the most cost-effective alternative for protecting pubic health and water quality. Thusfar, six separate development areas within the watershed have been targeted for community wastewater feasibility studies.

MANAGEMENT OF WASTEWATER DISPOSAL FROM NEW DEVELOPMENT

Existing standards for new disposal systems which serve new development in the watershed will remain in effect, including a one-acre minimum lot size requirement for existing lots. Shallow disposal fields are now required and additional measures will be considered for reduction of nitrate discharge in primary groundwater recharge areas with highly permeable sandy soils. Any significant house remodeling or home additions will require an upgrade of the system to meet the repair standards. New development could be accommodated in the commercial town areas where community disposal systems are developed.

WATER QUALITY MONITORING AND EVALUATION

Water quality sampling efforts and special studies will continue in order to identify specific problems, monitor long-term water quality (primarily bacteria and nitrogen levels), evaluate impacts of wastewater disposal on water quality, investigate related water quality issues, and guide any necessary changes in programs or policies. The second half of this paper describes the special work effort that is being devoted to the study and control of nitrogen discharges in the watershed.

SCHEDULE FOR IMPLEMENTATION

The San Lorenzo Watershed Management Plan includes a schedule which provides for completion of the initial evaluation of all parcels by 1995. As a part of the initial evaluation, upgrades of failing disposal systems will be required, and the suitability for long-term use of on-site disposal methods will be evaluated for all systems in each area. If parcel evaluations and follow-up feasibility studies indicate a need for a community disposal system in a particular area, such facilities will be developed over a two to three-year period

following development of funding and completion of technical studies and designs.

PROGRAM ADMINISTRATION AND FINANCING

Implementation of this Management Plan has been supported by the formation of County Service Area No. 12 (CSA 12), a countywide service area created by the Santa Cruz County Board of Supervisors in 1989 to provide for improved management of wastewater disposal in unsewered areas. CSA 12 service charges are collected from all properties in the county that have septic systems. Charges were first collected in Fiscal Year 1990-91. The charges for 1993-94 are $6.22 per parcel per year, and fund the following activities:

- development of septic tank septage disposal facilities;
- development and maintenance of a computerized information system to track septic system performance and maintenance;
- use of new water quality monitoring equipment to evaluate impacts of wastewater disposal;
- development of educational programs and materials; and,
- other countywide programs for enhanced septic system management.

In response to the increased need for more comprehensive wastewater management in the San Lorenzo River Watershed, the Board of Supervisors also created a specific zone of benefit, Zone A, of CSA 12 which includes all properties on septic systems in the watershed. An additional annual fee ($13.80 per parcel in 1993-94) is collected to help pay for programs specific to the San Lorenzo River Watershed. This additional revenue has allowed considerable expansion of the management activities which were conducted from 1985 to 1990. These expanded activities are reflected in the Management Plan.

Beginning in 1993-94, an additional charge under CSA 12 is collected for those parcels served by nonstandard systems; i.e., alternative, nonconforming, and haul-away systems. This charge pays the costs of the County's monitoring efforts, which are needed to ensure that the systems are continuing to perform adequately. Annual charges are $75 for nonconforming systems, $150 for haul-away systems and alternative system repairs, and $471 for new alternative systems (mounds and pressure distribution systems).

It is expected that any development of community disposal facilities will be funded either through formation of additional individual zones of CSA 12 or new county service areas which would encompass each sewered area and provide for collection of annual charges for payment of the local share of capital costs and annual operation and maintenance costs.

NITRATE MANAGEMENT STUDY

BACKGROUND

Since the 1950s, nitrate levels in the San Lorenzo River have risen from below 0.1 mg-N/L to approximately 0.4 mg-N/L (SCCHSA, 1989). 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 cold water habitat, instream and streamside recreation, and water

supply. Since the late 1970s, the City of Santa Cruz Water Department has reported increased taste and odor problems in water drawn from the San Lorenzo River, and is now spending more than $60,000/year for additional chemical treatment to address these problems. The City has an additional concern that instream biological growth increases the level of organic compounds in the river and, in turn, the level of trihalomethanes (THMs) and other disinfection by-products in the treated water supply. Under current conditions the City may have difficulty meeting anticipated new drinking water standards for THMs.

In connection with overall watershed management activities, the California State Water Resources Control Board has provided Federal Clean Water Act funds to the County of Santa Cruz Environmental Health Service to conduct a study for improved management of nitrate in the San Lorenzo River Watershed. The approach and specific components of this Nitrate Management Study have included the following:

- Measure growth of algae and other biological activity in the river to determine the extent to which that activity is related to nitrate;
- Measure current nitrate levels in surface water, shallow groundwater and deep groundwater in critical areas of the watershed;
- Conduct field surveys to identify and quantify potential nitrate sources, including septic systems, fertilized areas, stables, etc.;
- Using monitoring results and information from other studies, develop a budget which quantifies the primary sources of nitrate in the watershed;
- Identify and evaluate potential nitrate control measures for the sources identified in the San Lorenzo Watershed; and,
- Based on the need to reduce and/or control nitrate, and the cost-effectiveness of potential control measures, develop a comprehensive nitrate management plan for the San Lorenzo River Watershed.

NITRATE BIOSTIMULATION STUDIES

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 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 Questa Engineering Corporation and County staff. 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 study included a review of literature and historical data, and field investigations at six locations along the middle and lower reaches of the San Lorenzo River. These stations represented a variety of field conditions, with mean nitrate concentrations varying from less than 0.1 to 0.35 mg-N/L. Biological, chemical, and physical parameters were measured six times between July and December 1990. The preliminary conclusions of the study are based on data collected in Phase I and historical data from earlier studies. Work is continuing in Phase 2 of the Nitrate Management Study. Work to date appears to indicate the following general findings.

- There are many different factors affecting algae growth, and the amount of algae in the river at different stations is not necessarily related directly to nitrate levels at those stations.

- Algae growth, actinomycete growth, and taste and odors occur at locations with very low nitrate levels, and reduction of nitrate throughout the river to comply with the numerical objectives established by the Regional Board may or may not result in a reduction in algae, actinomycete growth, or taste and odor in the City of Santa Cruz drinking water supply.

EVALUATION OF NITROGEN SOURCES

To aid in establishing priorities for nitrate control strategies, an identification and quantification of sources of nitrogen in the watershed was made based on: (1) water quality data from surface and ground water; (2) development of budgets of nitrate discharge in tributaries and reaches of the river; (3) field assessment and tabulation of land use which contribute nitrogen; and, (4) correlation of observed tributary nitrogen loads with respective land uses.

Water Quality Monitoring: Water quality data were collected and analyzed to augment historic data in order to: (a) measure the movement of nitrate and other nitrogen compounds from different geographic areas of the watershed; (b) measure nitrogen discharges from different land uses; (c) measure the transformations of nitrogen as it moves through the system; and, (d) provide data to support the investigations of biostimulation. New and historical data were 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 (typically May through October). 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 biological activity. 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.

Watershed Nitrogen Budget: Watershed nitrogen budgets were prepared for various sub-basins and reaches of the San Lorenzo River to help understand the water quality-land use relationships. Using historical nitrate data from 1975-1990 and measurements or estimates of mean annual runoff at different stations, estimates were developed of the total annual nitrate load at ten different sampling points in the watershed. This was further segregated into the summer and winter nitrate contribution. This analysis showed, for example, the middle and upper portions of the watershed (through Felton) which encompass most of the developed areas using septic systems, yield an average of 56 tons of nitrate-nitrogen per year, of which about 5 tons flow in the five months from May to September. The summer low flow period is the time of greatest interest for management purposes because of potential recreation and water supply impacts. The nitrate yield of the basin actually decreases downstream to 46 tons annually and 2.8 tons during the summer months as the river flows for six miles through Henry Cowell Redwoods State Park into the Santa Cruz city limits. This reduction is due to instream nitrogen removal in the reach downstream of Felton. The mechanism for nitrogen removal is believed to be dentrification in organic bottom sediments and, perhaps, some uptake by riparian and aquatic vegetation. This removal is found to be much diminished to nonexistent during winter months.

Identification of Nitrogen Sources: In order to relate the instream nitrate loads to specific land use activities and other sources in the watershed, field surveys were made to identify

and quantify all potentially significant sources of nitrogen release. These efforts focused on the sandy soil areas of the watershed and assessed the amount of nitrogen release from on-site wastewater disposal systems, fertilizer applications, livestock, and other potential sources in individual sub-basins. The estimates of nitrogen release for each source were tabulated for each sub-basin of interest and compared to observed water quality data to estimate the amount of nitrate released to the streams from each source. This information was then related to the watershed nitrate budget to calculate overall watershed contribution by source. Some of the key factors and assumptions and findings with respect to the major nitrogen sources were as follows.

- Septic Systems. The estimated amount of nitrogen contributed by each household was calculated assuming septic tank effluent concentration of 50 mg/l of total nitrogen, a flow of 70 gallons of wastewater per capita per day, and an average occupancy of 2.8 persons per household. It was further estimated that, in typical soils, 25% of the nitrogen from septic systems is removed in the upper soils layers by plant uptake or denitrification. In sandy soil areas it was assumed that only 15% of the nitrogen is removed and 85% percolates as nitrate to groundwater, which was found to be supported by groundwater monitoring data.

- Sewered Areas. Nitrogen release from the one sewered area of concern in the watershed, the 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. Also, the release of nitrate to deep percolation was assumed to be 90%, due to the discharge of nitrified effluent in a very concentrated 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 ' x 30' grass lawn, four 30' x 4' beds of shrubs and flowers, and one 10' x 4' 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 15% nitrogen fertilizer) twice per year. It was assumed garden areas had applications of one pound per square foot (0.0012 lb. of nitrogen with a 12% nitrogen fertilizer) twice per year. "Moderate" landscaping was generalized to consist of one 4' x 40' row of plants along the use and one 4' x 15' bed of plants, both receiving fertilizer applications of 0.0012 lb. nitrogen/sq. ft twice per year. Because fertilizer is applied on the ground surface, specifically to promote plant uptake, it was assumed that 30 to 50% of the applied nitrogen percolates to groundwater as nitrate in sandy soils of the watershed.

- Livestock. It was assumed that each horse or cow generates 175 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, because much of the nitrogen is in the urine, which readily percolates, it was assumed that 75% of the nitrogen produced in stable areas is released to the soil. In small ranchette areas, it was assumed that there is no manure removal, and that all nitrogen produced is released to the soil. Because nitrogen from livestock is released on the ground surface, there is potential for nitrogen removal through ammonia volatilization, vegetation uptake, and other factors. It was assumed that 25 to 50% of the nitrogen released may percolate as nitrate to groundwater, depending on soil conditions; the higher delivery rate was

assumed for very sandy soils.

- 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 of California (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 nitrogen loss to groundwater from this source was adjusted during the calibration process to obtain calculated groundwater nitrate concentrations similar to those observed in predominately undeveloped areas. The loss rate was estimated to be 10% in the loamy soil areas, and approximately 50% in the very sandy soil areas.

- Scotts Valley Plume. A significant source of nitrate exists in the heavily developed Scotts Valley sub-basin area and cannot be easily categorized by any particular land use type. The nitrate probably comes from a combination of past on-site sewage disposal practices from an area that was sewered in 1986, significant landscape fertilization, golf course fertilization, land disturbance, and historical agricultural activities. Nitrate concentrations is groundwater underlying the area averaged about 5 mg-N/L in spring 1991. This nitrate-rich groundwater contributes to the nitrate load of the San Lorenzo River and was evaluated as a single mass discharge, based on groundwater flow and water quality monitoring data.

Summary of Nitrogen Sources: The results from the individual sub-basin budgets were combined with the overall watershed budget to estimate the relative contribution from each 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 and added to comparable values from other sub-basins to determine the watershed nitrate contribution from each source. The results of this analysis are shown in **Table 1**, indicating septic system effluent to be responsible for about 55 to 60 percent of the nitrate load in the river during the summer months.

DEMONSTRATION PROJECT FOR NITROGEN CONTROL

Given the relative significance of septic system discharges determined from the nitrogen balance studies, the County of Santa Cruz contracted for design and installation of two nitrogen control systems (as demonstration projects) targeted at reducing nitrogen discharges from on-site sewage disposal systems. The systems are planned to be monitored for at least one year of operation to evaluate their effectiveness. From this information, a determination will be made regarding the extent to which these systems can be used throughout the watershed to reduce the nitrate problem.

On-site septic systems serve the vast majority of development in the watershed. Septic systems, especially in areas of sandy soils, contribute significantly to nitrate loading because of the high nitrogen content in sewage, and because relatively little nitrogen removal occurs in a typical septic tank-leachfield system. The most significant mechanism for nitrogen removal, denitrification, requires that nitrogen be in the nitrate (or nitrite) form, which does not typically occur until the septic tank effluent (with mainly ammonia and organic nitrogen forms) has migrated several feet into the soil below the leachfield. At this point, other requisite conditions for denitrifying bacteria are not ordinarily present (i.e., anaerobic environment, carbon source).

TABLE 1

ESTIMATED CONTRIBUTIONS BY SOURCE TO TOTAL SUMMER NITRATE LOAD IN THE LOWER SAN LORENZO RIVER

NITROGEN SOURCE	DRY SUMMER		NORMAL SUMMER	
	lbs. N	Percent	lbs. N	Percent
Septic Systems in sandy areas	3,420	38	7,000	38
Septic Systems in non-sandy areas	1,620	18	4,050	22
Sewer discharge from B.C. Country Club	1,800	20	2,000	11
Landscaping/fertilizer use	180	2	370	2
Livestock and stables	540	6	1,100	6
Natural sources in sandy areas	720	8	1,850	10
Natural sources in non-sandy areas	360	4	930	5
Scotts Valley nitrate plume	360	4	1,100	6
TOTAL	9,000	100	18,400	100

Reduction in nitrogen loading from septic systems must focus on altering the normal process described above at either the treatment stage (septic tank) or the disposal system (drainfield), or both. Modifications to drainfields for enhancement of nitrogen removal would be costly and complex; this would be the case for new installations, but even more so for the thousands of existing septic systems which are contributing to the present nitrate loading in the basin. However, significant reduction in nitrogen loading can also be achieved through modifications (or additions) to standard septic tank treatment, as evidenced from significant research literature in this area. Moreover, some of the modifications would be readily adaptable to existing installations (many of which are small and tightly constrained sites); and this is a significant issue to be considered in the overall effectiveness and practicality of a nitrogen control strategy for the San Lorenzo River Watershed.

The two nitrogen control systems developed by the County's consultant (Questa Engineering Corporation) were for: (1) a recirculating gravel filter; and, (2) an intermittent sand filter. Both filters were designed to make use of a standard 1,500-gallon septic tank as the containment vessel. The general criteria which guided these designs were as follows:

- The designs were to be prepared for convenient retrofit applications to existing septic systems, as well as for incorporation into new installations.

- The designs were to be for application with individual residential or small commercial septic systems, with average wastewater flows in the range of 200 to 250 gpd.

- The target range for nitrogen removal is 50 to 80 percent beyond that normally achieved by septic tanks.

- Access and recommended procedures for monitoring were incorporated in the

designs to allow for verification of nitrogen removal efficiency of the system.

Prospective demonstration sites were reviewed with County staff to identify sites that are typical of local conditions and do not contain unusual constraints. The key physical factors considered were: (1) equipment access to the existing septic system location; (2) condition and ease of access into the existing septic tank; (3) available yard area for the nitrogen control system; (4) adequacy of electrical service for pumps; and, (5) estimated wastewater flow for the site.

The two demonstration sites selected for installation of the nitrogen control systems were caretaker's residences on public lands in the watershed. System #1, the recirculating gravel filter, was installed as a retrofit to the existing septic system at the park ranger's residence at the City of Santa Cruz's Loch Lomond Reservoir. System #2, the intermittent sand filter, was installed on the septic system for the caretaker's residence at the County's Quail Hollow Ranch park. Both systems were installed by a local septic system contractor and the systems were put into operation in December 1993. Monitoring of system performance through the first three months of start-up operation showed total nitrogen removal in the range of 40 to 55 percent. Monitoring is planned to be continued through the end of 1994, when a final assessment will be made of demonstration system performance and their applicability to septic system repairs and new systems in the watershed.

Another possible approach to meet local nitrogen control needs is to promote denitrification within shallow leachfields - an established strategy, but one which is difficult to apply to deep sandy soils in an area with winter rainfall and a dry summer. Balance Hydrologics and County staff are monitoring nitrogen concentrations in percolate beneath the 12-foot deep-trench leachfields commonly used in local sandy soils, for comparison with concentrations measured beneath very shallow leachfields. Monitoring is based on an array of 27 pressure vacuum lysimeters in conjunction with standard soil and groundwater tests. The leachfields draw upon a single septic tank, with half of the effluent routed to each leachfield. Water use in the home and effluent quality prior to splitting are closely monitored. Study results are periodically released, reinforcing the County's goal of encouraging on-site system renovation through community education.

SUMMARY

The San Lorenzo Valley River Watershed in California is an example of a rural-recreation area on the fringe of a major population center where on-site sewage disposal practices have contributed to significant water quality and public health problems. Because of high costs and lack of public support for public sewers, the Santa Cruz County Health Department and the California Regional Water Quality Control Board have endeavored over the past ten years to develop a comprehensive wastewater management plan for the basin. The plan relies upon the continued use and maintenance of on-site systems, along with routine monitoring, special water quality studies, public education and application of improved technology and practices to address long-term sanitation, public health and nitrate management needs in the watershed.

REFERENCES

1. Hecht, B., White, C., and Flaschka, I, 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. Balance Hydrologics, Inc. report to Santa Cruz County Environmental Health Services.

2. Esmaili, H. and Hecht, B., 1978. Nonpoint Sources of Groundwater Pollution in Santa Cruz and Monterey Counties, California. HEA report to the Association of Monterey Bay Area Governments. Multipaged.

3. Johnson, N.M., Hecht, B., and Esmaili, H., 1982. San Lorenzo Valley On-Site Wastewater Disposal Management Study. HEA Report to Santa Cruz County Environmental Health Division.

4. 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.

5. Questa Engineering Corporation, January 31, 1994. Design Report for San Lorenzo Valley Nitrogen Control Demonstration Project, prepared for Santa Cruz County Environmental Health Services.

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

7. Ricker, J., 1979. Hydrology Technical Section, San Lorenzo River Watershed Management Plan. Santa Cruz County Planning Department Report.

8. White, C. and Hecht, B., 1994a. San Lorenzo River Nitrogen Control Demonstration Measures: Nitrogen Movement Below Deep and Shallow Leachfields in Sandy Soils, Glen Arbor Area, Santa Cruz County. Balance Hydrologics report to Santa Cruz County Environmental Health Service.