1992

MALIBU WASTEWATER MANAGEMENT STUDY

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PREPARED FOR THE CITY OF MALIBU

recycled paper

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March 11, 1992

#778

Dear City of Malibu:

Enclosed is Peter Warshall and Associates' and Philip Williams and Associates' report "Malibu Wastewater Management: A Human Ecology of the New City." This report completes the July 19, 1991 "Agreement for Planning and Engineering Evaluation Consulting Services" with the City of Malibu.

The report is, as requested, an evaluation of the existing conditions of wastewater management within Malibu and a planning document for the City of Malibu's future. The heart of the report is the home-site survey in which many citizens kindly provided us with detailed understanding of their septic tank system and allowed us to snoop around their properties investigating their soils and system function. We would like to thank the City and its citizens for helping us in our work during our four month residency at Peter Warshall and Associates' Malibu Field Station.

We have written the report for the citizens of Malibu as well as for the City Council and local, state and federal agencies. We have tried to keep our writing simple and, whenever possible, non-technical. As the first major planning document produced for the city, we felt the report should be engaging as well as informative and utilitarian.

Thank you.

Peter Warshall
PEWARA

Philip Williams
PWA

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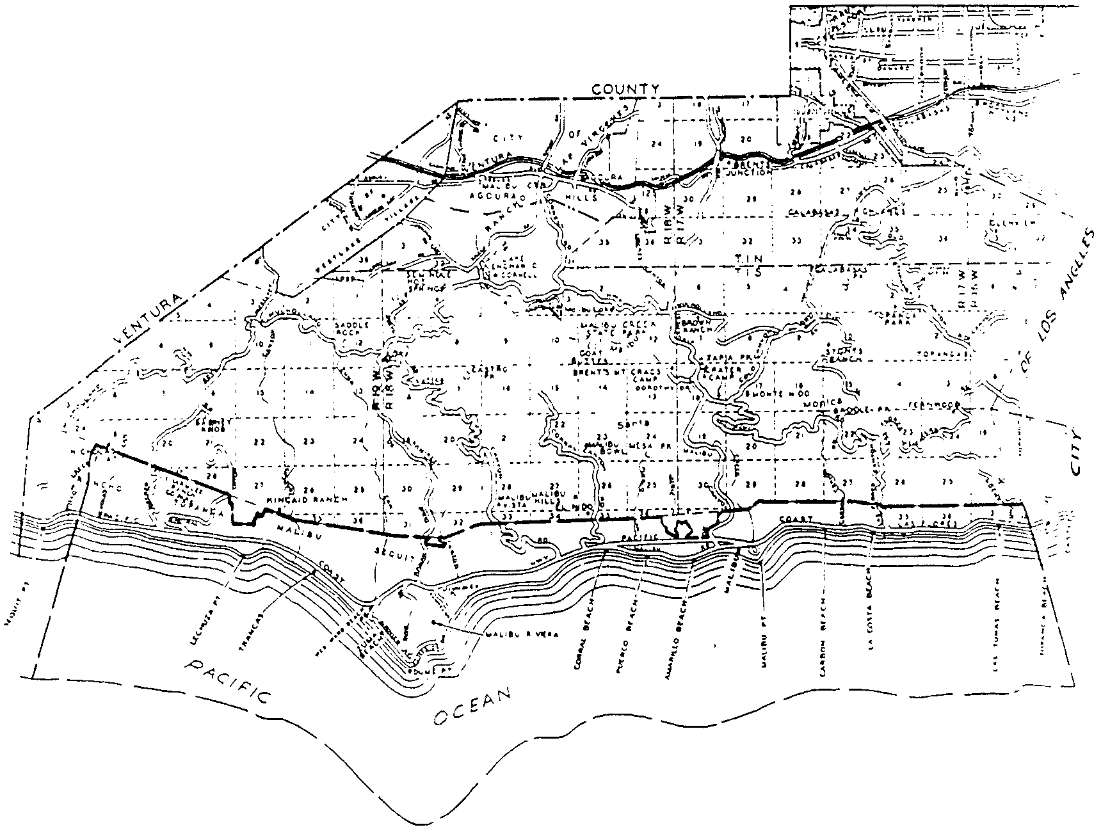
MALIBU WASTEWATER MANAGEMENT STUDY

A Human Ecology of the New City



PREPARED FOR THE CITY OF MALIBU MARCH 1992

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Executive Summary

Malibu has been struggling with wastewater management for over 30 years. Philip Williams and Associates (PWA) and Peter Warshall and Associates (PEWARA) were contracted by the City of Malibu (COM) to research and write a plan for the city's three aspects of wastewater management: existing on-site wastewater systems, package plants, and nonpoint sources of potential pollution. The plan includes policy and administrative recommendations. In addition, PEWARA was asked to resolve certain disputed issues relating to an asserted critical need for an areawide sewer system. These assertions primarily concerned a health hazard risk from septic tank effluent along the coastline, an increase in instability of various hillslopes from the discharge of septic tank effluent, and an abnormally high percentage of "functional failures" as determined by the Los Angeles County Department of Health (DOH). The final wastewater plan adopted by the COM will be formulated following hearings based on this report. Some of the hearing's findings must be accepted by various state agencies (e.g., Coastal Commission) for the city to implement the adopted plan.

The Inventory of Previous Studies

In order to write wastewater guidelines, the previous investigations of watersheds, climate, geology (as it relates to on-site sewage systems), groundwater, soils, coastline, population, parcel sizes, on-site wastewater systems, and water usage have been inventoried. There are about 4,200 use and part-time use parcels with on-site wastewater systems in Malibu and probably about 4,000 on-site systems. Approximately 960 homes are connected to local package plants. There are 3,800 single family residences, 1,018 multiplexes (including apartments and condominiums), and 140 commercial and institutional parcels that have on-site systems (Chapter II). Malibu does not have an easily defined generation of wastewater because of the wide variety of uses (weekend, year-round, seasonal) and household sizes, peak flows from summer visitors and "party homes," and wide variations in effluent strength among commercial on-site systems.

The elongated **shape** of the COM impacts the costs of trucking pumped septage, the cost and design of conveyance lines, and the time necessary to repair power outages and water or sewer line breaks. There are over 60 watersheds within the city's boundaries, 22 of which extend inland of the city's north boundary and will require joint-powers agreements with upstream residents and agencies in order to control nonpoint water quality reaching the coast. Zuma Creek and Malibu Creek floodplains and wetlands have been designated for possible restoration and integration into constructed wetland treatment systems.

The **climate** of Malibu has an important impact on on-site wastewater management. The maritime climate allows for year-round evapotranspiration (ET) -- ranging from 2 to 7 inches per month. Consecutive years of above normal rainfall have been the major events associated with landslides. Various storms increase the frequency of power outages and line breakages as well as damage to coastline on-site systems. Various gaps in climatic information are discussed and recommendations for further studies indicated (Chapter II).

The **geology and groundwater hydrology** of Malibu is complex. This complexity prevents broad generalizations regarding the fate of effluent following disposal and requires individual parcel site evaluation (and more costly fieldwork) to ensure proper treatment, reuse and disposal. From the literature, DOH files, and field reviews, particular concerns with deep seepage pits on inland sites became apparent. In transmissive bedrock, seepage pit sizing for disposal has not been based on verifiable techniques. Some additional treatment occurs within the fractured and/or transmissive bedrock because some geological formations "de-lithify" or slake (i.e., return to a soil-like condition with the application of effluent). In some areas, the inland use of deep seepage pits has increased the potential for effluent discharge to shear zones of slide masses. A review of the data on "piping" and "daylighting" of treated effluent revealed no areawide problem. One or two unverified local problems need re-testing and can be mitigated with proper on-site design.

The soils of the city are equally complex. The scale of existing soil maps does not allow their use for drainfield design (Chapter II). A review of DOH files revealed that site evaluation for on-site systems had not provided written descriptions of porosity and soil structure of the "soil" layers that sit on top of bedrock. Percolation tests have been performed but in a manner unique to Los Angeles County and not verified for their accuracy. The "shallow trench pump in" test required for larger flows is unknown in Malibu. The long-term acceptance rate test for transmissive or fractured bedrock is not acceptable by contemporary standards (Chapter XI).

The incorporation of soils into wastewater reuse has only been described for spray irrigation and even this description was based on modelling, not long-term fieldwork. The use of soils for near surface subirrigation requires site-by-site evaluation due to the lack of previous studies. There are no design standards for the placement of drainfields in artificial soils or engineered fill. There are locations exhibiting soil creep, settling and mass movement. These soil deformations can shear or bend long conveyance lines and need careful consideration in design and repair costs of subarea sewage systems.

In summary, the data on perched water tables, impermeable soils, thin soils, piping, floodplain hydrology and "interaction failures" (the asserted impact of combined effluents from many on-site systems saturating a soil and daylighting) have not been mapped, collated, or summarized by DOH or any other agency. At best, the information is anecdotal. No areawide mapping of any of these constraints or specified localities with documented evidence could be found in previous investigations.

Plants are important to Malibu on-site wastewater management. They turn "wastewater" into a resource for plant growth and save on irrigation water and costs. There are no studies on the choice of the best plants for wastewater reuse (i.e., efficiency of ET for various species, relative water use for shrubs/trees/grasses/native species, evergreen vs. deciduous, root depth, wetland species). The reuse of wastewater could save 60% of *outdoor* usage (indoor flow reductions savings are additive). On landslide masses, this savings prevents deep percolation into the slide mass and is more cost-effective than off-site sewering.

Non-human animal species are a wastewater concern in Malibu Lagoon. In addition to health standards, the water quality standards set for the lower creek and lagoon depend on the species of biological interest (e.g., steelhead or jacknife clam). Previous investigations on nutrients and salinity have not designated what species and habitats should set the monthly receiving water standard (Chapter VIII).

The Malibu Coastline

The Malibu coastline is approximately 25 miles long with a variety of beach types ranging from cliffs to cobbles to sand to landslide debris. The Malibu coastline is important to wastewater management because of (1) the asserted health risk associated with beachfront on-site systems; (2) the asserted health risk associated with storm damage; and (3) the combined influences of watershed development, coastal armoring by sea walls and bulkheads, coastal drift, and on-shore/off-shore sand movement on beach profiles. It has been asserted that sand starved beaches may contribute to a greater health risk than sand rich beaches because of a potential shorter detention time of treated effluent within the sand (Chapter IV). In addition, it has been asserted that the frequency of higher sea levels harms the treatment (decay rate) of potential pathogens.

Chapter IV reviews DOH material and existing literature on beachfront systems on both coasts. DOH assertions about a **health hazard** and critical need for off-site sewers are not supported by the evidence. A risk analysis of potential health hazards by degree of treatment, exposure, and contagion showed that water quality in the surfzone met recreational standards and that the most reliable studies to determine health risks had not been performed. Only the weakest studies had been performed, and the data for those studies had neither been reliably collected nor appropriately analyzed. An oversimplified model by DOH of the relation of tidal surges to treatment by dilution, dispersion, pathogen die-off rates, and exposure possibilities is replaced in this report by a more complete understanding of what occurs to the concentrations of potential pathogens between the drainfield and possible emergence in the surf zone.

The impacts of **storm damage** on health are not documented. There are no reliable water quality data and no epidemiological data to document an increased health risk. The life span of drainfields damaged by storms is about 18 years, just two years less than the federal standard used by DOH. No drainfields with recently constructed bulkheads have been damaged. Interviewed homeowners vociferously challenged the asserted claim of damage to some on-site systems and claimed that DOH confused damage to protective barriers with damage to the septic tank system. DOH is in partial agreement with home-owner claims. There were no records kept of the extent of damage. An emergency preparedness program is proposed for heavy storm situations.

Effluent and Landslides

Approximately 250 landslides have been mapped in the COM. The 15 largest landslides contain 350 homes, although not all of these homes can be considered endangered by earth movement. There are about 285 homes adjacent to these slide areas that could possibly become endangered by movement of the slide mass.

Chapters III and IX review **the importance of septic tank effluent** to various landslide masses. The Los Angeles County Department of Public Works (DPW) and others have asserted that effluent significantly raises the water level and submerses the shear zone(s) of slide masses, decreasing their stability. Earlier statements had been based on a gross oversimplification of the causes of landslides with little understanding of the ambiguous nature of the safety factor and the limitations of fieldwork and testing methods. These chapters attempt to compare effluent recharge with irrigation recharge, natural groundwater inputs, surface runoff infiltration, and other sources of groundwater in order to determine the relative importance of effluent. Besides groundwater levels, 15 other factors contributing to landslide movement are "red flagged." On particular slides, addressing concerns other than groundwater may be of primary importance (e.g., Rambla Pacifico). In almost every instance, above normal rainfall and infiltration to the slide mass occurred over consecutive years before the initiation of landslide movement.

In conclusion, alternatives to off-site sewers are presented. These include neighborhood wastewater flow reductions by indoor water conservation (a 10 to 40% decrease in wastewater), a re-design of on-site systems to dispose of effluent by ET (not deep percolation) with an additional 60% reduction of effluent and irrigation recharge, and a surface runoff management program. These less costly technical interventions remove the necessity for off-site sewers. Dewatering as a method to intercept all forms of recharge (rain, runoff, leaks, irrigation, and effluent) is preferred because of the non-uniform flow of subsurface water and the inability to determine precisely the contributions from artificial recharge. An analysis of the major slides shows that off-site sewering would have minimal to no impact on the safety factor. (The Big Rock report by Bing Yen was not available at the time of this report's publication.) Chapters IX and XI discuss the hazards of long conveyance lines in areas of earth movement.

The On-Site Survey

Chapter VI describes the on-site survey conducted by PEWARA of 203 addresses and 242 systems (about 5 to 6% of Malibu's systems). The survey was city-wide, consisting of a sample from (1) volunteers selected to represent a variety of environmental situations, commercials, multiplexes, and single family residences, and (2) a sample of homes visited as part of the DOH 1988 study and found by DOH to be "functional failures". Volunteers with problem systems were chosen over volunteers with working systems. These two samples of predominantly problem volunteers and DOH functional failures biased the results toward a "worst case" situation.

PEWARA found 11% of the on-site systems sampled to be marginal or to have problems requiring immediate attention. This is typical for older communities with systems of varying ages, built under varying codes, by various contractors, and with various amounts of use or abuse. Other similar communities have a 15 to 20% annual repair rate

DOH claims regarding the rate of "functional failures" over the last 20 years could not be verified. Only 22% of the homes re-visited fit the DOH definition of functional failure without dispute. 37% did not meet DOH's own criteria, apparently because the collators of the information misunderstood the criteria of the project director. 13% were disputed by home-owners. 29% had insufficient information in DOH files or from homeowners to confirm surfacing effluent or chronic system back-up into the home. The 1988 DOH study cannot be used to judge the comparative success or failure of on-site systems in Malibu.

The PEWARA survey revealed the following:

All systems: The average septic tank was 1,000 gallons -- an adequate size for most single family residences. Occasional older homes had 750 gallon tanks which should be upgraded in remodeling or replacement. Maintenance did not include pumping the second chamber of the septic tank. This practice may have led to increased pumping rates of the first chamber, movement of suspended solids and increased biological oxygen demand (BOD) into the drainfield, and shorter drainfield life spans. The average drainfield size was adequate for single family residences (SFRs) but strong standard deviations in drainfield size indicated that some had inadequate infiltrative surface. Drainfield age was above the federal norm of 20 years. Depending on location, drainfield age varied from 23 to 25 years before replacement, with large standard deviations. The technology to reduce odors and nuisance flies, although employed in other areas for over 20 years was unknown in Malibu.

Beachfront homes: Drainfields were not uniformly in sand. Some were in engineered fill and others in slide debris. The septic tank and drainfield had diverse locations with some on the street side of homes, some on the ocean side on the drainfield and a few within the footprint of the home. "Sand creep" into the drainfield gravel was a common problem, reducing the effectiveness of treatment. 77% of the homes surveyed already had bulkheads and 12% had "inland" systems. In other words, 89% of the on-site systems were protected from most major storms. 8% of the homes had greywater systems. Some of the older drainfields and septic tanks were undersized and needed upgrading. Newer systems met reasonable engineering standards. Many parcels had not used their "reserve area." A reserve area is unnecessary along the coast as repairs and replacements of drainfields removed the whole drainfield and replaced it with engineered fill. Equipment paths were a problem in some areas (e.g., Malibu Colony). In these areas, on-site systems should be designed for the longest possible life span.

Inland: 90% of the systems were seepage pits from 10 to 60 feet deep. The design was somewhat dangerous and technically unsound with a hollow vs. gravel-filled excavation. The seepage pits were not designed with a knowledge of uniform flow technology nor with adequate site evaluation. About 30% of the homes had greywater systems, primarily for supplemental irrigation during the drought.

Multiplex systems: A small number of multiplex systems were surveyed. The age of the drainfields decreased as the number of units increased (e.g., apartment drainfields had half the life span of duplexes). In cases of marginal systems, poor design appeared to be common.

Commercial on-site systems: There were more marginal and problem systems here than in any other group. These systems suffered most from poor design, poor site evaluation, lack of consideration of effluent strength and loading rates, peak flows, non-uniform flow distribution, soil aeration, surface runoff and groundwater movement. Some condominiums and other commercial clusters used cartage of effluent to survive. Typical of other communities, restaurants had the shortest-lived drainfields. Many drainfields were under pavement and many had odors with no mitigating design features. Poor maintenance schedules were common. Of all the situations encountered, the commercial systems on smaller parcels and the poorly designed condominiums were in greatest need of improved design, installation and maintenance.

The most important report recommendation is the improvement of on-site design, installation, maintenance, and site evaluation. Malibu has been living with design regulations that are technically indefensible and work contrary to long-term functioning of on-site systems (Chapter V). Poor design is the major cause of shortened on-site system life spans. In some cases, design features were 20 to 30 years out-of-date. Chapter XI provides custom-design strategies for (1) landslides areas, (2) new and remodelled single family residences on the beach and inland, (3) commercial on-site systems, and (4) multiplexes. These include three levels of wastewater loading rate reduction (indoor flow reduction, greywater reuse, and combined wastewater reuse), reduction of effluent strength by intermittent sand filters, increased soil aeration and uniform flow distribution by dosing and, if necessary, groundwater diversion by interceptor or curtain drains. Various kinds of custom-designed drainfields are recommended for the multitude of environmental situations encountered in Malibu.

Subarea Results of Survey

Malibu is in a state of transition. It is writing new zoning laws, absorbing the results of many studies, and determining a future based on areawide vs. subarea vs. on-site sewering. PEWARA found no beach or inland sites that required off-site sewering. But, in some cases, future housing and "vertical" development might stress existing drainfield capacities. PEWARA was asked to look only at existing conditions.

Chapter IX reviews subareas where homeowners have expressed an interest in off-site sewers or where we felt it was reasonable to consider such an option. The two most difficult situations encountered were condominiums that have ruined their disposal areas with no other land for new disposal areas (the Point Dume Highlands), and commercial establishments on small parcels which may require replacement of the existing drainfield with imported bed material (the northside of Pacific Coast Highway). The subareas analyzed with various options presented include: the Civic Center, Paradise Cove, the Point Dume Highlands, the major landslide areas with significant housing, the east end of Pacific Coast Highway (PCH), Malibu Road and Malibu Colony, and the northside commercials along PCH.

Four options for the **Civic Center area** are presented. Three employ constructed wetlands as part of the treatment and multiple use design (e.g., restoration of steelhead runs, linear parks, wetland restoration). Special strategies for **landslide areas** include shallow drainfields, reuse of effluent and greywater for subirrigation, surface runoff management, dewatering of all sources of groundwater, and indoor water conservation. Decentralized alternatives for specific subareas include neighborhood systems, acquisition of neighborhood reserve areas for future drainfields, a small volume treatment facility such as a recirculating gravel filter, connection to existing package plants, and integrated actions by neighborhoods such as water conservation to lower groundwater levels within a slide mass.

Package Plants

There are five package plants in Malibu. Trancas, Latigo Bay Shores, and Maison de Ville dispose of treated effluent by subsurface disposal. Malibu Mesa and Point Dume use spray irrigation. Although there have been no serious water quality violations and the plants appear to be well run, some of the plant's parts show corrosion and are near the end of their service life. In most cases, the property on which the wastewater treatment plant is located is more valuable than the plant itself. In addition, the value of the site is most important as an accepted location for a treatment facility. The COM needs to better understand ownerships and leased lands as well as jurisdictional authority over the package plants. Most of the package plants appear to have additional capacity but the state of the subsurface drainfields must be evaluated before any additional expansion is contemplated.

Nonpoint Sources

Malibu has 62 watersheds, 22 of which extend beyond the city limits. The nonpoint concerns are the sand budget for Malibu beaches; first flush pollution that carries surface runoff to creeks; and the nutrients, potential pathogens and salinity of lower Malibu Creek and Lagoon. Chapter VIII provides a model for increased nonpoint changes in water quality for in-city areas of Malibu. It also describes the nutrient budget of Malibu Creek, showing that Tapia is the major source of nutrient. Malibu Colony generates negligible nitrogen contributions to the Lagoon. A study of algal blooms, lagoon circulation patterns and nutrients is needed. The greatest need, however, is to determine seasonal water quality standards for the receiving waters for Malibu Creek and Lagoon.

The potential health risk in Malibu Lagoon has not been documented. Future studies should concentrate on tracing the sources of potential bacterial or viral pathogens and not general water sampling which will always contain high background levels of indicator organisms from birds, fish, and mammals. Water quality studies should focus on the breaching of the sand bar and stormdrains. Given hydraulic characteristics of the

Lagoon and the soil textures of Malibu Colony, adjacent to the Lagoon, these on-site systems do not appear to be a source of potential pathogens.

Future work on "pocket wetlands" for surface runoff treatment, the formation of watershed groups and joint-powers agreements to manage both in-city and extra-limital sources of nonpoint pollution, and an ordinance and educational pamphlets for storm water runoff control are necessary.

Future Administration and Policy Decisions for Wastewater Management

The COM has extensive powers under municipal law to regulate on-site, nonpoint, and centralized wastewater treatment. Chapter X recommends a **new department** of Environmental Management and Consumer Protection to integrate the various aspects of permit procedures and transform wastewater management from the previous "punitive-authoritative" style to a more "consultative-democratic" approach. The consultative-democratic approach will emphasize departmental extension service capacities with instructional pamphlets and manuals, an easy licensing program for simple greywater systems, coordination with neighborhood (watershed) groups, custom-designing for long-term and sustainable systems, and preventative conflict resolution vs. post-crisis lawsuits.

There are **two phases of development of policy and administrative organization for the new city:** the start-up phase (about two years) and the long-term management phase. The COM start-up requires: writing regulatory ordinances for water conservation, greywater use, and on-site wastewater management. These ordinances include a manual for site evaluation, geotechnical coordination with landslide concerns, design regulations, permits, licenses for simple greywater systems, and procedural guidelines. In addition, a computerized data base and a code of ethics for pumping are recommended. Access to the second chamber of septic tanks by the installation of risers is the most immediate city-wide technological intervention required.

In order to improve accountability in design and to educate the new staff of the COM, a two-year **peer review process** is recommended. The peer review will cross-check plans, soil evaluations, and installation; ensure that the designers understand and custom-design for the "red flags" (environmental constraints), as well as supply explicit justification for their design. It is recommended that the designers (civil engineers, soil engineers, sanitarians, et al) be **certified for practice within the COM.** There appear to be no designers with experience in intermittent sand filters in southern California. Other long-term concerns such as the licensing for daily cartage of effluent and unresolved questions such as the relation of the new COM to state agencies are discussed.

Many residences with marginal or problem on-site systems and many commercial enterprises wanting to upgrade, renovate or build are waiting for a clear direction on sewage management. They do not want to have to pay twice: for an upgrade on their on-site system and then again for a collector sewer. **The future of the Malibu Sewer Assessment District** and its finances are in crucial need of definition in 1992 so that the COM may implement its on-site wastewater management. Chapter XI gives costs for on-site systems. The COM can levy fees, charge for licenses, increase taxes by a very small amount, or form special assessment districts. The major question of **revenues** for the on-site section of the new department remains unresolved.

Chapter XII summarizes demonstration projects and further studies as well as findings of the report.

Performance of a Constructed Wetlands in Treating Urban Stormwater Runoff

James N. Carleton, Thomas J. Grizzard, Adil N. Godrej, Harold E. Post, Les Lampe, Pamela P. Kenel

ABSTRACT: An investigation was conducted on the pollutant removal performance of a constructed wetlands treating stormwater runoff from a residential townhome complex in northern Virginia. Constituent event mean concentrations for 33 runoff events between April 1996 and May 1997 were measured based on flow-weighted composite samples collected at the facility's inlet and outlet. With the results from a limited number of grab samples representing ungauged overland drainage from an adjacent wooded area, estimated removals were positive for most constituents and typically exceeded those obtained at a nearby companion wetland study site, consistent with expectations based on the relative ratios of wetland area to drainage area at the two sites. Median load removals of all constituents were greater for a subset of 22 storms that had inflow volumes less than the maximum volume of the marsh. Orthophosphate phosphorus and ammonia removals were significantly better during spring of 1996 than spring of 1997. Lysimeter data suggest a possible explanation for this, which is development of anaerobic conditions in the shallow sediments in 1997. Outlet concentrations of oxidized nitrogen were consistently lower in base flow than in storm samples, suggesting that removal of this constituent occurred primarily between, rather than during, storm events. *Water Environ. Res.*, **72**, 295 (2000).

KEYWORDS: urban runoff, nonpoint source pollution, constructed wetlands

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Introduction

Natural wetlands are transitional ecosystems that exist at the interface between aquatic and terrestrial systems. Because of their position in the landscape, they are frequently the default recipients of stormwater runoff, including that which drains agricultural lands and urban developments. Numerous investigations in different regions of the country (Strecker et al., 1992) have demonstrated that various wetland types can act as sinks or transformers of nutrients and other constituents of stormwater runoff (Mitsch et al., 1989). However, wetlands can also be degraded by nonpoint source pollution. Construction of wetlands designed specifically as best management practices (BMPs) for treatment of stormwater runoff is attractive in part because natural wetlands need not be affected. Previous authors, after reviewing the literature, have concluded that constructed wetlands typically performed slightly better and with less variability than natural wetlands at removing various constituents (Strecker et al., 1992). However, although constructed wetlands have become established methods of secondary wastewater treatment, their applicability for treatment of stormwater runoff has been less extensively studied (Kadlec and Knight, 1996).

In a companion study to this one, a constructed urban marsh, referred to herein as "Franklin Farms," was established in a former dry detention basin receiving drainage from a 16.1 ha subdivision in Chantilly, Virginia (OWML, 1990). Pond area at full pool was 0.13 ha or 0.8% of the total drainage area. Although total constituent load removals for the entire set of 23 storms were disappointing (−8.2 to 15% for nutrients), performance (>59% for nutrients) was found to be substantially better for a subset of storms with volumes less than the capacity of the marsh. The authors concluded that the facility was undersized with respect to its drainage area.

The site in the present study, referred to herein as the "Crestwood" wetlands, drained a townhome complex near Route 234 in Manassas, Virginia, approximately 50 km (30 mile) from Washington, D.C. Before modification, the facility was a dry detention basin containing numerous wetland plants growing in the wet zone along a well-defined flow channel. The basin was equipped with a single stormsewer inlet, which transported runoff from an estimated 1.3 ha drainage area within the townhouse complex. An additional 1.6 ha of wooded and grassy land is immediately upland of the pond on one side (Figure 1) and serves to separate the complex from a working stone quarry nearby. At full pool, the area of the pond is approximately 0.07 ha or 2% of the total drainage area. Although details of the initial construction of the detention pond were not available, the facility is thought to be underlain by an impermeable clay or compressed earth layer. The primary purpose of the present study was to examine the pollutant removal performance at the Crestwood wetlands using a mass balance approach and investigate any seasonal trends in removal efficiencies. Based on its greater area relative to drainage area, it was hypothesized that long-term removal efficiencies at Crestwood would exceed those at Franklin Farms.

Methods and Materials

Crestwood Site Retrofit. Before its conversion to a wetlands, the detention basin had been completely surveyed (Figure 2). In December 1995, the detention basin was modified with the addition of a 0.46-m (1.5-ft) weir (referenced to the invert of the original outlet structure) at the outlet. A 31.8-mm- (1.25-in.-) diam orifice was installed in the weir to impound a pool of water at a depth of 0.15 m (0.5 ft) at the riser, creating 8.58 m^3 (303 ft^3) of permanent storage below the orifice, with an additional 124.5 m^3 (4397 ft^3) of extended detention storage above, for a total of 10 mm (0.4 in.) of storage distributed over the gauged drainage area. The orifice was sized to drain the pool from the top of the weir to the orifice invert in 24 hours.

Station Equipment. Automatic flow gauging–sampling stations were located at the inlet (WE20) and outlet (WE10) of the facility inside fiberglass utility sheds. Inlet and outlet flow passed through Palmer–Bowlus flumes (which had an outlet diameter of 381 mm) to allow flow measurements. At each station, a submerged Keller-PSI Model 200S (Hampton, Virginia) pressure transducer inside the flume fed signals to a computer through a modem port. The

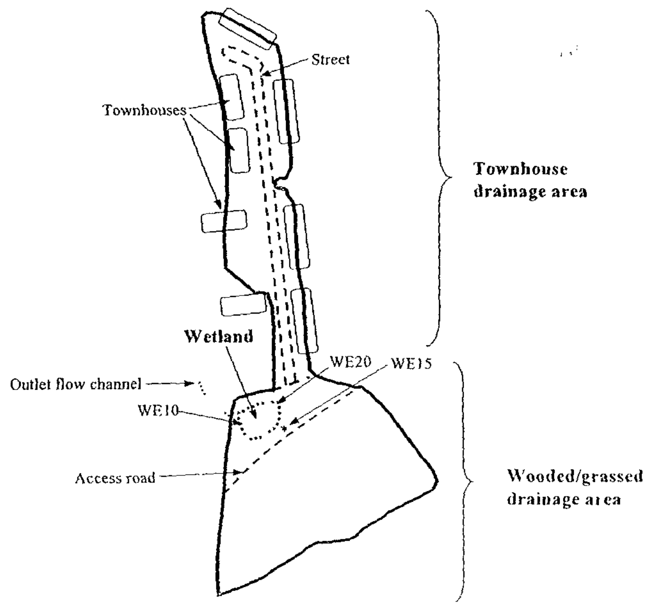


Figure 1—Relative locations of wetland and drainage area features.

computer converted the signal to a stage reading, then calculated the associated discharge from the stage and a rating curve stored in memory. An increase in stage of 0.006 m (0.02 ft) or more during a 5-minute interval triggered a mode in which 200-mL samples were collected at set increments of cumulative flow. Sampling continued until the hydrograph declined either to zero flow (WE20) or to base flow (WE10). Samples were automatically combined, yielding flow-weighted composites from which event mean concentrations (EMCs) for each storm were estimated. Base flow monitoring was performed by collecting grab samples from the pool near the outlet on a weekly-to-biweekly basis.

Overland Runoff Grab Samples. Volume measurements of the first several storm events during the study showed substantial discrepancies between inlet and outlet flow volumes, with the outlet volumes typically being somewhat higher. Tests were therefore conducted on two occasions (November 6, 1996, and March 28, 1997) to verify the accuracy of the flow readings. The procedure involved opening a metered hydrant within the townhome parking lot to deliver known volumes of water at known flow rates to the basin for comparison with the flows and volumes estimated by the equipment. These experiments confirmed that the observed discrepancies were not the result of equipment malfunction, gross miscalibration, or flume rating curve inaccuracies.

Periodically during and following rainfall events, a substantial amount of water was observed to be flowing overland into the facility from the grassy–wooded area adjacent to the pond. Calculations suggested that this extra input might account for the greater flow volumes appearing at the Facility outlet. A portion of this runoff flowed through a 150-mm- (6-in.-) diam polyvinyl chloride (PVC) drainage pipe located outside the perimeter fence of the site. The pipe drained a small depression adjacent to a dirt access road, which was located between the facility and the wooded area. On three occasions, during runoff events, grab samples were collected directly from the PVC drainage pipe (WE15) to characterize the chemical nature of the overland input. For comparative purposes, an additional three samples were also collected during runoff events in 1998.

Soil-Pore Water Monitoring. Three soil-water lysimeters were installed at the facility to allow infiltrating and percolating pore water to be sampled. Lysimeters were constructed from 1.5-m (5-ft) lengths of 64-mm- (2.5-in.-) diam PVC pipe (OWML, 1990). Lysimeter installation entailed excavating a 0.9-m (3-ft) hole in the soil and inserting the lysimeter. The hole was then backfilled and tightly packed with soil to prevent downward leakage of surface water. Two lysimeters (WE50, WE60) were installed within the area of the permanent pool near the outlet of the pond, at depths of 0.15 and 0.3 m (0.5 and 1.0 ft) below the bottom of the pool (reference datum was 0 m above the original outlet invert), respectively. The third lysimeter (WE70) was installed above the permanent pool level in one of the banks of the basin (reference datum was 0.76 m [2.5 ft] above the original outlet invert) to a depth of 0.46 m (1.5 ft) below the ground level. Lysimeter samples were collected concurrently with base flow samples, unless a storm was in progress. Approximately 24 hours before sample collection, the lysimeters were charged by placing a vacuum of approximately 18 mm Hg on them using a hand-held pump. Samples were retrieved by ejecting them under positive pressure using a hand-held pump.

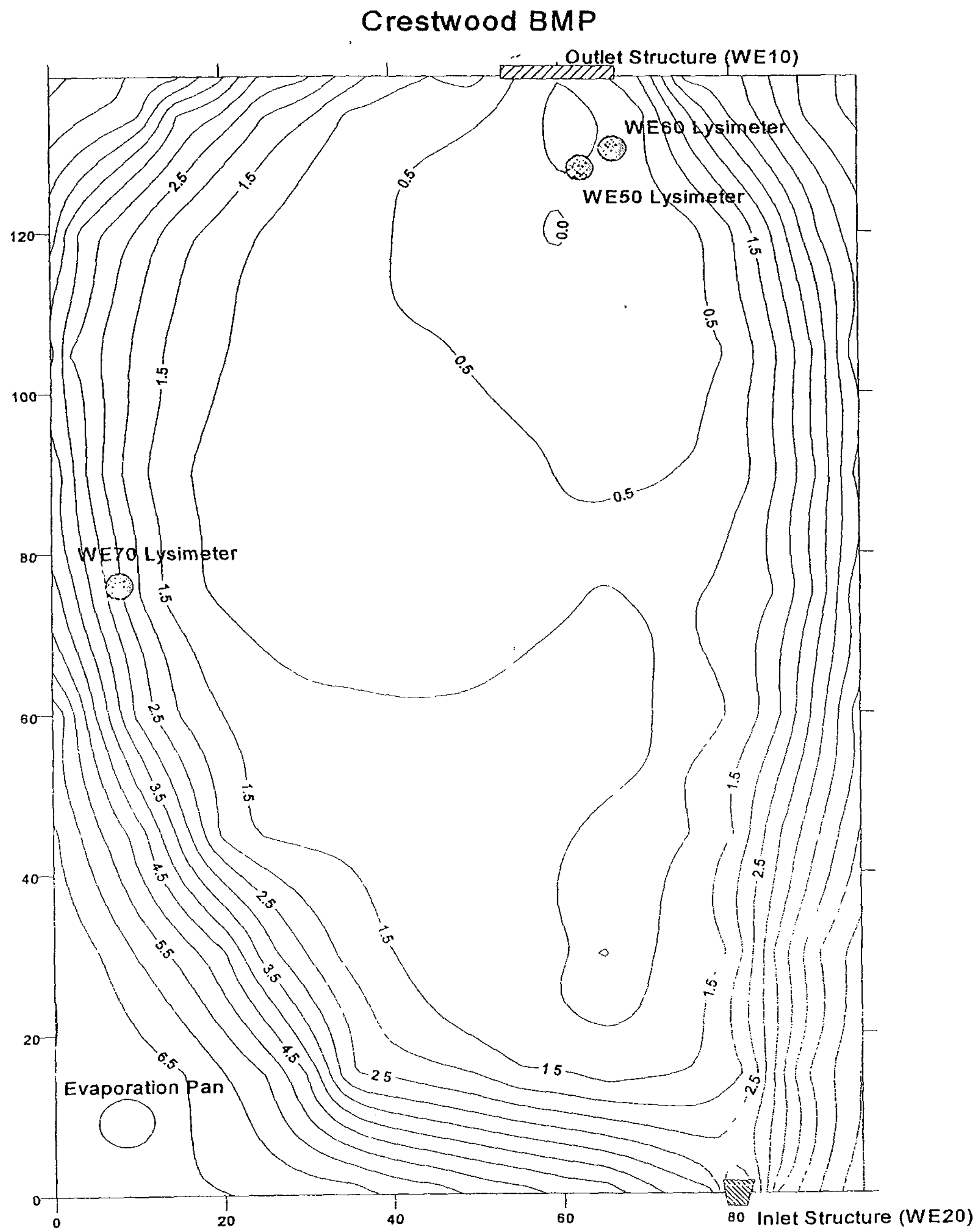
Precipitation Measurements. A tipping-bucket rain gauge (Weather Measure Corporation [Sacramento, California], Model P501) was situated on top of the inlet instrumentation shed at the site. At 0.25 mm (0.01 in.) increments of rainfall, the bucket would become full and tip, thereby triggering a contact closure signal that was relayed to a solid-state totalizing rainfall recorder mounted in the equipment shelter. The recorder accumulated a count of the bucket tips and recorded incremental rainfall as a function of time.

A wet–dry precipitation collector (Aerochem Metrics [Bushnell, Florida] Model 301), located on-site within the perimeter fence and 1.5 m above the ground, was used to collect atmospheric deposition samples. The collector included separate vessels for wetfall (WE40) and dryfall (WE30) samples. Wetfall samples were manually collected following rainfall events. Dryfall vessels were collected after approximately 2 weeks of exposure. Sample buckets were transported to and from the field with the lids on and taped down.

In the laboratory, wetfall volumes in the bucket were measured and recorded along with the pH of the sample. Samples were mixed as needed before transfer to sample bottles for analysis. Dryfall samples were prepared by the removal of gross contamination such as bird droppings or leaves, before 200 mL of reagent grade water was added to the bucket. After rubbing down the sides of the bucket with a rubber-edged scraper, samples were transferred to 250-mL volumetric flasks and diluted to the mark with Milli-Q (Millipore Corporation, Bedford, Massachusetts) water.

Sample Handling and Analysis. Between uses in the field, sample bottles were cleaned with phosphorus-free detergent in hot tap water, then a 15-minute soak in 50% hydrochloric acid, followed by three rinses with tap water and two rinses with Milli-Q (deionized) water. Samples were transported in iced coolers. On receipt at the laboratory, each sample was given a unique identification number for unambiguous in-house identification.

Samples were analyzed for various forms of nitrogen and phosphorus, chemical oxygen demand (COD), total petroleum hydrocarbons (TPH), physical parameters including total suspended solids (TSS), and five trace metals—aluminum (Al), chromium (Cr), copper (Cu), lead (Pb), and zinc (Zn). Analyses included both total (i.e., acid-extractable) and "soluble" (filtered through Whatman [Clifton, New Jersey] glass microfiber filters) forms of each metal, which are referred to in this report with the prefixes "T" and "S," respectively (e.g., TCu and SCu refer to total and soluble


Crestwood BMP

X and Y coordinates are relative values, given in feet
Vertical Datum: Outlet Structure invert (feet).

Inlet Structure Invert Elevation = 0.463 m (1.52 ft)

Outlet Structure:
Permanent Pool Elevation = 0.152 m (0.5 ft)
Max Pool Elevation at weir top = 0.475 m (1.5 ft)
Overflow Elevation = 0.741 m (0.43 ft)

Figure 2—Contour map of Crestwood Marsh BMP.

forms of the metal, respectively) Nutrient analyses were performed with a Bran and Luebbe (Buffalo Grove, Illinois) TrAAcs 800 system, as described in Technicon Methods 780-86T through 787-86T (Bran and Luebbe, 1987) and modified by the Occoquan Watershed Monitoring Laboratory (Manassas, Virginia). Trace metals were analyzed using a PerkinElmer (Norwalk, Connecticut) Model 5100 atomic absorption spectrophotometer as described in either U.S. Environmental Protection Agency (U.S. EPA) (U S.

EPA, 1979) or Standard Method 3111 (APHA et al., 1992) and modified by the Occoquan Watershed Monitoring Laboratory Metals, TSS, COD, turbidity (TURB), TPH, pH, and total hardness were analyzed according to published American Public Health Association (Washington, D C.) and U S EPA methods (APHA et al., 1992, and U S EPA, 1979).

Some constituents, notably TPH and both extractable and soluble forms of Al, were left censored, that is, many measurements were below the analytical detection limit (LOD) Measurements below the LOD were substituted with one-half the LOD When simultaneous measurements of related constituents gave occasional incongruous results [e g , orthophosphate (OP) > total phosphate (TP)], the greater value was substituted for the more inclusive parameter (e g , OP value substituted for TP value)

Performance Calculations. To characterize the performance of a BMP, the true interest is ultimately in its long-term effects on total pollutant mass flux Such an approach requires an accurate accounting of all mass inputs and outputs, including base flow, during a period of time sufficient to represent the range of weather conditions expected Unfortunately, practical and financial considerations seldom allow information to be obtained at this level of detail In the case of the Crestwood wetlands, the investigation was limited to analysis of a discrete series of runoff events, along with limited information about base flow output and ungauged input, during an approximately 1-year period Because a complete long-term mass accounting was not possible, system efficiency was estimated using three different calculation methods, each of which examined the available data from a different perspective These are described as follows

(1) The median EMC reduction (MED) is based on the median % EMC reduction over all monitored storms The MED calculation illustrates changes in concentration taking place between gauged inlet and outlet during typical runoff events.

$$\mathrm{MED} = \left[\text{Median of} \left(\frac{(\mathrm{EMC}_{\mathrm{inlet}} - \mathrm{EMC}_{\mathrm{outlet}})}{\mathrm{EMC}_{\mathrm{inlet}}} \right) \right] \times 100 \quad (1)$$

(2) The median load reduction (MOL) is based on the median % load reduction over monitored storms. The MOL calculation reflects changes in constituent loads taking place between gauged inlet and outlet during typical runoff events. Separate MOL calculations were performed for the entire set of storms and a subset of 22 storms that had gauged inflow volumes less than the maximum pool volume of the wetlands.

$$\mathrm{MOL} = \left[\text{Median of} \left(\frac{(\mathrm{load}_{\mathrm{inlet}} - \mathrm{load}_{\mathrm{outlet}})}{\mathrm{load}_{\mathrm{inlet}}} \right) \right] \times 100 \quad (2)$$

(3) The long-term efficiency (LTE) is based on the difference between the estimated total input (inlet + overland + wetfall + dryfall) and estimated total output (storms + base flow) loads over all monitored storms. This calculation incorporates mass fluxes over all known input and output pathways both during and between runoff events and thus attempts to characterize the total performance of the system.

$$\mathrm{LTE} = \left[1 - \frac{(\Sigma V_{\mathrm{outlet}}\mathrm{EMC}_{\mathrm{outlet}}) + V_B\mathrm{FWA}_B}{(\Sigma V_{\mathrm{inlet}}\mathrm{EMC}_{\mathrm{inlet}}) + V_R MC_R + WF + DF} \right] \times 100 \quad (3)$$

Where

V_B = total base flow volume,
FWA_B = flow-weighted average base flow concentration,
V_R = estimated total overland flow volume,
MC_R = median overland grab sample concentration,
WF = direct wetfall loading to pool, and
DF = direct dryfall loading to pool

Statistical Analysis. Seasonal trends in load removal efficiencies, as measured by paired inlet and outlet storm loads only (overland loads not included), were examined using Statistical Analysis System 6.02 (SAS, Cary, North Carolina) software Because analyses for metals were not performed for all storms, there were insufficient data to examine seasonal trends in metal removals (e g , only one event was analyzed for some seasons), therefore, statistical analysis was performed only for nutrients, COD, TSS, and TURB Data were analyzed using analysis of variance (ANOVA) Because the ANOVA test is not designed to handle data sets containing both positive and negative values, removal percentages were subject to an additive transformation (a large positive number was added to each removal percentage) to convert all values to positive For each constituent, removals were then grouped according to season (spring, summer, fall, winter, and spring2) Constituents that met the required assumptions of normality and homogeneity of variance (oxidized nitrogen [OX–N], total nitrogen [TN]) were analyzed using ANOVA Constituents that did not meet these assumptions (OP, total soluble phosphorus [TSP], ammonia [NH_3], soluble and total Kjeldahl nitrogen [SKN and TKN], COD, TSS, and TURB) were subject to logarithmic transformation and retested for normality and homogeneity. Constituents that still failed the tests for homogeneity or normality (all constituents) were then rank transformed and retested Rank-transformed constituents that met the homogeneity and normality assumptions (all except TSP) were then subjected to ANOVA. Constituents for which the ANOVA test identified significant seasonal differences were subject to pairwise *t*-tests with a Bonferroni adjustment to control for the cumulative experimentwise error rate ($\alpha = 0.05$) to identify which seasons differed significantly from one another. Because TSP data could not be normalized, a separate analysis was performed using the nonparametric Wilcoxon rank sum test, which does not require the data to be normally distributed.

Results

Water Mass Balance. Linear regression analysis of outlet versus inlet volumes resulted in an r^2 value of 0.94 and a slope of 1.39. To obtain a satisfactory flow balance, the rational method was used with a runoff coefficient of 0.2 to estimate the overland flow volume. Although this method improved (but was still weak at) accounting for the volume discrepancies of individual storms (Figure 3), it resulted in only 3% difference between estimated long-term total inflow and outflow (Table 1).

Atmospheric Contributions. Calculated annual wetfall and dryfall deposition rates are presented in Table 2 along with rates from similar studies previously conducted in the greater Washington, D.C., area and the southeast. In general, atmospheric loadings of nutrients and Zn at the Crestwood wetlands were comparable to the earlier studies. However, loadings of Cu and Cd were 1 to 2 orders of magnitude lower. Wetfall loadings of Al seemed to be approximately 1 order of magnitude greater than those at Franklin Farms, whereas dryfall loadings were approximately 1 order of

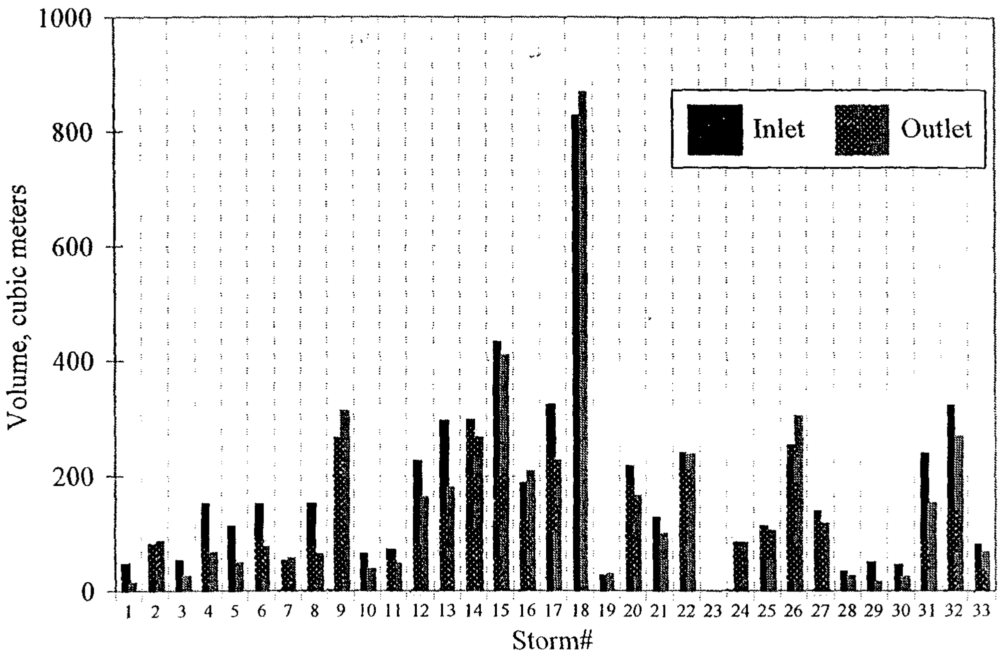


Figure 3—Inlet (including estimated overland) and outlet storm volumes for monitored storms.

magnitude lower. However, the results for Al should be interpreted cautiously because the data were highly censored, that is, most of the results were below the analytical detection limit. Consistent with the Franklin Farms study, wetfall nitrogen loadings were substantially greater than dryfall loadings by approximately 1 order of magnitude, whereas wetfall and dryfall phosphorus depositions were more similar. Wetfall and dryfall Zn loadings were also similar. For all other metals, observed wetfall loadings were approximately 2 to 5 times greater than dryfall loadings.

Characterization of Runoff. Table 3 presents median inlet and outlet (WE10, WE20) EMCs, wetfall sample (WE40), and ungauged area (WE15) grab sample concentrations of the various constituents measured. Median urban runoff concentrations from other studies in the Washington, D.C., metropolitan area are presented as well, for comparative purposes. The table shows that for nutrients, TSS, COD, and all metals except Pb, the WE20 samples at the Crestwood site were similar to urban runoff concentrations measured in the other studies. For the forested runoff, results for the 1998 samples were typically consistent with the study samples, demonstrating that the composition of the overland drainage did not change greatly over time (Table 4). During the study, field pH in base flow samples ranged from 6.2 to 9.8.

Lysimeter Samples. Median values of all constituents for each of the three lysimeters are presented in Table 5. Concentrations of OP and TP in each sample were similar, with both frequently falling below detection limits. Ammonia and TKN concentrations were typically greatest in the WE50 samples, followed by WE60 and WE70, respectively. In comparison with other nitrogen species, oxidized nitrogen concentrations in the three lysimeters seem to follow one another closely. The Al, Cd, Cu, and Pb results were mostly below detection limits. By contrast, concentrations of Zn were observed more often at detectable levels. During the study, field pH in lysimeter samples ranged from 5.7 to 7.2.

Table 1—Crestwood water mass balance for monitored storms April 1996 through May 1997.

Inputs, m^3		Outputs, m^3	
Gauged inlet	3280	Gauged outlet, storms	4904
Estimated overland	2520	Gauged outlet, baseflow	907
Direct precipitation	355	Evapotranspiration	164
Total	6163		5975
Difference, %	−3		

Outlet Base Flow Monitoring. Plots of base flow concentrations as a function of the instantaneous outlet flow at sampling time showed an inverse relationship between concentration and flow rate for most constituents (e.g., Figure 4 for TN). This relationship between flow and concentration was accounted for in the long-term mass removal calculations by calculating the flow-weighted mean base flow concentration for each constituent along with total base flow volume, thereby estimating total base flow export.

Pollutant Removal Performance. For many constituents, the estimated overland load was a significant fraction of the total input, in some cases exceeding even the gauged inlet load. For these constituents (TSP, TP, SKN, TKN, TAl, SAl, TCu, SCu, SPb, and SZn), inclusion of the overland input is sufficient to offset the difference between apparent import and export. For most constituents, the LTE method therefore gave the best performance of the three calculation methods used (Table 6).

Discussion

Compared to other studies of urban runoff in the Washington, D.C., metropolitan area, constituent concentrations in townhouse drainage at the Crestwood site seem to be similar for some constituents (NH_3 and oxidized nitrogen), slightly lower for others (OP, TSP, TP, TKN, TN, TSS, COD, TCu, and TCd), and substantially lower for a few (TPb and TZn) (Table 3). Thus, in

Table 2—Estimated annual atmospheric deposition rates: wetfall and dryfall.

Location	Measurement type	Nutrients, kg/ha OX-N	NH_3-N	TKN	TN	OP	TSP	TP	Trace metals TCu	TPb	TZn	TCd	TAl
SE U.S. (TN)[a]	Total	7.55	2.52										
Suburban D.C.[b]	Total	6.38	1.20	8.2	14.4	0.30		0.57	0.24	0.49	1.51	0.10	
Franklin Farms	Wetfall	3.74	3.28	3.75	6.64	0.12	0.16	0.20	0.13		0.54	0.08	1.39
	Dryfall	1.02	0.58	2.17	3.46	0.08	0.10	0.38	0.82		1.69	0.24	79.3
	Total	4.76	3.86	5.92	10.10	0.20	0.26	0.58	0.95		2.23	0.31	81
Crestwood	Wetfall	5.53	4.03	4.65	10.29	0.10		0.15	0.02	0.02	0.7	0.01	13.09
	Dryfall	0.82	0.47	1.99	2.86	0.08		0.24	0.01	0.01	0.69	0.002	5.69
	Total	6.35	4.50	6.64	13.15	0.18		0.38	0.03	0.03	1.37	0.01	18.78

[a] Lindberg et al (1986)

[b] Maryland Department of Environment (1987)

general, the Crestwood drainage seems to be relatively "clean" for urban runoff in the national capital area. In part, this may reflect variations among previously studied sites in terms of proximity to local sources of atmospheric pollutants and differences in land uses within the watersheds. The substantially lower Pb concentrations in urban runoff at Crestwood compared with earlier studies probably reflects the reduction in leaded gasoline usage that has occurred since those studies were conducted. This trend is also evident in the atmospheric data, which shows much lower aerial deposition rates for Pb compared with earlier studies, as illustrated in Table 2. Aerial loadings of Cu and Cd were also lower at Crestwood (by 1 to 2 orders of magnitude), whereas loadings of nutrients and Zn were comparable to results from earlier studies.

Comparison between concentrations in rainfall (WE40) and both townhome (WE20) and "forested" runoff (WE15) suggests that both subwatersheds (townhomes and forested area) are net

Table 3—Median concentrations at Crestwood and sites of other urban runoff studies.

Site	Nutrients and physical parameters OP, mg/L	TSP, mg/L	TP, mg/L	NH_3 –N, mg/L	SKN, mg/L	TKN, mg/L	OX –N, mg/L	TN, mg/L	TSS, mg/L	TURB, NTU	COD, mg/L	Trace metals TAl, µg/L	SAl, µg/L	TCd, µg/L	SCd, µg/L	TCu, µg/L	SCu, µg/L	TPb, µg/L	SPb, µg/L	TZn, µg/L	SZn, µg/L
Crestwood, WE20 (inlet storms)	0.04	0.05	0.14	0.13	0.37	0.81	0.56	1.40	37	19	45.5	<2000	<2000	1.2	<1.0	7.6	2.8	1.5	<3.0	61	33
Crestwood, WE15 (overland flow input)	0.06	0.09	0.17	0.03	0.64	1.22	0.10	1.31	32	80	47.1	<4200	<2000	<1.0	<1.0	12.0	6.3	4.3	<3.0	39	24
Crestwood, WE40 (wetfall)	0.005		0.005	0.31	0.50	0.35	0.34	0.74				<2000	<2000	<1.0		<2.0		<3.0		23	
Crestwood, WE10 (outlet storms)	0.02	0.04	0.10	0.04	0.61	0.80	0.22	1.06	11	16	56.3	<2000	<2000	<1.0	<1.0	4.6	2.3	<3.0	<3.0	21	24
Crestwood, WE10 (outlet baseflow)	0.01	0.03	0.08	0.02	0.69	0.94	0.09	1.06	7	8	36.9	<2000	<2000	<1.0	<1.0	5.5	4.5	<3.0	<3.0	27	16
Franklin Farms, UM40	0.17	0.16	0.35			1.44	1.22	2.66													
NE Washington DC, HL30[a]	0.06		0.37	0.11		2.24	0.46		43	13	53.2			1		18.1		14.8		212	
Townhouse/ Garden Apts., DC area 208[b]	0.08		0.43	0.12		2.08	0.51	2.67	106.3		88.3			5		22		334		148	
Townhouse/ Garden Apts., DC area NURP[b]	0.14		0.35	0.34		1.62	0.70	2.40	32.8		43.8					29		151		74	
NURP urban site overall[c]		0.12	0.33			1.50	0.68	2.18[d]	100		65					34		144		160	

[a] Rabanal and Gizzard (1995)

[b] Washington Metropolitan Area Urban Runoff Demonstration Project (NVPDC, 1983)

[c] Results of the NURP Volume I—Final Report (U.S. EPA, 1983)

[d] Inferred value: sum of median TKN and median OX–N

Table 4—Concentrations in overland runoff from forested–grassy area.

Date	OP, mg/L	TSP, mg/L	TP, mg/L	NH_3 –N, mg/L	SKN, mg/L	TKN, mg/L	OX –N, mg/L	TN, mg/L	TSS, mg/L	TURB, NTU	COD, µg/L	TAl, µg/L	SAl, µg/L	TCd, µg/L	SCd, µg/L	TCu, µg/L	SCu, µg/L	TPb, µg/L	SPb, µg/L	TZn, µg/L	SZn, µg/L
Dec 31, 1996	0 05	0 05	0 11	0 02	0 33	0 87	0 1	0 97	32	80	31 2										
Mar 3, 1997	0 06	0 12	0 23	0 04	0 95	1 56	0 09	1 65	70	120	47 1	2100[a]	1000[a]	0 5[a]	0 5[a]	12	6 3	4 3	1 5[a]	39	24
Apr 28, 1997	0 08	0 15	0 23	0 03	1 3	1 52	0 02	1 54	27	80	66 3										
June 15, 1998	0 07	0 09	0 14	0 13	0 95	1 3	0 07	1 37	25	55	40 8	2200[a]	2000[a]	0 5[a]	0 5[a]	8 9	3 7	1 5[a]	1 5[a]	39	17
June 22, 1998	0 08	0 09	0 16	0 04	0 6	0 95	0 3	1 25	24	45	37 4										
June 28, 1998	0 10	0 12	0 18	0 04	1 27	1 65	0 08	1 73	55	100	70 6										
Median, 1996, 1997[b]	0 06	0 12	0 23	0 03	0 95	1 52	0 09	1 54	32 0	80	47 1	2100	1000	0 5	0 5	12	6 3	4 3	1 5	39	24
Median, 1998	0 08	0 09	0 16	0 04	0 95	1 30	0 08	1 37	24 8	55	40 8	2200	2200	0 5	0 5	8 9	3 7	1 5	1 5	39	17
Median, overall	0 075	0 105	0 17	0 04	0 95	1 41	0 085	1 46	29 5	80 0	44 0	2150	1600	0 5	0 5	10 5	5 0	2 9	1 5	39 0	20 5
Mean, overall	0 073	0 103	0 18	0 05	0 90	1 31	0 11	1 42	38 7	80 0	48 9	2150	1600	0 5	0 5	10 5	5 0	2.9	1 5	39 0	20 5
Standard deviation, overall	0 018	0 034	0 048	0 040	0 38	0 33	0 097	0 28	19 23	27 75	16 10	70 71	848 5	0 00	0 00	2 19	1 84	1 98	0 00	0 00	4 95
%CV	23 9	33 3	27 7	80 0	42 1	25 3	88 3	19 9	49 6	34 7	32 8	3 3	53 0	0 0	0 0	21 0	36 8	68 3	0 0	0 0	24

[a] Values below detection limit, reported as one-half LOD

[b] Values used in performance calculations

sources for some constituents (OP, TP, TKN, TN, TCu, and TZn) and net sinks for others (NH_3) (Table 3). That the forested runoff contained greater concentrations of TCu and TPb than the townhouse drainage is surprising In 1998, forested runoff concentrations of Cu were similar to those in 1997, although Pb concentrations had decreased to below the detection limit (3 µg/L) The source of metals in the forested runoff is unknown

The high TSS removal at the Crestwood wetlands is consistent with the results of other researchers (Barten, 1987, and Wotzka and Oberts, 1988) The percentage of TP as TSP was typically greater in outlet (WE10) than in inlet (WE20) EMC samples, reflecting a relatively greater loss of insoluble than soluble phosphorus during passage through the wetlands This is consistent with sedimentation as a removal mechanism for particulate-associated phosphorus The fact that removals for extractable (i e., total) forms of metals were slightly greater than for the soluble forms suggests that retention of metals took place in the wetlands also primarily via sedimentation of particulate-associated forms. This is consistent with the results of previous researchers, who have documented the buildup of metals within the sediments of detention basins and wetlands (Baker and Yousef, 1995; Crites et al., 1997, Mesuere and Fish, 1989, Schiffer, 1989, and Wigington et al., 1983)

Ammonia removal was significantly better (α = 0 05, Bonferroni pairwise *t*-test) in spring 1996 than in both fall 1996 and spring 1997 Orthophosphate removal was also better in spring 1996 than in spring 1997 Oxidized nitrogen removal was significantly better in summer 1996 than in fall 1996. An interesting trend was seen in the lysimeter data for spring 1997, when NH_3 concentrations in WE50 increased substantially, while those in WE60 and WE70 did not (Figure 5) Beginning at approximately the same time, the lysimeter OX–N data show a marked decrease in concentration, which persisted through the end of the study (Figure 6). Together, these data suggest that reducing conditions likely developed in the shallow sediments during spring 1997 The resulting decrease in nitrification and release of sediment-bound OP to the water column would tend to decrease the removal of NH_3 and OP at this time, which is consistent with the observed seasonal differences in performance for these constituents.

Unlike most constituents, base flow concentrations of OX–N were consistently lower than storm (outlet) concentrations (Figure 7), suggesting that OX–N removal primarily occurred during the quiescent periods between storms. In contrast, solids-associated

Table 5—Lysimeter median values.

Constituent	WE50	WE60	WE70
OP, mg/L	0 005	0 005	0 01
TSP, mg/L	0 01	0 005	0 015
TP, mg/L	0 01	0 005	0 01
NH_3-N, mg/L	0 10	0 04	0 005
SKN, mg/L	0 75	0 22	0 03
TKN, mg/L	0 61	0 3	0 02
OX–N, mg/L	0 12	0 1	0.085
TN, mg/L	0 73	0 43	0 11
SCd, µg/L	<1 0	<1 0	<1 0
SCu, µg/L	<2 0	<2 0	<2 0
SPb, µg/L	<3 0	<3 0	<3 0
SZn, µg/L	20	17	7 5
SAl, µg/L	<2000	<2000	<2000

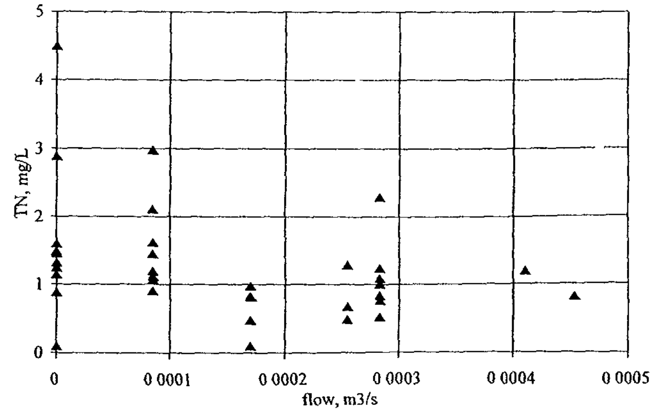


Figure 4—Base flow TN concentration versus flow rate.

Table 6—Wetland removal efficiencies.

	Crestwood				Franklin Farms[a]	
Constituent	**LTE**	**MED**	**MOL**	**MOL[b]**	**All storms**	**Subset 1[b]**
OP	35 8	35 4	−11 9	11 0	−5 5	59 0
TSP	48 1	20 0	−11 9	−10 4	−8 2	66 0
TP	45 9	33 3	−0 3	6 5	8 3	76 0
NH_3-N	54 7	68 8	62 7	76 1	−3 4	68 0
SKN	19 8	−26 6	−64 4	−61 1	5 8	67 0
TKN	25 5	−3 1	−50 0	−23 1	15 0	81 0
OX-N	39 4	61 7	40 8	48 2	1 2	68 0
TN	21 7	21 9	−24 9	−2 9	−2 1	76 0
TSS	57 9	57 9	49 6	65 2	62 0	93 0
COD	21 9	−21 0	−65 3	−54 1	—	—
TPH	−110 1	0 0	−33 6	−22 5	—	—
TAl	68 4	0 0	−27 6	−8 1	—	—
SAl	45 5	0 0	−27 6	−8 1	—	—
TCd	30 8	50 0	41 5	64 4	—	—
SCd	28 0	0 0	27 6	57 4	—	—
TCu	65 5	0 0	1 0	14 0	—	—
SCu	47 7	−22 2	68 7	−34 9	—	—
TPb	74 7	0 0	10 6	63 9	—	—
SPb	33 2	0 0	−26 6	−8 1	—	—
TZn	29 2	23 4	−17 8	10 3	—	—
SZn	35 5	11 1	14 3	22 5	—	—

[a] Estimated long-term total load removals

[b] Estimates for subset of storms with inflow volume < wetland capacity

constituents may be mostly removed by settling during storm events. The inverse relationship observed between outlet flow rate and base flow concentrations may reflect greater algal densities occurring in the water column during quiescent conditions.

In terms of long-term performance, the Crestwood wetlands was typically within the range of percent removal estimates reported in other urban stormwater wetland studies (Barten, 1987; City of Baltimore, 1989; OWML, 1990; and Meiorin, 1989). As hypothesized, long-term removals typically exceeded those observed at the Franklin Farms wetlands, confirming the importance of adequate sizing as a design feature. Similarly, median load removals for all constituents were greater for storms with gauged inflow volumes less than the maximum pool volume of the wetlands (Table 6). Results from the literature suggest performance would improve further with the addition of a detention pond or sediment forebay to pretreat runoff before it enters the wetlands (Martin and Smoot, 1986, and Wotzka and Oberts, 1988). Design guidance documents typically recommend the inclusion of such a feature, which would extend the

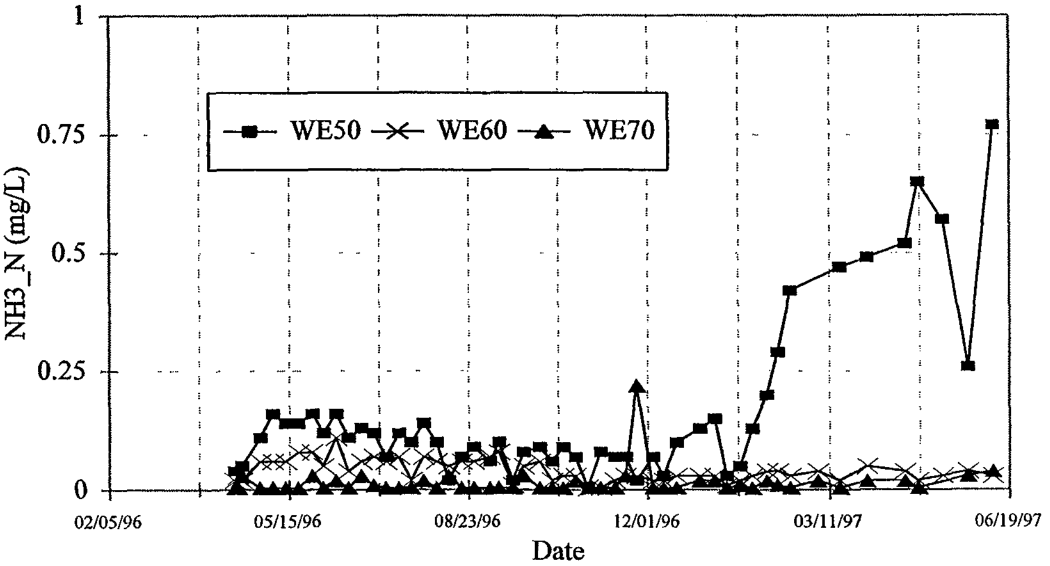


Figure 5—Lysimeter NH_3-N data, mg/L.

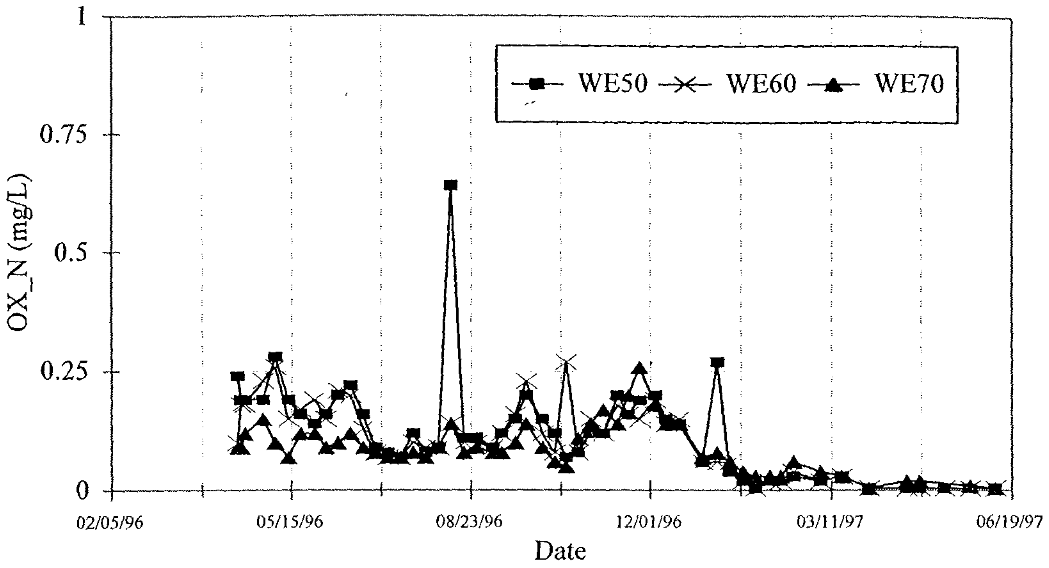


Figure 6—Lysimeter OX–N data, mg/L.

lifetime of the wetlands, allowing periodic cleanout of accumulated sediments without disruption of the vegetation.

Conclusions

In this study, with the simple addition of an outlet weir, a dry detention pond was converted to a stormwater wetlands with a diverse assemblage of volunteer plant species. Overall, constituent removals were comparable to what might be anticipated for a similarly sized wet detention pond (U.S. EPA, 1983). These results suggest that this approach may have promise for providing a low-cost retrofit to improve water quality at older detention facilities where water quality improvement was not a primary design issue.

Ungauged overland flow from the wooded–grassy area constituted approximately 41% of the long-term total hydrologic input to the wetlands, assuming that a runoff coefficient of 0.2 for this area resulted in a good match (~3% difference) between estimated long-term total hydrologic inputs and outputs, although this method was less effective at explaining the inlet–outlet flow imbalances for individual storms.

Aerial atmospheric pollutant loadings were comparable to results from other studies in the Washington, D.C., area. Results

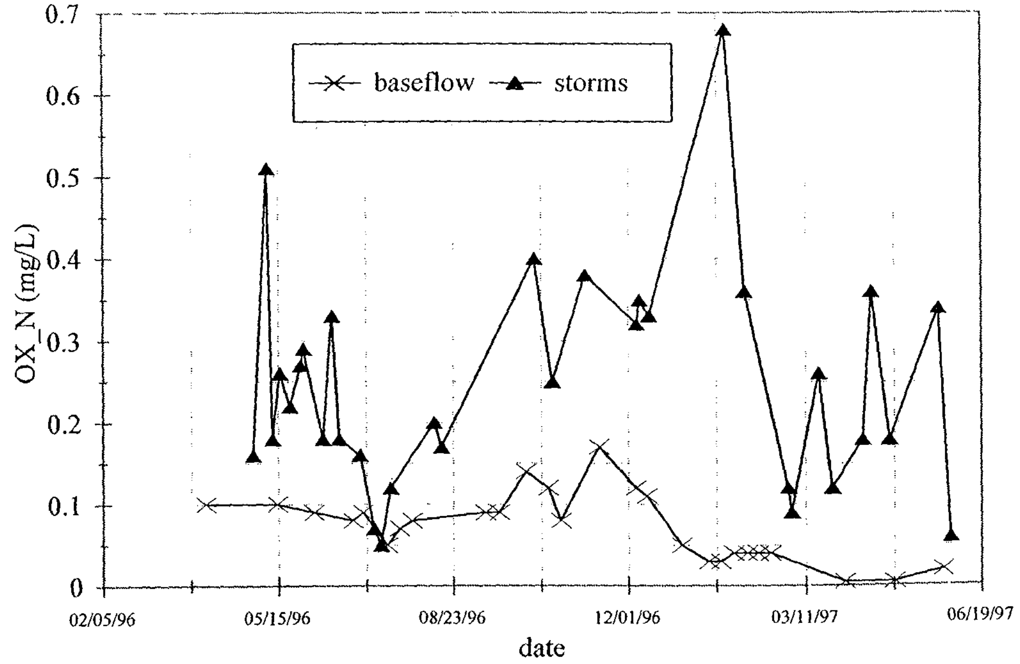


Figure 7—Outlet storm EMC and base flow sample concentration comparison: OX–N, mg/L.

suggest that both the townhouse and forested subwatersheds are net sinks for ammonia and net sources of organic nitrogen, phosphorus, and some metals.

Most constituent EMCs were lower in outlet than in inlet samples. Estimated long-term efficiency for the facility, which included overland runoff contributions, was positive for most constituents Results typically fell within the range of values reported in other runoff wetland studies Long-term performance for nutrients was substantially greater than that measured at the nearby Franklin Farms wetlands, consistent with Crestwood's greater ratio of wetland surface area to drainage area Similar to Franklin Farms, median load removals for all constituents were greater for storms with runoff volumes smaller than the capacity of the wetlands.

Ammonia removal was significantly better ($\alpha = 0.05$) in spring 1996 than in both fall 1996 and spring 1997 Removal of OP was also better in spring 1996 than in spring 1997 Oxidized nitrogen removal was significantly better in summer 1996 than in fall 1996 No significant seasonal differences were observed for any other constituents Lysimeter data suggest that the observed seasonal differences may have been related to the eventual development of anaerobic conditions in the shallow sediments of the wetlands Outlet base flow OX–N concentrations were consistently lower than outlet storm concentrations, suggesting that oxidized nitrogen removal occurred primarily during quiescent periods between storms

Acknowledgments

Credits. Funding for this research was provided in part by the Water Environment Research Foundation, Alexandria, Virginia The authors thank the staff of the Occoquan Watershed Monitoring Laboratory, Manassas, Viriginia, for installing and maintaining the monitoring equipment and for collecting and analyzing the samples

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Submitted for publication December 8, 1998; revised manuscript submitted August 24, 1999; accepted for publication December 13, 1999.

The deadline to submit Discussions of this paper is September 15, 2000.

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Performance of a Constructed Wetlands in Treating Urban Stormwater Runoff

James N. Carleton, Thomas J. Grizzard, Adil N. Godrej, Harold E. Post, Les Lampe, Pamela P. Kenel

ABSTRACT: An investigation was conducted on the pollutant removal performance of a constructed wetlands treating stormwater runoff from a residential townhome complex in northern Virginia. Constituent event mean concentrations for 33 runoff events between April 1996 and May 1997 were measured based on flow-weighted composite samples collected at the facility's inlet and outlet. With the results from a limited number of grab samples representing ungauged overland drainage from an adjacent wooded area, estimated removals were positive for most constituents and typically exceeded those obtained at a nearby companion wetland study site, consistent with expectations based on the relative ratios of wetland area to drainage area at the two sites. Median load removals of all constituents were greater for a subset of 22 storms that had inflow volumes less than the maximum volume of the marsh. Orthophosphate phosphorus and ammonia removals were significantly better during spring of 1996 than spring of 1997. Lysimeter data suggest a possible explanation for this, which is development of anaerobic conditions in the shallow sediments in 1997. Outlet concentrations of oxidized nitrogen were consistently lower in base flow than in storm samples, suggesting that removal of this constituent occurred primarily between, rather than during, storm events. *Water Environ Res*, 72, 295 (2000)

KEYWORDS: urban runoff, nonpoint source pollution, constructed wetlands

Introduction

Natural wetlands are transitional ecosystems that exist at the interface between aquatic and terrestrial systems. Because of their position in the landscape, they are frequently the default recipients of stormwater runoff, including that which drains agricultural lands and urban developments. Numerous investigations in different regions of the country (Strecker et al., 1992) have demonstrated that various wetland types can act as sinks or transformers of nutrients and other constituents of stormwater runoff (Mitsch et al., 1989). However, wetlands can also be degraded by nonpoint source pollution. Construction of wetlands designed specifically as best management practices (BMPs) for treatment of stormwater runoff is attractive in part because natural wetlands need not be affected. Previous authors, after reviewing the literature, have concluded that constructed wetlands typically performed slightly better and with less variability than natural wetlands at removing various constituents (Strecker et al., 1992). However, although constructed wetlands have become established methods of secondary wastewater treatment, their applicability for treatment of stormwater runoff has been less extensively studied (Kadlec and Knight, 1996).

In a companion study to this one, a constructed urban marsh, referred to herein as "Franklin Farms," was established in a former dry detention basin receiving drainage from a 16.1 ha subdivision in Chantilly, Virginia (OWML, 1990). Pond area at full pool was 0.13 ha or 0.8% of the total drainage area. Although total constituent load removals for the entire set of 23 storms were disappointing (−8.2 to 15% for nutrients), performance (>59% for nutrients) was found to be substantially better for a subset of storms with volumes less than the capacity of the marsh. The authors concluded that the facility was undersized with respect to its drainage area.

The site in the present study, referred to herein as the "Crestwood" wetlands, drained a townhome complex near Route 234 in Manassas, Virginia, approximately 50 km (30 mile) from Washington, D.C. Before modification, the facility was a dry detention basin containing numerous wetland plants growing in the wet zone along a well-defined flow channel. The basin was equipped with a single stormsewer inlet, which transported runoff from an estimated 1.3 ha drainage area within the townhouse complex. An additional 1.6 ha of wooded and grassy land is immediately upland of the pond on one side (Figure 1) and serves to separate the complex from a working stone quarry nearby. At full pool, the area of the pond is approximately 0.07 ha or 2% of the total drainage area. Although details of the initial construction of the detention pond were not available, the facility is thought to be underlain by an impermeable clay or compressed earth layer. The primary purpose of the present study was to examine the pollutant removal performance at the Crestwood wetlands using a mass balance approach and investigate any seasonal trends in removal efficiencies. Based on its greater area relative to drainage area, it was hypothesized that long-term removal efficiencies at Crestwood would exceed those at Franklin Farms.

Methods and Materials

Crestwood Site Retrofit. Before its conversion to a wetlands, the detention basin had been completely surveyed (Figure 2). In December 1995, the detention basin was modified with the addition of a 0.46-m (1.5-ft) weir (referenced to the invert of the original outlet structure) at the outlet. A 31.8-mm- (1.25-in.-) diam orifice was installed in the weir to impound a pool of water at a depth of 0.15 m (0.5 ft) at the riser, creating 8.58 m^3 (303 ft^3) of permanent storage below the orifice, with an additional 124.5 m^3 (4397 ft^3) of extended detention storage above, for a total of 10 mm (0.4 in.) of storage distributed over the gauged drainage area. The orifice was sized to drain the pool from the top of the weir to the orifice invert in 24 hours.

Station Equipment. Automatic flow gauging–sampling stations were located at the inlet (WE20) and outlet (WE10) of the facility inside fiberglass utility sheds. Inlet and outlet flow passed through Palmer–Bowlus flumes (which had an outlet diameter of 381 mm) to allow flow measurements. At each station, a submerged Keller-PSI Model 200S (Hampton, Virginia) pressure transducer inside the flume fed signals to a computer through a modem port. The

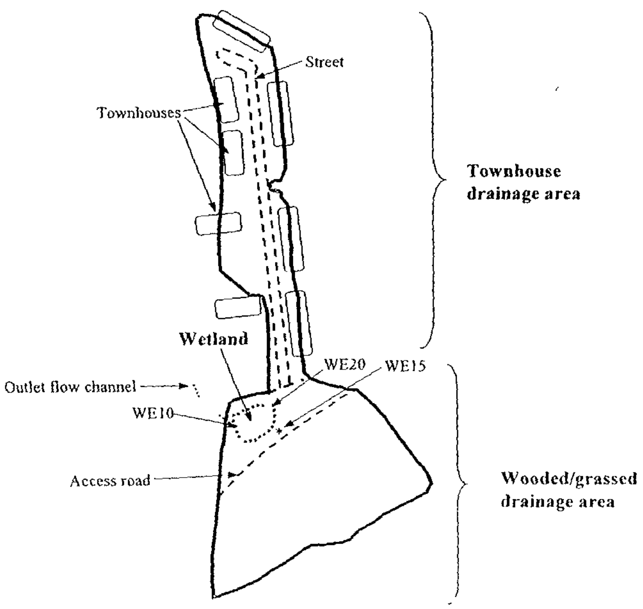


Figure 1—Relative locations of wetland and drainage area features.

computer converted the signal to a stage reading, then calculated the associated discharge from the stage and a rating curve stored in memory. An increase in stage of 0.006 m (0.02 ft) or more during a 5-minute interval triggered a mode in which 200-mL samples were collected at set increments of cumulative flow. Sampling continued until the hydrograph declined either to zero flow (WE20) or to base flow (WE10). Samples were automatically combined, yielding flow-weighted composites from which event mean concentrations (EMCs) for each storm were estimated. Base flow monitoring was performed by collecting grab samples from the pool near the outlet on a weekly-to-biweekly basis.

Overland Runoff Grab Samples. Volume measurements of the first several storm events during the study showed substantial discrepancies between inlet and outlet flow volumes, with the outlet volumes typically being somewhat higher. Tests were therefore conducted on two occasions (November 6, 1996, and March 28, 1997) to verify the accuracy of the flow readings. The procedure involved opening a metered hydrant within the townhome parking lot to deliver known volumes of water at known flow rates to the basin for comparison with the flows and volumes estimated by the equipment. These experiments confirmed that the observed discrepancies were not the result of equipment malfunction, gross miscalibration, or flume rating curve inaccuracies.

Periodically during and following rainfall events, a substantial amount of water was observed to be flowing overland into the facility from the grassy–wooded area adjacent to the pond. Calculations suggested that this extra input might account for the greater flow volumes appearing at the Facility outlet. A portion of this runoff flowed through a 150-mm- (6-in.-) diam polyvinyl chloride (PVC) drainage pipe located outside the perimeter fence of the site. The pipe drained a small depression adjacent to a dirt access road, which was located between the facility and the wooded area. On three occasions, during runoff events, grab samples were collected directly from the PVC drainage pipe (WE15) to characterize the chemical nature of the overland input. For comparative purposes, an additional three samples were also collected during runoff events in 1998.

Soil-Pore Water Monitoring. Three soil-water lysimeters were installed at the facility to allow infiltrating and percolating pore water to be sampled. Lysimeters were constructed from 1.5-m (5-ft) lengths of 64-mm- (2.5-in.-) diam PVC pipe (OWML, 1990). Lysimeter installation entailed excavating a 0.9-m (3-ft) hole in the soil and inserting the lysimeter. The hole was then backfilled and tightly packed with soil to prevent downward leakage of surface water. Two lysimeters (WE50, WE60) were installed within the area of the permanent pool near the outlet of the pond, at depths of 0.15 and 0.3 m (0.5 and 1.0 ft) below the bottom of the pool (reference datum was 0 m above the original outlet invert), respectively. The third lysimeter (WE70) was installed above the permanent pool level in one of the banks of the basin (reference datum was 0.76 m [2.5 ft] above the original outlet invert) to a depth of 0.46 m (1.5 ft) below the ground level. Lysimeter samples were collected concurrently with base flow samples, unless a storm was in progress. Approximately 24 hours before sample collection, the lysimeters were charged by placing a vacuum of approximately 18 mm Hg on them using a hand-held pump. Samples were retrieved by ejecting them under positive pressure using a hand-held pump.

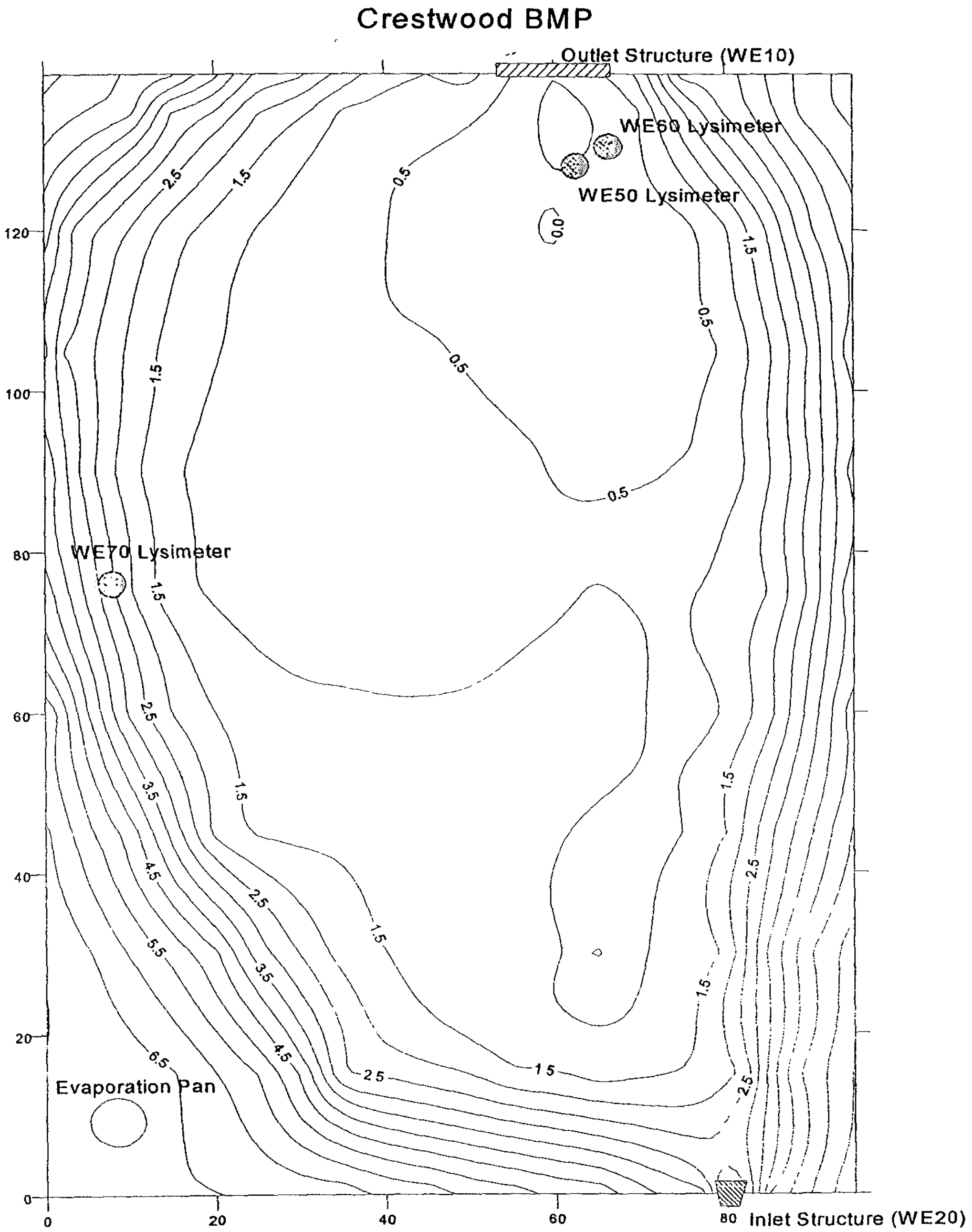
Precipitation Measurements. A tipping-bucket rain gauge (Weather Measure Corporation [Sacramento, California], Model P501) was situated on top of the inlet instrumentation shed at the site. At 0.25 mm (0.01 in.) increments of rainfall, the bucket would become full and tip, thereby triggering a contact closure signal that was relayed to a solid-state totalizing rainfall recorder mounted in the equipment shelter. The recorder accumulated a count of the bucket tips and recorded incremental rainfall as a function of time.

A wet–dry precipitation collector (Aerochem Metrics [Bushnell, Florida], Model 301), located on-site within the perimeter fence and 1.5 m above the ground, was used to collect atmospheric deposition samples. The collector included separate vessels for wetfall (WE40) and dryfall (WE30) samples. Wetfall samples were manually collected following rainfall events. Dryfall vessels were collected after approximately 2 weeks of exposure. Sample buckets were transported to and from the field with the lids on and taped down.

In the laboratory, wetfall volumes in the bucket were measured and recorded along with the pH of the sample. Samples were mixed as needed before transfer to sample bottles for analysis. Dryfall samples were prepared by the removal of gross contamination such as bird droppings or leaves, before 200 mL of reagent grade water was added to the bucket. After rubbing down the sides of the bucket with a rubber-edged scraper, samples were transferred to 250-mL volumetric flasks and diluted to the mark with Milli-Q (Millipore Corporation, Bedford, Massachusetts) water.

Sample Handling and Analysis. Between uses in the field, sample bottles were cleaned with phosphorus-free detergent in hot tap water, then a 15-minute soak in 50% hydrochloric acid, followed by three rinses with tap water and two rinses with Milli-Q (deionized) water. Samples were transported in iced coolers. On receipt at the laboratory, each sample was given a unique identification number for unambiguous in-house identification.

Samples were analyzed for various forms of nitrogen and phosphorus, chemical oxygen demand (COD), total petroleum hydrocarbons (TPH), physical parameters including total suspended solids (TSS), and five trace metals—aluminum (Al), chromium (Cr), copper (Cu), lead (Pb), and zinc (Zn). Analyses included both total (i.e., acid-extractable) and "soluble" (filtered through Whatman [Clifton, New Jersey] glass microfiber filters) forms of each metal, which are referred to in this report with the prefixes "T" and "S," respectively (e.g., TCu and SCu refer to total and soluble



X and Y coordinates are relative values, given in feet
Vertical Datum: Outlet Structure invert (feet).

Inlet Structure Invert Elevation = 0.463 m (1 52 ft)

Outlet Structure:

Permanent Pool Elevation = 0.152 m (0.5 ft)

Max Pool Elevation at weir top = 0.475 m (1.5 ft)

Overflow Elevation = 0.741 m (0.43 ft)

Figure 2—Contour map of Crestwood Marsh BMP.

forms of the metal, respectively). Nutrient analyses were performed with a Bran and Luebbe (Buffalo Grove, Illinois) TrAAcs 800 system, as described in Technicon Methods 780-86T through 787-86T (Bran and Luebbe, 1987) and modified by the Occoquan Watershed Monitoring Laboratory (Manassas, Virginia). Trace metals were analyzed using a PerkinElmer (Norwalk, Connecticut) Model 5100 atomic absorption spectrophotometer as described in either U.S. Environmental Protection Agency (U.S. EPA) (U S.

EPA, 1979) or Standard Method 3111 (APHA et al , 1992) and modified by the Occoquan Watershed Monitoring Laboratory. Metals, TSS, COD, turbidity (TURB), TPH, pH, and total hardness were analyzed according to published American Public Health Association (Washington, D C.) and U S. EPA methods (APHA et al., 1992, and U S. EPA, 1979).

Some constituents, notably TPH and both extractable and soluble forms of Al, were left censored, that is, many measurements were below the analytical detection limit (LOD). Measurements below the LOD were substituted with one-half the LOD. When simultaneous measurements of related constituents gave occasional incongruous results [e g , orthophosphate (OP) > total phosphate (TP)], the greater value was substituted for the more inclusive parameter (e g , OP value substituted for TP value)

Performance Calculations. To characterize the performance of a BMP, the true interest is ultimately in its long-term effects on total pollutant mass flux Such an approach requires an accurate accounting of all mass inputs and outputs, including base flow, during a period of time sufficient to represent the range of weather conditions expected Unfortunately, practical and financial considerations seldom allow information to be obtained at this level of detail In the case of the Crestwood wetlands, the investigation was limited to analysis of a discrete series of runoff events, along with limited information about base flow output and ungauged input, during an approximately 1-year period Because a complete long-term mass accounting was not possible, system efficiency was estimated using three different calculation methods, each of which examined the available data from a different perspective These are described as follows

(1) The median EMC reduction (MED) is based on the median % EMC reduction over all monitored storms The MED calculation illustrates changes in concentration taking place between gauged inlet and outlet during typical runoff events

$$\mathrm{MED} = \left[\text{Median of} \left(\frac{(\mathrm{EMC}_{\mathrm{inlet}} - \mathrm{EMC}_{\mathrm{outlet}})}{\mathrm{EMC}_{\mathrm{inlet}}} \right) \right] \times 100 \quad (1)$$

(2) The median load reduction (MOL) is based on the median % load reduction over monitored storms. The MOL calculation reflects changes in constituent loads taking place between gauged inlet and outlet during typical runoff events. Separate MOL calculations were performed for the entire set of storms and a subset of 22 storms that had gauged inflow volumes less than the maximum pool volume of the wetlands.

$$\mathrm{MOL} = \left[\text{Median of} \left(\frac{(\mathrm{load}_{\mathrm{inlet}} - \mathrm{load}_{\mathrm{outlet}})}{\mathrm{load}_{\mathrm{inlet}}} \right) \right] \times 100 \quad (2)$$

(3) The long-term efficiency (LTE) is based on the difference between the estimated total input (inlet + overland + wetfall + dryfall) and estimated total output (storms + base flow) loads over all monitored storms. This calculation incorporates mass fluxes over all known input and output pathways both during and between runoff events and thus attempts to characterize the total performance of the system.

$$\mathrm{LTE} = \left[1 - \frac{(\Sigma V_{\mathrm{outlet}}\mathrm{EMC}_{\mathrm{outlet}}) + V_B\mathrm{FWA}_B}{(\Sigma V_{\mathrm{inlet}}\mathrm{EMC}_{\mathrm{inlet}}) + V_R MC_R + WF + DF} \right] \times 100 \quad (3)$$

Where

V_B = total base flow volume,
FWA_B = flow-weighted average base flow concentration,
V_R = estimated total overland flow volume,
MC_R = median overland grab sample concentration,
WF = direct wetfall loading to pool, and
DF = direct dryfall loading to pool

Statistical Analysis. Seasonal trends in load removal efficiencies, as measured by paired inlet and outlet storm loads only (overland loads not included), were examined using Statistical Analysis System 6 02 (SAS, Cary, North Carolina) software. Because analyses for metals were not performed for all storms, there were insufficient data to examine seasonal trends in metal removals (e g , only one event was analyzed for some seasons), therefore, statistical analysis was performed only for nutrients, COD, TSS, and TURB Data were analyzed using analysis of variance (ANOVA) Because the ANOVA test is not designed to handle data sets containing both positive and negative values, removal percentages were subject to an additive transformation (a large positive number was added to each removal percentage) to convert all values to positive For each constituent, removals were then grouped according to season (spring, summer, fall, winter, and spring2) Constituents that met the required assumptions of normality and homogeneity of variance (oxidized nitrogen [OX–N], total nitrogen [TN]) were analyzed using ANOVA Constituents that did not meet these assumptions (OP, total soluble phosphorus [TSP], ammonia [NH_3], soluble and total Kjeldahl nitrogen [SKN and TKN], COD, TSS, and TURB) were subject to logarithmic transformation and retested for normality and homogeneity Constituents that still failed the tests for homogeneity or normality (all constituents) were then rank transformed and retested. Rank-transformed constituents that met the homogeneity and normality assumptions (all except TSP) were then subjected to ANOVA. Constituents for which the ANOVA test identified significant seasonal differences were subject to pairwise *t*-tests with a Bonferroni adjustment to control for the cumulative experimentwise error rate ($\alpha = 0.05$) to identify which seasons differed significantly from one another. Because TSP data could not be normalized, a separate analysis was performed using the nonparametric Wilcoxon rank sum test, which does not require the data to be normally distributed.

Results

Water Mass Balance. Linear regression analysis of outlet versus inlet volumes resulted in an r^2 value of 0.94 and a slope of 1.39. To obtain a satisfactory flow balance, the rational method was used with a runoff coefficient of 0.2 to estimate the overland flow volume. Although this method improved (but was still weak at) accounting for the volume discrepancies of individual storms (Figure 3), it resulted in only 3% difference between estimated long-term total inflow and outflow (Table 1).

Atmospheric Contributions. Calculated annual wetfall and dryfall deposition rates are presented in Table 2 along with rates from similar studies previously conducted in the greater Washington, D.C., area and the southeast. In general, atmospheric loadings of nutrients and Zn at the Crestwood wetlands were comparable to the earlier studies. However, loadings of Cu and Cd were 1 to 2 orders of magnitude lower. Wetfall loadings of Al seemed to be approximately 1 order of magnitude greater than those at Franklin Farms, whereas dryfall loadings were approximately 1 order of

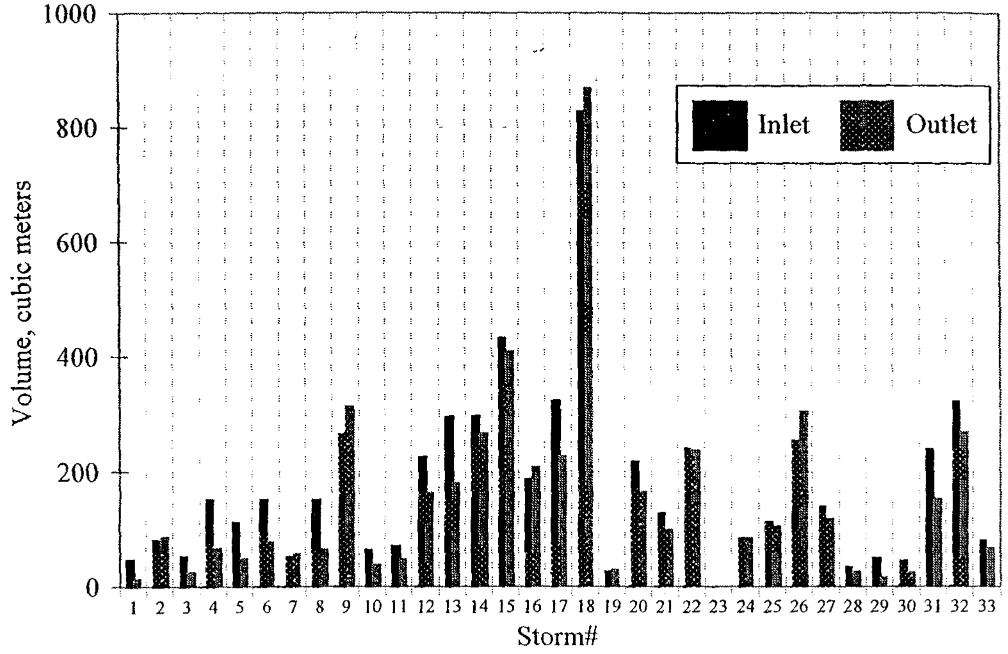


Figure 3—Inlet (including estimated overland) and outlet storm volumes for monitored storms.

magnitude lower. However, the results for Al should be interpreted cautiously because the data were highly censored, that is, most of the results were below the analytical detection limit. Consistent with the Franklin Farms study, wetfall nitrogen loadings were substantially greater than dryfall loadings by approximately 1 order of magnitude, whereas wetfall and dryfall phosphorus depositions were more similar. Wetfall and dryfall Zn loadings were also similar. For all other metals, observed wetfall loadings were approximately 2 to 5 times greater than dryfall loadings.

Characterization of Runoff. Table 3 presents median inlet and outlet (WE10, WE20) EMCs, wetfall sample (WE40), and ungauged area (WE15) grab sample concentrations of the various constituents measured. Median urban runoff concentrations from other studies in the Washington, D.C., metropolitan area are presented as well, for comparative purposes. The table shows that for nutrients, TSS, COD, and all metals except Pb, the WE20 samples at the Crestwood site were similar to urban runoff concentrations measured in the other studies. For the forested runoff, results for the 1998 samples were typically consistent with the study samples, demonstrating that the composition of the overland drainage did not change greatly over time (Table 4). During the study, field pH in base flow samples ranged from 6.2 to 9.8.

Lysimeter Samples. Median values of all constituents for each of the three lysimeters are presented in Table 5. Concentrations of OP and TP in each sample were similar, with both frequently falling below detection limits. Ammonia and TKN concentrations were typically greatest in the WE50 samples, followed by WE60 and WE70, respectively. In comparison with other nitrogen species, oxidized nitrogen concentrations in the three lysimeters seem to follow one another closely. The Al, Cd, Cu, and Pb results were mostly below detection limits. By contrast, concentrations of Zn were observed more often at detectable levels. During the study, field pH in lysimeter samples ranged from 5.7 to 7.2.

Table 1—Crestwood water mass balance for monitored storms April 1996 through May 1997.

Inputs, m^3		Outputs, m^3	
Gauged inlet	3280	Gauged outlet, storms	4904
Estimated overland	2520	Gauged outlet, baseflow	907
Direct precipitation	355	Evapotranspiration	164
Total	6163		5975
Difference, %	−3		

Outlet Base Flow Monitoring. Plots of base flow concentrations as a function of the instantaneous outlet flow at sampling time showed an inverse relationship between concentration and flow rate for most constituents (e.g., Figure 4 for TN). This relationship between flow and concentration was accounted for in the long-term mass removal calculations by calculating the flow-weighted mean base flow concentration for each constituent along with total base flow volume, thereby estimating total base flow export.

Pollutant Removal Performance. For many constituents, the estimated overland load was a significant fraction of the total input, in some cases exceeding even the gauged inlet load. For these constituents (TSP, TP, SKN, TKN, TAl, SAl, TCu, SCu, SPb, and SZn), inclusion of the overland input is sufficient to offset the difference between apparent import and export. For most constituents, the LTE method therefore gave the best performance of the three calculation methods used (Table 6).

Discussion

Compared to other studies of urban runoff in the Washington, D.C., metropolitan area, constituent concentrations in townhouse drainage at the Crestwood site seem to be similar for some constituents (NH_3 and oxidized nitrogen), slightly lower for others (OP, TSP, TP, TKN, TN, TSS, COD, TCu, and TCd), and substantially lower for a few (TPb and TZn) (Table 3). Thus, in

Table 2—Estimated annual atmospheric deposition rates: wetfall and dryfall.

Location	Measurement type	Nutrients, kg/ha							Trace metals				
		OX–N	NH_3–N	TKN	TN	OP	TSP	TP	TCu	TPb	TZn	TCd	TAl
SE U.S. (TN)[a]	Total	7.55	2.52										
Suburban D.C.[b]	Total	6.38	1.20	8.2	14.4	0.30		0.57	0.24	0.49	1.51	0.10	
Franklin Farms	Wetfall	3.74	3.28	3.75	6.64	0.12	0.16	0.20	0.13		0.54	0.08	1.39
	Dryfall	1.02	0.58	2.17	3.46	0.08	0.10	0.38	0.82		1.69	0.24	79.3
	Total	4.76	3.86	5.92	10.10	0.20	0.26	0.58	0.95		2.23	0.31	81
Crestwood	Wetfall	5.53	4.03	4.65	10.29	0.10		0.15	0.02	0.02	0.7	0.01	13.09
	Dryfall	0.82	0.47	1.99	2.86	0.08		0.24	0.01	0.01	0.69	0.002	5.69
	Total	6.35	4.50	6.64	13.15	0.18		0.38	0.03	0.03	1.37	0.01	18.78

[a] Lindberg et al. (1986)

[b] Maryland Department of Environment (1987)

general, the Crestwood drainage seems to be relatively "clean" for urban runoff in the national capital area. In part, this may reflect variations among previously studied sites in terms of proximity to local sources of atmospheric pollutants and differences in land uses within the watersheds. The substantially lower Pb concentrations in urban runoff at Crestwood compared with earlier studies probably reflects the reduction in leaded gasoline usage that has occurred since those studies were conducted. This trend is also evident in the atmospheric data, which shows much lower aerial deposition rates for Pb compared with earlier studies, as illustrated in Table 2. Aerial loadings of Cu and Cd were also lower at Crestwood (by 1 to 2 orders of magnitude), whereas loadings of nutrients and Zn were comparable to results from earlier studies.

Comparison between concentrations in rainfall (WE40) and both townhome (WE20) and "forested" runoff (WE15) suggests that both subwatersheds (townhomes and forested area) are net

Table 3—Median concentrations at Crestwood and sites of other urban runoff studies.

Site	Nutrients and physical parameters											Trace metals									
	OP, mg/L	TSP, mg/L	TP, mg/L	NH_3 –N, mg/L	SKN, mg/L	TKN, mg/L	OX –N, mg/L	TN, mg/L	TSS, mg/L	TURB, NTU	COD, mg/L	TAl, µg/L	SAl, µg/L	TCd, µg/L	SCd, µg/L	TCu, µg/L	SCu, µg/L	TPb, µg/L	SPb, µg/L	TZn, µg/L	SZn, µg/L
Crestwood, WE20 (inlet storms)	0.04	0.05	0.14	0.13	0.37	0.81	0.56	1.40	37	19	45.5	<2000	<2000	1.2	<1.0	7.6	2.8	1.5	<3.0	61	33
Crestwood, WE15 (overland flow input)	0.06	0.09	0.17	0.03	0.64	1.22	0.10	1.31	32	80	47.1	<4200	<2000	<1.0	<1.0	12.0	6.3	4.3	<3.0	39	24
Crestwood, WE40 (wetfall)	0.005		0.005	0.31	0.50	0.35	0.34	0.74				<2000	<2000	<1.0		<2.0		<3.0		23	
Crestwood, WE10 (outlet storms)	0.02	0.04	0.10	0.04	0.61	0.80	0.22	1.06	11	16	56.3	<2000	<2000	<1.0	<1.0	4.6	2.3	<3.0	<3.0	21	24
Crestwood, WE10 (outlet baseflow)	0.01	0.03	0.08	0.02	0.69	0.94	0.09	1.06	7	8	36.9	<2000	<2000	<1.0	<1.0	5.5	4.5	<3.0	<3.0	27	16
Franklin Farms, UM40	0.17	0.16	0.35			1.44	1.22	2.66													
NE Washington DC, HL30[a]	0.06		0.37	0.11		2.24	0.46		43	13	53.2			1		18.1		14.8		212	
Townhouse/ Garden Apts., DC area 208[b]	0.08		0.43	0.12		2.08	0.51	2.67	106.3		88.3			5		22		334		148	
Townhouse/ Garden Apts., DC area NURP[b]	0.14		0.35	0.34		1.62	0.70	2.40	32.8		43.8					29		151		74	
NURP urban site overall[c]		0.12	0.33			1.50	0.68	2.18[d]	100		65					34		144		160	

[a] Rabanal and Gizzard (1995).

[b] Washington Metropolitan Area Urban Runoff Demonstration Project (NVPDC, 1983).

[c] Results of the NURP Volume I—Final Report (U.S. EPA, 1983)

[d] Inferred value, sum of median TKN and median OX-N

Table 4—Concentrations in overland runoff from forested–grassy area.

Date	OP, mg/L	TSP, mg/L	TP, mg/L	NH_3 –N, mg/L	SKN, mg/L	TKN, mg/L	OX –N, mg/L	TN, mg/L	TSS, mg/L	TURB, NTU	COD, µg/L	TAl, µg/L	SAl, µg/L	TCd, µg/L	SCd, µg/L	TCu, µg/L	SCu, µg/L	TPb, µg/L	SPb, µg/L	TZn, µg/L	SZn, µg/L
Dec 31, 1996	0.05	0.05	0.11	0.02	0.33	0.87	0.1	0.97	32	80	31.2										
Mar 3, 1997	0.06	0.12	0.23	0.04	0.95	1.56	0.09	1.65	70	120	47.1	2100[a]	1000[a]	0.5[a]	0.5[a]	12	6.3	4.3	1.5[a]	39	24
Apr 28, 1997	0.08	0.15	0.23	0.03	1.3	1.52	0.02	1.54	27	80	66.3										
June 15, 1998	0.07	0.09	0.14	0.13	0.95	1.3	0.07	1.37	25	55	40.8	2200[a]	2000[a]	0.5[a]	0.5[a]	8.9	3.7	1.5[a]	1.5[a]	39	17
June 22, 1998	0.08	0.09	0.16	0.04	0.6	0.95	0.3	1.25	24	45	37.4										
June 28, 1998	0.10	0.12	0.18	0.04	1.27	1.65	0.08	1.73	55	100	70.6										
Median, 1996, 1997[b]	0.06	0.12	0.23	0.03	0.95	1.52	0.09	1.54	32.0	80	47.1	2100	1000	0.5	0.5	12	6.3	4.3	1.5	39	24
Median, 1998	0.08	0.09	0.16	0.04	0.95	1.30	0.08	1.37	24.8	55	40.8	2200	2200	0.5	0.5	8.9	3.7	1.5	1.5	39	17
Median, overall	0.075	0.105	0.17	0.04	0.95	1.41	0.085	1.46	29.5	80.0	44.0	2150	1600	0.5	0.5	10.5	5.0	2.9	1.5	39.0	20.5
Mean, overall	0.073	0.103	0.18	0.05	0.90	1.31	0.11	1.42	38.7	80.0	48.9	2150	1600	0.5	0.5	10.5	5.0	2.9	1.5	39.0	20.5
Standard deviation, overall	0.018	0.034	0.048	0.040	0.38	0.33	0.097	0.28	19.23	27.75	16.10	70.71	848.5	0.00	0.00	2.19	1.84	1.98	0.00	0.00	4.95
%CV	23.9	33.3	27.7	80.0	42.1	25.3	88.3	19.9	49.6	34.7	32.8	3.3	53.0	0.0	0.0	21.0	36.8	68.3	0.0	0.0	24

[a] Values below detection limit, reported as one-half LOD

[b] Values used in performance calculations

sources for some constituents (OP, TP, TKN, TN, TCu, and TZn) and net sinks for others (NH_3) (Table 3). That the forested runoff contained greater concentrations of TCu and TPb than the townhouse drainage is surprising. In 1998, forested runoff concentrations of Cu were similar to those in 1997, although Pb concentrations had decreased to below the detection limit (3 µg/L). The source of metals in the forested runoff is unknown.

The high TSS removal at the Crestwood wetlands is consistent with the results of other researchers (Barten, 1987, and Wotzka and Oberts, 1988). The percentage of TP as TSP was typically greater in outlet (WE10) than in inlet (WE20) EMC samples, reflecting a relatively greater loss of insoluble than soluble phosphorus during passage through the wetlands. This is consistent with sedimentation as a removal mechanism for particulate-associated phosphorus. The fact that removals for extractable (i.e., total) forms of metals were slightly greater than for the soluble forms suggests that retention of metals took place in the wetlands also primarily via sedimentation of particulate-associated forms. This is consistent with the results of previous researchers, who have documented the buildup of metals within the sediments of detention basins and wetlands (Baker and Yousef, 1995; Crites et al., 1997; Mesuere and Fish, 1989; Schiffer, 1989; and Wigington et al., 1983).

Table 5—Lysimeter median values.

Constituent	WE50	WE60	WE70
OP, mg/L	0.005	0.005	0.01
TSP, mg/L	0.01	0.005	0.015
TP, mg/L	0.01	0.005	0.01
NH_3-N, mg/L	0.10	0.04	0.005
SKN, mg/L	0.75	0.22	0.03
TKN, mg/L	0.61	0.3	0.02
OX–N, mg/L	0.12	0.1	0.085
TN, mg/L	0.73	0.43	0.11
SCd, µg/L	<1.0	<1.0	<1.0
SCu, µg/L	<2.0	<2.0	<2.0
SPb, µg/L	<3.0	<3.0	<3.0
SZn, µg/L	20	17	7.5
SAl, µg/L	<2000	<2000	<2000

Ammonia removal was significantly better (α = 0.05, Bonferroni pairwise *t*-test) in spring 1996 than in both fall 1996 and spring 1997. Orthophosphate removal was also better in spring 1996 than in spring 1997. Oxidized nitrogen removal was significantly better in summer 1996 than in fall 1996. An interesting trend was seen in the lysimeter data for spring 1997, when NH_3 concentrations in WE50 increased substantially, while those in WE60 and WE70 did not (Figure 5). Beginning at approximately the same time, the lysimeter OX–N data show a marked decrease in concentration, which persisted through the end of the study (Figure 6). Together, these data suggest that reducing conditions likely developed in the shallow sediments during spring 1997. The resulting decrease in nitrification and release of sediment-bound OP to the water column would tend to decrease the removal of NH_3 and OP at this time, which is consistent with the observed seasonal differences in performance for these constituents.

Unlike most constituents, base flow concentrations of OX–N were consistently lower than storm (outlet) concentrations (Figure 7), suggesting that OX–N removal primarily occurred during the quiescent periods between storms. In contrast, solids-associated

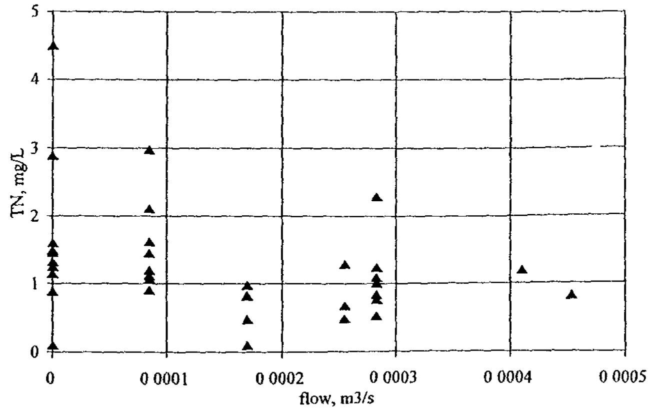


Figure 4—Base flow TN concentration versus flow rate.

Table 6—Wetland removal efficiencies.

Constituent	Crestwood LTE	Crestwood MED	Crestwood MOL	Crestwood MOL[b]	Franklin Farms[a] All storms	Franklin Farms[a] Subset 1[b]
OP	35 8	35 4	−11 9	11 0	−5 5	59 0
TSP	48 1	20 0	−11 9	−10 4	−8 2	66 0
TP	45 9	33 3	−0 3	6 5	8 3	76 0
NH_3-N	54 7	68 8	62 7	76 1	−3 4	68 0
SKN	19 8	−26 6	−64 4	−61 1	5 8	67 0
TKN	25 5	-3 1	−50 0	−23 1	15 0	81 0
OX-N	39 4	61 7	40 8	48 2	1 2	68 0
TN	21 7	21 9	−24 9	-2 9	−2 1	76 0
TSS	57 9	57 9	49 6	65 2	62 0	93 0
COD	21 9	- 21 0	−65 3	−54 1	—	-
TPH	−110 1	0 0	−33 6	−22 5	—	—
TAl	68 4	0 0	−27 6	- 8 1	—	—
SAl	45 5	0 0	-27 6	−8 1	—	—
TCd	30 8	50 0	41 5	64 4	—	—
SCd	28 0	0 0	−27 6	57 4	—	—
TCu	65 5	0 0	1 0	14 0	—	—
SCu	47 7	-22 2	−68 7	- 34 9	—	—
TPb	74 7	0 0	10 6	63 9	—	—
SPb	33 2	0 0	−26 6	−8 1	—	—
TZn	29 2	23 4	−17 8	10 3	—	—
SZn	35 5	11 1	14 3	22 5	—	—

[a] Estimated long-term total load removals

[b] Estimates for subset of storms with inflow volume < wetland capacity

constituents may be mostly removed by settling during storm events The inverse relationship observed between outlet flow rate and base flow concentrations may reflect greater algal densities occurring in the water column during quiescent conditions.

In terms of long-term performance, the Crestwood wetlands was typically within the range of percent removal estimates reported in other urban stormwater wetland studies (Barten, 1987; City of Baltimore, 1989; OWML, 1990; and Meiorin, 1989). As hypothesized, long-term removals typically exceeded those observed at the Franklin Farms wetlands, confirming the importance of adequate sizing as a design feature. Similarly, median load removals for all constituents were greater for storms with gauged inflow volumes less than the maximum pool volume of the wetlands (Table 6). Results from the literature suggest performance would improve further with the addition of a detention pond or sediment forebay to pretreat runoff before it enters the wetlands (Martin and Smoot, 1986, and Wotzka and Oberts, 1988). Design guidance documents typically recommend the inclusion of such a feature, which would extend the

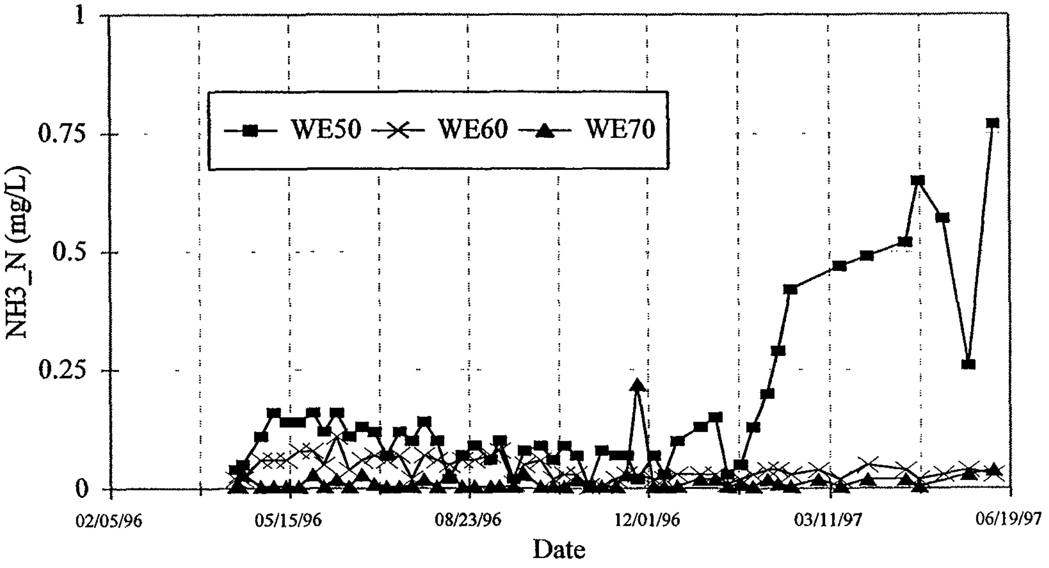


Figure 5—Lysimeter NH_3-N data, mg/L.

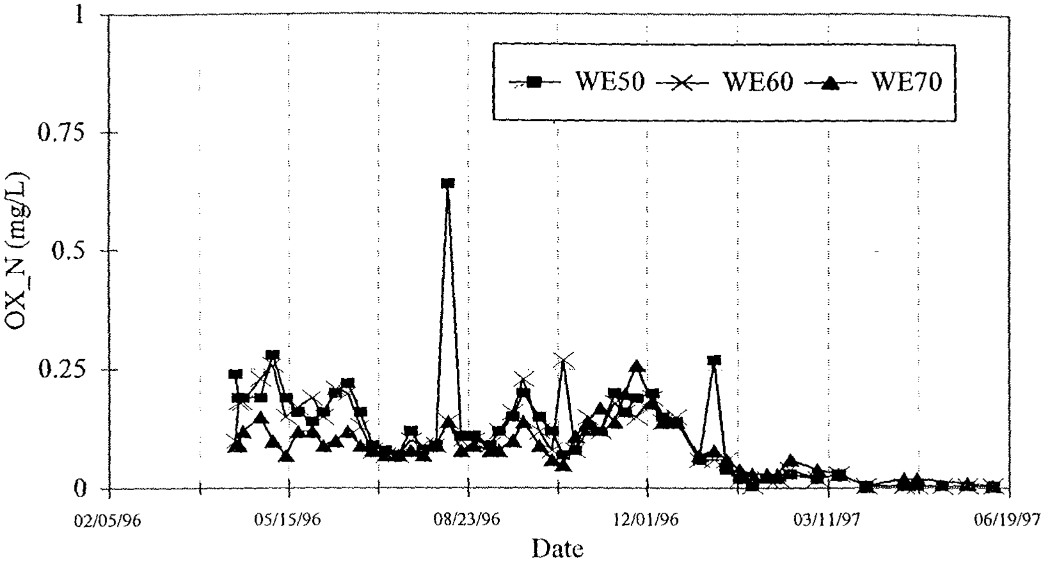


Figure 6—Lysimeter OX-N data, mg/L.

lifetime of the wetlands, allowing periodic cleanout of accumulated sediments without disruption of the vegetation

Conclusions

In this study, with the simple addition of an outlet weir, a dry detention pond was converted to a stormwater wetlands with a diverse assemblage of volunteer plant species Overall, constituent removals were comparable to what might be anticipated for a similarly sized wet detention pond (U S EPA, 1983) These results suggest that this approach may have promise for providing a low-cost retrofit to improve water quality at older detention facilities where water quality improvement was not a primary design issue

Ungauged overland flow from the wooded–grassy area constituted approximately 41% of the long-term total hydrologic input to the wetlands, assuming that a runoff coefficient of 0 2 for this area resulted in a good match (~3% difference) between estimated long-term total hydrologic inputs and outputs, although this method was less effective at explaining the inlet–outlet flow imbalances for individual storms

Aerial atmospheric pollutant loadings were comparable to results from other studies in the Washington, D C , area Results

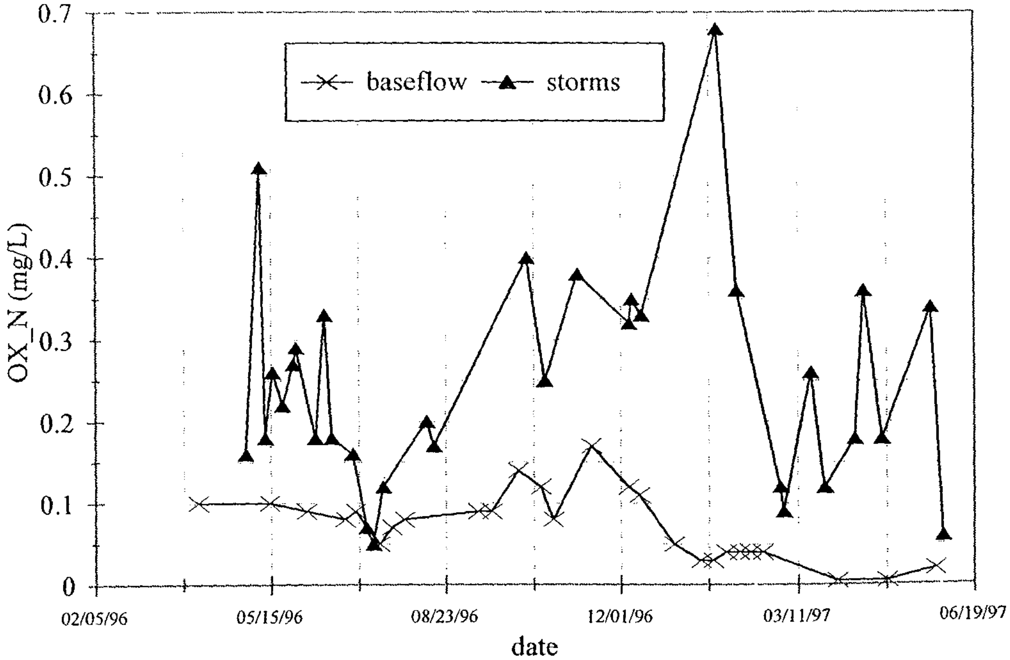


Figure 7—Outlet storm EMC and base flow sample concentration comparison: OX-N, mg/L.

suggest that both the townhouse and forested subwatersheds are net sinks for ammonia and net sources of organic nitrogen, phosphorus, and some metals.

Most constituent EMCs were lower in outlet than in inlet samples Estimated long-term efficiency for the facility, which included overland runoff contributions, was positive for most constituents. Results typically fell within the range of values reported in other runoff wetland studies Long-term performance for nutrients was substantially greater than that measured at the nearby Franklin Farms wetlands, consistent with Crestwood's greater ratio of wetland surface area to drainage area Similar to Franklin Farms, median load removals for all constituents were greater for storms with runoff volumes smaller than the capacity of the wetlands

Ammonia removal was significantly better ($\alpha = 0.05$) in spring 1996 than in both fall 1996 and spring 1997 Removal of OP was also better in spring 1996 than in spring 1997 Oxidized nitrogen removal was significantly better in summer 1996 than in fall 1996 No significant seasonal differences were observed for any other constituents Lysimeter data suggest that the observed seasonal differences may have been related to the eventual development of anaerobic conditions in the shallow sediments of the wetlands Outlet base flow OX--N concentrations were consistently lower than outlet storm concentrations, suggesting that oxidized nitrogen removal occurred primarily during quiescent periods between storms

Acknowledgments

Credits. Funding for this research was provided in part by the Water Environment Research Foundation, Alexandria, Virginia The authors thank the staff of the Occoquan Watershed Monitoring Laboratory, Manassas, Viriginia, for installing and maintaining the monitoring equipment and for collecting and analyzing the samples

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Submitted for publication December 8, 1998; revised manuscript submitted August 24, 1999; accepted for publication December 13, 1999.

The deadline to submit Discussions of this paper is September 15, 2000.

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Cover Letter
Executive Summary

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CHAPTER 1: INTRODUCTION TO THE HISTORY AND SCOPE OF THE PROJECT

I.1 A Brief History

Malibu has struggled with wastewater management for over 30 years (Table I.1). Before 1985, Los Angeles County (LAC) proposed three bond issues for regional, centralized treatment of sewage. They were rejected by voters. In 1985, the Department Chief of the LAC Department of Health Services (DOH) declared that a sewer was a "critical need" based on considerations of public health. In the six years that have followed, a dispute between Malibu residents, volunteer and hired experts, lawyers and the County has continued: Is there a critical need based on a health hazard? One purpose of this report is to assess health risks related to existing wastewater facilities and to try to resolve the on-going dispute (Chapters III and IV).

In 1986, LA County offered a second reason for a collector sewer. Along with various consultants, they stated that the east end landslides (e.g, Big Rock, Rambla Pacifico, Las Flores) had a greater probability of moving because septic tank effluent "lubricated" the contact between the slide mass and the bedrock it sat upon. This claim has also been a dispute between geologists, consultants, the County, and Malibu citizenry. Another goal of this report is to review the safety risk caused by septic tank effluent to various slide areas (Chapters III and IX) throughout the city.

Throughout this thirty year period, some Malibu citizens have argued that, based on public health and geological safety concerns, no area wide collector and conveyance sewers were necessary. Others insisted that the "Big Sewer" would be more detrimental economically, environmentally, and in terms of land use management than maintaining on-site practices. Another group was not sure what the best management plans should include but was skeptical of the Big Sewer alternative and the imposition of the Big Sewer without a vote. A final group believes that the Big Sewer is the only reasonable alternative no matter how it is financed. All parties agreed that there has been no clear wastewater management plan that seriously considered maximizing the best on-site treatment and reuse practices available, applying neighborhood solutions such as communal drainfields or package plants, and minimizing the need for outfall pipes, long conveyance piping, and a single centralized treatment/disposal system. This report is the first such endeavor (Chapters X and XI).

A third strand of Malibu history is important. In order to achieve greater control over the area's destiny, Malibu residents attempted in 1976 to incorporate as a city. Incorporation lost by 114 votes. By 1990, incorporation became one strategy for residents to achieve greater control over the future of community wastewater management. In June 1990, residents voted by 84% to become an incorporated city. Incorporation allows the City to set reasonable but innovative standards for on-site wastewater management and gives it greater control over non-point and point sources of water pollution. This is the first major study under contract to the new City of Malibu.

The resolution of existing disputes is not only crucial to decisions about public health and safety. It will greatly affect the taxes paid by various property owners and the future plans of many commercial enterprises. The Municipal Improvement Act of 1913 has been invoked and an assessment district approved by the County and Coastal Commission. Somewhere between 15% and 25% of the assessed parcels have filed a legal protest and wish to be excluded from the assessment district because they feel they receive no benefits. This report may help some parcel owners decide on the desirability of re-activating the lawsuit. In addition, many residences with problem or marginal on-site systems and many commercial enterprises that want to upgrade, renovate or build are waiting for a clear direction on sewage management. They do not want to have to pay twice: an upgrade of their on-site system and then for a collector sewer. Hopefully, this report will generate a clear plan so that investments in wastewater facilities can be made.

Finally, the future direction of wastewater management in Malibu will also be reviewed by the Coastal Commission, the Regional Water Quality Control Board, and the State Department of Health. The management of nonpoint sources includes a wide variety of agencies and non-governmental organizations ranging from Caltrans to the Santa Barbara Harbor District. These organizations will be influenced by the resolution of the above disputes and the ability of the new city to take on responsibility for point, dispersed, and nonpoint wastewater problems (Chapter VIII).

1.2 Scope and Limits of this Study

This study hopes to produce a useable plan that will help guide the City in future wastewater management. The study focuses on existing on-site treatment and disposal/reuse systems ("septic tank systems with subsurface drainfields"), the package

Table 1.1: Wastewater Management History In Malibu

1913	Passage of the Municipal Improvement Act which allows the assessment of private property if demonstrable health or safety threats are present.
1960	2,823 housing units and 6,486 persons in U.S. Census in the Malibu area.
1964	Ballot for incorporation defeated.
1966	General plan for the Malibu area includes a regional sewer. Proposed County sewer bond issue for regional treatment plant defeated.
1968	Proposed LAC Sanitation District No. 33 sewer bond issue defeated for a gerrymanded patchwork of parcels located throughout the now existing city.
1970	4,535 housing units and 11,709 persons in U.S. Census.
1971	Regional Water Quality Control Board and County consider plans for a $16.5 million treatment plant near Corral Canyon with mile long effluent outfall of 42" for 27 miles of coast. Would accommodate 72,000 people. Adjacent Corral Canyon thermal outfall for projected nuclear power plant cancelled. Proposed County sewer bond issue defeated. Ballot for incorporation defeated.
1971	LAFCO reduces sewer district boundaries to six miles of Malibu coast. Corral Canyon plan terminated. Las Virgenes Municipal Water District becomes planning agency.
1976	City incorporation defeated by 114 votes.
1979	Agency changed to Southern California Association of Governments (SCAG) 208 project. "Waste Treatment Management for the Malibu/Topanga Area" conducted by County Engineer. Proposed regional sewer with outfall at Civic Center, greater enforcement of UPC, and no more package plants. Required more water quality data.
1981	Malibu/Santa Monica Mountains Interim Area Plan projected population of 60,000 for smaller Malibu area.
April 1985	LAC Department of Health Letter by Robert Gates, Director of Health Services, to LAC Board of Supervisors states that there is a critical need to have centralized sewerage because of health hazard to residents and visitors. This statement included a table on ocean water quality, pumping records, and septic tank system repair rates.
1986	DHS Chief of Toxics Epidemiology Program states that there is very little evidence linking human disease to pollutants in Santa Monica Bay.
Dec 1986	Coastal Commission Land Use Plan certified. Recommended regional sewer to accommodate regional housing growth.
1986/1987	Board of Supervisors authorizes $1.3 Million study by JM Montgomery engineers to build a gravity-flow collector system, central treatment plant and an outfall to Santa Monica Bay. Montgomery's "Wastewater Management Facilities, Malibu Area" proposes gravity sewer with centralized treatment at Corral Canyon with outfall and conveyance of sewage east of Big Rock to Hyperion plant. Extensive comments and the vast majority of responses by citizens of Malibu to Draft EIRs opposed to this proposal.

Table 1.1: Wastewater Management History In Malibu (Cont'd)

July 1987	In a letter to Department of Public Works, Malibu Township Council disputes and contradicts all claims in 1985 Robert Gates letter on health hazard.
Sept/Oct 1987	Robert Gates writes second letter stating there is a health hazard in Malibu caused by on-site systems. LA Times article reviews County data and finds County claims "grossly overstated with little evidence to support claims." Hundreds of Malibu residents attend LAC Board of Supervisors meeting. Board refuses to certify Montgomery EIR but continues decision of health hazard. It then directs DOH to do further studies to "determine in more detail the size and nature" of the health hazard.
Sept 1988	DOH study ("Waste Water Management Study, Malibu Area") on status of on-site systems claims "existing individual sewage disposal systems are failing causing public health hazards and nuisances due to subsurface soil conditions, high groundwater table, substandard and undersized leaching disposal areas, and limited parcel areas."
Oct 1988	Citizens Committee and Engineering-Science study recommend an east-end STEP system and a Civic Center gravity alternative with a creek release to Corral Creek. Questa Engineering report"On-Site Wastewater Disposal Investigation of Malibu Area."
Nov 1988	Ultrasystems Draft EIR on STEP system alternative with outfall. Bechtel Environmental Supplemental Draft EIR. Critical commentary by MTC and many citizens of the basis for declaring a health hazard, geologic hazards, and the need for the proposed sewerage system as a "best management" practice.
Jan 1989	Board of Supervisors meeting hears experts and citizens dispute conclusions of EIR. Ultrasystems releases final EIR on STEP system with Corral Creek outfall.
May 1989	LAFCO approves application for cityhood with stipulation that LAC maintain control over wastewater management for up to 10 years.
Sept 1989 to Feb 1990	Coastal Commission denies, then approves, modified version of assessment district for proposed sewer. MTC and others file suit questioning assessment as unconstitutional.
June 1990	Residents vote to incorporate and select their first City Council. County legal challenges delay start of cityhood.
Aug 1990	Coastal Development Permit Application for combined STEP/gravity system submitted by LAC Department of Public Works. Projects population to grow to 20 to 22,000 by 2010. Coastal Commission holds up permit decision. "Legal truce" declared between City and County.
March 1991	City of Malibu incorporates.
July 1991	Contract for "Malibu Wastewater Management Study" awarded to Philip Williams and Associates and Peter Warshall and Associates by COM for examination of existing on-site wastewater management.

plants within city boundaries (Chapter VII), and in-city nonpoint sources of pollution from runoff (Chapter VIII). The study hopes to define where existing on-site practices are adequate, where they require upgrading, and what subareas, if any, should consider a neighborhood collection and conveyance system to a more centralized treatment/disposal/reuse site (Chapter IX). The study hopes to resolve City-County differences which may presently be considered by the Coastal Commission. From this point of view, the report is not a narrow "technical" or "engineering" document, but a more comprehensive report on policy, administrative organization, and the water and wastewater practices within Malibu households.

This study is the result of the work of 14 consultants. The City contracted to Philip Williams and Associates of San Francisco (PWA) who, in turn, hired Peter Warshall and Associates of Tucson (PEWARA) as subcontractors. This joint effort had to cover material from landslides to littoral cells, from coliform bacteria to pumping records. The diversity of expertise was enormous. The list of participants and their job tasks can be found in Appendix A.

In contrast to previous studies which concentrated only on "Malibu" from Topanga to the Civic Center area, this study includes the whole of the new city which extends from the east end of Topanga State Beach to San Nicholas Beach. On the other hand, it does not include the Pepperdine area, Monte Nido, and Topanga, which were excluded from the city.

The study occurred before the new city of Malibu had gathered all the baseline information necessary to operate a city. As opposed to other cities, the consultants could not walk in the door and ask for a pile of relevant reports and maps. Extensive time was given to helping the city compile its first "inventory" of relevant material. Extensive delays occurred in receiving information. The more we explored the inner workings, the more new items and concerns appeared. For instance, a small item on potential nonpoint sources of pollution turned into a major investigation of stormdrains.

One significant product of this project is a "library" to help this new city in its general plan update. The consultants wrote 14 "Technical Memos" for specific topics. Each technical memo covers a much broader, but more detailed analysis than could be included in this report. Most memos ranged from 20 to 50 pages which would have created a 700 page report without any integrated focus. For those interested in more broad-ranging views on particular subjects, the Technical Memos can be obtained from the City. For instance, the technical memo on the Malibu Coast is the first overview of all problems and background information on waves, currents, tides, littoral cells, beachsand budgeting, and coastal hazards compiled for the city. The Technical Memos are listed in Appendix B.

This study has very specific limits.The study is limited to existing wastewater facilities. Because the city has yet to write its general plan, this study could not take into account future areal development, especially in areas such as the Civic Center. It did not review areas where in-filling or vertical remodelling of homes could lead to large increases in wastewater loading. Future in-filling and home additions could overwhelm on-site practices on particular parcels without careful management of wastewater loads. Readers should be aware that this is not a site-specific design report. Neighborhood or city-wide site-specific designs will still be needed.

Previous sewerage proposals emphasized long conveyance networks with centralized treatment plants and outfall pipes to creeks. We were instructed not to replicate or even review the previous engineering designs. We were instructed not to make cost comparisons between the County proposed STEP/gravity sewerage project and any on-site alternatives. Our goal was to look for areas that required help in on-site wastewater management and convey sewage to a more central location only when on-site systems would not work. Part of the reason to decentralize was to create smaller volumes of treated effluent in more dispersed locations that would be easier to reclaim/reuse for beneficial purposes.

There were time and financial limits on the study which prevented certain kinds of monitoring and fieldwork in Phase 1 of the study (e.g, groundwater quality in the Malibu Lagoon area, dye tests of particular on-site systems). Certain reports that would have been relevant to our study were not available. These included the Bing Yen report on Big Rock Mesa, a UCLA report on storm runoff, various water quality data collected by Tapia and Heal the Bay, and various clarifications of Coastal Commission/City relationships. Other reports (Chapter III) were too scattered in files and too variable in quality to become part of this study. These included reports from the Los Angeles County Building and Safety Department and Division of Engineering Materials. Review of data from these reports has been suggested for a future phase of the study.

On the other hand, certain options and additions to the contract were added by the City. The options included creation of a city-wide landslide map, a discussion of landslides and earth movement as they relate to on-site systems, a review of the "blue-sky" amendment to the Uniform Plumbing Code (UPC), a review of the UPC itself, and a review of the Los Angeles County greywater ordinance. A review of the pipeline projects will be made an addendum to the contract. During a "trial" period, Peter Warshall & Associates (PEWARA) will help the city plan check and train employees in the new design criteria. The scope and limits to fieldwork are summarized in Appendix C.

I.3 Acknowledgments

This report is simply the product of the good will, humor, patience, and cooperation of the Malibu citizens, local contractors and consultants who gave their knowledge freely and easily. We hope that reading the report has its informative and enjoyable moments.

In particular, certain Malibu residents helped us by gathering materials and volunteer labor. Mary Ayerst, Herve and Syl Babineau, Dr. Andrew Benton (Pepperdine), Aristid Berk, Thea Brodkin, Mike Caggiano, Marilyn Dove, Mary Frampton, Emily and John Harlow, Dr. Jeff Harris, Dr. Dan Hillman, Faye Hove, Anna Hutchinson, Charlene Kabrin (Malibu Realty), Lucille and Walt Keller, Doug Kirk (Surfrider Foundation), Don Kowalewsky, Bill and Fini Littlejohn, Paula Login, Isabelle Miller (Fred Sands Realty), John Murdock, Elsie Muslin, Carl Randall, Jo Ruggles, Valerie Sklarevsky, Dan and Irma Segal, Sy Sudar, Mary and John van Hammersveld, Carolyn and Kinter van Horn, Michael Vignieri, Larry and Sara Wan, Dorothy White, Al Winikoff, Perina Wiley and Missy Zeitsoff are as much a part of the making of this report as we are. We would like to thank Jason and Taleb for helping lift our spirits and anchoring us to everyday reality at the same time.

Others spent hours helping us contact and convince participants to join the survey. We thank Martin Cooper, Rob MacLoud, Ivan Goff, Bill and Fini Littlejohn, Janet McPherson, Bob Patten (Malibu Property Owners Association), Gil and Joanne Segal, Susan Shaw, and Geary Steffen (Las Tunas Homeowners Association).

Harold Ball (Orenco Corp.), Barbara Cameron, Robert Cooper (UC, Berkeley), Jean Dillingham, Dr. Rim Fay, Mark Gold (Heal the Bay), Robert Kourik, and Dr. George Tchobonoglas all offered much needed review and technical advice. Richard Sherman (Topanga Unlimited) and Darrel Roy, Jr. (Roy Brothers Drilling Co.) provided us with crucial information of local on-site practices. Tom Lubisich (Wastec, Gene's and Daisy's Pumping) deserves special acknowledgment for answering many and strange requests for pumping records, as well as helping us understand the ins-and-outs of the pumping and cartage business in Malibu. Cynthia Miller, Charles Alexander and Bill Johnson designed and produced the cover.

This work would have been impossible without the clarity and diligence of John Knipe (the City's Public Works Director). The City Council and the Wastewater Committee were amazingly participatory in and supportive of our work and we greatly appreciate their active involvement and advice. So many agency workers helped us that they are listed in a separate page of acknowledgments at the end of the report. We would like to thank, in particular, the health officers at the Malibu DOH office for allowing us extra time to review and photocopy files.

CHAPTER II: THE HUMAN ECOLOGY OF ON-SITE AND NONPOINT WASTEWATER MANAGEMENT

This chapter provides a brief sketch of the new City of Malibu (COM): its watersheds, soils, geology, coastline, population, and wastewater systems. It then describes, in brief, how each aspect of the area's ecology influences on-site and nonpoint wastewater management. Finally, it reviews the status of our present knowledge concerning the ecology and wastewater generated within the city.

II.1 The New City of Malibu: the Environmental Setting

The City of Malibu is about 21 miles long as the crow flies (longer as the car drives). At its widest, the city is 4.5 miles. Its southernmost point is Point Dume, though its jurisdiction extends offshore to the LA County line. Its northernmost point is in the northwestern corner which is also the highest and unnamed peak (1,750 feet). Malibu's "stringbean" shape makes it a highly unusual municipal planning area. Its shape influences many aspects of wastewater mangement (e.g., the distances travelled by pumping trucks and the design of wastewater conveyance lines).

The City is located at approximately 34° latitude and 118° longitude. All cities on this latitude experience the same hours of daylight and night --the major energy source of wastewater treatment and disposal for both constructed wetlands and on-site evapotranspiration. The maximum energy for warming soils, chemical reactions and plant growth is 20 megajoules (MJ) per square meter per day in December and 42 MJ per square meter per day in July. This "clear sky" radiation is the same in Malibu, Kabul (Afghanistan), the Khyber Pass (Pakistan) and Hiroshima (Japan), all of which lie at 34°. However, Malibu's coastal position, climate, and the presence of turbid atmosphere reduce the "clear sky" energy input by half in January and 30% in July.

Watersheds

Malibu has about 60 watersheds (natural collecting areas that focus runoff to a common channel) along about 25 miles of coastline (Figure I.1). Twenty-two long and narrow "interior" watersheds extend beyond the City limits. Locally, they are called creeks and canyons. The largest of these is Malibu Creek (115 square miles or 74,000 acres). Other large watersheds (>1,500 acres) include Lechuza, Trancas, Zuma, Corral, Carbon and Las Flores canyons. The watersheds completely within city limits are "coastal" or "beach" watersheds. Many of these small, in-city watersheds have no name. Some have their headwaters start just a few hundred feet inland from the ocean. Others such as the Big Rock, Latigo Shore Beach, Piedra/Pescador Beach, and Puerco Beach coastal watersheds have high residential densities, significant runoff, and unstable slopes that must be considered in wastewater management.

Watersheds are the basic units to discuss nonpoint sources of pollution and sediment (Chapter VIII) as well as any layout for conveyance systems for neighborhood or subarea sewage systems (Chapter IX) . They define the downstream and downhill consequences of landslides and the size of the floodplains that may occasionally inundate home-site drainfields or influence the height of local water tables. Watershed shape controls the aspect (the compass direction of a slope), elevation, rainfall, and steepness of slope -- all important in considering on-site wastewater management. In particular, hillslope steepness influences the kinds of machinery that can excavate seepage pits, the resistance of the soil to downhill creep, the ability of a hill to "pipe" effluent, and, with geology, the susceptibility of the slope to movement.

Surface drainage

The city has 21 blueline "streams" (actually streambeds) designated by the U.S. Geological Survey on their topographic maps. Their usefulness in wastewater planning is discussed in the next section.

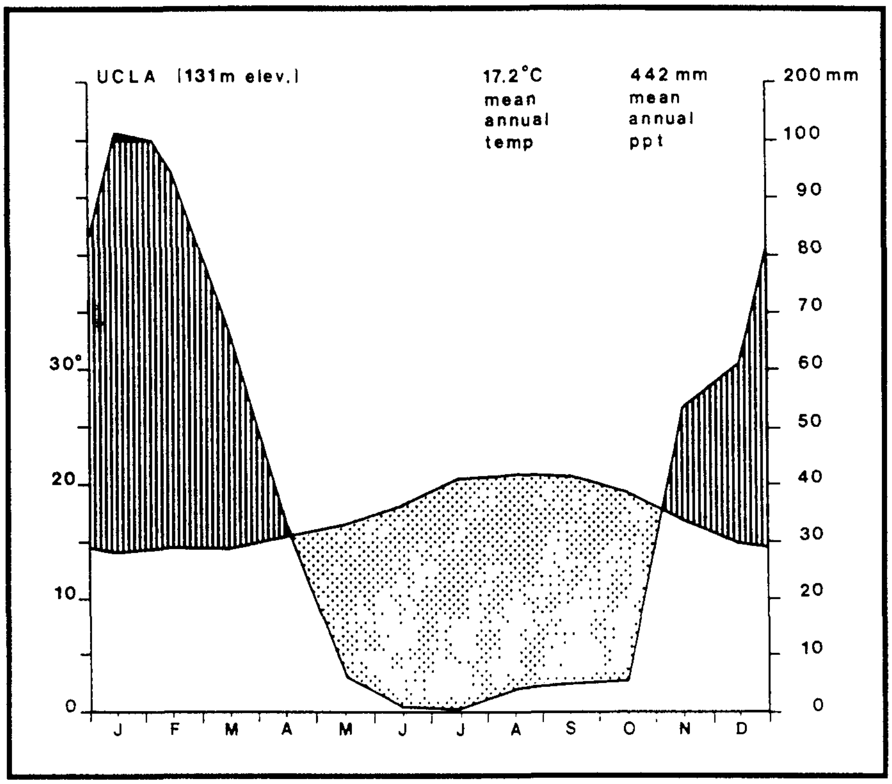
Two floodplain/deltas have particular importance: Zuma Creek and Malibu Creek. Zuma Creek has potential for wetland restoration (Sorensen, 1982). Malibu Creek's delta contained a natural freshwater marsh which has been partially landfilled. The area is still subject to high groundwater tables and extensive flooding. Malibu Creek ends in a seasonal estuary which is now artificially opened-and-closed when lagoon waters surpass 3 to 5 feet in height (Gearhart and Waller, 1989). Given the massive destruction of wetlands in California (over 90% since Anglo-European arrival), Malibu Lagoon is a small (32 acres) precious, remnant resource for southern California. It plays a major role in the planning for wastewater management for the city. The upper Malibu Creek watershed, the Tapia/Las Virgenes Wastewater Reclamation Plant, the Texaco outfall, stormdrain outlets, surface and subsurface drainage in Malibu Colony, channelization and bridge projects, grading, the impervious surface within the watershed, Rindge and other upstream dams, must be reckoned with when considering the design of any future treatment and disposal systems for the Civic Center area (see Chapters VIII and IX).

Climate

Malibu has two seasons: a mild, moist and sometimes rainy season from November to April; and a long, warm, and, excepting coastal fogs, relatively dry season from May to October (Figure II.1). It ranges from semi-arid along the coast to sub-humid at several hundred feet above sea level. Pronounced differences in temperature, rainfall, humidity, and fog drip over short distances make Malibu a patchwork of microclimates. The small range in temperature and humidity closest to the coast (under the strong influence of the marine atmospheric layer) made Malibu an ideal place to cultivate orchids and frost-sensitive fruit orchards. It allows some year-round disposal of effluent by evapotranspiration (ET) with maximal ET between April and October. Temperatures below 40°F are extremely rare. Winter temperatures range from 48 to 64 °F. Summer temperatures from 58 to 75°F. With increasing elevation, both the amount of rainfall and ranges in temperatures and rainfall increase (Figure II.2 and Table II.1).

Global and regional climates, including such newly discovered factors such as El Nino, global warming, the Pacific and Hawaiian high pressure cells, determine the long-term average rainfall and partially define the vegetation. In turn, rainfall amounts and duration act as a major influence on erosion and slope stability. However, it is the character, frequency and magnitude of the most intense storm events that produce the major human impacts. The average annual number of days with thunderstorms is less than five per year. But, a few intense storms usually produce most of the annual precipitation. Exceptionally wet years such as 1916, 1938, 1969, 1978, and 1980 are commonly separated by lengthy rainfall-deficient periods. During a 9 day storm period, a single event such as the February 16, 1980 storm which generated 7.9 inches (20 cm) of rain in one day in the central Santa Monica Mountains, can cause localized landsliding, flooding and erosion. Of all the kinds of storms, these major storm events yield most of the sediment for replenishing beaches (Chapter VIII), and may cause flooding that can temporarily render on-site wastewater systems dysfunctional. These events are also notorious for causing centralized sewer pump stations and outfalls to discharge raw sewage and, in Malibu, even

Figure II.1: Yearly Rainfall Analogous to Malibu. Graph of two curves: mean monthly temperature overlaid on curve of mean monthly rainfall. Period of drought shown by dots; period of relatively more humid climate and increased soil moisutre shown by vertical stripes.



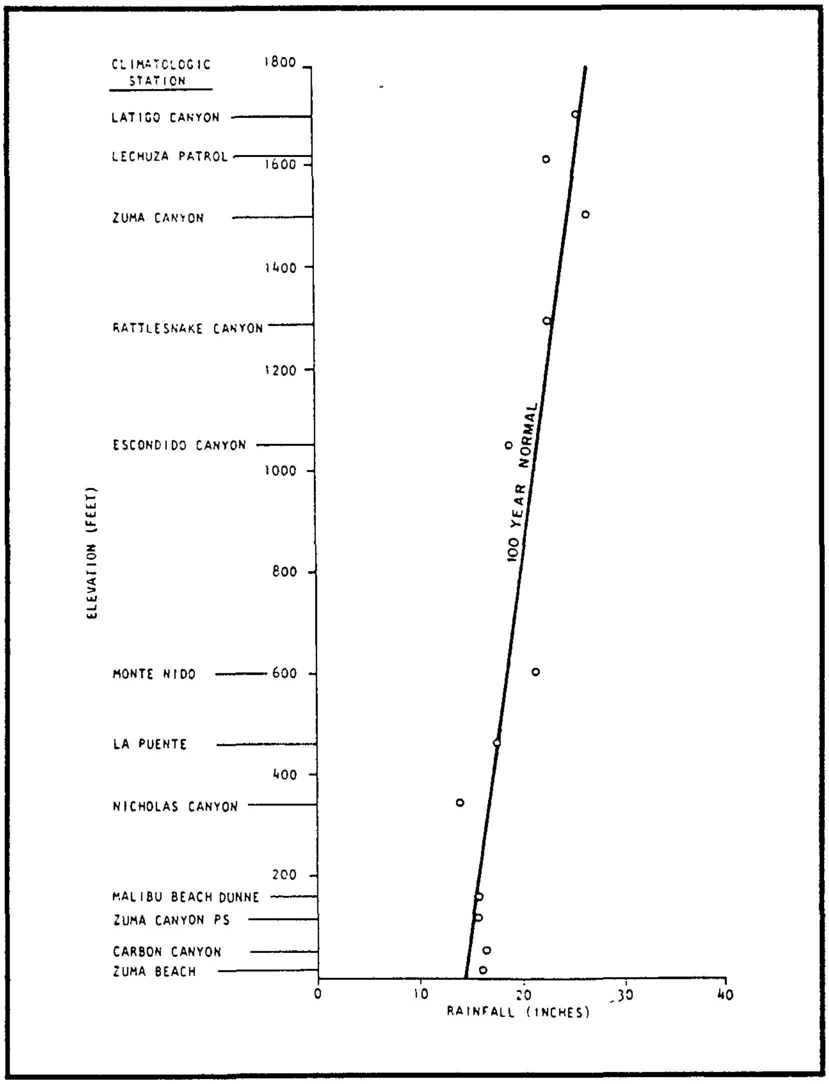


Figure II.2: Rainfall by Elevation in Malibu

Table II.1: Precipitation Normals Data

Weather Station	*Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Santa Monica Pier	15	3.3	3.0	2.1	1.0	2.10	.02	.03	.15	.11	.16	1.7	1.9	13.69
Oxnard	4.9	3.6	3.1	2.2	1.2	0.12	.04	.01	.05	.28	.20	1.8	2.0	14.35
Big Rock Mesa	250-500	3.3	3.5	2.6	1.4	0.20	.10	.00	.10	.20	.60	1.4	3.3	16.70
UCLA	430	4.4	3.7	2.6	1.3	0.24	.04	.01	.16	.19	.22	2.1	2.4	17.39
Topanga	745	6.8	5.0	3.8	1.9	0.28	.02	.02	.14	.22	.27	3.0	3.4	24.79
Lechusa	1600	5.8	4.4	3.1	1.7	0.30	.60	.10	.90	.27	.27	3.0	3.2	22.12

* Elevations in Feet for Weather Stations

small earth movements tend to break waterlines, gas lines, and electric lines. Such outages and breakages are an important factor in considering wastewater treatment in Malibu (Chapter VI).

Global climate also governs the shape, the height, and the period of waves along the Malibu beaches. In extreme cases these waves can cause coastal erosion, undermine, overtop, and flood drainfields with saline water.

In California, drought conditions renew interest in water conservation, greywater systems for irrigation and fire protection and increase homeowner concern for water reuse and wastewater systems that can recycle. Wet years shrink these interests but stimulate discussion about the relative importance of rainfall, storms, and septic tank effluent in the processes of soil creep, debris slides, and landslides (locally known as "geosurfing"). Finally, evapotranspiration (ET) is an important aspect of effluent disposal in areas where deep percolation is suspected to exacerbate the risk of a landslide . The best technical options for reducing deep percolation by disposing of some of the effluent through ET (Table II.2) is a major task in Phase 2(Chapter XI). How much ET can be relied upon in a climate with fog, drizzle, low clouds as well as Santa Ana winds, clear skies, and semi-arid chaparral? Malibu averages 45 days of fog per year but is highly variable.

Earth Materials: Geology

Geologic formations within the city range from the Cretaceous period (about 80 million years ago, the dinosaur period) to the most recent time (the Holocene Epoch of the Quaternary Period). The oldest rocks include the Tuna Canyon Formation from the Cretaceous in a relatively small area of Malibu in the general vicinity of Tuna Canyon, and the Sespe Formation of the Oligocene Epoch (25-33 million years ago, the time when rhinos and mastodons first appeared in North America) which is found in a larger area ranging from Big Rock to Pepperdine University. The rocks of these formations are the strongest and, where they remain intact (without fractures), they are the least transmissive rocks in the city.

The greatest volume of rock mass in Malibu comes from a series of geologically young sandstones, mudstones, and volcanic flows and related sediments. Ten to twenty million years ago (during the Miocene period when grasses evolved and the Great Basin

Table II.2:
Estimates of Evaporative Demand in Potential Evaporation for the Big Rock Mesa (Normal Year) in Inches (Lunt, 1984)

Month	Demand-1	Demand-2	Grass	Trees
January	2.5	2.7	2.2	3.3
February	3.3	3.2	2.6	3.3
March	4.1	4.1	3.3	4.9
April	4.9	4.9	3.9	5.1
May	5.8	6.1	4.9	6,4
June	6.6	6.2	5.0	6.5
July	7.0	6.9	5.5	7.1
August	7.0	6.1	4.9	6.4
September	5.8	5.2	4.2	5.5
October	4.6	4.3	3.4	5.1
November	3.6	3.0	2.4	3.6
December	3.1	2.5	2.0	3.0
Annual Total	58.3	55.2	44.3	60.8

1: From DWR, 1974
2: From W.O. Pruitt, UC Davis (p.c.)
3: From 0.8 x Column 2
4: Potential ET with trees assumes a 50% increase over grass during the period October thru May, and a 30% increase for the other months.

mountains began to elevate), they were laid down mostly undersea, though some are onshore floodplain deposits. Within the last 4 million years, the tectonic forces pushing Malibu northward have also pushed it upward. The undersea formations have risen above sea level to form the coastal benches and upland hills. For instance, the white-colored Monterrey Shale seen from the beach around Point Dume was deposited on the abyssal ocean floor and uplifted more than 10,000 feet to its present position. The land continues to rise at the much slower rate of 0.3 mm per year. While this appears small, there is the possibility that this average may take place in sharp jumps. West of Point Dume these rates may be high enough to cause the beaches to grow (progradation). The transmissive layers of mudstones and other similar rocks are a major path of reentry of effluent into the water cycle.

The widespread fracturing of the rocks due to tectonism (bending, folding, sliding), particularly rocks associated with the Cenozoic (the most recent geological) era, provides Malibu with a second means by which effluent reenters the water cycle. Almost all hill systems (Chapter IV) take advantage of faulted and fractured bedrock and localized deep weathering to dispose of septic tank effluents. The degree of fracturing and weathering is highly variable and large areas of the bedrock remain strong and impermeable. Seepage pits excavators may go on long and expensive searches for the transmissive sections of bedrock. Some pits are 60 feet deep. These depths may place the effluent below the root zone of plants and, in some cases, in a direct flow path toward the slide plane. There is considerable disagreement as to what extent this occurs, under what circumstances, and the degree of danger it may present (Chapters III and IX). Other concerns related to fractured rock include "piping" through fractures which may channel partially treated and diluted effluent to the surface ("daylight") and alleged breakouts that can cause localized erosion. Chapters III and IV addresses these speculations.

Earthquake-induced rupture, earth vibration and local seismic sea waves must be considered in any planning of a conveyance sewer, subsurface pump stations, emergency preparedness programs for power outages or sewer line breakages, and liquefaction. Both wave erosion and earthquakes can trigger landslides. Because this study did not consider sewage systems with long conveyance lines and large pump stations, the City decided a study of the potential seismic hazards in Malibu was not necessary at this time. Similarly, the likelihood of damage from tsunami waves was considered so low that a special study was considered unwarranted. Tsunamis from distant sources should not have a significant impact on beachfront homes and drainfields because the areas of the Pacific in which they originate face Malibu's coast at an angle and should result in an attenuated wave height that decreases impact on the shoreline. The channel islands and submarine banks will absorb much of the tsunami wave energy before it reaches shore. On the other hand, local seismic sea waves have no known history but theoretically could present a serious risk. Interesting details can be found in Antony Orme's Technical Memo 10.

Soils and Deposits Involved in On-Site Treatment and Disposal

The term "soil" has as many definitions as there are professions concerned with the study of the earth. The agronomist is concerned primarily with the near surface section that contains a microbial community and supports plant life. The geologist and soil scientist emphasizes the in situ evolution of soils and distinguishes "soil" from "rock" based on the physical changes that have significantly altered rock strength, texture, structure and mineralogical characteristics. The soils engineer may make little distinction between soil and rock, focusing instead on their differences in physical character and, in particular, their mass and strength.

For on-site wastewater treatment and disposal, soil and rock are two forms of potentially porous material that can (1) maintain the structure of the disposal field excavation; (2) biologically clog and filter; (3) chemically renovate; (4) adsorb viruses and some bacteria; and (5) disperse effluent from the drainfield. From the technical point of view, the soil and bedrock have been compared to anaerobic and aerobic trickling filters under periodic application of wastewater. However, soil provides much better treatment than engineered filters, especially bacteria and virus removal. For the purposes of this report, soil will be considered the porous medium that sits on top of bedrock.

The Soil Conservation Service (SCS), an organization concerned mainly with agriculture, mapped 22 soil series with 47 subclasses within Malibu (Appendix D). Malibu is even more complex because within each mapped area are inclusions of other soils. For the purposes of on-site treatment, a small inclusion (a few hundred square feet) can be utilized for drainfield treatment and disposal even if the surrounding soil area is generally unsuitable. Or, the soil can be avoided altogether by digging a seepage pit into bedrock.

Soil can be a "dead" porous medium such as beach sand or weathered bedrock that comes to life with the addition of effluent. The "living soils" with their bacteria, algae, fungi, and other microfauna are crucial to improved treatment. The living layer forms the drainfield bottom and sidewalls called a "biological mat" or "bio-mat". The biological mat plays a crucial role -- retaining, detaining, and causing pathogens to die off at increased rates. The biological mat is predominantly anaerobic and controls the flow of effluent. The sizing of the drainfield should be based on the permeability of the mat. On-site treatment balances the creation of a biological mat with the hydraulic load. In Malibu, the beach sands and granulated bedrock fractures and fragments start out as dead porous media and are transformed into biologically active filters.

The texture of the soils in Malibu ranges from pure sands to pure clays. The clayey soils play a complex role in Malibu. If effluent keeps the soils moist during drought periods, they can prevent rapid infiltration and transmission of rainfall and runoff, delaying and modifying the impact of early winter storms on landslides. On the other hand, if the soils are shrink-swell clays, water can promote soil creeping, and pipe bending, breaking and grade alteration. In turn, these surface deformations can break and bend utility lines causing outages, spills and other difficulties for the conveyance of water, electricity, or sewage over unstable slopes.

Clays assist in the conversion of effluent to a high quality water. When inter-layered with sands (e.g., Malibu Lagoon) they help improve water quality. On the other hand, they accept water slowly and require larger drainfields. On the other extreme, beach sands percolate so rapidly that wastewater specialists are most concerned with wastewater treatment prior to the formation of a biological mat when the effluent has the chance of moving rapidly without complete treatment (Chapter IV).

Treatment of effluent does not stop after the wastewater has left the drainfield. The surrounding soil will provide further treatment. In Malibu, in situations where the seepage pit is in fractured or transmissive bedrock, treatment may continue. Some types of Malibu bedrock slake or de-lithify to a more soil-like (loose, granular) condition. This is common among some mudstones. The fractures become filled with this less porous but still transmissive material and support anaerobic microbial communities. These communities provide further treatment of effluent.

Soils store and transmit the water for plants. The infiltration rates, permeability or percolation rates, the available water holding capacity, and soil depth will govern the ability of a soil to accept effluent and subirrigate plants. These characteristics of Malibu soils have been broadly categorized by the SCS study (Technical Memo 12). More refined data will become increasingly important to homeowners interested in greywater and combined wastewater reuse (Chapter XI).

Some soils form hardpans which act like impervious bedrock and perch rain water. These perched water tables can decrease the volume of the aerated (non-saturated) soil surrounding the drainfield. The smaller envelope of aerated soil accelerates the formation of the impervious biological mat and may allow more extensive movement of bacteria and virii. Perched water tables and impervious bedrock pose the same design constraints to on-site wastewater management.

Some soils are "artificial." In particular, asphalt and pavement act as an impervious "top soil" that reduces soil aeration and ET from the drainfield, especially if the paving excludes pockets of plantlife (Technical Memo 6). Artificial fills can be very useful in on-site wastewater treatment. But, problems of compaction, preferential flow, decayable organics, and impervious inclusions must be addressed in the design and installation phases (Chapter XI).

Groundwater

Groundwater is important to wastewater management because:

-- high groundwater levels may reduce the assimilative capacity of the surrounding soils as well as the envelope of soil aeration that maintains an aerobic environment;

-- groundwater is the primary issue in determining the risk of slope instability. Within the slide masses, it is important to know how much effluent contributes to groundwater levels in localized areas.

-- the effectiveness of additional treatment of effluent within the saline or fresh groundwater along the beachfront is a health risk concern.

Groundwater is the least understood of all of Malibu's environmental influences. Groundwater can perch on various layers so that a local area may have two or three "groundwaters" that behave differently (e.g., Rambla Pacifico). How much water is recharged by rain, surface runoff, leaky pipes or pools, septic tank effluents or irrigation water into the groundwater has been difficult to assess because of the great complexities of subsurface flow in Malibu. The amount and retention time of groundwater stored underground, its quality, seasonal and annual fluctuations, directions of movement and points of discharge from seeps, springs or creeks are, at best, only roughly determined (Chapter III). Even in Big Rock, the most intensely studied area in Malibu, work has not provided definite information on subsurface recharge and discharge. About all that can be said is that groundwater fluctuates with drought, storms, dewatering, effluent and spray irrigation inputs, and, temporarily at least, from earthquakes.

The Malibu Coast

The Malibu coast is unique in its abrupt transition from ocean to mountains and its east-west orientation. The off-shore islands that modify waves, currents, tides, storms, sediment transport, and tsunamis are actually extensions of the Santa Monica Mountains, only the peaks rise above sea level. The City has a unique microclimate for California, well-known to horticulturalists, that derives from the marine atmospheric layer and other oceanic influences.

For nonpoint pollution and wastewater management, the major interests are: the asserted health risk created by occasional storm damage to drainfields or, even less frequently, septic tanks; the frequency and importance of saline waters on the treatment process from periodic elevation of the sea level; the increased or decreased detention of the effluent plume beneath seasonal and locally varied beach profiles; and the importance of streams, cliffs and currents to beach replenishment (and, consequently, the beach profile). A debatable assertion has been made that drainfields require bulkheads and bulkheads are primarily responsible for beach sand depletion.

There is no one type of beach profile in Malibu. There are 1.2 miles (2 km) of rocky cliffs in the vicinities of Point Dume and Sequit Point. Sandy beaches dominate most of the coast. Sandy beaches are sometimes wide enough to protect cliffs behind the beach and ocassionally, as at Trancas Beach, are backed by incipient dunes. Gravel beaches are notable off San Nicholas, Los Alisos, Trancas, Zuma, Ramirez, Escondido, Solstice, Corral, Puerco, Malibu, Las Flores, Piedra Gorda, Pena, and Tuna canyons. The depth of these gravel/cobble beaches to bedrock is not well known.

The beach profiles of Malibu vary with location and season as well as over periods of decades. For example, the wide sandy Zuma beaches maintain a predominantly steep foreshore, low-gradient nearshore bottom with offshore bars and, depending on tidal stage, plunging or surging breakers. In contrast, Malibu beach usually has a shallow concave beach face, a gently sloping nearshore bottom, and spilling or plunging breakers. Las Tunas beach varies depending on storm-wave frequency and sediment supply. This variety causes difficulties in generalizing about beach profiles and the fate of drainfield effluent plumes (Chapter III). Although many residents talk of “winter” vs. “summer” profiles, coastal geomorphologists speak of “reflexive” vs.”deflective” profiles and indicate that sometimes the low beach profile can occur in summer months. This is important to wastewater managers as low profile beaches provide the greatest opportunity for treated effluent to seep through or under bulkheads and encounter beach crowds. Longer-term changes in beach profiles have been postulated. For instance, Las Tunas beach appears to be retreating between 8 inches to 1.4 feet (0.20 to 0.43 m) per year for the last 60 years. Zuma Beach appears to be rising.

Beach profiles in Malibu are complex phenomena (Figure II.3). North of Point Dume to Point Sequit, there are no major sources of sediment for beach replenishment except cliff retreat. Most of the beach sediment appears to come from upcoast from the Santa Clara and Ventura Rivers as well as Calleguas Creek by way of "longshore currents." This downcoast drift of sediment is stopped at Point Dume and very little continues past the point. The City's management of the nearshore and on-shore sediment budget for the coast west of Point Dume (called the "Zuma littoral cell") must include concerns for upcoast dams, flood control structures, Santa Barbara Harbor, groins, and other human influences on the sources of sand replenishment. Management will require regional joint-powers agreements.

East of Point Dume the beach profiles have always been sand-starved because of the influence of Point Dume and nearby marine canyons. The major sources of beach sediment are cliff erosion and Malibu Creek, whose erosive flows contain sediment low in sand content. With the modifications of Malibu Creek (especially upstream dams) and the armoring of the shoreline for road and home protection (Figure II.4), the beaches from Point Dume to Topanga (part of the "Santa Monica littoral cell") have been further depleted. In this case, the city should have more influence over the local sediment budget and beach profile (e.g., beach replenishment along Las Tunas beach). Further details on the importance of longshore currents, wave-induced currents, strong rip currents, onshore/offshore flows and storm waves and swells with periods of 1 to 30 seconds to the sediment budget can be found in Technical Memo 10.

The height of the sea level is a complex measurement based on a "net" geometry cast over the land and correlated to sea heights in 1929. It is influenced by the rise and fall of both the land (from plate tectonics) and the sea (e.g., post-glacial melting). More important to wastewater management are the daily and seasonal sea level changes on the scale of feet and the frequency of exceptional events that can raise sea levels to impressive heights. The daily change occurs from the tidal regime. There are usually 2 high waters of different heights and 2 low waters of different heights each day. The maximum tide is

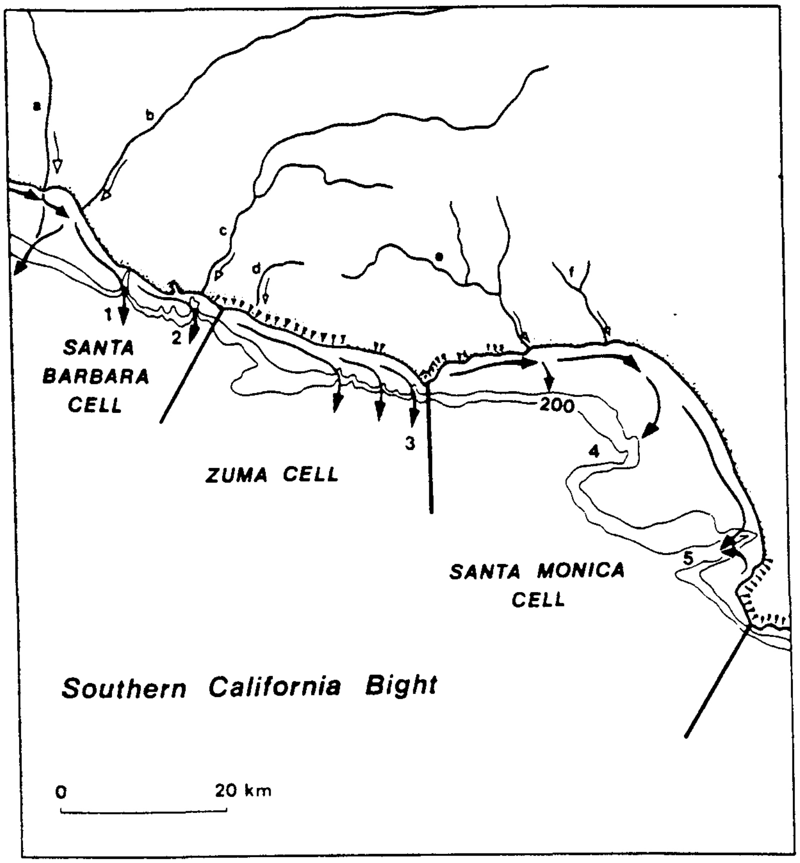


Figure II.3: Littoral Cells of the Malibu Coast.
Black arrows indicate predominat littoral drift. Open arrows inidcate major river sediment sources. Active seacliffs shown by barbs. Submarine contours are 100 and 200 m.

1 - Hueneme Cyn,
2 - Mugu Cyn
3 - Dume Cyn
4- Santa Monica Cyn
5 - Redondo Cyn
a - Ventura River
b- Santa Clara River
c - Calleguas Creek
d - Big Sycamore Creek
e - Malibu Creek,
f - Topanga Creek.

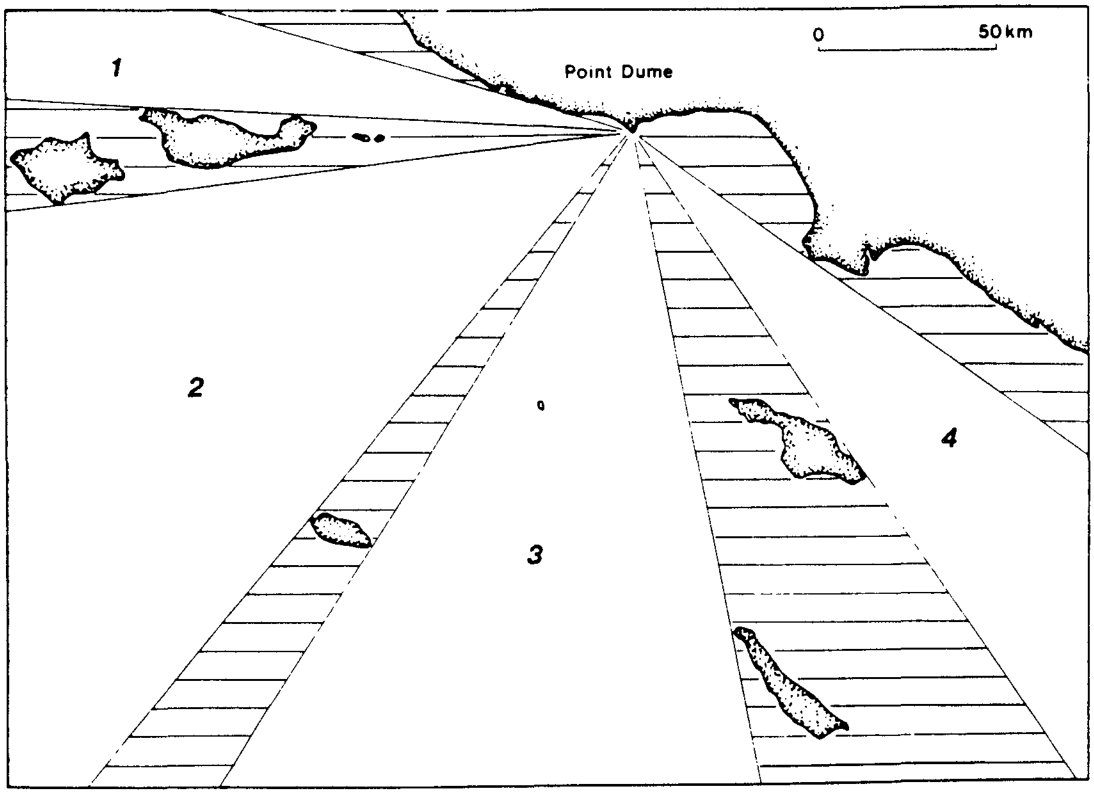


Figure II.5: Ocean swell exposure at Pont Dume.
(1) Westerly swells move up Santa Barbara Channel, penetrate the Malibu coast between Point Mugu and Anacapa Island (refracted and weakened). (2) Westerly to southwesterly swells move onshore between Channel and San Nicholas Isalnds. (3) Southwesterly and southerly swells approach between San Nicholas and San Clemente Islands. (4) Narrow window between Santa Catalina Island and Palos Verdes peninsula for southeasterly swells. Swells are further modified by submarine banks.

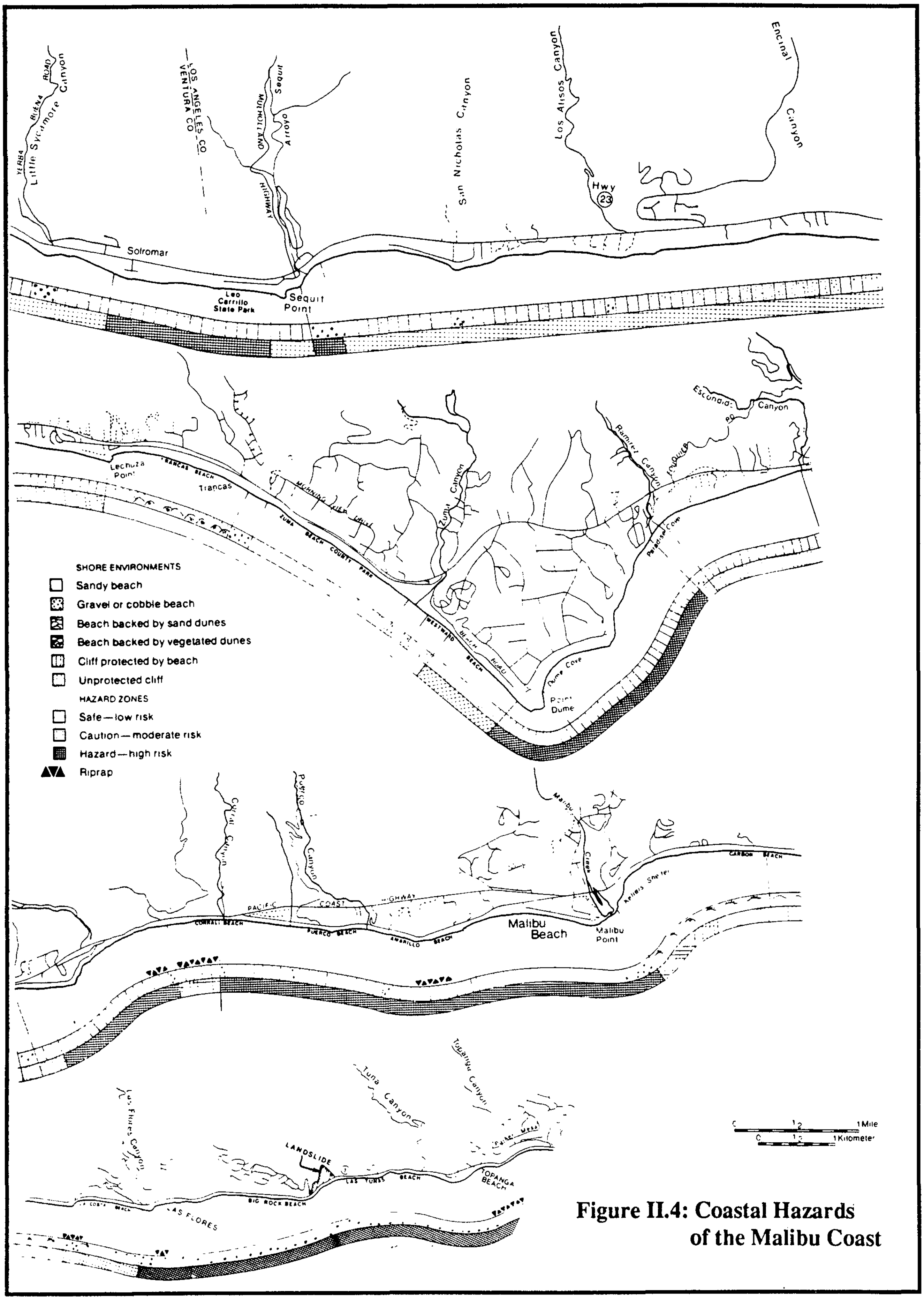


Figure II.4: Coastal Hazards of the Malibu Coast

Table II.3: Tidal Elevations in Meters at Santa Monica, 1960-78

	To MLLW	To NGVD
Highest Observed Water Level (January 28, 1983)	2.43	1.63
Mean Higher High Water (MHHW)	1.65	0.85
Mean High Water (MHW)	1.42	0.62
Mean Sea Level (MSL)	0.85	0.05
National Geodetic Vertical Datum of 1929 (NGVD)	0.80	0.00
Mean Lower Water (MLW)	0.29	-0.51
Mean Lower Low Water (MLLW)	0.00	-0.80
Lowest Observed Water Level (December 11, 1933)	-0.79	-1.59

about 11 feet (3.2m) above mean lower low water (MLLW). Tidal oscillations of 8 feet (2.5m) above MLLW have been suggested as the planning tool for a 100 year period (Table II.3). The sea level is generally lowest in March-April and rises about 6 inches (150 mm) in August-September.

About 80% of all swells along the Malibu coast approach initially from the west-southwest or southwest. The more westerly "seas" commonly arrive in the afternoons at any time of year. The pulsating Hawaiian high pressure cell and the low pressure cells that generally move eastward from the Gulf of Alaska dominate the wave regime of the Malibu coast. Relatively rare are southerly swells that appear during the summer months. These swells are commonly 6 feet but can reach impressive heights of 10-15 feet. Very occasionally, hurricane induced swells or portions of the hurricane itself off the west coast of Mexico will travel as far as Malibu (September 1939). Finally, extra-tropical swells originating near Antarctica and New Zealand may reach the Malibu coast with great power.

Swells approach Malibu through windows between the offshore islands (Figure II.5). Exposures differ east and west of Point Dume. Malibu is especially vulnerable to swells and storm waves coming from the south-to-west quadrant, which slip though the "window" between San Clemente and the Channel Islands. Swells from the extreme south are blocked by Palos Verde peninsula and the islands.

In extreme cases, high tides, medium to high seas, storm surges and exceptional events such as El Nino combine to overtop and undercut bulkheads and, if they are on the beachside, damage on-site systems. For instance, extra-tropical 33 foot breakers pounded the south-facing coasts in September 1934 and August 1983 but were somewhat mitigated, in Malibu, by the coastline's westerly orientation and the breaking effect of the offshore islands. The El Nino event of 1983 raised sea levels by as much as 10 inches (262 mm) and played an important role in the degree of home damage (Chapter III).

In summary, the frequency of various heights of sea level (including extreme storm events) plus the size, shoreward extent, and shape of the beach profile regulate any human potential exposure to treated drainfield effluent . The sea level also determines the vertical distance of non-saturated flow and, indirectly, the dilution and dispersion rates of any potential pathogens. In turn, the beach profile is closely tied to sediment budgets that can be influenced by in-city policy and joint-powers agreements.

Vegetation

The native vegetation of Malibu includes soft chaparral, coastal sage, riparian (creek-bottom), remnant oak woodland, remnant lagoon, remnant coastal dune, and exotic landscaped vegetation. The plantlife has strong connections to wastewater treatment. If wetland polishing or treatment becomes a choice of the city, then these plants do the job of chemical renovation, filtration, and adsorption of potential pollutants and pathogens. The reuse of effluent requires a change in plantlife from winter wet/summer dry natives to winter wet/summer wet natives or exotics. The partial disposal of effluent from deep seepage pits requires specific deep-rooted trees. The partial irrigation (and consequent reuse and disposal) of greywater by grass or shrubs requires a choice of species that can tolerate alkaline waters. The reuse of treated wastewater can also irrigate fire resistant plants that help reduce risks to property.

Animal Life

Animal life has two important connections to wastewater management. First, the excreta of various animals (fish, birds, mammals) confuses monitoring programs trying to track potential health hazards or nuisances. For instance, a duck in the lower Malibu Creek area may produce five times the coliform bacteria (in number/gram of feces/day) of a human. Coliform is an indicator that other harmful bacteria may be present. It is not harmful itself. It is not possible using coliforms to accurately determine if there is a potential health hazard because of the wildlife contribution of confounding bacteria. Second, the treatment, disposal or reuse of wastewater directly impacts the species and distribution of wildlife. For instance, the amount of freshwater released to Malibu Creek by Texaco, Tapia or any proposed treatment plant will change the salinity of the lagoon and the species that can survive (Chapters VIII and IX).

II.2 Population, Parcels and the Number of On-Site Systems

The demographic definition of Malibu is in a state of flux. The resident population, according to various sources, ranges from 15,000 to 20,000. The number of year-round residents, weekenders, seasonal users, or mixed home users was recorded on our survey but it is impossible to know if it reflects the population at large. Some homes have "typical" families, while others visit their homes 2 or 3 times a year. These diverse uses make generalizations about wastewater loadings difficult. In the summer months, the city receives an additional 8 million visitor-days by a unknown number of visitors. They use the approximately 15 restrooms along the beaches, 20 chemical toilets, and the facilities provided by many commercial establishments (Table II.4).

There are approximately 6,500 parcels within the city (Tables II.5 and II.6). About 4,985 have structures that could potentially generate wastewater year-round. About 3,800 are single-family residences and about 1,012 are apartments, duplexes, triplexes, quadruplexes, and multiplexes (including condominiums, a nursing home, and two mobile home parks). Approximately 140 additional parcels generate wastewater on a less regular basis. These include motels, hotels, schools, clubs, the RV park, offices, stores, banks, churches, synagogues, service stations, industrial buildings, restaurants, combinations, shopping centers, warehouses, fraternal organizations, racquet clubs, stadiums and parks with restrooms. There are about 1,535 parcels that generate no wastewater (parking lots, easements, utility corridors, vacant farmland, vacant commercial, and vacant single-family residential parcels). The number of parcels that generate wastewater for the city's 5 package plants is not known (Chapter VII). The package plants serve about 960 homes.

Table II.4: Beach Wastewater Facilities

LOCATION	RESTROOMS	NOTES
Topanga	0	Concession plus new restroom planned for next few years
Las Tunas	0	Restroom planned in 6-7 years
Malibu Surf Riders	1	Built 1986
Pt. Dume	3	Another planned in 10 years
Zuma Beach	9	On-going $6.5 million restoration
San Nicholas	1	Small restroom

Table II.5: Estimated Total Parcels

Type	Total
Residential Built-Out	4015
Residential Vacant	1304
Commercial Built-Out	118
Commercial Vacant	287
Condominiums	879
Co-Ops	12
Mobile Home Parks (2 parks)	3
Residential/Store Mix	25
	6643 *

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* From: Hulan Daniels, PC Consulting Group. A parallel estimate by PEWARA counted 6484 parcels. The differences, given methodology, are not considered significant.

Table II.6: Built-Out Parcels by Size

Size	Residential	Commercial	
≤ 1/8 acre	304	16	
1/8 to 1/4 acre	812	13	
1/4 to 1/2 acre	789	24	
1/2 to 3/4 acre	474	6	
3/4 to 1 acre	278	8	
>1 acre	1358	36	
subdivided	---	15	
	4015	118	**Total: 4133**

The number of parcels are not identical to the number of on-site systems (septic tanks plus drainfields). Sometimes, a single parcel can have have multiple systems. Sometimes, a cluster of parcels can have only one system. Sometimes, a parcel that generates wastewater will have no on-site system. For instance, Point Dume Mobile Home Park serves about 290 units with no septic tank or drainfields (Chapter VIII). The Paradise Cove Mobile Home Park serves 262 units with about 32 on-site systems plus an overflow system. The number of parcels, units, and on-site systems is particularly difficult to predict because of the variety of arrangements that include apartment complexes (Table II.7). There are about 4,200 use and part-time use parcels with on-site systems and probably about 4,000 on-site systems.

Table II.7: Apartments and Multiplexes

Type	Buildings	Total Units	Type	Buildings	Total Units
Duplex	110	220	Triplex	44 (43)	132
Quadruplex	42	168	Five-plex	11	55
Six-plex	7	42	Seven-plex	5	35
Eight-plex	5	40	Ten-plex	3	30
Twelve-plex	2	24	Thirteen-plex	1	13
Fourteen-plex	1	14	Fifteen-plex	2	30
Twenty-two plex	1	22	Forty-seven plex	1	47
			Totals	235 (234)	872 (869)

II.3 A Review of Previous Knowledge Of Malibu Ecology and Wastewater Management

This section briefly reviews existing printed material on the ecology of wastewater management for Malibu. Some of the Technical Memos are the best reviews of all material related to a subject on Malibu now available. In particular, Technical Memo 4 on landslides, Technical Memo 12 on climate, and Technical Memo 10 on coastal hydrology should be read for more complete coverage of the subject than can be incorporated into this report. For the sake of brevity, only those sections directly bearing on wastewater management have been extracted from the Technical Memos.

Watersheds

There are three maps of Malibu's watersheds. Figure I.1 is a map (enlarged from a USGS 1: 24,000 topographic map) by PEWARA for this report. It emphasizes the city's boundaries, floodplains, blue-line streams, coastal as well as the inland watersheds whose land area includes part of the city. The Los Angeles County Regional Planning Department has delineated (also on the 1:24,000 USGS maps) the entire boundaries of the watersheds that extend further inland. The recently updated CalTrans map includes their stormdrains and culverts. These maps are adequate for planning purposes but for administration of individual watersheds (e.g., the east PCH landslide areas) more detailed maps are required.

Surface Drainage

The USGS blue-line streams within the city are a qualitative designation added by the cartographer based on some criteria, perhaps riparian vegetation, but not explicitly stated. They designate a significant "intermittent" flow that is more regular or common where the channel is shown with a blue-line. As far as can be determined, the blue-line reaches have not been updated with actual flow data or flood frequency data since before 1981. Malibu Creek has become an almost artificially created year-round stream by Tapia discharges. This change of status is not reflected on the map. In short, the blue-line designation has to be used with a great deal of circumspection. There are many channels that are not significantly different hydrologically from streams without blue-line status. In approaching Malibu stream channels, new criteria need to be developed based on riparian vegetation, floodplain width, erodibility, presence of sensitive species such as steelhead, and human influences on the channel shape.

Climate

Technical Memo 12 reviews climate data from LAX, NOAA, the California Department of Water Resources and local reports (e.g., Lunt, 1984). In general, macro- and micro-climatic information important to wastewater treatment and reuse is not well known. The lack of Malibu data forced Pepperdine (Bright, 1983) to use a complex computer model to simulate its ability to reuse treated wastewater for spray irrigation. Large gaps in the desired data include photosynthetic active radiation (sunshine for plant growth) as it is modified by days of fog, low and high cloudiness; temperature, and ET patterns as they vary with elevation and seasonal winds. There is no land-based wind data from Malibu, no fog or cloudiness data, and no pan evaporation rates. There is a need for at least one active rainfall station for every 200 feet of elevation. At the moment, there is no rainfall station between 600 and 1,000 feet and if the El Puente, Monte Nido, Zuma Beach Patrol, Rattlesnake Canyon, and Escondidio stations are closed, then very large elevation gaps exist (Figure II.2, Table II.8). Reestablishment of the Zuma Canyon patrol station which closed last year and had accumulated 50 years of data should be a high priority.

Soil and Deposits

The published soil maps of Malibu lack the precision and accuracy to base any area wide planning or design for on-site wastewater systems. The mapping shows what can be expected in a 20 acrea area. SCS (1986) mapped soils at 1: 24,000 (1" = 2,000 feet) and ENVICOM (1977) at 1: 250,000 (1" = 4 miles). For soil information to be useful, the ideal scale should approach 1: 1200 (1" = 100'). This scale would allow meaningful drainfield design for areas as small as 200 square feet.

The soil classes of these maps have ranges of characteristics (e.g., permeability) that are too broad and, generally, measured too crudely for wastewater treatment system design. The SCS soil survey identified 22 soil series and 47 subclasses within city limits (Appendix D). Both Steve Wert and Joe Tabor sampled various areas of Malibu and compared their sample with SCS designations. In select areas, they agreed with SCS only

Table II.8: Rainfall Stations for the Malibu Area

Station Name	Date of Operation	Elevation	Average Rainfall (in.)
Trancas Beach	1930-1990	15 ft	13.82
Santa Monica	1926-1991	44 ft	14.06
Carbon Canyon	1939-1991	50 ft	14.83
Zuma Canyon Patrol	1940-1990	115 ft	15.66
Malibu Beach-Dunne	1949-1991	160 ft	14.69
Nicholas Canyon	1957-1991	340 ft	13.73*
Monte Nido	1939-1990	600 ft	21.52
Topanga Ranger Station	1927-1991	745 ft	24.00
Lechuza Patrol Station	1932-1991	1620 ft	26.51

* Incomplete
Data from Los Angeles County Flood Control, Hydrology Division

half the time. The mapping was apparently done on a reconnaissance level of accuracy which resulted in some large areas being incorrectly mapped. For instance, in the 27000 area of Winding Way, a 20 acre parcel of Diablo Clay was incorrectly mapped as Castaic silty clay loam.

The scale and patchiness of Malibu soils limit the usefulness of broadbrush studies for wastewater planning (e.g., Questa, 1988). In Chapter IV, beach deposits, wastewater treatment and the limits of present knowledge will be discussed. To the best of our knowledge, what actually happens to effluent in the porous, fragmented, slaked, and fractured portions of Malibu bedrock has never been studied to the best of our knowledge.

Earth Materials and Movement/Geology

There are three major maps of the bedrock geology of the City: Campbell (1970) for the Point Dume quadrangle at a scale of 1: 12,000; Dibblee and Ehrenspeck (1990) for the

Triunfo Pass quadrangle (west Malibu) at a scale of 1: 24,000; and Yerkes and Campbell (1980) for the Malibu Beach and Topanga quadrangles (east Malibu) at scale of 1: 24,000. There is no overall seismic map of Malibu. Until this contract, there was no single map of the historic, active, and prehistoric landslides and debris flows for the city. Campbell (1977) mapped landslides in the Point Dume quadrangle. Detailed geologic work has focussed on particular landslides (Big Rock, Eagle Pass Road, Rambla Pacifico, Calle de Barco, Carbon Canyon and Mesa, Malibu Colony Drive, Latigo Shore and Canyon, Encinal Canyon and others) and parcel-specific geological engineering. But, even with these studies, huge gaps in our understanding of the detailed causality of landslides remain, particularly with regard to the hydrologic balance.

Geotechnical reports for certain sites are contained in the Engineering Materials Division of the Department of Public Works (LA County) and the Building and Safety Department of the City. Because of time and contract limitations, the dispersed nature of the reports, and the need to carefully review each one for accuracy, these reports were not analyzed in any systematic manner. A sampling of reports at the City of Malibu Building and Safety Department (which came from the County) showed that they include some good and some not so good information on borehole geology, piezometric records, and soil mechanical strength tests. To adequately verify each report is a major undertaking and this study did not require mechanical soil strength information as much as seasonal groundwater fluctuations, soil mottling, texture of the top 4 feet and soil permeability rates which were rare items in the sample reviewed. The latest Bing Yen summary and final reports on Rambla Pacifico and Big Rock Mesa are not yet available.

Groundwater

There is no overall map of the hydrogeology of Malibu showing fluctuations in area and depth of subsurface water, direction of flow, "ponding" by subsurface barriers, etc. The geotechnical reports tend to list the groundwater level on one day in one season of one year. This is difficult to interpret. In sampling City geotechnical reports, PEWARA found not one contained information of soil mottling caused by fluctuating groundwater. To begin to collect adequate data, it is recommended that inland home constructions which require 2 foot diameter holes for testing seepage pit infiltration should not re-fill the test holes. Instead, many can be lined and provide COM with long-term full-spectrum geotechnical monitoring. This can forewarn of any groundwater buildup and increased hillslope movement risks. For large scale developments, especially those with irrigation, the costs of this monitoring should be part of the building permit. Further groundwater work near Malibu Lagoon is recommended (Chapter VIII). Areal contributions to groundwater from uphill septic tank effluents and water reuse projects should be monitored and recorded by the city geologist. For instance, the impacts of uphill spray irrigation from Pepperdine on groundwater along Malibu Road are a concern to residents along Malibu Road.

Coastal Hydrology

The primary observation to emerge from Dr. Orme's study is the existence of significant gaps in knowledge about the Malibu Coast. This ignorance is greater than for other coastal areas. Prior reports have often used the same data so that there is much repetition but little progress. Certain tacit assumptions in earlier works are often repeated but are questionable and cannot be substantiated without fieldwork (e.g., sediment and mobility studies associated with the Las Tunas groins).

For the study of sediment budgets, Malibu data inadequacies include the tide data, the wind data, the deepwater data for the Malibu coast, and the refraction and shoaling data which are 30 years old. Perhaps more important, there are no studies on Malibu beach profiles similar to work at Ventura, no studies of shore-normal and longshore currents, and no studies of the Zuma littoral cell.

The priority areas related to beachfront sewage systems are:

(1) The dynamics of beach profiles. There have been no studies of the seasonal and yearly changes of Malibu's beach profiles and what causes them. The importance of bulkheads on beach profiles and the importance of beach profile control of the effluent plume (time and distance to emergence, if still recognizable) is not known and often complex (Chapter IV). A method called the "swept prism" approach defines the subaerial and submerged portions of a beach and nearshore zone by frequent surveys. The results demonstrate maximum and minimum profiles and the frequency of a given elevation. The changing profiles can be correlated with wave actions resulting from bulkheads, littoral processes and sediment budgets. This study -- coupled with a study of sub-beachsand tidal flux, effluent treatment, dispersion and dilution -- is crucial to any definite detailed determination about the fate of treated effluent on the surfzone waters.

(2) The dynamics of on-shore/off-shore sand movement. Part of determining the causes of beach profile shape and stability is understanding how much comes from the littoral process (the shore-parallel forces), and how much from the onshore/offshore sediment transport. This information needs to be known for the city's coast.and would help resolve the question of the importance of bulkheads to the shaping of the beach profile.

(3) Littoral processes: Up to now, Malibu has relied on deepwater wave data and wave hindcasting techniques to determine shallow-water wave heights, wave periods, wave types, angles of wave approach, longshore current velocity and direction, width of the surf zone, and wind speed and direction. What is needed is an actual time series for Malibu as exists for the Ventura coast (Orme, 1991). These data are crucial to understanding the coastal response of Malibu's beaches.

(4) Malibu Creek and beach sand budget management: The existence of dams upstream from Malibu Lagoon and the restructuring of the lagoon have altered the sediment budget to the nearby beaches. Dr. Orme has suggested that Rindge Dam be removed or considered a source for beach replenishment. This study requires more details on tributary creeks and sediment flows along the coast from Point Dume to Topanga.

Vegetation

There is only one study of plants important to evapotranspiration (Bright, 1983). There are only brief discussions of plants vulnerable to greywater irrigation. There is a need to define multi-use land plants that can reuse effluent, reduce fire risk, increase wildlife, reduce water use in slide areas, and provide deep roots to extract effluent and groundwater from slide prone areas.

If the City should decide to create wetlands to improve storm water runoff quality or to treat effluent from a small volume treatment plant, then more research on wetland species is required in Phase 2.

Animal Life

In reviewing the data concerning animal life, the largest gaps related to wastewater management were: (1) contributions of nitrogen compounds and bacterial levels of various animals found in the lagoon vicinity and along the coastline; (2) determining which animal "indicator" species to use to establish receiving water standards by season within the lagoon (e.g., gobi, steelhead, particular clams). All others are concerns with human behavior.

II.4 A Review of Malibu Water Use and Wastewater Loadings

The most important aspect of design is the establishment of reasonable wastewater loadings and peak loadings for on-site systems. No direct measurements of wastewater loadings for residential or commercial buildings has been made for Malibu. Los Angeles County (Coastal Commission Permit, 1990), the Coastal Commission, and the Malibu Township Council (see below) have all used indirect methods to determine reasonable loading rates. There have been no studies and little discussion of peak loadings which are crucial to the proper design of institutional and commercial on-site systems.

Steve Wert (Technical Memo 11) made an extensive review of single family residence wastewater loadings to collector sewers and septic tanks. Wastewater loadings are often taken from indirect sources such as water use records and flow measurements in gravity sewer lines. Water use figures are usually inflated because they include water for car washing, irrigation, swimming pools, jacuzzi or hot tub which do not enter the septic tank. The most reliable data come from water tight small diameter collection systems of which pressure and variable grade sewers are the most common. There are no studies available for high income homes. In addition, in Malibu, irrigation can occur in winter months in dry winters and during long inter-storm droughts. Winter time water use data can include substantial irrigation.

The County proposed sewerage system, using district-wide Waterworks District No. 29 figures, estimated that sewage flows might be 345 to 640 gpd per dwelling (LAC, 1990, Attachment 13) for a home of 2.5 persons discharging 60% of the household water into the septic tank. This rate is equivalent to 230-430 gallons per person per day. If these indirect assessments are true (see Chapter VI for a more direct assessment of Malibu), the amount of conservation required would be minimally 28% and maximally 61% just to meet the County's engineering design standard on 250 gpd per dwelling (see Chapter XI for more water conservation). Wert determined that actual flows for large/high income homes to the septic tank were likely to be closer to 185 gpd per dwelling (Technical Memo 11) -- roughly 50 to 70% less than the County estimate.

For commercial areas, George Tchobonoglas (Letter, Oct. 1989) has outlined the estimation of wastewater loadings for commercial areas. Three methods are common: (1) using a gross areawide "flow factor" and applying it to existing acreage (e.g., person equivalents per acre of commercial area), an unsatisfactory method which does not include unique features of developments; (2) applying "unit flow factors" by functional uses of a commercial area (churches, cleaners, hotels, etc.), an approach which can be refined through tax assessor records of building sizes, parking lots, and irrigated area; and (3) measuring actual water use rates for different types of commercial development and setting Malibu specific unit flows. This is the preferred method but suffers, as described above, from estimating uses that go to the septic tank vs. other uses such as washing down the sidewalk and irrigation.

Previous studies by the County and Coastal Commission used the "gross areawide flow factor" method, the least accurate method available. Commercial areas, in County estimation, use 4,000 gallons per day per acre (about 90 gpd/1,000 sq. ft.). The Coastal Commission staff mandated quantities at 2,000 gpd per acre (45 gpd/1,000 sq. ft.) for all commercial properties. Work by Tchobonoglas based on functional units refined these quantities (Table II.9). Water usage ranged from 4 gpd/1,000 sq.ft. for parking lots to 4,170 gpd/1,000 sq. ft. for fast food restaurants. Crucial to the design of commercial on-site systems and not included in the above estimates are the surge flows ("peak flow factor"). For example, if a church has a flow of 4,000 gallons each Sunday and does not modulate this flow with a holding tank, then the average for design purposes is 4,000 gallons per day, not 4,000 gallons/7 days (Orenco, 1991).

In Malibu, the wastewater generated in public beach restrooms and parking lots has a particularly acute peak load and requires more detailed analysis. Beach restrooms have as much potential to pollute as any beachfront home or restaurant. PEWARA did not review any design documents from Beach and Harbors Department.

Table II.9: Flow Factors for Determining Flow Rates in Zoned Commercial Areas (Tchobonoglas, 1991)

Facilities & Uses	Unit	Flow Rate, gal/unit•d	Conversion Factors ft^2/unit	Flow Rate, gal/ft^2•d
Churches	Seat	1.0	10	0.1
Cleaners	Square Foot	1.0		1.0
Fast Food Restaurants	Seat	100	24	4.17
Fire Stations	Employee	45	50	0.9
Food Markets	Square Foot	0.1		0.1
Hotels	Guest	60	400	0.15
Industrial	Square Foot	0.1		0.1
Miscellaneous	Square Foot	0.1		0.1
Offices	Employee	20	200	0.10
Parking Lots	Square Foot	0.004		0.004
Research Facilities	Employee	50	450	0.11
Residential	Person	75	500	0.15
Restaurants	Seat	80	27	3.0
Retail	Square Foot	0.1		0.1
Schools	Student	20	40	0.5
Service Stations	Pump Bay	1,000	1,000	1
Theaters	Seat	3	6	0.5
Unknown	Square Foot	0.1		0.1

Summary: Malibu interior use is what counts in calculating wastewater loadings. Actual Malibu water use records for homes that are low to high irrigators, for homes with year-round vs. seasonal use, for homes with single on-site systems, and for homes with parties are discussed in Chapter VI. For a home with little water conservation, the design standard of 250 gpd per dwelling seems reasonable, if not overly conservative. The Tchobonoglas commercial projections by review of actual floor:area ratios and unit factors provide a reasonable basis to plan for Malibu wastewater loadings, if the surge flows, special wastewater qualities, and seasonal flows are taken into account. Peak loads require more attention in design, especially on sites where winter rains and summertime beach crowds can have short-term but deleterious impacts on drainfields.

CHAPTER III: ON-SITE WASTEWATER TREATMENT AND DISPOSAL--REAL AND ASSERTED CLAIMS ABOUT GEOHAZARDS, SOILS, AND GROUNDWATER

II.1 Previous Investigations of On-Site Systems

There have been three studies addressing on-site systems in Malibu. The James Montgomery (1986) report reviewed existing water quality along the beach, took one water sample, and quoted a review of Department of Health (DOH) files. The DOH performed many small studies. The summary DOH document, the 1988 "Wastewater Management Study, Malibu," presents the alleged causes and documentation of on-site system problems in the area proposed for centralized sewering by Los Angeles County. Questa (1988) presented a pre-feasibility report of on-site systems by subareas with a commentary on the possibilities of revising existing codes and creating an on-site management district.

Besides discussions of administrative frameworks appropriate to Malibu, there have been three sorts of studies: water quality data by five different agencies and public interest groups; reviews of County files (Montgomery, DOH), on-site system field surveys, predominantly from beachfront property line boundaries (DOH), and unspecified fieldwork (DOH and Questa). In addition, contractors, DOH employees, and other agencies have recorded anecdotal information and observations without any specific studies.

Since 1985, numerous claims have appeared stating that septic tank systems cause health hazards in Malibu (DOH, 1985; DOH, 1987; DOH, 1988; Montgomery, 1986) or contribute to the instability of landslide areas (e.g., Montgomery, 1986; Bing Yen, 1991). In addition, many other aspects of Malibu's environment have been considered serious constraints to the design and installation of on-site systems. Thse are listed in Table III.1 without any implication of severity, areal extent or reality. Finally, various aspects of human management have been implicated in on-site system problems. Thse are listed in Table III.2 without any implication as to severity or reality. All of these assertions have been repeated by various agencies and contractors (e.g., Questa, 1988; Ultrasystems, 1989).

This chapter addresses soils, groundwater, and landslide concerns as documented in previous studies. Specific landslide areas are addressed in Chapter IX. Concerns for beachfront wastewater treatment, health hazards, and storm damage are discussed in the next chapter. Since most of the concerns expressed in Table III.2 are human management problems, they will be discussed in Chapter X.

Table III.1: Real and Asserted Problems with On-Site Wastewater Treatment and Disposal

GEOLOGY/TOPOGRAPHY

Piping and lateral flow: Breakouts of septic tank effluent by piping through fractures. Breakouts by lateral flow on impermeable rock before adequate treatment. Breakouts that may cause local erosion.

Increased landslide risk: Potential impacts of home sewage effluent disposal on landslide cohesiveness; slide plane "lubrication" and/or soil mass weight. A safety hazard.

Watershed characteristics: Toe-of-slope cutting may reduce setbacks and increase the probability of breakouts.

Local soil and rock movement: Pipe breakage, flow equalization, and hydraulic head changes for off-site systems and some on-site systems caused by rock and soil movements.

Slopes: Along with other geological conditions, slope may become less stable with effluent saturation; may allow breakouts of untreated effluent; and may be too steep for equipment.

Perched water: Non-transmissive bedrock that causes a perched water table may interfere with treatment and/or disposal.

SOILS/DEPOSITS

Impermeable or slowly permeable soil: Layers can prevent timely disposal and exaggerate perched water tables.

"Excessive" percolation rates: Beach sand may prevent adequate treatment.

Thin soil profiles: Relatively non-transmissive bedrock may prevent adequate infiltration area for treatment and disposal and may induce soil creep.

Artificial soils and fill: Preferential flow and land settling can occur.

Assimilative capacity and neighborhood overloading: Allegedly some effluent plumes have combined and caused unknown problems.

TERRESTRIAL HYDROLOGY

Seasonally perched groundwater: May interfere with treatment, disposal or plumbing (adequate vertical separation).

Flooding: Inundation of drainfields during floods may prevent adequate treatment, disposal and/or use of plumbing.

Microclimate: May limit the ability of disposal by evapotranspiration.

COASTAL HYDROLOGY

High tides: Inundation of drainfields during high tides may interfere with treatment process.

Storm surges: Inundation of drainfields from storm surges may interfere with treatment.

Wave damage: Storms may destroy part of septic tank system causing temporary loss of treatment and disposal facilities (emergency safety hazard).

Sand loss from bulkheads: Coastal Commission concern that large bulkheads narrow beaches to the detriment of the public and may lower the sand profile.

BIOLOGY

Evapotranspiration: Plants to maximize evapotranspiration are unknown.

Salinated sands: Biological treatment within salinated sands is unknown.

ENERGY SUPPLY

Power outages that may impact the use of effluent or sump pumps.

Cartage: Costs of hauling septage (pumpings) long distances.

Table III.2: Human Management Implicated in On-Site System Problems

HYDRAULICS AND WATER QUALITY

Overloading: Too much wastewater for drainfield infiltration surface can cause premature daylighting (ponding) and clogging of the system.

Pulse flows: Parties, hotels, RV parks, beach visitor facilities or peak hours in restaurants may require flow equalization.

Grease in restaurants must be handled separately.

Greywater: Re-use of greywater for near surface use or storage has not been planned nor designed carefully.

Septage: Heavy metal contents of septage may cause difficulties with sludge disposal.

Component design and installation: Poor design and installation has shortened the longevity of drainfields and septic tanks.

Drinking water contamination: Alleged lack of setbacks between drinking water pipes and drainfield or actual discovery of effluent in water meter box.

PROPERTY

Additional space does not exist to replace drainfield or accommodate drainfield with proposed or actual wastewater loading rate.

Inaccessible space: House construction makes the additional space inaccessible for replacement or additional drainfield or new septic tank installation.

Retrofit Costs: The inability or refusal of some citizens to pay costs to replace, repair or retrofit poorly designed and functioning systems pertains to both on-site and off-site systems.

HUMAN RESOURCES

Quality Personnel: Difficulty for some citizens to find experienced designers in Malibu area.

Technology transfer: County refusal to adopt improved design standards over the last twenty years.

Improper Codes: Obsolete and poor design parameters that reduce life span of systems.

III.2 Soils and Groundwater Claims and Concerns

Since 1985, a wide-ranging number of soil and groundwater conditions have been asserted to be the causes of on-site system problems (Table III.1). For instance, DOH has claimed that: "existing individual sewage disposal systems are failing causing public health hazards and nuisances due to subsurface soil conditions [and] high groundwater table..." The alleged severity and areal extent of these conditions has contributed to the claim that there is a critical need for off-site conveyance, treatment, and disposal of sewage for certain subareas of the city. In addition, it is strongly claimed that on-site conditions aggravate already existing geohazards within the city. Soil creep and landslides have been attributed to the deep percolation of drainfield effluent.

Table III.3: Adequacy of DOH Studies

Claim	Collated Addresses	Collated Data	References to Data Used	Geographical Distribution	Time Distribution	Methods for Analysis & Notes
Monitor Well Data	No	No	No	No	No seasonal, no yearly fluctuation	DOH says it reviewed its files. No seasonal flux of groundwater levels in files.
Soils/ Geology Site Specific Data	No	No	No	No	NA	DOH says it reviews "hundreds of files" from Building & Safety permanent files and Materials Engineering Division.
Permeability Rates	No	No	No	No	NA	DOH says it meant percolation, not permeability
Tidal & Coastal Surveys	No	No	No	No	No seasonal or yearly flux for tides & surges	DOH reviewed Building & Safety coastal engineering files.
Seasonal Groundwater	No	No	No	Partial No Map	No seasonal or yearly flux data	No method. DOH claims "field observations". No records of field observations available. No stormdrain-related studies.
Seasonal Groundwater	No	No	No	No aerial maps	No	None. Documents refer to other references that have no references.
Onsite Systems "Flush" with Groundwater	No	No	No	Partial	No seasonal data or tidal data	
Loss of "Minimum" Distance	No	No	No	No aerial map; no beach profile study.	No	Based on conceptual model for adherence to codes. Model only indirectly related to proper treatment & disposal.
Effluent Plumes & Assimilative Capacity	No	No	No	No	No	Cites Questa report and EIR. Based on general feelings of writer. No data found in Questa or EIR.
"Interactive Failures"	No	No	No	No	No	No method given.
Piping	No	No	No	No	No	DOH says it reviewed files.
Overloads: Commericial/ Apt.	No	No	No	NA	NA	Compared water use & codes. DOH claims water use was greater than design approved by DOH.

The claims concerning on-site system soils and groundwater include the following:

a. "Data from monitoring wells and hundreds of site specific private soils and geology reports on file at DOH Services and Building and Safety were reviewed. In addition, permeability rates along the with tidal and coastal surveys were incorporated. . . " (DOH, 1988: pp 5-6).

b. "Some systems were actually installed flush with known groundwater tables" (DOH, 1988: pp 5-6).

In order to determine the adequacy of the data and interpretation of the data, a questionnaire was sent to DOH. After DOH's response by letter, a meeting followed. Table III.3 indicates that the data from monitoring wells, soils and geology reports, permeability rates, and tidal and coastal surveys were never collated by DOH. No reference bibliography with monitoring well data and site-specific soil and geology surveys exists listing DOH sources of data. No standard summaries of permeability averages, locations, well locations, season of measurement, etc. were made. Discussion with the DOH project manager made it clear that "permeability rates" were sometimes "percolation rates" and may have been, in some instances, hydraulic conductivities. No tabulation of these data had been made. No correlation between permeability rates used for on-site drainfields and soil types had been made by DOH. The evidence for seasonal and annual fluctuations of groundwater in floodplain areas had not been collated or mapped. No studies could be cited. Locations of flooding and floodplains with high groundwater that interfered with treatment or plumbing were anecdotal or unrecorded observations by various health officers.

In other words, the meaning of "review," in terms of summary data or the ability to generalize about Malibu or the County's proposed sewerage assessment area, remains unclear (Table III.3). DOH simply stated that the individual dossiers on particular systems and monitoring data exist. The COM could review hundreds of files, collate data, map them and determine water table flux, percolation and other variables. These tasks would be expensive and would require days of searching dossiers and evaluating their accuracy. In short, the project would perform the work that it appears DOH never accomplished. This was considered beyond the scope of the present contract.

The Coastal Application by the LAC (1990) raised a claim that had not been previously mentioned by DOH in its 1988 study:

> "Urbanization. . .poses a significant sanitation problem which cannot be solved by traditional rural septic tank practices because of lack of space for. . .effluents to be . . .filtered by natural underground seepage phenomena. Effluent plumes. . . merge and overload the ability of the ground to absorb such relatively large volumes of fluids." (Coastal Application, Attachment 3, 1991: 1)

Based on a review of DOH materials, Peter Warshall and Associates's (PEWARA) questionnaire and follow-up meeting, DOH had no evidence for any of these phenomena nor had they mapped areas of high risk, lack of space, merging effluent plumes, "interaction failures" or "loss of regional assimilative capacity".

There have also been claims that extensive piping of effluent through fractured bedrock is a sanitation problem or an erosion problem. Again, no mapped or recorded and collated site-specific evidence was available through DOH. Occasional coliform in some dewatering liquids were found at to be at low levels. They could have originated from a wide array of sources (dogs, horses). They had not been collated or analyzed by Bing Yen or DOH. We asked major contractors and installers of septic tank systems if they had seen "daylighting." They had no examples. The city geologist had one example which we investigated. We noted some daylighting along the western beach bluffs and in road cuts but, given the study's limitations, could not attribute the moisture to effluent. We continued to search for anecdotal and field evidence for daylighting as part of our general fieldwork. So little clear evidence for daylighting of effluent was found that a site specific search for fractured rock piping was dropped from contract requirements.

We had hoped that DOH would suggest specific areas in which PEWARA would be able to test its site-specific design skills. Instead, we pursued soil and geology concerns as a part of the home-site survey. For instance, DOH did not mention a significant problem in Malibu which warrants attention: the use of cut benches and artificial and graded fill. These fills can allow preferential flow of effluent, land settlement that up-ends piping, and early failure of the infiltrative surface (Chapter XI). Our fieldwork was limited (Appendix C) in part because the survey occurred during the summer months when water tables were lowest and, because the survey occurred after consecutive years of drought which meant that groundwater elevations were significantly lower.

Finally, PEWARA collated the number of homes in various floodplains from Federal Emergency Management Agency (FEMA) maps. Approximately 160 habitable structures were counted (150 single family residences and multiplexes and 11 commercial buildings) within the 100-year floodplain boundary. Fewer were found using the Capital Flood Control map of Malibu Creek. All the commercials were within the Malibu Creek floodplain which has not been remapped since stormdrains and fill changed overland flows. Over 100 homes were located along the beachfront or inland road of Malibu Colony, which has a virtually non-existent stormwater drainage system. Malibu Road had 26 buildings and Zuma Canyon (Bonsall Road) had 18 buildings within the 100-year floodplain. The number is small, except for the Malibu Creek subarea. A parcel-by-parcel review would be needed to determine whether on-site system operations would actually be harmed by flooding.

In summary, while problems with perched water tables, impermeable or slowly permeable soils, thin soil profiles, and flooding undoubtedly exist for particular parcels, previous studies have not shown them to exist on an areawide basis, or in large numbers, or to a degree which cannot be met through the proper design, construction, installation and operation of on-site systems.

III.3 Landslides and On-Site Systems: Assessment of Risks

There are about 250 recognized landslides of all sizes and histories within the City of Malibu. Another 40 have been identified from aerial photos (Figure III.1) but have not been verified in the field. Almost all slide events have occurred during major winter storms. By contrast, during the drought years of 1984-91, when cultural (human) influences might have predominated, there have been no significant slides. On the 15 largest slides (some composite), there are about 350 homes, though all of them are not in danger. Perhaps 285 structures on slopes adjacent to slides may be in danger. About 20 homes have been lost to landslides in the the last 20 years.

A major goal of land use planning in landslide areas is to maximize the security and the value of parcels and homes and to minimize their devaluation because of potential earth deformation or movement. Technically, we want to make landslide areas more stable (Michael, 1991). If stabilization of a landslide area can be achieved, then property values might increase and abandoned or endangered building sites can become active building sites. In addition, property owners could avoid the lawsuits that may take place after a slide occurs. To make a landslide more stable, a trade-off of costs and benefits occurs. Property owners want to determine the best procedures and may choose from: buttressing, recompacting, storm runoff management, creek channel armoring, dewatering by wells, hydrauger dewatering, water conservation, arid plant landscaping, or an off-site collector sewer.

In most landslide areas which have homes, septic tank effluent enters the bedrock from seepage pits. During construction, geologists search around a property until they find the right location and depth to transmit effluent at 5 times the volume of the septic tank in one day. Their only restriction is groundwater. The bottom of the pit must be 10 feet above the groundwater at the moment of drilling. If they encounter groundwater, they simply backfill 10 feet with dirt and fragmented bedrock. The resulting pits can be shallow (6 to 10 feet) or deep (60 feet below the surface). The deep pits are obviously below the root zone which, in extreme (e.g., certain eucalyptus), can reach 30 feet. The effluent from shallow pits or trenches divides its flow between evapotranspiration, incorporation into plant biomass (plant flesh) and deep percolation. The deepest pits percolate all the effluent, except for lateral flows that may emerge as seeps or springs.

Because the installer has searched for a transmissive layer, there is some likelihood that this layer connects to another layer that may connect to a slide plane. But, the classic model of a cone of water "showering" out from a seepage pit into the surrounding soils does not apply in almost all Malibu situations. The effluent takes an irregular course through fractures or porous areas of the bedrock and may pond behind impermeable layers or faults. It may even leave the slide plane area by percolating through the slide plane, moving downhill of the plane or moving laterally on a relatively impermeable above the slide plane. (The same is true of infiltrated rain and irrigation water that has seeped below the root zone.)

The conclusion is obvious: the design of the drainfield in Malibu has encouraged deep percolation rather than partial disposal by evapotranspiration (ET) and biomass incorporation. If, in particular circumstances, there is a concern that seepage pit effluents might reach, or contribute, to landslide risk, then a reasonable method of mitigating the risk would be the construction of shallower pits and increased reuse of wastewater for subirrigation. Bing Yen (1991) has estimated that 80 to 90% of the effluent from deep seepage pits enters the groundwater that may immerse the shear zone of a slide plane. On

LEGEND

■■■■■■■	City boundary
━━━ (#)	Landslides mapped by Yerkes and Campbell, Campbell, and Dibblee for rock types (see Bibliography)
░	Landslides mapped by Dibblee on his map series, 1990.
▨	Landslides or landslide scars photointerpreted by Scarborough, December 1991, from stereo aerial photos, not field checked
▦	Prehistoric debris flows and slurry sheets mapped by Campbell on Pt. Dume Quadrange only
──	Generalized geologic contacts taken from published mapping

Qal	recent alluvium
Tv/ Tva	Vaqueros Formation
Tc/ Tcd	Calabasas Formation
Tt	Topanga Formation
Tm	Monterey Formation
Tb/ Tr	Trancas Formation
Tco/ Tcor/ Tbv	Conejo Volcanics
Tz	Zuma Volcanics (related to Conejo Volcanics)
db	intrusive diabase
Ti	intrusive Miocene volcanics
Ttle/ Ttue/ Ttlc/ Ttls	various Lower Topanga Formation Equivalents (Durrell,1954) mapped on several quadrangles
Tmz	Martinez Formation
Ts	Sespe Formation
Tcc	Coal Canyon Formation
Kz	sediments of Zuma Canyon
Kt	Tuna Canyon Formation

Note: This map is simply a compilation of previous maps with about fifteen additional landslides from more recent geotechnical reports and field surveys. Photo-interpreted slides have not been field checked. Given the scale of the map, this map should not be used to determine if a particular house or building is on, adjacent to or away from a slide area. This map is basically an educational tool and a planning guide for the city, home owners and watershed groups. It provides a summary of otherwise difficult to obtain and technically difficult to read geologic maps listed in Bibliography.

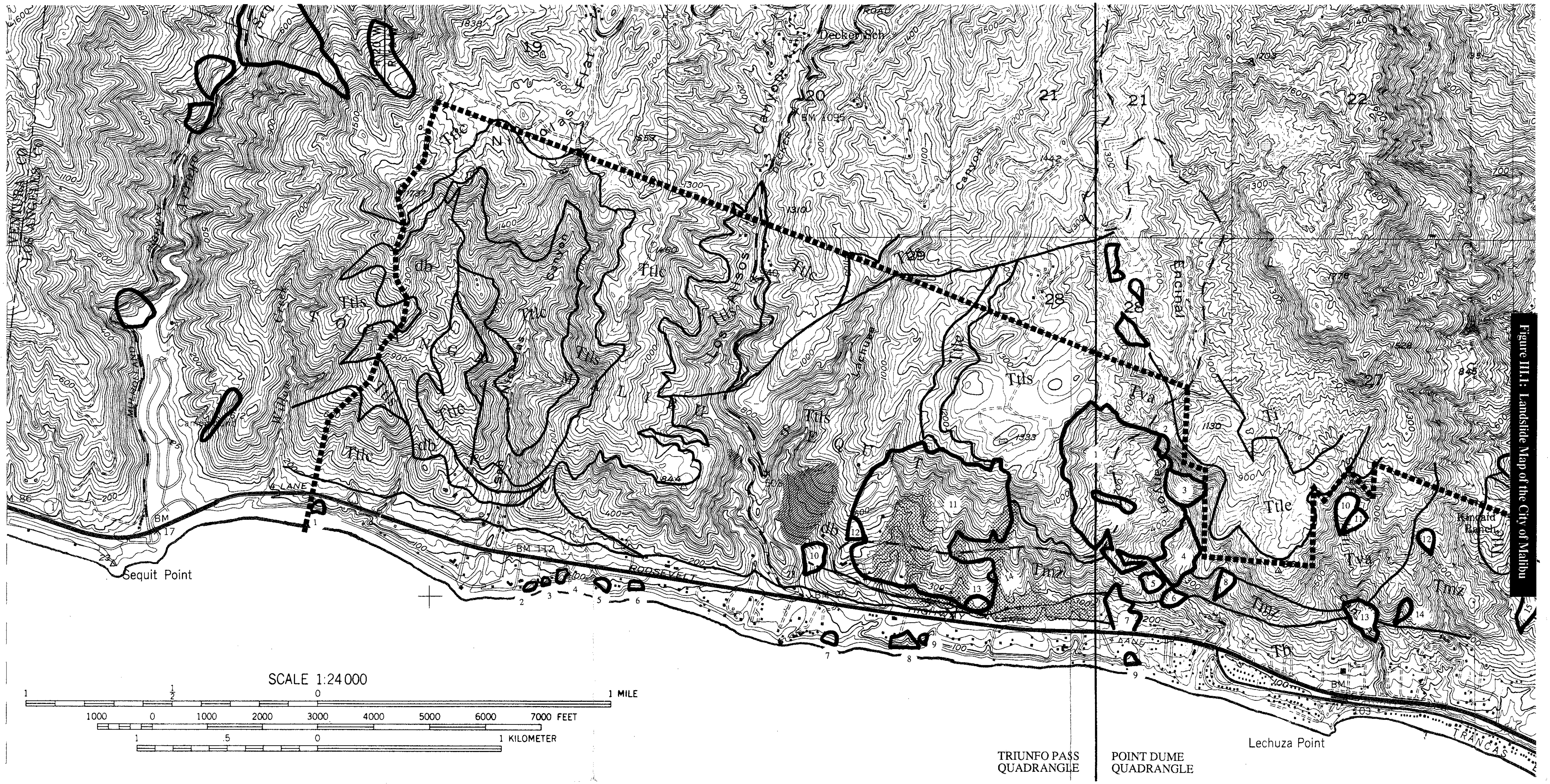
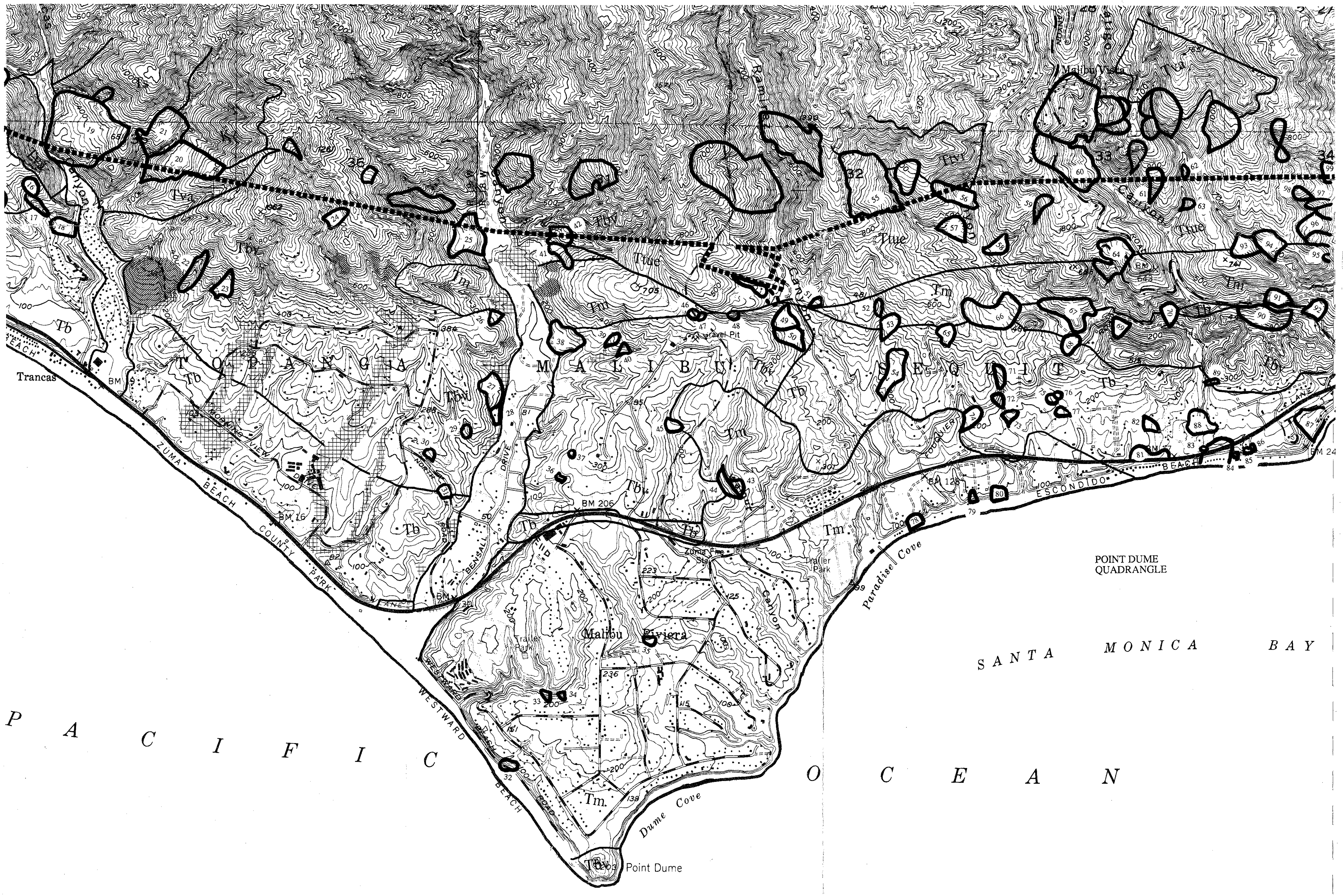
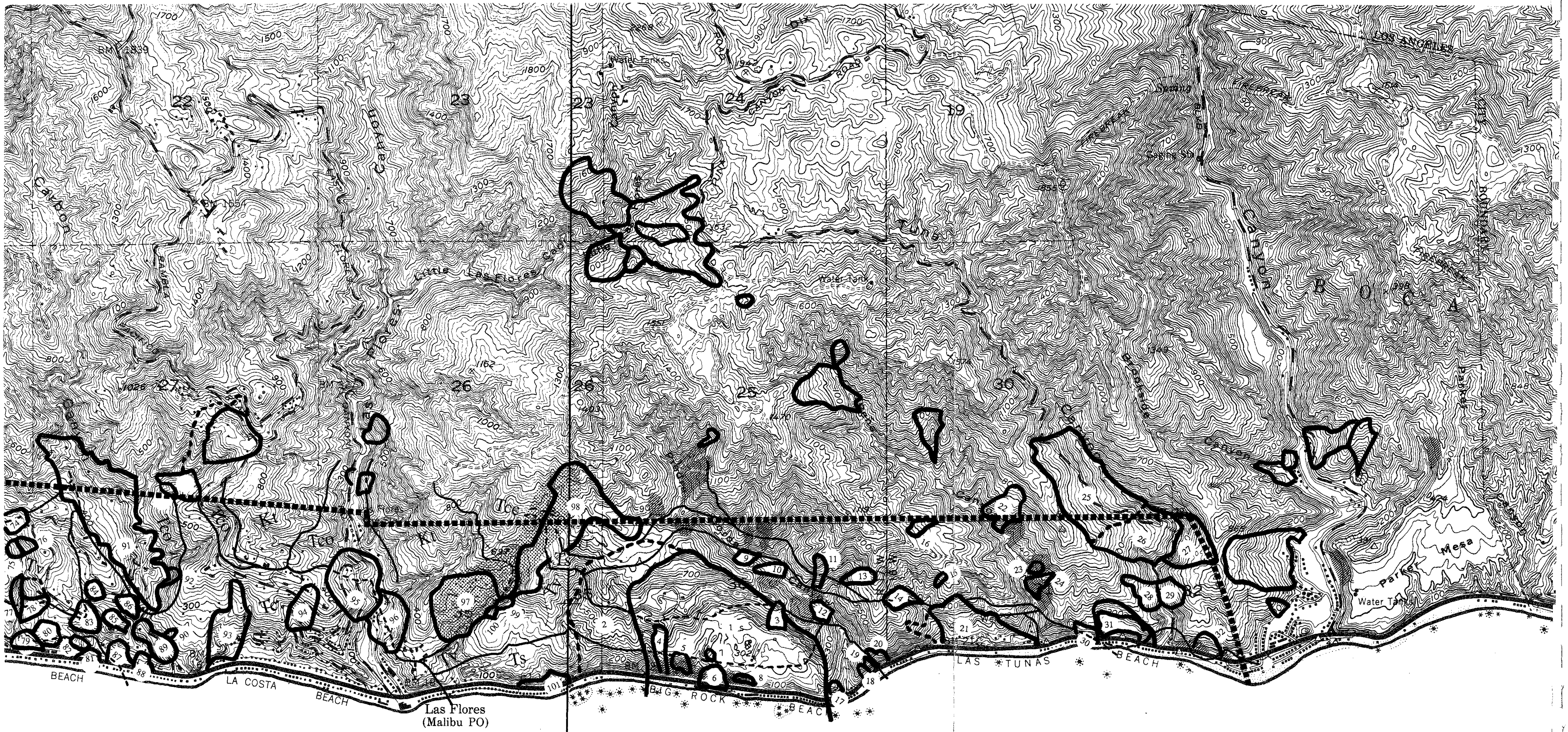


Figure III.1: Landslide Map of the City of Malibu



Trancas
T O P A N G A
M A L I B U
S E Q U I T
Malibu Vista
Malibu Riviera
Trailer Park
Zuma Fire Sta
Gravel Pit
ZUMA BEACH COUNTY PARK
WESTWARD BEACH ROAD
BENSALL DRIVE
ESCONDIDO BEACH
Paradise Cove
Dume Cove
Point Dume
POINT DUME QUADRANGLE
SANTA MONICA BAY
P A C I F I C
O C E A N
BM 206
BM 16
BM 125
BM 24
Tb
Tm
Tbv
Tva
Ttue
Ts


Malibu Bowl
Mesa Pk
Malibu Hills
El Nido
Corral Canyon Road
Puerco Canyon
Winter Canyon
Malibu Canyon Road
Solstice Canyon
Malibu Sch
Malibu Pt
Kellers Shelter
Amarillo Beach
Tm+Ti
Tm+Tz
Ts+Tv
Tz
Ts
Tv
Qal
Tcd
26
25
29
28
35
36
MALIBU
MALIBU BEACH QUADRANGLE
POINT DUME QUADRANGLE



MALIBU BEACH
QUADRANGLE

TOPANGA
QUADRANGLE

the other hand, no more than 20% of the water used to irrigate the landscape enters the groundwater. If these estimates are correct, the conversion of deep seepage pits to a shallow, subsurface irrigation system would dispose of 60 to 70% more effluent through ET. Instead of 80 to 90% of the effluent percolating below the root zone, only 20% of the effluent discharged by an on-site system could possibly enter the groundwater.

Wastewater reuse for subirrigation with shallow drainfields should be added to the list of technical options mentioned above. It is surprising that this particular option has never been explicitly discussed by previous investigators in terms of on-site design, costs, and potential values of reuse. This technical option, or variety of technical options, is explained in Chapter IX on subarea options and Chapter XI on technical options. In addition to wastewater reuse, the amount of effluent entering the slide mass can be reduced by water conservation. Under careful management, 40% reductions in wastewater loads have been achieved. These options are further discussed in Chapter XI.

III.4 Geohazard Risk Analysis and On-Site Systems

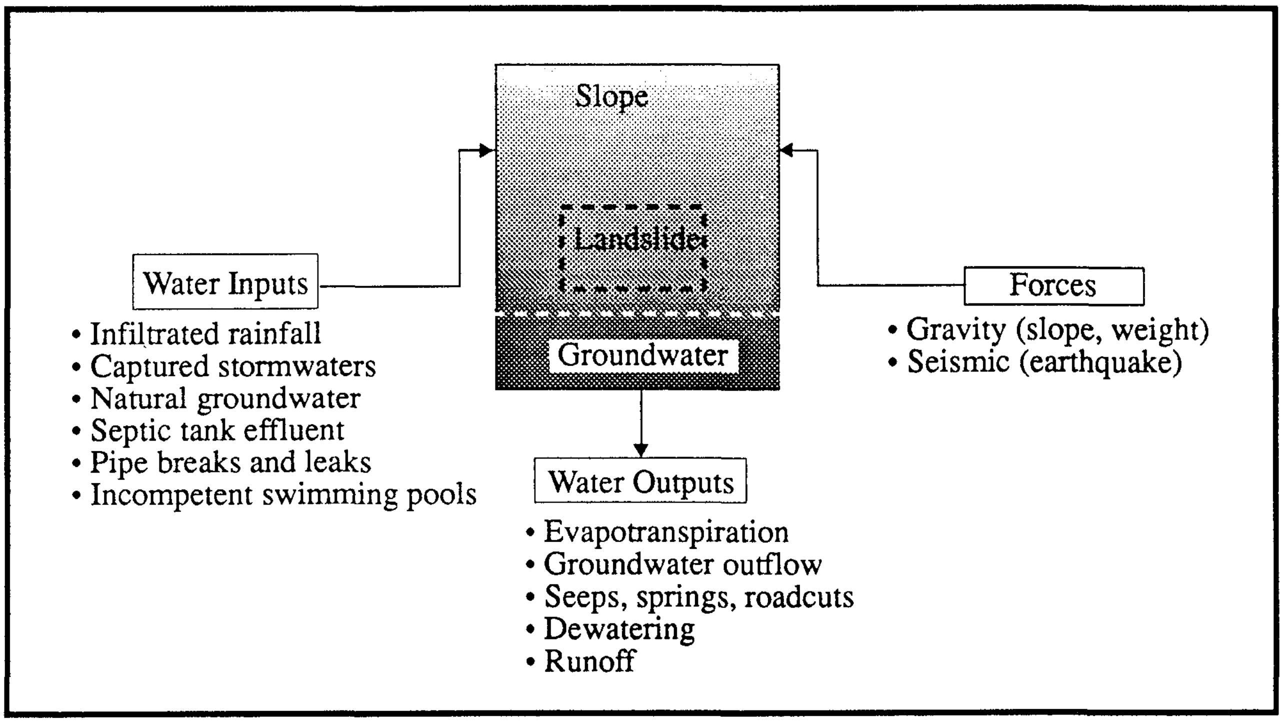
The risk of landsliding has been commonly stated in terms of the "safety factor" for slope stability. Below the factor of 1, the slide is moving; above 1, it is stable. Between 1.25 and 1.50, most property owners feel comfortable enough to ignore the landslide and continue building and watering their lawns. Technical Memo 14 gives the more appropriate geophysical and mathematical framework. The "safety factor" is a form of risk analysis and like all risk assessment has a degree of uncertainty. These uncertainties arise from (1) basing the safety factor on relatively few soil and rock samples, (2) assuming that the samples represent the conditions throughout the slope, and (3) assuming the absence (or limited occurrence in a particular manner) of soil pore pressure, which is difficult (if not impossible) to verify in the field.

For example, in the case of Big Rock, Evans (1986) calculated the safety factor to be 1.25. But Evans, knowing the limits of his information, calculated that the value could be as much as 10 to 20% inaccurate. This means that the safety factor could be as low as 1.04 to 1.14 or as high as 1.38 to 1.5. It is highly doubtful that a safety factor for the Big Rock slide can ever be determined more accurately. The continued use of on-site wastewater systems on the Mesa should be considered within this limitation of geologists' abilities to specify risk more accurately.

In addition to the safety factor, concerned professionals have tried to sort out the importance of various causes that push the safety factor to one or less. By understanding the relative weights of various causes, they attempt to "custom design" technological interventions to increase safety. Off-site sewering was proposed as one of these technological interventions. However, like the safety factor, pin-pointing on-site effluent as a relatively important cause of landslide risk runs into the limits of our present ability to accurately know the water balance (or budget) within a slide, and the volume and direction of movement of the various water inputs (Figures III.2 and III.3).

From the point of view of risk analysis, the following uncertainties concerning the relative importance of effluent in any slide have not been resolved: (1) an uneven rainfall distribution so that various elevations receive different amounts of rainfall (perhaps by a

Figure III. 2. Input/Out Diagram of a Landslide



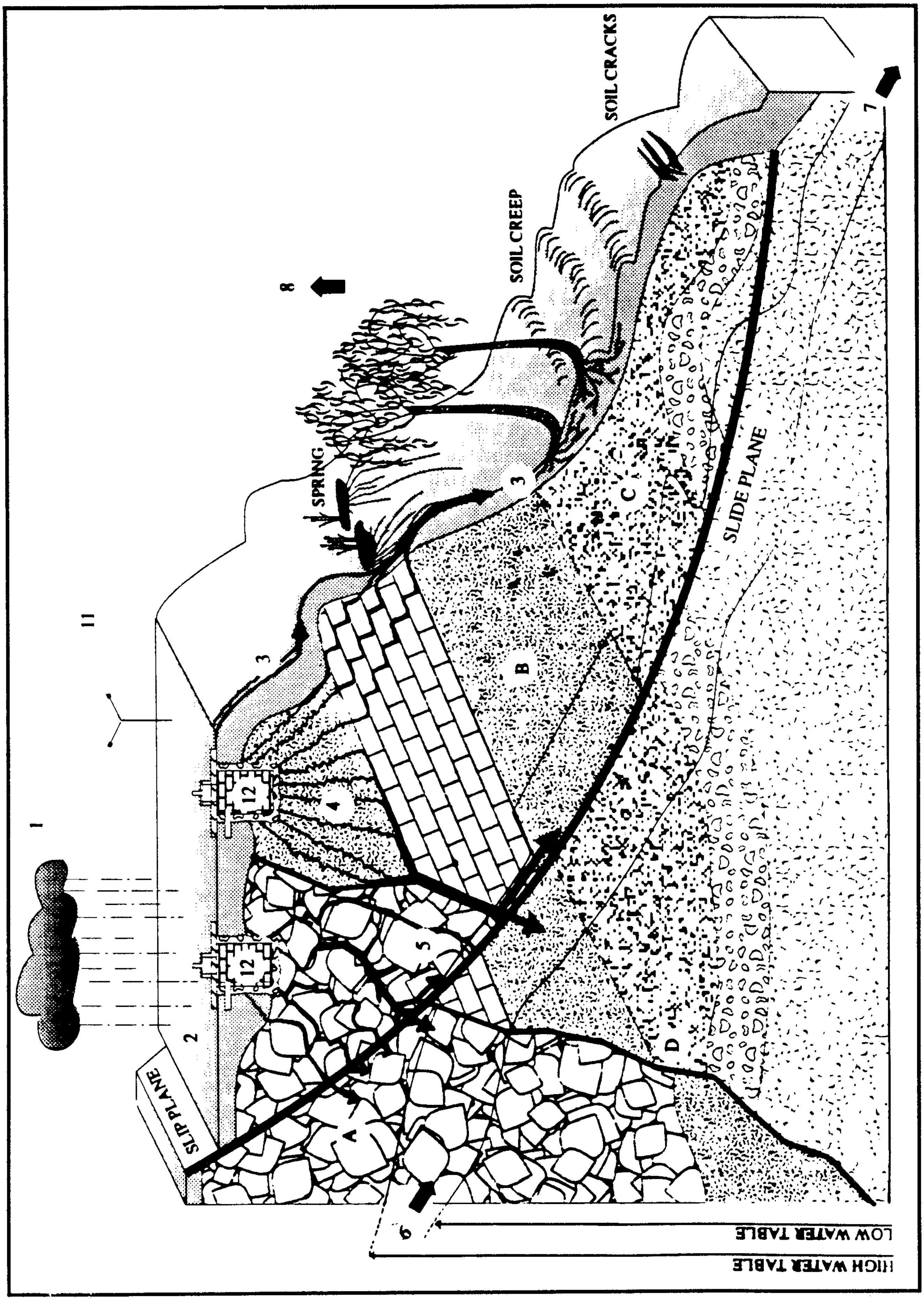
factor of 2); (2) poorly known ET rates for various aspects of the hillslope and natural vegetation vs. landscaped; (3) an uneven, unpredictable vertical distribution of the groundwater table (or tables) as it encounters a complex array of various rocks and shear zones; (4) virtually unknown discharge paths of effluent, irrigation, and infiltrated rainwaters (inputs) that are difficult to accurately predict without detailed exploratory drilling and monitoring; (5) absence of current city-wide hydrological models for normal groundwater flow from the highlands taking into account presence of "spongy" terrace deposits or drainage basin geometry; (6) virtually unknown rate of outflow from the slide mass from seeps, springs, transmissive slide planes and regular groundwater outflow; and (7) an *a priori* unpredictable landslide tendency for new failures in high-slope areas because of unpredictable hydrological and structural constitution of the bedrock.

In short, the crucial conclusions, how much of the slide plane is immersed in groundwater and where the groundwater comes from, will never be known without a long-term expensive program of geomonitoring or a geothermometric study, such as that described by Michael (1988). "Safety factors" and the ability to disentangle the relative importance of septic tank effluent from other sufsurface water inputs should be considered in this context of unknowns.

To take the case of Big Rock once again, the inability to disentangle relative causes led Evans and others to suggest that dewatering Big Rock was a best management practice because it did not become entrenched in a detailed, cause-specific risk analysis. Evans pragmatically accepted that many sources of water were possible and the job at hand was to lower the groundwater table. Having accomplished the decrease in groundwater levels and volumes, the need for additional expensive technical interventions becomes questionable.

Finally, although groundwater enters into the assessment of all slide hazards, other factors must be weighed in making decisions about sewering on Malibu slides. Technical Memo 4 has "red flagged" some of these situations for the use of planners and residents as an aid to choosing the best technical intervention, if necessary. These red flags include:

-- particular geological formations that appear to be more slide prone than others (especially those with soft clay-rich layers, shrink-swell clays, crumbly terrace deposits or highly faulted and fractured bedrock);
-- the coincidence of bedding planes of the rock with slope;
-- the juncture of two different rock formations;
-- undercutting of slopes by meandering stream or wave erosion;


HIGH WATER TABLE
LOW WATER TABLE
SLIP PLANE
1
2
12
12
4
5
A
3
11
B
D
SPRING
3
C
SLIDE PLANE
8
SOIL CREEP
SOIL CRACKS
6
7

- the cutting of slopes by humans for roads and the building of benches;
- the use of artificial fill or recompacted earth materials for home building sites and roads;
- ancient landslide debris (debris from landslides many hundreds and probably thousands of years in age);
- the total volume of potential wastewater and irrigation water that could be entering the slide from homes on the slide and from homes in a geologic zone
- the distribution and location of homes within the slide;
- the size of the slide relative to the volume of artificially recharged effluent and irrigation water; and
- the steepness of the slope, especially proximity to steep-walled canyons or sea cliffs.

Chapter IX applies these "red flags" to the major inhabited landslides of Malibu and tries to assess, given all the qualifications above, the need for off-site sewering.

III.5 County Claims

In the 1970s and 1980s, assertions by the County Department of Public Works and others that septic tank effluents caused landslides have more recently been modified. Elimination of drainfields in specific slides would now "... relieve persistent ground stability problems in urbanized sections of Malibu by reducing contributions of excess

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Figure III.3: Cross-Sectional Drawing of a Typical Landslide

This figure portrays the water budget of a slide mass. Inputs and outputs include (1) consecutive years of high rainfall; (2) infiltration of rainfall; (3) runoff of rainfall from both impervious surfaces built by humans and natural runoff; (4) deep percolation below the root zone; (5) "piping" of water through fractured bedrock; (6) inflow of groundwater from uphill watershed or aquifer; (7) outflow of water from slide mass and spring; (8) outflow of water by evapotranspiration or storage in plant tissue (biomass). Artificial recharge from septic tanks or landscape irrigation (11) may be important. Two seepage pits (12) are illustrated.

The figure illustrates three types of rock formations that recharged water might encounter: (A) dense, brittle bedrock with fractures; (B) porous, transmissive, homogeneous bedrock; (C) layers of complex bedrock with varying transmissivity. Faults (D) are possible routes taken by recharged water into or through the slide plane. Note that the high groundwater line submerses the slide plane. The low water table is below the slide plane and will not directly impact stability. More complex slides with multiple slide planes are not illustrated.

Four symptoms of slippage are shown: soil cracks, soil creep, the slip plane or head scarp and the J-shaped tree trunks.

groundwater supplies which aggravate the stability problems through undesirable lubrication of the soil and rock particles" (Coastal Development Permit Application, Attachment 3, 1991).

In this paragraph, County claims are excessively vague from the technical point of view. It has little meaning to a property owner's understanding of the degrees of risk, choice of technical options (e.g., dewatering, buttressing, sewering, water conservation, re-design of on-site systems), the costs of the technical options to reduce risks, and their comfort level with the costs vs. the benefits. To be rendered stable (a safety factor preferably between 1.25 to 1.50), we asked the County to confirm that a sewer would achieve these safety factors or that a combination of a sewer with dewatering would achieve this goal for Big Rock. The County would not commit itself to stating that a safety factor greater than one could be achieved nor that property assessment values would increase with a sewer system on Big Rock or by implication, on other proposed landslide areas for sewering. (Bing Yen was prohibited from answering questions about the safety factor directly, because of legal and contractual relationships.) The County rightly stated that additional construction and building on slide prone areas was in the hands of the City.

It is clear from both the technical point of view and the policy point of view that there are no guarantees that increased safety or increased property values would result from sewering. Each group of property owners on each particular slide should have the opportunity to balance risks, costs, and benefits for their unique slide situation and the types of technological interventions available. The present assessment district precludes this choice.

III.6 Utilities: Energy and Water

The topography and geology increase the opportunity of electric supply failures for any pumped wastewater system. Southern California Edison (1991) states:

> Most of the electric lines in Malibu are overhead, a few underground. The overhead lines are subject to car-hit-pole accidents, birds or animals in the lines, salt water corrosion along the beach, high winds, contractors hitting them with cranes, tree limbs in the lines, fires, floods, mudslides as well as equipment failures. As a result of natural forces, terrain distance and lines traversing through sparsely inhabited areas, the power supply is not as relieable as in flatter, more urban areas. Any plans for sewers should include ample redundant power back up systems.

> During the fire of 1978, some parts of Malibu were without power for 30 hours. An earthquake along the Malibu fault could cause extended outages, possibly 2-3 days.
>
> The duration of outages in Malibu has increased... due to the state rule... which requires patrolling a power line to check for wires on the ground before reenergizing the line, to prevent fires.... In Malibu, restoring power takes much longer, even if the tree limb is out of the line or the metallic balloon has fallen to the ground, due to the time it takes to patrol narrow canyons and hill roads. If the electrical problem takes place at night, the outage takes even longer to rectify."

Between January 1990 and September 1991, about 122 power outages took place in the city. Most outages lasted 4 hours.

Malibu also has an above average number of waterline breaks. PEWARA briefly reviewed Waterworks District 29 leak report (1991) but was not authorized to perform any detailed analysis. The majority of breaks appear to be from corrosion or a combination of corrosion and earth movement. A smaller number are directly attributable to contractor accidents or deformation and shearing caused by land movement. As opposed to most communities, Malibu has extensive above-ground waterlines with slip joints and flexible copper laterals in order to accomodate earth settlement and movement. Waterline breaks have been reported for all major slides and may be hidden (if underground) adding signifcant volumes to the slide mass (e.g., Calle del Barco). Minimally, highly flexible pipes are required for all conveyance systems. These pipes need to be buried to prevent deterioration by sunlight and to reduce the chances of raw sewage spills on public streets. Cracks in buried pipes without alarm systems (Chapter IX) can cause considerable volumes of wastewater to seep into a slide mass before detection.

III. 7 Summary and Conclusions

The assumption that because groundwater is one common cause of landsliding, a collector sewer system will necessarily benefit properties now served by septic tank systems is based on a gross oversimplification. Slides occur without any contributing drainfield effluent. Most Malibu slides have occurred during major storm events and after consecutive years of above average rainfall. Under these circumstances, the volume and the input/output flow of septic tank effluent through the slide mass may have only a minor influence on the stability problem. On rare occasions, slides move during periods of drought, without any septic tank effluent or abnormal rain contributions.

Removing effluent will, at best, make slides less unstable, but it will not prevent mass movement without other investments in technical options such as dewatering and buttressing. Dewatering, in particular, is more useful than sewering because it removes all sources of groundwater recharge (effluent, irrigation, surface runoff, rainfall infiltration, and pipe leakages), not just effluent. Even these interventions may not stop particular slides. Because of multiple causation and the absence of information, geoengineers and County agencies have not committed themselves to a particular increase in the safety factor from sewering. The property owner, who desires higher home or land values or who wishes to expand a structure, does not benefit unless all parties concerned (buyer, seller or resident) are assured that whatever technical option is selected, it is accompanied by a new level of safety backed by agencies and geoengineering testimony.

In general, the DOH claims about environmental constraints to on-site system functioning are poorly documented. There is no areawide condition that indicates the need for subarea or areawide sewering. The most frequently asserted claim, that septic tank effluent causes or is a major cause of slope instability, has not been subjected to risk analysis for the slide areas proposed for off-site sewering. Nor is it clear what benefits would actually be achieved from off-site sewering by residents on these landslides. This question will be addressed in more detail in Chapter IX. Other aspects of soils and groundwater have been incorporated into the home-site survey.

CHAPTER IV: ON-SITE SYSTEM TREATMENT AND DISPOSAL -- REAL AND ASSERTED CLAIMS ABOUT HEALTH HAZARDS ALONG THE MALIBU COASTLINE

In Malibu, the most commonly voiced concerns about wastewater and potential health hazards are: (1) potential cross-connections between waterlines and drainfields; (2) surfacing effluent from "interactive" failures; and (3) pathogens from beachfront homes, Malibu Colony homes near the lagoon, and non-specified homes within floodplain or high groundwater areas. Any cross-connections between waterlines and sewer lines are simply a plumbing problem, commonly fixed by moving pipes or protecting them with special coatings. As stated in Chapter III, there is no evidence for "interactive" failures with surfacing effluent either inland or along the coast. No evidence exists, nor has any agency implied, that inland systems are causing health hazards on an areawide or even on a localized basis (confirmed by Harry Stone, Department of Public Works). Inland concerns have focused on geologic hazards, not on health. The remaining issue is potential health hazard from coastal homes with on-site systems. This chapter addresses this issue in detail.

IV.1 Beachfront Wastewater Treatment

What actually occurs to on-site effluent along Malibu's beaches, and similar beaches in North Carolina, Maryland, Florida, Washington, and other parts of California, does not seem to have been studied in the field nor given serious theoretical attention (Vorhees, 1991). Although not explicitly stated in any DOH document, the assertion that Malibu beachfront systems are causing a health hazard can most reasonably be stated as follows: The sand has large pores, small surface area for its grain size, no organic matter, chemically active clay, and therefore is not effective at treatment. In addition, there are a few periods in which the tidal surge may reduce the distance between the drainfield and the saturated zone, preventing further treatment in the sand or soil surrounding the drainfield and, perhaps, damaging the biological mat (Chapter II). Finally, the distances and the lag-times to daylighting are asserted to be too short to provide sufficient die-off of pathogens.

Before we could review health risks or suggest improvements to treatment and disposal along Malibu's beachfront, a "model" of what happens to pathogens on their "passage" from household wastewater to the sea appeared necessary (Table IV.1 and Figure IV.1). The model includes some technical terms that may not be familiar to the

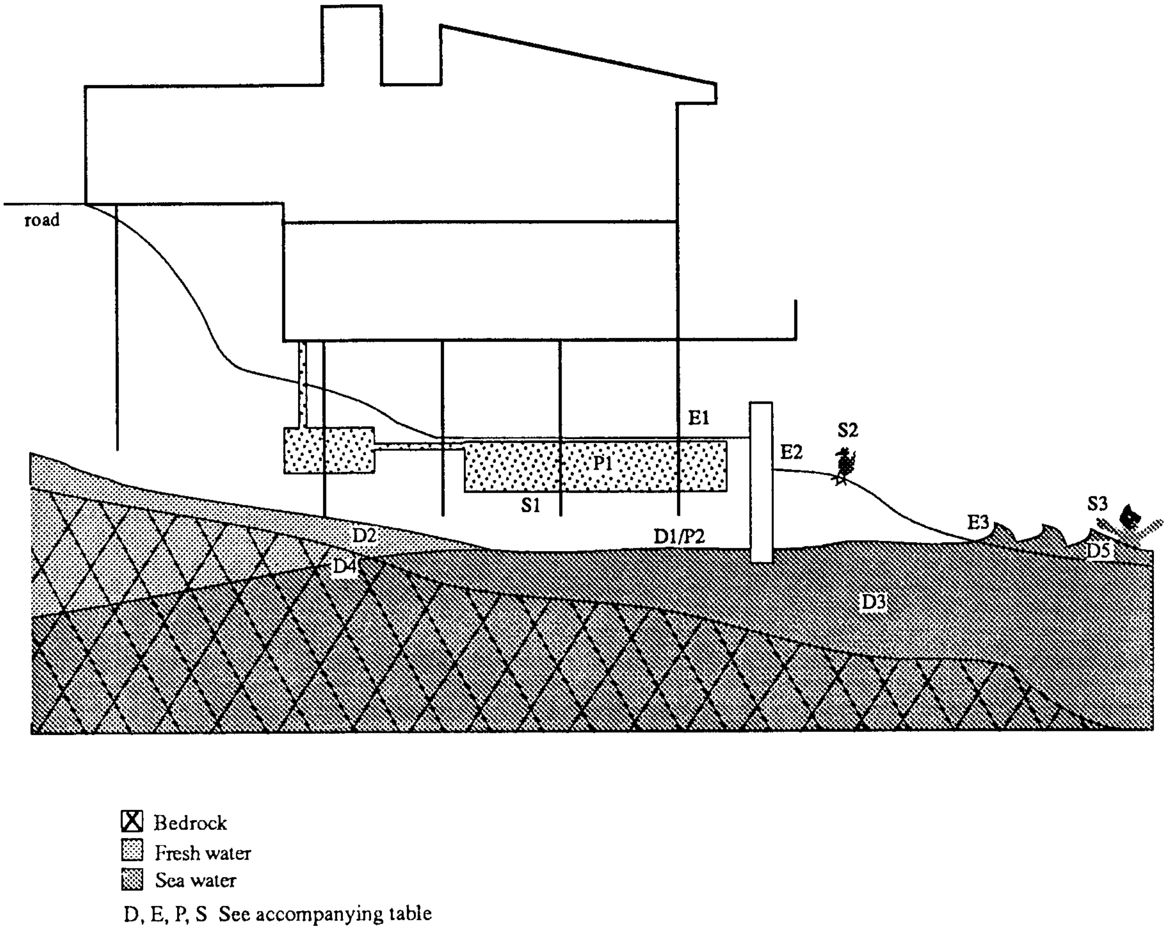


Figure IV.1: Treatment and Re-entry of Effluent into Environment

reader. These terms are defined in the glossary. The conceptual model states that, at any point in the passage of septic tank effluent from the drainfield to the ocean, "sanitary significance" can be defined as the concentration or "dosage" of the pathogen or indicator at that point of the passage. The pathogens carried inland by the subterranean flood tide can essentially be ignored. The "points" in the passage of potential pathogens from the home to the ocean that change the concentration of organisms include: (1) the source points and source strengths (human and non-human); (2) the dispersivity (flow direction of major flow and flow perpendicular to it) of the treated effluent and diluted effluent; (3) the porosity of the medium (e.g., sands, intermixed silts and clays, gravels, cobbles or fractured bedrock); (4) the hydraulic conductivities (see below); (5) the hydraulic gradients

Table IV.1: Treatment and Re-Entry of Home Effluent into the Environment

Item	Involvement	Typical Influences
Sources & source strength	S1 Drainfield effluent S2 Non-human sources S3 Humans in surfzone & offshore sources	Concentration of pathogens determined by treatment in septic tank and drainfield. Birds, dogs, horses, and fish contribute indicator and and a few pathogens to groundwater. Humans may add pathogens during recreation. Offshore sources can be transported to beach.
Dispersivity	D1 Dispersion from drainfield to first layer below	Basic vertical movement to (1) freshwater lens; (2) sub-surface tidal flux; (3) bedrock or soil. Bulkheads, buried rock "knobs" or building structures are barriers to horizontal movement.
	D2 Dispersion within freshwater lens	If encountered. May be seasonal with rain, runoff and increased subsurface flow from inland.
	D3 Dispersion in subsurface tidal flux	Dispersion inland (flood tide) and toward beach (ebb tide). May be at an angle to beach profile. Complex.
	D4 Dispersion in fractured bedrock.	Only at ebb tide, if bedrock drains.
	D5 Dispersion in surfzone	Dilution, dispersion from turbulence & currents.
Porosity	P1 Drainfield materials	Type of sand and biological "mat" will influence porosity.
	P2 Materials around drainfield	Beachsand and inclusions within beachsand (silt, clay, gravel) will influence porosity. If layered, additional "P"s (P3, P4...) can be used (e.g., cobbles below sands).
Hydraulic conductivity cause	K1 Discharge through sands surrounding drainfield K2 Discharge through sands containing freshwater lens K3 Discharge through sands or cobbles w/marine waters K4 Discharge through bedrock	Discharge rates depend on density of water, acceleration by gravity, viscosity, tortuosity and size of pores (P). Turbulent flows and density of freshwater lens cause strong deviations from laminar flows assumed by D'arcy's law. Flood tides reverse "discharge" direction.
Hydraulic gradient	G1 Gradient from drainfield bottom to first significantly different layer G2 Gradient influenced by beach bottom G3 Gradient based on bedrock	The steeper the gradient, the faster the movement of effluent. But, complex gradient changes will cause daily and seasonal changes in beach profile.
Decay rates	X1 Within septic tank X2 Within drainfield X3 In sand between drainfield & first significantly different layer X4 In sand in freshwater lens X5 In sand or cobbles in saline water X6 In surfzone or deeper waters	Temperature, predation, pH, osmotic pressure (salinity), energy sources, dissolved oxygen, sunlight (UV in surface waters) and rates of flux will all influence die-offs of pathogens and indicators.
Retardation	R1 Adsorption in septic tank to sediment R2 Adsorption in drainfield & associated biological mat R3 Adsorption in layers between drainfield & emergence	Clays and silts at any point in process can reduce or detain indicator or pathogen organisms.
Exposure	E1 Drainfield surface E2 Bulkhead or protective wall E3 Surfzone or marine waters	

(in general, the steeper the gradient, the faster the movement of effluent); (6) the decay rates (pathogen die-offs from changes in temperature, salinity, pH, osmotic pressure, energy sources, oxygen, and sunlight in surfzone); and (7) the "retardation" (slowing of effluent movement and increased pathogen treatment by the biological mat and the silts and clays intermixed with sands).

The "point of passage" model is complex with 3 potential sources, 5 dispersion rates, 3 porosities, 3 hydraulic conductivities, 2 or 3 hydraulic gradients, 5 or 6 decay rates, 1 retardation rate, and 3 possible points of exposure (Table IV.1). The points of potential exposure are: the surface of the drainfield should it clog, overload and allow effluent to emerge on the drainfield surface; leakage of inadequately treated effluent through the bulkhead or retaining wall with a low beach profile; and contact with marine waters in the surfzone or deeper waters. In winter, high tides or surging seas commonly occur . This is a season in which potential pathogens might move longer distances because of an uninterrupted continuum of saturated sand. But, human exposure rates are very low as humans rarely swim or even walk the beaches in these storms. The "worst case" situation appears to be a reduced beach profile in summer when the effluent plume might emerge from beneath a seawall at low tides and the probability of beach-goer exposure is highest. Commonly, summer beaches in Malibu have high beach profiles reducing this "early emergence" risk. The worst case health risk does not appear to be high seas with storm damage when dilution, mixing, and low exposure rates would lower health risks considerably. *There are no actual studies with dyes or indicator organisms demonstrating a hydraulic connection of liquid from drainfields through bulkheads or into the surfzone.*

The sands around the beachfront drainfields allow for fast percolation. Joe Tabor and Dr. J. T. Winneberger tested some sands with a permeometer. The sands could accept almost the whole gallonage of one residential home (about 250 gallons per dwelling per day) through one square foot of beach sand surface. This high percolation rate would normally constrain the use of beach sands. But, a biological "mat" of algae and other organisms grows among the sand grains. The biological mat is the primary "biotechnology" to reduce the concentration of pathogens in the drainfield sands (P1, R2, and X2). The biological mat demonstrates well-documented abilities to slow down the effluent flow and treat pathogens by filtration, retention, and chemical renovation (see Box). Further reductions in the concentrations of potential pathogens continue after percolation through the biological mat (P2, X3 to X6, and R3).

The decay rates (the reduction in the concentration of pathogens) also depends on the ability of the pathogens and indicators to survive the transition from effluent or fresh groundwater to saline waters and to survive turbulence from tidal flux which may cause rapid changes in osmotic pressure and other variables. Decay rates appear to be greater in saline waters than freshwaters for most pathogens and indicators, but the detection of death by standard laboratory techniques is complicated by "nonculturable" stages of various live bacteria and viruses (Table IV.2). The longer the detention time beneath the sand (influenced by the Ds, Ks, and Gs in Table IV.1), the greater the reduction in potential pathogens. The sub-sand detention time has not been studied. The sub-sand tides and seasonal water tables complicate detention time and dispersion, especially when the tidal flows are at an angle to the shoreline. Angled flood tides may carry the treated effluent plume partially up or down the beach. Under these circumstances, it is difficult to trace any organism to its source (a septic tank or a seagull or a swimmer). The "block of subsurface water" into which the effluent enters also dilutes the pathogen/indicators populations.

Decay rates change significantly (as does dispersion) when the effluent plume (if it is even identifiable at this point) emerges into the surfzone (X6, D5). Oxygen, poor energy sources, and sunlight play a major role in reducing the concentration of pathogens in the surfzone.

Treatment of Septic Tank Effluent by Sands with a Biological Mat

***Total Coliforms:** 2-4 feet of well-drained sand with a biological mat will reduce bacterial concentrations to a level that meets most state and federal standards (loading rate = 1.24 gpd per square foot).

***Fecal Coliforms:** In sandy soil, 40 inches were requred to remove fecal coliforms.

***Viruses:** Properly dosed and loaded, 2 feet of medium sand have been very effective in removing viruses from treated drainfield effluent. The presence of a biological mat further improves detention, retention, and adsorption of viruses. There are no studies that have found viruses in the effluent from a septic tank, despite deliberate dosing of the influent.

*This information is for predominantly aerobic/anaerobic trickle filtration by sands that are influenced by freshwater (vs. saline waters). Freshwater saturated conditions allow bacteria and viruses to move greater distances. References in Technical Memo 2.

In summary, after treatment by the biological mat, reduction of potential pathogen concentrations to safe levels relies on dilution, dispersion, detention, the alien saline environments, and the rather unknown biology of salinated sands, especially saturated sands. As explained below, the evidence for a health hazard to beach visitors does not exist. Should an agency desire a deeper understanding of how potential pathogen concentrations are reduced before possible emergence in the surf zone, then field investigators need to study the seasonal changes in beach profile (the "swept prism" study in Chapter II), the water quality of the sub-sand receiving waters, dilution and dispersion of the effluent plume, the biological mat under the influence of saline water, and the influence of flood and ebb tides.

IV.2 The Health Hazard Question: the Malibu Coast

It is clear everyone wants to achieve the same goal: a maximization of the pleasure of water contact sports and a minimization of high dosage and health-threatening exposure to pathogens. Beyond this there is a parting of the ways. For instance, what standards and what degrees of risk are acceptable is, in part, a personal decision. EPA recommends a geometric mean of 35 enterococci/100 ml which corresponds to an acceptance of 19 cases of acute gastroenteritis per 1,000 swimmers. Some health officers and swimmers are willing to take this risk for the pleasure of swimming. Others refuse. Others might want to compare this degree of risk with the risk of drowning or stepping barefoot on sands wetted by rinse water from a washing machine. Statistically, the level of risk is somewhat circular reasoning because the level of acceptable risk must be decided upon before the actual calculations are made.

In reviewing the state-of-the-art discussions and fieldwork of shoreline risks and comparing them to the point-of-passage model as it pertains to Malibu, large gaps of information became apparent. These include the following unanswered questions:

Degree of Treatment: What is the concentration of indicator organisms or pathogens as they emerge into the surfzone or deeper waters of the ocean? Do salty (salinated) sands and the saltwater environment increase or reduce the concentrations of indicator organisms or pathogens? What is the detention time within the beach sand, cobbles or fractured bedrock before emergence? What is the effect of retention (adsorption) from silt and clay impurities on some of the beaches or within the fractured bedrock? What is the death rate of pathogens subjected to the stress of multiple, fluxing saline gradients?

Table IV.2: Methodological Problems with Interpreting Water Quality Data

The design of monitoring programs in surfzone and partially salinated sands: The type of sample, location, timing of sampling with tidal flux, day of the week, and frequency of sampling become extremely important in making risk judgments, especially when thousands of beach visitors can be impacted. Even lab work can produce varied results with the same sample. Occasional split samples analyzed by different labs is an important aspect of accurate monitoring. These have not been included in Malibu beach shoreline monitoring program.

Confounders: Epidemiologists normally list "confounders" which complicate the assessment of health risk. These include susceptibility differences (age, sex, previous health history) and multiple exposures to other activities besides water contact sports. For instance, a public restroom or snack bar could be the source of contagion for people visiting the same beach.

Confounders cause confusion when many sources contribute the same microbial indicator group or pathogen. Storm drains and non-human sources (seagulls, ducks, rodents, dogs, rabbits, horses) are obvious confounders. Longshore currents carrying specific pollutants from Hyperion may confound sampling. Estuarine and environments that fluctuate in pH, temperature, salinity, dissolved oxygen, and nutrients loads (Malibu lagoon) can produce widely varied coliform, fecal coliform and streptococci densities. After-growth blooms of various members of the coliform group occur frequently.

The suite of indicators: The indicators that provide the strongest evidence of risks to human health in marine environments are simply not known. Total coliform and fecal coliform are considered unreliable indicators of pathogens in marine environments (James and Evison, 1979). In fact, since 1963, the American Association of Engineers has rejected coliforms as a good indicator of health hazard in seawater. Seawater fecal coliforms have little, if any, quantifiable association with human disease, including viruses (Grimes and Colwell, n.d.). The "fecal coliform group" includes non-fecal bacteria which increases the frequency of false positives (Rose, n.d.; James and Evison, ibid.). Members of the fecal coliform group may remain in a viable but not culturable state increasing false negatives (Grimes, 1986).

Enterococcus is currently a preferred indicator in marine environments. Enterococcus densities exhibit many of the problems associated with fecal coliforms: non-human sources, sensitivity to temperature, pH and salinity that can alter densities, and viability in non-culturable states. Enterococcus is viewed by the County (Petralia, 1989) as weak evidence for potential disease outbreaks and beach closures. E. coli ecology in marine waters and a correlation with human disease is under study.

The importance of transmission of bacterial, protozoan and viral diseases between non-humans and humans in marine environments is largely speculative.

How does the freshwater lens floating on the subsurface tidal flux, the subsurface tidal flux itself, or the barriers to flow such as bedrock, bulkheads, and impure sands influence dispersion and concentration of potential pathogens?

Degree of Exposure: What is the possibility of any exposure of the public to treated and diluted effluent? Do exposure risks change with the shape of the beach profile (winter vs. summer or beach location) or distance to the mean high tide line? Are different water users (children wading in the surfzone vs. surfers vs. swimmers) differently exposed

Table IV.3: Health Risk Assessment and On-Site Systems

Indicator	Malibu
Highest Risk	
Pollution of drinking water in wells	Not Applicable
Cohort epidemiological study	None
Case history analysis of clinical symptoms	None
Clogged drainfields with no replacement area	Not reported
Storm damaged systems with no replacement area	Not reported
Home closures from health violations	Not reported
Waterlines within ten feet of sewage lines	Yes
Requiring Further Investigation: Risk Implied	
Labelled isotopes for nutrient pollution	None
Hydraulic conductivity in high groundwater areas	None
Seeded antibiotic pathogens or viruses	None
Saline groundwater elevations	No fieldwork
Human specific viruses	None available
Requiring Further Investigation: Risk Unknown	
Anecdotal evidence of clustered clinical symptoms	None
Enteroccus in surfzone (> 35 MPN/100 ml)	Safe Limits
Replacement records	Yes,causes unknown
Fecal coliform in shellfish tissue	None
Least Reliable Risk Indicators	
Pumping Records	County and citizen data.
Total coliform in saltwater*	Meets standards.
Fecal coliform in saltwater*	Meets standards.
Repair and addition records	County /citizen data.
Greywater by-pass records	County/citizen data

* Meets water sports contact standards. Many of these samples were performed under highly variable conditions of tidal stage. No correlation with pH, salinity nor water temperature known. No split sample verifications have been reported. Wide variance is anticipated.

to the dispersion of pathogens in seawater? Are shellfish actually exposed to any dosages of effluent that might originate from septic tanks?

Degree of Contagion: How contagious are human pathogens transmitted in saltwater (vs. freshwater) environments? What threshold dose initiates clinical symptoms of various waterborne diseases in oceanic environments (especially enteric viruses)? How infectious are the inactive (sometimes nonculturable) viruses and bacterial pathogens in sediments when they are stirred up by waves, surges, or feet?

In reviewing the Malibu data, we found no discussion of <u>any</u> of these questions. The simple lack of awareness of this very complex situation, in which some of the effluent can actually be pushed inland by flood tides and the microbes can undergo severe environmental stress and rapid die-off, forewarns that any dogmatic statements about health risks are open to severe doubt. In addition, Table IV.2 lists problems in interpreting water samples and choosing the useful indicators in Malibu surfzone monitoring.

IV.3 Coastline Health Hazards and Risk Analysis

The methodology used to assess "potential health hazard" is risk analysis, a complex and relatively new field of study. The hope of risk analysis is to distinguish degrees of risk. Table IV.3 lists various approaches to assessing health risk. They are listed by the degree of risk which can be inferred from each type of study. Risk ranking includes how traceable the source and strength of potential health hazard might be; our knowledge of the speed, discharge, direction and cohesiveness of the effluent plume, and whether the study addresses infectious dosage, organism and exposure directly or indirectly (indicators). The **strongest studies** directly connect pathogen presence to human disease outbreaks or incidence. They try to account for confounders by controls and nul hypotheses (Table IV.2). If positive, they require immediate action. The **"risk implied" studies** cannot generate as strong an inference as the first group. They show a connection between the effluent plume and the receiving water body (potential exposure) but provide no information about dosage (density of pathogen and virulence) and incidence of disease. If positive, they require studies that track possible pathogens to their sources, but no immediate action. On the other hand, the presence of human specific viruses implies possible dosage and exposure but gives no information about dosage strength or sources. If found, human-specific viral studies require studies that track virii to their source. **The "risk unknown" studies** cannot trace the effluent plume to its source and have too many confounders to implicate on-site systems. It is impossible to assign any level of health risk from these studies, let alone implicate septic tank drainfield effluents. If positive, they may indicate the need for further study. A careful review of possible sources and potential dosages of pathogens is the first step toward deciding how much more work is necessary. The **least reliable indications of health risk** do not directly measure pathogens, incidence of disease, sources of pathogens, confounders, dosages of pathogens, and relative exposure. They tend to be based on two or more assumptions. These least reliable studies require many more "ifs" than more accurate studies. These studies are usually a poor use of financial resources. For instance, if (and only if) fecal coliforms can be shown to be reliable indicators of human pathogens (vs. non-human) in the saline lagoon waters, and, if (and only if), the fecal coliform concentration can be related to some effective dosage of a human pathogen, then the health risk will require action. Neither of these hypotheses concerning fecal coliforms can be verified.

Strong Indicators of Risk

There have been no waterborne disease outbreaks in Malibu. Since few homes use wells, there is no concern about groundwater pollution influencing drinking water. There are no epidemiological cohort studies nor case history studies for the Malibu shoreline. Twenty-seven homes may have waterlines closer than the 10 foot setback required by County regulations (DOH, 1988). However, there is no evidence of inter-connection or waterborne disease. None of these homes have received a health warning or code violation notice. None have been ordered or encouraged to review their piping system in more detail. If necessary, these few homes can be brought up to code with ease. Casing of sewage or waterlines when they cross each other is standard County practice. There have been no known cases of homes permanently closed because of a public health hazard, or of homes and businesses permanently closed because an on-site system could not be replaced or repaired. In short, none of the strongest indications of health risk have been reported for Malibu.

"Risk Implied" Studies

To track a hydraulic connection between effluent and exposure, labelled isotopes of nitrogen, dye tracers and extensive piezometer wells can map the movement of groundwater. No such studies have been made. To track the source of potential pathogens, attenuated viruses or special bacteria strains can be used as tracers. None of these tracers have been used in Malibu beachfront locations. In short, no studies that might imply or deny potential exposure to health risks have been made along the Malibu shoreline.

PEWARA reviewed some of the DOH statements and data concerning coastline groundwater levels and saline water intrusion into the drainfield, sent a letter requesting clarification, and attended a follow-up meeting. As noted above, the decay rates of pathogens increase in saline waters, some pathogens are stranded inland by flood tides, and the influence of the saline water on the biological mat is not known. The direction of movement of pathogens within the saline groundwaters and the dilution of pathogens by the saline groundwater had never been studied. DOH stated:

> "Monitoring well data revealed that in a number of areas along the coast, groundwater fluctuated as much as six feet depending on rainfall and tidal conditions." (DOH, 1988, pp 5-6)

DOH had no referenced studies, no collated data, no field data, no maps, and no site specific analysis to support these conclusions. DOH could not specify exact locations along the coast at the meeting or in the DOH letter (Scanlon, 1991). The distance between mean lower low water and mean higher high water at Santa Monica Pier is about 5.2 feet and the 100-year tidal elevation change used for planning is 8 feet (Technical Memo 10). If, by groundwater flux, DOH means extreme tidal levels, then 6 feet will undoubtedly occur even without rainfall. But, without relating drainfield elevation to tidal levels or a lens of floating freshwater on top of the saline groundwater, the flux has little meaning.

> ". . .it is estimated that approximately 15 to 20 times each year. . .the groundwater may reach a height that will cause a loss of minimum separation for a significant number of sewage disposal systems along the ocean front."

According to Robert Saviskas (DOH), this conclusion was based on a conceptual study, not a field study. It assumed an average mean high tide to be 3.2 feet above sea level. It assumed that only when the drainfield bottom was 9.2 feet above sea level, the drainfield would be free of inundation. When the bottom of the drainfield was 4.2 feet ASL, then tidal flows will "cause a loss of minimum separation." The Saviskas minimum separation is believed to be the bottom of the drainfield and is somewhat in conflict with the letter response from DOH (October 1991) which stated that the "minimum separation" was from the 1988 UPC. In either case, we were not satisfied with the DOH conceptual model because its validity was not tested by the reality of Malibu beachfront homes. In Malibu, homes vary in distance from the mean local sea level boundary, and drainfields vary in their relative elevation to the NGVD or the local sea level elevation.

We asked DOH what was a "significant number of sewage systems along the beachfront." DOH responded that "significant," meant: "a number large enough to be an important consideration" (Letter, DOH, 1991). Since the DOH had no locations, no clustering and no hard numbers, we could not judge whether the problem was a few widely spaced systems or a group of systems that could be handled by a more decentralized treatment plant. Generally, we asked homeowners about groundwater height during the home-site survey (Chapter VI). We did not try to second guess DOH about locations within the Malibu Sewer Assessment District. However, we surveyed half the homes with a mapped mean high water line cutting through their property.

What little evidence does exist came from the Flood Insurance Maps (FEMA) shows the Malibu shoreline to start at 11 feet above sea level. Whatever the accuracy of these maps, they indicate that drainfields below 9.2 feet are probably the exception, not the rule. The spring tides (the higher tides which would include the majority of the 15-20 losses of minimum separation) could not inundate the drainfield itself at these elevations, though it might rise to within five feet of the bottom of the drainfiled for the few hours of the highest tide. There is no evidence that this temporary rise in the general drainfield area has any deleterious impacts on pathogen treatment. The need for a subarea sewer should demonstrate that the homes involved actually conform to the model or are harmed by occasional saline waters entering the drainfield vicintiy. Without any verification, the DOH conceptual model cannot be used to justify subarea sewers.

The presence of human specific viruses are good indicators that some source of human fecal contamination occurs within the watershed. It cannot be used to judge risk unless source, minimum infectious dose, and exposure can be judged (Gerba and Haas, 1988). No such studies have been made along the Malibu coastline.

"Risk Unknown" Group of Indicators

No anecdotal evidence of waterborne diseases contracted along the Malibu shoreline, with the exception of Malibu Lagoon, has been recorded. Enterococcus and E. coli have become preferred indicators in estuarine and marine environments. Malibu enterococcus samples have met EPA and Ocean Plan standards along the shoreline (i.e., they have exceeded standards only 3 times or less than 1%). E. coli studies have not been made. No analysis could be found of shellfish tissues for nearshore locations in Malibu or the location of shellfish beds to the nearest septic tank drainfields. Such an analysis would not pinpoint sources of contamination or disease incidence but would establish whether the shellfish surfzone standard has any real health risk associated with it.

Finally, replacing drainfields might indicate that there was temporary trouble. No public health risk can be implied unless the replacement was ineffective and dangerous levels of pathogens or pollutants continued to leave the property. The DOH (1988) called many replacements "failures". This is equivalent to saying that anyone replacing an old car with a new one must have replaced it with another car that does not work. Or, if someone continues to replace their car, all the replaced cars must have been dysfunctional. Chapter VI includes a partial survey of some of the homes that have replaced their drainfields in the last 20 years.

Least Reliable Indications of Health Risk

The County relied on the least reliable methods to establish health risk. These included pumping records, greywater systems, septic system repair rates, and total coliform and fecal coliform standards in marine environments.

Bacterial standards: The Malibu shoreline has met Ocean Plan standards for water contact sports with a few exceptions. By bacterial standards, the Malibu shoreline is considered to have the best relative ratings compared to other parts of Santa Monica Bay, with the exception of Malibu Lagoon (Heal the Bay, 1990; 1991). Water quality has improved from 1983 to 1987 along the Malibu shoreline (LACDOH), except near storm drains and creeks. This shifts the source of pollution from on-site systems to nonpoint sources (Fay, August 1988). Despite Malibu's superior record for Santa Monica Bay, there are many bacteriologists who dispute the usefulness of coliforms and fecal coliforms as an indicator of health risk in marine environments (see Table IV.2). The correlation of coliforms with human disease is even open to question in the best study performed (Cabelli, 1983).

The "shellfish" standards used in various reports were wrongly applied. Surfzone samples were taken. The standard requires water column sampling. No distance relationship between shellfish beds and sampling points has been made. As noted, no tissue analysis has been made.

Pumping records require documentation of the reasons for which the septic tank was pumped. If it was pumped because of backing-up, was this related to drainfield failure, plumbing or septic tank blockage, or sludge accumulation? If the drainfield was not absorbing effluent, did the untreated effluent surface? If it surfaced, was it in an area with human contact? If there was potential exposure, how long was the effluent in potential contact with other humans? The County (1988) data claim that 90% of the pumping was due to incipient drainfield failure. This claim has been strongly denied by the major pumper from a review of his pumping records and by citizen re-surveys of both the pumping records and the home residents (Lubisich, 1988; Keller, 1989; Dove, 1991). They have argued that 95% of the pumpings have had nothing to do with incipient drainfield failure.

PEWARA's review of the previous data show that the County claim is inadequately documented. It is clear that the 90% claim of incipient drainfield failure is not justified. The records were based on billings, not a review of causes of pumpings nor a field review of drainfield functioning. An unknown but substantial number of billings were not for pumping. Many pumpings were preventative and for maintenance purposes (e.g., before big parties, to unclog lines with roots, to compensate for water leaks, to replace or add parts to the system, to re-route plumbing during construction, to replace an aging tank or tank top, to remove accumulations of sand/debris in tanks, to please new owners or renters, to relocate the system during remodelling or landscaping, by routine habit, or through ignorance of how to check sludge levels rather than pump). In addition, some residents claim that certain pumpers merely "topped off" the liquid and left the sludge or only pumped one chamber so that they had to pump more often. The Malibu Township Council survey and written questionnaire found that 80% of the homeowners polled stated that the County data were inaccurate (Murdoch, 1989).

Greywater by-passes: In Malibu, the County considers greywater lines to be an indicator of the inability of septic tank systems to treat and to dispose of household wastewater safely. The County has claimed that in one survey 20% of the 766 beachfront homes inspected had illegal greywater by-passes either with above-ground disposal or subsurface disposal (DOH, 1988). In another survey, 43% of 562 beachfronts had alleged by-passes. There have been no indications of health problems from these by-passes, but violation of code notices have been issued by the County. According to Malibu DOH (Bart Slutski, p.c.), many of these systems now have underground disposal, a method recently approved by County code, or have been re-connected to the septic tank system. If the original County claim was correct, those greywater by-passes that are re-connected should eventually reveal problems with drainfield function, assuming no other changes. A maximum of three years has passed since many of the homes reconnected. Our survey (Chapter VI) checked some of these homes to see what had happened.

In addition, a Malibu Township Council poll of Malibu residents indicated that not all greywater systems were to improve septic tank system function. Some were a method of water conservation in which greywater was used for irrigation. Some "by-passes" came from jacuzzis, spas, partially enclosed showers in the backyard, and hot tubs in which sand (a debris that could rapidly fill septic tanks) was diverted to the beach. Some were built to avoid awkward plumbing arrangements. Some homeowners claimed that alleged greywater pipes were actually French drains used to lower groundwater levels in planted areas or stormwater drains from roofs and streets. How many homes the County accurately identified with greywater systems and how many they mistakenly identified has never been resolved.

This issue is no longer relevant to any discussion of collector sewers vs. on-site systems because (1) the County data are of questionable accuracy, (2) many shoreline greywater violations have been corrected to meet County standards, (3) exposure to and dosage rates for greywater health risks are uncertain, and (4) greywater systems have recently become legally buildable. It is important to design good greywater systems for those who want to use them and to educate Malibu residents on the benefits of those that work well. To this end, the survey discussed the history and reasons for past and present greywater systems with homeowners (Chapter VI).

Repair and addition rates: Repair and additions have little, if no, relationship to potential health hazard. Only extreme repetition of repairs of a similar nature (e.g., replacing a drainfield every five years) should be considered an indication of the continual inability of an on-site system to treat and dispose of effluent. DOH claimed that the repair rate was 45.5% (Montgomery, 1985) along the beachfront. This percentage was later dropped by DOH. The repair rate, called "functional failures", in the Malibu proposed assessment area were resurveyed in 1988 (DOH, 1988). Keller (1989) recalculated the repair rate from DOH data because the County had varied the denominator arbitrarily (i.e., it used a denominator that maximized the repair rate but was inconsistent within the statistical sample). According to Keller, the annual repair rate was 1 to 2.4% of the systems surveyed for a 20 year period (excluding storm damaged systems). In comparison to other older communities, this is not an abnormal repair rate (Winneberger, 1984). All repairs met County standards. To resolve this dispute, PEWARA re-surveyed the histories and present functioning of a sample of the DOH study (Chapter VI).

IV.4 Beachfront Health Risk Summary

In Malibu, the assertions that have been made about the need for an off-site sewage system within the Malibu Sewer Assessment District are not supported by the data. In addition, establishing a critical need will always be open to question. The adequacy of the data concerning health hazards along the beachfront from on-site systems suffer from inherent difficulties of water sampling in marine environments; unsubstantiated correlations between indicators and pathogens; use of the wrong indicators for the most common diseases; inability to separate out the source of pollution from other background possibilities (especially non-human animal sources and stormwater); enormous gaps in our understanding of minimal infectious doses that trigger clinical symptoms from contact with or ingesting nearshore waters; and differences in human judgement of acceptable risk.

The data on potential health hazards from septic tank systems have been organized by their reliability and their power to draw conclusions (direct or indirect measurement, sources, dosages, exposures). The most reliable types of studies that might strongly imply health risks, have never been attempted. In other words, even if there is a critical need, none of the studies that would signal "criticality" exist. Even studies that demonstrate risk, but with lower levels of reliability, have not been attempted. The data from studies that have the weakest risk implications (pumpings, greywater by-pass, shellfish standard, and repair rates) were inadequately collected and verified. The most widely accepted indicator of the possible presence of pathogens in marine waters (e.g., enterococci) has been studied and meets current standards. The shoreline coliform indicator densities, which have debatable sanitary significance in marine waters, all meet current standards for water contact. In short, there is neither a strong nor a weak implication of health risk from beachfront septic tank systems.

IV.5 Storm Damage and Health Concerns

Storm damage is inevitable along the Malibu Coast. No matter how barricaded against high tides, El Nino events, low pressure systems, storm waves, and wind-stressed waves, some damage will occur to some homes. Recent climatic history points to the winter storm events of 1978, 1980 and 1983 as useful indications of future events. These scale storms will recur on an irregular basis, certainly at least once every 25 years (Table IV.4). The clustering of major storms in the 1978-1983 period is viewed by Dr. Orme

Table IV.4:
Unsheltered Deepwater Extreme Wave Characteristics, Southern California Bight, 1900-1988

Date	H_S (feet)	T (seconds)	Azimuth (degrees)	Source
March 1904	17.9	12.0	225	MA
March 1912	17.5	11.5	270	MA
December 1914	13.0	9.9	180	MA
January 1915	16.3	11.8	205	MA
February 1915	16.5	12.4	280	MA
January 1916	14.0	9.6	250	MA
February 1926	12.6	16.0	260	MA
April 1926	11.8	13.8	270	MA
December 1937	11.6	16.4	270	MA
September 1939	26.9	14.0	205	MA
January 1943	16.2	10.8	180	MA
March 1952	11.7	11.7	250	MA
January 1953	16.0	19.2	260	MA
January 1958	18.1	14.0	270	PWA1
April 1958	25.1	18.0	293	PWA 1
February 1960	18.3	19.0	294	PWA 1
February 1963	19.5	14.0	269	PWA 1
February 1969	15.6	15.0	284	PWA 1
December 1969	14.4	21.0	276	PWA 1
August 1972	12.7	18.0	156	PWA 2
January 1978	18.6	17.0	284	PWA 1
February 1980	15.6	15.0	225	PWA 1
January 1981	15.4	18.0	265	PWA 1
January 1981	21.5	16.0	269	PWA 1
September 1982	11.1	16.0	158	PWA 2
December 1982	20.4	11.0	293	PWA 1
January 1983	21.0	21.0	283	PWA 1
February 1983	17.1	17.0	275	PWA 1
March 1983	23.6	19.0	263	PWA 1
January 1988	26.4	17.0	260	PWA 1

Multiply H_S (Significant Wave Height in Feet) by 0.3048 to obtain meters.
From Marine Advisors (MA), 1960, and Pacific Weather Analysis (PWA), 1983 and 1987, contained in Moffatt & Nichols, 1989.

(Technical Memo 10) as an artifact of a random distribution of events. At this time, it is believed that deepwater wave heights of about 8 feet (2.4m) will recur at 10-year intervals, 12 feet (4.0m) at 25 year intervals, 15 feet (4.6m) at 50 year intervals and about 17 feet (5.3 meters) at 100 year intervals. Of the storms analyzed between 1900 and 1988, 25 occurred from December through March, 2 occurred in April and one in September. The major storm disasters occur at the time when there are the fewest visitors to the beach, greatly reducing the rates of exposure to potential pathogens. In addition, the high tides, storm surges, and turbulence dramatically increase dilution, dispersion, and perhaps die-off rates of any possible pathogens. Since the mid-seventies, wave uprush studies have been required by LAC. According to a firm which has tracked sea protection, wave uprush studies and the impacts of storms (David Weiss Engineers, 1991), no home built after these studies began or with a bulkhead based on wave uprush criteria has been damaged.

The DOH study implied that high tides and storm surges, wave topping or undercutting of the drainfield were major causes of the alleged health hazard. We were asked to review the data for this assertion. DOH used Building and Safety records (which do not usually distinguish between bulkhead damage and damage to drainfields and septic tanks) and DOH records from 1978 to 1988. These were recorded on an address-by-address basis in a spreadsheet. In addition, DOH sited 1983 coliform data that were claimed to be unusually high compared to background levels and/or other areas of Santa Monica Bay. These levels caused the beach closure of March 23, 1983. This beach closure took place one week to two months after the storms. It was based on continuing "raw sewage" discharge allegedly from Malibu on-site systems that elevated coliform levels above safe conditions. The closure lasted two months and stopped when the summer crowds arrived in June.

DOH surveyed 785 homes along the beachfront. According to DOH, 544 homes had no storm damage recorded (69%); 176 homes had some degree of storm damage (22%) to their on-site systems once in 10 years; 60 homes (8%) had some degree of storm damage twice in the decade; 5 homes had 3 storm damage events (0.6%). These homes were predominantly on east PCH and Malibu Road. During the home survey, PEWARA questioned residents about storm damage. The DOH claims of storm damage were the most controversial of topics in the survey. Many homeowners stated that their bulkhead was damaged but not their septic tank system. Their claims could not be dismissed. In one case, the septic tank was on the inland side of the house and could not be reached by waves. Robert Saviskas (p.c.), the DOH project manager, also stated that the review of Building and Safety files may have led to errors as County Building and Safety was concerned with damage to buildings and other structures, not just damage to the septic tank system. PEWARA could not resolve all these disputes nor quantify the extent of the dispute.

Some of the storm damage was very minor -- an exposed tip of a drainfield pipe that was re-covered with sand after an hour's worth of shovelling. These minor damages cannot be called a major source of fecal coliforms or pathogens. Some were complete washouts -- septic tank, drainfield and home. DOH did not make a list of addresses with the type or extent of damage. They did not list the dates of damage. By two months after the storms, most homes had repaired minor damage, obtained chemical toilets or were using neighbors' bathrooms. A few of the homes with more serious damage to the drainfield or septic tank had greywater systems while waiting for completion of structural support for their homes.

Of the PEWARA survey homes with definite storm damage to the system, the average age of the drainfield was 18 years (N = 33). In other words, the drainfield had gone about eighteen years without need for repair, additions or replacement before a storm damaged it. This is close to the 25-year cycle of high storms predicted by oceanographers and not much shorter than the LAC design-life of an on-site system (20 years).

The claim to a potential health hazard from effluent entering the nearshore marine waters is not documented for the many reasons explained earlier in the chapter. In addition, no 1983 fecal or coliform data were collated in the DOH report nor were they available in collated form from DOH (Petralia, p.c.). We found 1983 data from local sources and found that the very high coliform counts occurred consistently at only one location near Malibu Road, not the general surfzone. They were not related to the location of storm damaged drainfields (unless the home was near a storm drain). No comparisons with other samples from other parts of Santa Monica Bay had been made. Non-septic tank sources, including storm drains and the stirring of the Hyperion outfall and sludge bed from the storm currents, were not eliminated as potential sources of coliforms. Later documents show that the DOH closure of the Malibu beaches was a "precautionary" measure and was not based on coliform counts.

Summary: Storm damage will occur. The emergency situation requires an emergency preparedness program of which one element is wastewater management. This might include a retainer for priority access to chemical toilets, extra septic tanks that can be moved on-site for holding tanks, plugs for any opened pipe, and assistance in constructing safe greywater systems until drainfields or septic tanks can be replaced or repaired. There is no evidence that these emergency situations create a health hazard. No increase in sickness has been reported, no careful monitoring of effluent discharges has been tabulated, and there are no confirming data from coliform indicators. During storms, building structures appear to be more at risk than health, life or limb.

Finally, septic tank effluent pumping system (STEP) alternatives to on-site beachfront systems may require bulkheads if the septic tank is on the beach side of the home. Any electrically dependent device such as a STEP-system pump can become damaged or find itself inoperative in storm situations. An emergency preparedness program for septage pumping and chemical toilets will be required for STEP septic tanks as well as passive septic tanks.

Portraits of Extreme Storms Along the Malibu Coast

September 1939: A hurricane forced waves to approach Malibu from the south-southwest at 14 second intervals with wave heights as high as 8.2m.

Winter 1977-78: A southerly shift in the mean storm track led to above-average rainfall and storm waves. February 5-14 produced exceptional storms with a frontal system passing over Malibu from the southwest. February 28-March 5 produced a series of low pressure troughs which helped to elevate the seas. With storm seas, the low pressure, and exceptionally high tides (2 m) combined, coastal erosion escalated. In March, breakers reached 4m for several days and, because of the high tide, broke closer to shore. Some beaches dropped 2 to 3m, undermining the sand and house supports. Waves destroyed some structures by direct impact. Malibu Colony Drive and Malibu Road from Malibu Point to Corral Beach were hard hit. Here the beach was eroded up to 3 m, exposing basal cobbles, and boulders. The high water mark crept under the homes. The area from Malibu Point to Topanga was also hit hard.

Winter 1980: High pressure in Cañada forced storm tacks south. February 13-21 saw 6 low pressure systems move across Malibu in rapid succession, triggering heavy rainfall, strong onshore winds, widespread flooding, hillslope movement, coastal erosion and damage to homes. On February 16, storm waves and surges were superimposed onto a spring tide which enhanced coastal erosion at high tide and sand removal at low tide. From Corral Beach to Topanga, the coast was hit hard. PCH had frequent landslides.

Winter 1983: In late January and February 26 to March 4 winter storms coincided with high tides -- a combination enhanced by the El Nino conditions. Mean wave heights of 3 m with 8-second periods were measured on March 2 and 3. Some breakers rose 5m. The February high tide exceeded 2m. Significant wave heights of over 7m hit the coast. Beaches dropped 2-3m. Homes were lost in Las Flores Beach and Malibu Road and there was severe damage to piers and other structures. The high seas brought in flotsam and sand that did further damage. Beach losses were partially balanced by floods of sediment from Malibu, Corral, Escondido, Ramirez, Zuma and other canyons. Steepened shallow storm waves on top of a storm surge, spring tide and El Nino water has great potential for coastal damage.

CHAPTER V: PREVIOUS ON-SITE SYSTEM CODES, REGULATIONS, AND MANAGEMENT

The Malibu area, when unincorporated, functioned under a series of changing codes related to on-site system design and installation, greywater systems, nonpoint pollution, and water conservation. These codes have not been constant. The Uniform Plumbing Code (UPC) as it pertains to on-site systems changed slightly every three years and the specialty codes for the beachfront changed about once every ten years. PEWARA reviewed the old codes from unincorporated times, the up-coming "blue-sky" ordinance that has been proposed to the COM (Technical Memo 6) and the LAC greywater ordinance (Technical Memo 7). Waterworks District No. 29 and County ordinances related to water conservation were not reviewed, but general needs for water conservation and water usage as they relate to wastewater have been incorporated into this report and appear in Technical Memo 11. Nonpoint sources have many agencies involved (Section V.4).

V.1 Wastewater Codes, Regulations and Agencies

Various governmental agencies have or have had review process over design and installation. The most immediate was LAC Department of Health (Table V.1). They have handed over design and monitoring responsibility to the city but appear to retain powers of abatement for health and safety violations. The Coastal Commission (CC) will use the County's Land Use Plan (LUP) until the city's LUP and Local Coastal Plan (LCP) is certified. The legal standard of review remains Chapter 3 policies of the Coastal Act. The CC has review powers over new systems, sea wall protection, and major wastewater projects throughout the city. The CC has asserted that approval of any new on-site codes will depend on the approval of the Regional Water Quality Control Board, the County Engineer Facilities, and the Department of Health Services (P218). All the approval powers of the County Engineer Facilities have been passed to the City.

The Regional and State Water Quality Control Board are involved with the package plant permits, especially if there is any discharge. The Regional Water Quality Control Board (RWQCB) has jurisdiction over on-site systems when they feed a drinking water supply. This is not the case in Malibu. Nevertheless, the RWQCB has taken an active interest in areas with on-site management districts that substitute for more centralized treatment facilities (e.g., Stinson Beach). LAFCO retains review

Table V.1: On-Site Regulations Active in Unincorporated Malibu

County of Los Angeles. n.d. "Procedures [sic] for Application of Approval of Private Sewage Disposal System Construction." Department of Public Health. Environmental Management. 5 page mimeo.

County of Los Angeles. 1981. "Private Sewage Disposal System Design Requirements for Beach Front Property." No. 610.11. Department of Health Services, Environmental Management, Policy and Operations Manual.

County of Los Angeles. 1990. "Private Sewage Disposal System Design Requirements for Beach Front Property." No. 610.11. Department of Health Services, Environmental Management, Policy and Operations Manual.

International Association of Plumbing and Mechanical Officials. 1988. "Appendix 1, Private Sewage Disposal Systems." Uniform Plumbing Code.

U.S. Department of Health, Education, and Welfare. 1967. Manual of Septic-Tank Practice. Public Health Service, Publication 526.

powers over "spheres of influence," especially annexations (e.g., if Monte Nido wanted to become part of an on-site management administrative framework organized by the city).

This section is largely based on Technical Memo 3 by Dr. J. T. Winneberger who reviewed the UPC and LA County "design codes" under which Malibu has been working. This section can only briefly summarize his 51 page report. Dr. Winneberger concludes: "Mandates of Los Angeles County have been found: (1) without sound technical and experiential foundations; (2) inadequate for practices in Malibu; (3) arbitrary and capricious; and, (4) in need of replacement." He adds that on-site space that could have accommodated a good disposal system has been used for an inferior disposal system; commercial systems, especially restaurants, have been deprived of recent engineering tools and skills (e.g., sand filters, charcoal filters) that have been available for 20 years; engineers have been constricted to poor design by the mandates in codes; the codes themselves have gone out-of-date with no attempt to modernize them; specific setbacks have directed designers away from useful soil horizons for treatment and disposal; tests to determine the long-term assimilative capacity and infiltrative surface area of receiving soils have been wrongly applied or employ the wrong procedures to achieve desired results; life spans of systems, especially commercial systems, have been unnecessarily shortened (e.g., no aeration compensation for paved over systems); and nuisance odors have been unnecessarily common. The planning of on-site systems has been for planned obsolescence, not for long-term practices.

Table V.2 summarizes some of the design and installation problems that have "crippled" good on-site practices in Malibu. A few examples are warranted:

-- The UPC considers that the bottom area is the effective infiltration surface for gravel-filled excavations used for drainfields that are shaped like boxes (e.g., "trenches" or "beds"). The UPC then considers the sidewall area as the more effective infiltration surface for excavations shaped like cylinders (seepage pits). Trying to accommodate research done in the 1960s, LAC modified the codes and said that the use of bottom-areas requires 50% more surface area than sidewalls. But, this has no technical basis for any of these uses of sidewalls or bottom areas. The codes allow all the total infiltrative surface of a seepage pit to count in a design, even though only a minute portion of the pit wall may actually transmit effluent.

-- The amount of infiltrative surface is determined by methods apparently unique to LAC and Malibu. No fieldwork has been done to see if these methods are valid.

-- Separation of the bottom of drainfields from groundwater suffers from a lack of technical justification. Cylinder-shaped holes are to be 10 feet above groundwater and box-shaped holes only 5 feet, even though the shape of the excavation has nothing to do with adequate separation from groundwater. These are arbitrary rules from the point of view of public health because they do not include total assimilative capacity of the soil, dispersion of effluent in the bedrock or subsoil, quantities, seasonality of the groundwater, etc.

- - The UPC limits trench length to 100 feet without any technical justification and has caused many builders severe problems trying to fit disposal fields into lots. This restriction prevents the designer from using the best design for assimilative capacity of the soil.

-- The UPC and LAC codes mandate percolation tests for soils to be applied to beachsand deposits (not soil) and fractured and transmissive bedrock inland. Applying soil-based testing to non-soils has led to all kinds of confusion about drainfield design, perc test design and performance, acceptable rates (too fast or too slow) and long-term rates. In addition, there are better methods of judging the long-term usefulness of soils (e.g., Santa Cruz County methods) which cannot be found in the UPC and LAC codes. The situation is, again, not a matter of stringency but of proper methods custom-designed to Malibu's particular situation. Chapters X and XI will address Malibu's wastewater management strategy in detail.

In summary, Dr. Winneberger and PEWARA come to the following conclusions:

(1) The present design features are neither more nor less stringent than other governmental regulations. Given the state-of-the-art, the codes are simply not defendable technically and are not effective in ensuring long-term functioning of on-site systems.

(2) Any replacement of existing codes will not be a change from one series of design restrictions to another. That is, some design features should have no exact rules. Custom-designing will give engineers and others more latitude to meet precise needs of commercial (e.g., restaurants) and residential lots (e.g., on landslide areas).

(3) This "freedom" to custom-design can be abused. The COM will need to create an administrative review process with strict guidelines to promote sustainable on-site practices.

V.2 Greywater Ordinance

LAC's greywater ordinance has been proposed for adoption by the COM. The thorough review can be found in Technical Memo 7 on greywater in Malibu and Chapter X. The ordinance is for residential occupancies, though some of the more important opportunities for wastewater reuse (combined or greywater) are in the commercial areas. The setbacks in the ordinance essentially eliminate its use on beachfront parcels. The ordinance prohibits use on geosensitive parcels. These restrictions essentially eliminate its use in Malibu. There are no references to remodels or additions, another major concern of Malibu.

Contrary to San Luis Obispo and Santa Barabara guidelines, there is nothing educational within the ordinance. Nor does the ordinance act as a friendly extension service. It is filled with punitive implications and high costs that can only discourage "inlaw" systems and will, by their difficulty, promote outlaw systems and conflicts with city representatives. The design is based on the UPC and suffers from all the problems listed above. It is partly over-designed (valved-off irrigation, concrete slab, screwed-down cover), partly under-designed (surge flows), and partly promotes non-defendable

TABLE V.2: ON-SITE CODE ANALYSIS

Item	LAC	UPC	USPHS	Comments
SEPTIC TANK				
Size	# bedrooms	# bedrooms	—	Not a good standard.
Baffles	Partitioned tanks	Partitioned tanks —		Needs new design
Venting	House vents	House vents	—	Increases odors; vector transmission. New design.
DISTRIBUTION BOX	UPC	Drawing	None	Replace with simpler plumbing.
DISPOSAL FIELD				
Type	Select	Select	Select	Wastes infiltrative surface; not well plumbed.
Depth of gravel	Trenches: 12-36" Pit: >10'	Trenches: variable Same		Unsound.
Width	Trenches: 18-36" Pit: 4-6' diameter	Same	12" + Pit: variable	Unsound limit.
Infiltration surface	Trenches:sidewall only	Trenches:bottom stressed Pits: sidewalls only		Sidewalls should be emphasized.
Length	100 feet rule	Same	60-100' suggestion	Unsound.
Groundwater separation	Trenches: 10' (misprint?)	Trenches: 5 feet 4 feet Pits: 10 feet		Should be based on site-specific judgment.
Spacing	Trenches: 4' +	4+ feet	6' centers	Not applicable to slopes. Depends on soil. Unsound.
Hillslope breakout	15'	15 feet	none	Site-specific judgment. Unsound.
Blue-sky	proposed	proposed	none	Aeration & compaction can be handled. Unsound.
Construction damage	Rake sidewalls	same	none	
Salinated Sands	–	--	–	
SOIL TESTS				
Trenches	Perc test (unique)	No test specified	Perc test	LAC is not empirical. Unique.
Pits	Water-fill pits	1991 UPC	None	Unsound.

restrictions (e.g., bottom area calculations, trench fills, line spacing). The official acceptance of a greywater system does not allow a compensating reduction in the blackwater system. Technical Memo 7 gives some indications of better approaches to greywater systems.

V.3 Water Conservation Ordinances

Metropolitan Water District of Southern California (MWD) supplies 100% of the water to Waterworks District 29 which supplies virtually 100% of the water to Malibu. In 1990, Waterworks District 29 asked for a voluntary cutback of 10% in water use. In February 1991, this 10% became compulsory. By March, the amount was increased to 20%. By May, this was required by an ordinance of the LAC Board of Supervisors. By July 25, under protest from some users, the ordinance was changed to allow 80% of the District average or 80% of the customer's historical usage (whichever is greater). In January and February, before these ordinances, more water than was allocated was used. In March (with rains), the savings was 44% below rationed levels -- showing the importance of rain for irrigation. Since then, the savings have been about 25% district wide.

The Coastal Commission has stipulations related to water conservation in the Land Use Plan. Some of these are pending with the County's proposed coastal permit for the STEP-system sewerage plan. The city has no ordinance at the moment nor any joint-powers agreement with Waterworks District 29 to promote more water conservation (Chapter X and XI).

V.4 Nonpoint Regulations

Section 319 (Nonpoint Sources Control) and 402 (Stormwater Permitting) of the 1987 Clean Water Act (CWA) provide the Federal context for nonpoint regulations and the NPDES (Nonpoint Discharge Elimination System) permits. In addition, the 1990 Coastal Zone Management Act (CZMA) reauthorization amendments included a new coastal nonpoint pollution control program to be implemented by states. The National Oceanic and Atmospheric Administration (NOAA) and Environmental Protection Agency (EPA) implement the program.

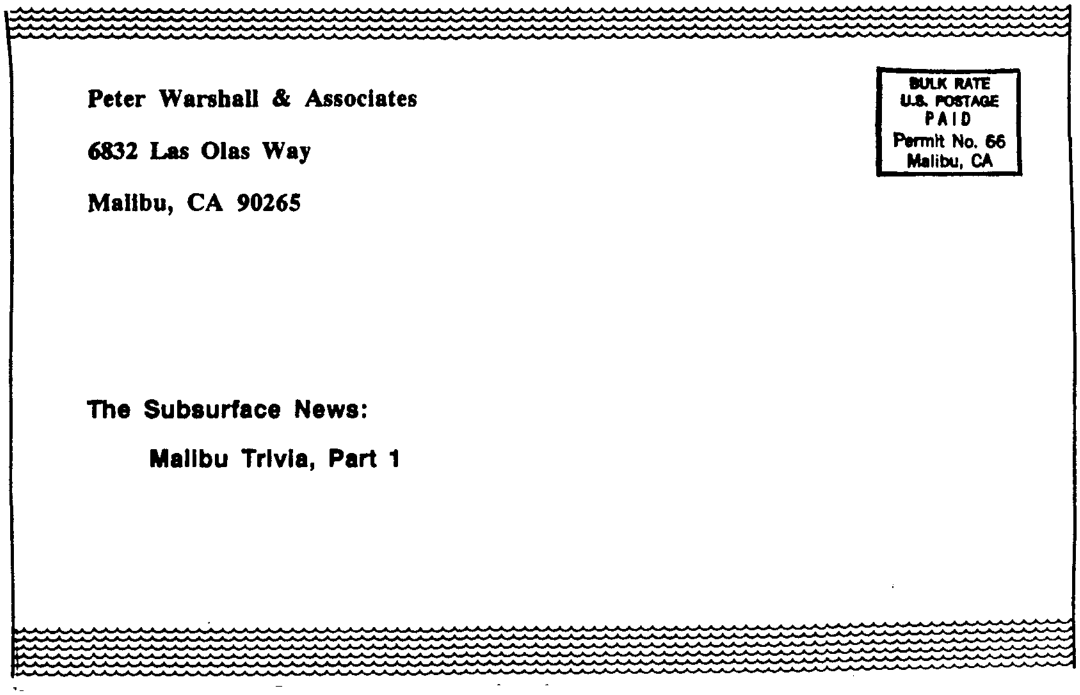
Enforcement and regulation come from state, county and local governments. The State Water Resources Control Board (SWRCB) follows the California Ocean Plan, the Thermal Plan, the Enclosed Bays and Estuaries Plan, and the Inland Surface Waters Plan. SWRCB has primary responsibility for Section 319 of the CWA and joint responsibility with the Coastal Commission for the CZMA.

The Los Angeles Regional Water Quality Control Board has adopted waste discharge requirements for stormwater/urban runoff for Los Angeles County. The five-year NPDES permit is issued to Los Angeles County. Incorporated cities (including Malibu) are co-permittees. The terms of the permit require that drainage areas and land uses be defined, available data on rainfall, runoff and water quality be compiled, and drainage systems be inventoried and mapped. The RWQCB also issues permits under the CWA, section 402.

The California Coastal Commission (CCC) is primarily charged with the state's Coastal Management Program. It also determines consistencies between the CZMA and state programs. As mentioned, it has joint authority with the SWRCB for nonpoint control under CZMA.

Within the city, the storm drains and culverts fall under four possible jurisdictions: the City of Malibu, Los Angeles County Flood Control District, CalTrans, and private landowners. In addition, some drains exist for which no agency claims responsibility. The fragmented system for management of storm flow makes it difficult to govern water quality standards and implementation. There are currently no uniform measures for Santa Monica Bay. The City has wide ranging authority to set its own standards and may set precedents for other cities.

The situation is complex for the 22 watersheds that extend beyond the city's boundaries. The outside city portions of the wastersheds may be the major producers of nonpoint pollutants that flow downstream into the city, the public beaches, and Santa Monica Bay (Chapter VIII). Analysis of extra-city sources and regulatory authorities was beyond the scope of this contract.



Peter Warshall & Associates

6832 Las Olas Way

Malibu, CA 90265

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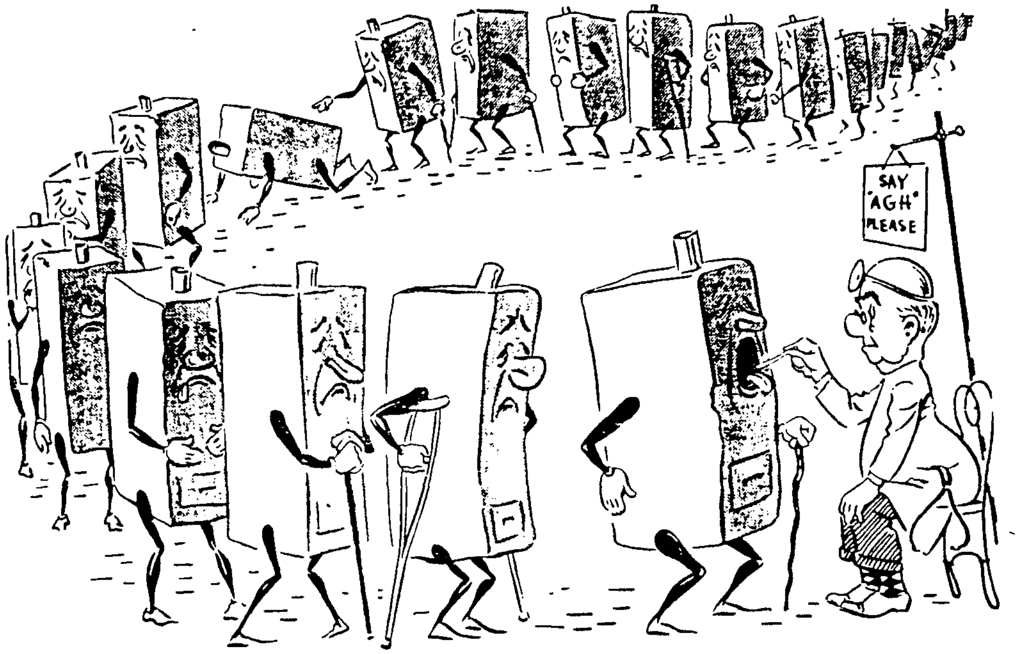
PAID
Permit No. 66
Malibu, CA

The Subsurface News:

Malibu Trivia, Part 1



The "Subsurface News" and an all-night local telephone were two ways that that PEWARA tried to reduce doubts about the home-site survey and encourage participants. Citizens groups voluntarily funded the "Subsurface News" which included the above cartoon form a 1940s spetic tank educational pamphlet.

CHAPTER VI: THE ON-SITE SURVEY

VI.1 The On-Site Wastewater Survey

The most unique part of this study was an intensive survey in cooperation with individual homeowners. The goals of this survey included: (1) resolving the disputed data that have appeared in previous reports and letters; (2) replacing the myths about septic tank system installation, design, treatment, disposal and reuse with a field-based understanding of the actual problems; and (3) finding an administrative and technical approach for dealing with the on-site problems observed and expressed by homeowners, pumpers, County inspectors, geotechnical engineers, and contractors. The survey hoped to give PEWARA and homeowners a better understanding of their on-site wastewater systems and ways to improve septic tank system function. In this sense, the survey was an "extension" service with a strong educational component.

VI.2 Methods

The survey definitons are outlined in the accompanying box. The survey had 2 distinct types or groups: a sample from the 241 addresses that had been categorized as "functional failures" on the County's 1988 spread sheets, and an additional 85 addresses from a sample of approximately 125 volunteers. Final interviews totalled 203 addresses (118 "functional failures" plus 85 volunteers) which contained about 247 separate on-site systems. About 40 volunteers could not be visited because of time and financial restraints. We selected volunteers in a wide geographic range of the city in order to become more intimate with the variety of site problems that might exist. We chose to interview the volunteers who told us they were having problems rather than the volunteers who said everything was just fine. In general, the volunteer and "functional failure" samples of single-family/year-round residences were comparable. They had the same number of problem and marginal systems (Technical Memo 13). The volunteer sample had slightly larger systems, numbers of people per home, bedrooms per home, and bathrooms per home than the sample of functional failures, but the differences were not statistically significant. The volunteer sample, many located inland, had 5 times the area irrigated than the County study which primarily addressed beachfront systems on small lots. The water use reflected this difference. Volunteers had a slightly higher percentage of greywater systems mostly involved with drought irrigation.

Survey Definitions for Statistical Purposes

Address: The location of a building or group of buildings no matter how many on-site systems were located on or partly on the property.

System or On-Site System: The actual number of systems regardless of property boundaries. For instance, a single address might have two buildings and one system or a single address might have one apartment complex and three systems. For the survey, systems were more important than addresses.

Volunteers: Residents who telephoned and who invited us to look at their on-site system(s).

Functional Failure Sample: A group of 241 addresses that the County Survey of 1988 had stated were "functional failures." The survey tried to contact as many of these addresses as possible. This sample was considered a "worst case" sample of on-site systems with a previously poor history of on-site system functioning.

The total number of on-site systems in the city is probably between 4,000 and 4,200. In other words, PEWARA has surveyed about 6% of Malibu on-site practices. The statistical consequences of this sample are discussed in Technical Memo 13. The sampling focussed on "worst case" situations and represents a much wider geographic range than previous studies.

The home site survey was also divided geographically into three groups: (1) beachfront; (2) inland; and (3) commercial (either inland or beachfront). In addition, some schools and other miscellaneous categories were visited. These were not rigidly defined categories. Some "beachfronts" were far back behind sand dunes and could be considered "inland" homes on sand deposits. Others were within the area of tidal flux but had seepage pits on the road side of the home within non-sandy landslide debris or inland-type soil profiles.

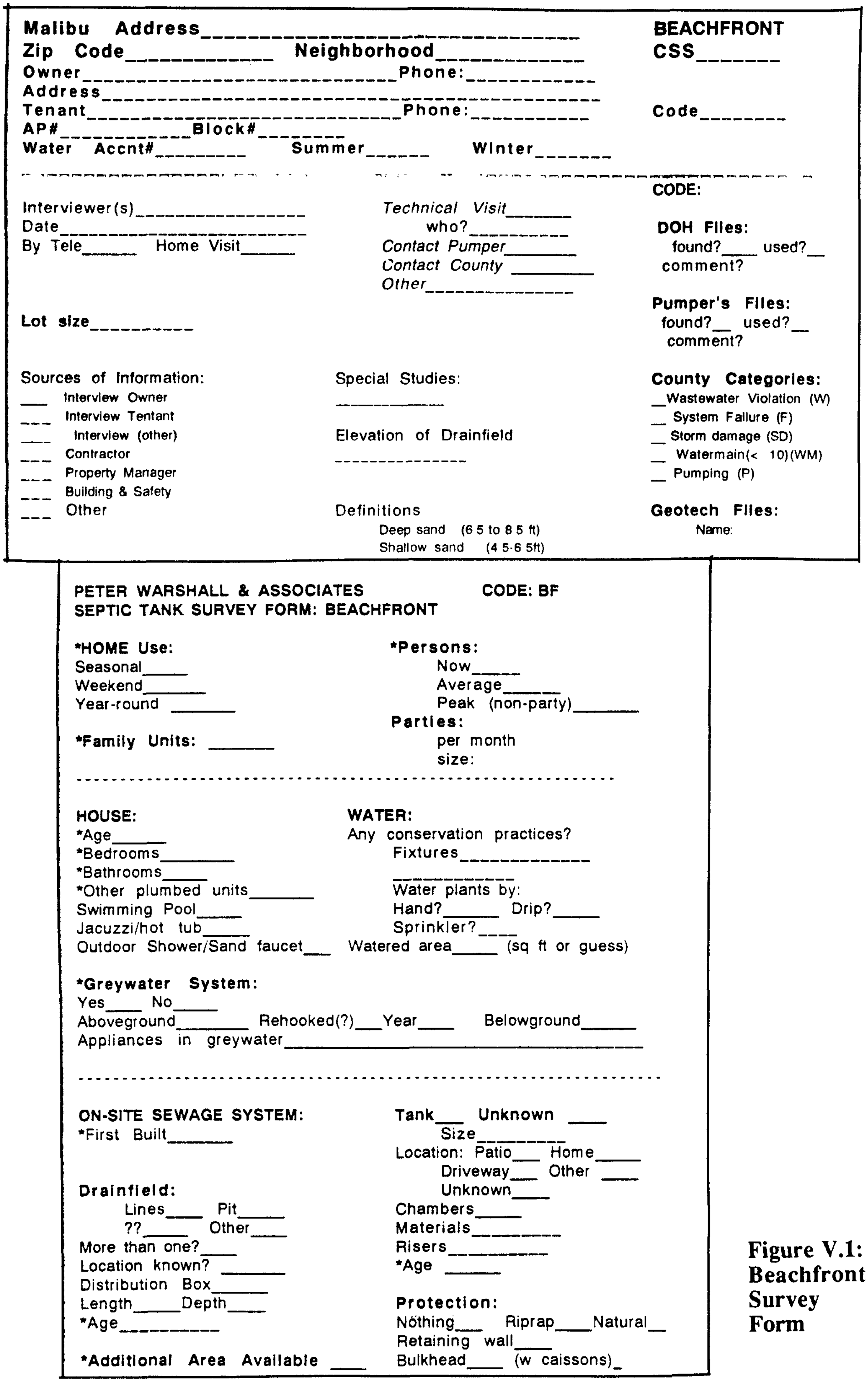
The survey forms (Figure VI.1) were custom-designed for inland vs. beachfront homes. For instance, seawall protection, depth to sand below the drainfield, location of the mean high water line, access to the drainfield below the porch or floor joists, and the existence of an outdoor "sand shower" were items on the beachfront form. Slope, runoff from patios and driveways that might flood the drainfield, size of irrigated area and its use (lawn, patio, arid-adpated vegetation), and the existence of previous geotechnical reports were important items on inland forms. Commercials had only the most general form as they did not conform to any one pattern. Restaurants, for instance, required much sleuthing to determine whether septic tanks could handle peak loads and whether grease traps were adequate.

In total, each survey form asked approximately 55 questions plus a less rigid question-and-answer section on the history of system problems (year, problem, date, repair/addition/replacement, effectiveness), pumping, layout, construction, and setbacks. We know of no other septic tank survey with such a detailed list of questions.

The steps in the survey were as follows:

Step 1. Fill out confidential questions. PEWARA promised that all data would be used in a statistical and anonymous manner. The contract states that all the individual residential or commercial data would not be made available to the city or other governmental agencies. The form was designed to increase confidentiality: the top with identifying information could be torn off and replaced by a code. Name, address, phone, parcel numbers, information from the DOH files (history of repairs and confirmed violations), and status in the DOH 1988 study (pumping, functional failure or storm damage) were all held confidential.

Step 2. Locate homeowner, representative or tenant and secure visit. "Locating" included finding telephone numbers from reverse files from real estate agents; personal contacts from neighbors, friends, homeowner and property owner associations; tracking backwards from an index of Malibu parcel information and statistics (Daniels, 1989), and voter registration lists. Support and request letters came from the Malibu Road Homeowners Association, Las Tunas Beach Residents Association, and personal letters from Gil Segal to Carbon Beach residents, from Bill and Fini Littlejohn and Ivan Goff to Malibu Colony residents, as well as a major mailing signed by the complete City Council.



Malibu Address____________________________ **BEACHFRONT**
Zip Code__________ **Neighborhood**__________ **CSS**______
Owner________________________**Phone:**__________
Address____
Tenant________________________**Phone:**__________ **Code**_______
AP#__________**Block#**________
Water Accnt#________ **Summer**_____ **Winter**______

CODE:

Interviewer(s)______________
Date______________________
By Tele_____ Home Visit_____

*Technical Visit*______
who?_________
*Contact Pumper*_______
Contact County ________
*Other*____________

DOH Files:
found?___ used?__
comment?

Pumper's Files:
found?__ used?__
comment?

Lot size_________

Sources of Information:
- ___ Interview Owner
- ___ Interview Tentant
- ___ Interview (other)
- ___ Contractor
- ___ Property Manager
- ___ Building & Safety
- ___ Other

Special Studies:
____

Elevation of Drainfield
____

Definitions
Deep sand (6 5 to 8 5 ft)
Shallow sand (4 5-6 5ft)

County Categories:
- __Wastewater Violation (W)
- __ System Failure (F)
- __ Storm damage (SD)
- __ Watermain(< 10)(WM)
- __ Pumping (P)

Geotech Files:
Name:

PETER WARSHALL & ASSOCIATES **CODE: BF**
SEPTIC TANK SURVEY FORM: BEACHFRONT

***HOME Use:**
Seasonal_____
Weekend______
Year-round ______

***Family Units:** ______

***Persons:**
Now_____
Average______
Peak (non-party)______
Parties:
per month
size:

HOUSE:
*Age_____
*Bedrooms_______
*Bathrooms_____
*Other plumbed units______
Swimming Pool_____
Jacuzzi/hot tub_____
Outdoor Shower/Sand faucet___

WATER:
Any conservation practices?
Fixtures___________
____
Water plants by:
Hand?_____ Drip?_____
Sprinkler?____
Watered area_____ (sq ft or guess)

***Greywater System:**
Yes____ No_____
Aboveground_______ Rehooked(?)___Year____ Belowground______
Appliances in greywater________________________________

ON-SITE SEWAGE SYSTEM:
*First Built_______

Drainfield:
Lines____ Pit_____
??_____ Other____
More than one?____
Location known? ______
Distribution Box______
Length_____Depth____
*Age_________

***Additional Area Available** ___

Tank___ **Unknown** ____
Size_________
Location: Patio___ Home_____
Driveway___ Other ____
Unknown____
Chambers_____
Materials________
Risers_________
*Age _____

Protection:
Nothing___ Riprap____Natural__
Retaining wall____
Bulkhead____ (w caissons)_

Figure V.1: Beachfront Survey Form

Setbacks
Coastal Acces Walks
Solid Surfaces
***House**
***Septic Tank**
***DF Perimeter**
***Protection Structure**
Greywater
Runoff outlets

***HISTORY(Interview):**

Current Functioning ______

Year	Problem	Addition, Repair, Replacement	Effective

***Pumping:**
Pumping Contract? Pumper

Date	Reason	Pumper

FIELDWORK: MAKE SKETCH

***Lot Condition:** Surface water____ Surfacing effluent______
Indicator plants____

***Drainfield run-on Problems?** Roof ___ Patio____ From street___
Drainfield Use: Gardening____ Landscape w Watering____
***Drainfield Access: Drainfield under solid surface?_________**
DF under wooden deck or house (clearance)?______
Other_____________
***Septic Tank on streetside of house?______**
Septic Tank under house?__________

***Depth to Bedrock____**
***Approximate drainfiled square footage _______________**
***Nearby irrigation/disposal possibility?______**

Peter Warshall did spots on KABU-TV and made requests in the first issues of "The Subsurface News." If a telephone number could be found, then attempts to contact the property manager, operations manager, tenants, house-sitters, and housekeepers followed.

Step 3. Visit home and interview homeowner, tenant, property manager or operations manager. Explain confidentiality provisions and go through as many questions as possible. Draw sketch of system location. Note possible locations for future expansion or nearby neighborhood drainfield area. Check DOH map and information with informant. Chat about landslides and storm surges and have tea when offered (or Ivan Goff's champagne). In specific situations, **soil bores or other measurements were recorded.**

Step 4. Decide **status of the system:** "functional," "marginal," or "problem." Enter status in confidential section.

Step 5. If contradictions exist between DOH and resident information, **verify** by revisiting files, calling pumper, searching city's Building and Safety files, requesting geotechnical reports, or talking to contractor. If needed, re-visit developed parcel or telephone for further information.

Step 6. Collect water use data for pre-rationing and post-rationing, summer and winter uses from Waterworks District No. 29 and **pumping data** from Wastec for marginal and problem systems.

Step 7. Collate and analyze all of the above.

VI.3 Survey Experience and Success

Step 1: We reviewed 207 addresses (247 on-site systems). The County had files for 87% (N =181) and schematics of the septic tank location for 77% (N = 159). 12% (N = 25) of the files could not be found despite searches with DOH personnel. At the start of the survey, Malibu volunteers helped us ferret out DOH files and record on-site system histories. This drew complaints from County DOH. They felt that complaint notices were not open to public scrutiny and that volunteers (or workers paid a dollar a day) were the public. We stopped using volunteers for collecting on-site system histories. The city volunteered time of one of its employees and DOH employees kindly extended their hours in order to let us work after the doors were closed to members of the public.

Step 2: Re-surveying County "functional failures." The hardest step in the process was locating a home owner, representative or willing tenant to re-survey the "functional failures." To encourage participation at cheap telephone rates, PEWARA set up a fieldstation in Malibu and had twenty-four hour phone reception. Of the 241 addresses (the DOH "functional failures") we attempted to contact, 55% responded. From our point of view, this was a remarkable success for Malibu but low compared to other surveys. The reasons for the 109 non-responses were carefully recorded. Tracking non-response data is the best method to control for bias. Previous surveys by the County did not analyze the causes of non-response, opening the surveys to a broader claim of biased sampling.

Despite all the methods of name search, 30 addresses (28% of the 109 non-response) could not be attached to a name. Many of the more well-known entertainers leave a series of wonderfully false and frustrating trails to hide their name, their property manager's name or their operation manager's name. Sixty-eight addresses (62% of the non-responses) had no traceable telephone number. This left letters as the only method of approach. Seventy-five (69%) of the 241 City Council letters received no response. About 27 letters (25%) from the City Council were returned with an unknown addressee. The 6% response rate is considered a success by target-market junk mailers.

When a phone number could be found, many citizens responded to the more personal contact. Nevertheless, 31 citizens provided true moments of frustration. For instance, we telephoned one address 12 times over a 2 month period, talked to 3 different people who promised the owner would call back, and got no response. The same home did not respond to the City Council letter nor a letter from Malibu Colony residents. In general, we tried a minimum of 3 times to telephone an address. Reasons for not responding included: out of town, too busy, represented too complex an ownership, could not find the appropriate authority in a petroleum multinational to agree to an interview, too important to be bothered, or had no desire to cooperate. There were 17 potential informants (16% of all non-response) who gave honest outright refusals. These citizens felt this study would hurt their contracting business or other plans for a more populous Malibu. We argued that we were not a planning or zoning project, but to no avail.

Step 3: The home visit. Exact appointment times were crucial to survey success in Malibu. There could be no casual visits as occur in more rural communities. Malibu is one long PCH corridor with about 95 dead-end roads branching off into cloistered neighborhoods. There are about 50 gates barring public access to many of these roads further cloistering the clusters of houses. There are many homes with their own gates within a gated neighborhood as well as gates for driveways to single homes. These gated neighborhoods require cards, dialing or actual review by guards in order to pass. In short, Malibu residents feel their property and the roads near their property are very private places.

We were occasionally stood up but, in general, those who accepted an interview were extremely hospitable and informative. Visiting homes took much longer than planned, in part because of Malibu's string bean shape (travel time), in part because it became impossible to cluster interviews in the same neighborhood, and in part because many Malibu residents had lots of good stories to tell.

The survey visited 170 addresses including volunteers and commercials and interviewed 33 more over the telephone with agreed upon site visits but without the representative present. About 6 of the DOH study "functional failures" turned out to be empty lots. At first, Carin and Tim Winneberger trained a group of Malibu citizens to accompany consultants on the home survey. We thought this would increase citizen trust. The strategy backfired. The presence of fellow citizens increased distrust. Many citizens were convinced that other citizens were informers to the DOH. Other citizens were unable to overcome previous political disagreements with the volunteers. We stopped including local residents in our survey. We tightened our confidentiality by coding our home survey forms.

Step 4: The final stages (verifying the homeowner's opinions by returning to the County files, requesting pumping records from Wastec, and water use data from Waterworks District No. 29) were straightforward with only minor glitches from missing records.

In general, the survey accomplished its goals of sampling a large enough group of the County "functional failures" and providing enough information to resolve on-going disputes. With practice, we observed repeat patterns among the commercial establishments and felt that we developed a solid understanding of business owner wastewater concerns. There was always the feeling that just around the corner, there was another special Malibu situation. This could not be avoided with the varied age, codes, styles of installation and design, and site characteristics. The rest of this chapter presents the results of the survey.

An unstated goal of the survey was to overcome citizen suspicion of any consultant or governmental agency involved with on-site systems. For 30 years, government agencies have been telling homeowners that they were polluting, causing health hazards, were irresponsible, illegal, or a public nuisance. For Malibu to change direction from an antagonistic and punitive government/citizen relationship to a cooperative relationship was and will be no easy task.

VI.4 The DOH 1988 Study and the Present Re-Survey

The County DOH listed 241 addresses (homes and commercials) as functional failures. The County surveyed their files but did not interview owners or owner representatives. A County "functional failure" was based on a Federal government statement that a normal life span of an on-site system should be 20 years. DOH considered homes between 1968 and 1988. The County's criteria for a "functional failure" were surfacing effluent (that was not a result of a momentary plumbing problem) and/or clogging of the drainfield. In particular, if a home was less than 10 years old, the DOH called a system a "functional failure" if any surfacing effluent or clogging event was corroborated by a health officer. If the home was older, 2 events in 20 years put the system into the functional failure category. Homes were <u>not</u> functional failures if the repair or replacement was for a remodel, addition or new construction, or if the event occurred before 1978, or if no events occurred between 1977 and 1988 for older homes (Robert Saviskas, p.c.). Only storm damage to drainfields and septic tanks that caused surfacing effluent, not damage to bulkheads or house structures, could be called a functional failure by DOH. DOH did not count greywater violations as a "failure".

PEWARA visited 118 of these residential addresses and read the files on which the DOH based its judgment. <u>Using the County's "functional failure" criteria</u>, only 22% met their own criteria without any dispute. That is, only 22% of the DOH files had corroborated surfacing effluent within the time periods required. 37% of those surveyed did <u>not</u> meet DOH's own criteria for a "functional failure." That is, even if the events reported on DOH spreadsheets were true (and many could not be verified), the system would not meet DOH criteria. The criteria were somewhat confusing and it appears that the collators of the data made many mistakes. Six of the addresses have no structures. They were vacant lots. DOH stated that the spreadsheets contained no known clerical errors (Saviskas, p.c.).

During PEWARA's home visits, about 13% of the functional failures were hotly disputed by homeowners. We were unable to resolve these disputes by comparing records within DOH with homeowner knowledge of their own system. Many of these disputes occurred over storm damage. Some homeowners had minor damage to their bulkhead that DOH claimed was major damage to their drainfield. Finally, 29% of the functional failures had insufficient information to confirm the claim within the DOH spreadsheet. In other words, we looked in the DOH files; we talked to the homeowner; and neither the homeowner nor the DOH records could confirm any event with surfacing effluent. In short, even if all the disputes were decided in favor of DOH, only 33% of the "functional failures" can be verified by their own information and criteria.

PEWARA wanted to be sure that these results were accurate. We returned to the DOH files and re-checked half the files in the "insufficient information" group and "does not meet DOH's own criteria" group. We tried to show the resident health officer our findings. Every re-check confirmed our previous findings. Example errors include:

-- A home on PCH that was called a functional failure in 1983. The file stated "storm damage, severely damaged house" and "took out septic tank." But, when we visited the home, the septic tank was and had been located on the inland (PCH) side of the house and no part of the system had been touched by the storm.

-- A house on Malibu Road was cited in 1982 and 1987 as failing. But, the home had been destroyed in 1978 and the house shell was empty in 1982 and 1987.

-- A home on Malibu Road was cited in 1978 for a home addition which was not related to any surfacing effluent. In 1985, the home was cited again. There was a sewage overflow from a leaky toilet (according to owner) or a broken water main (according to DOH). In this circumstance, we counted the home as a "failure" even though we found that the situation had been caused by a plumbing problem, not drainfield clogging, and all parties agreed that the problem was resolved within a few days.

Occasionally, greywater violations were treated as equivalent to surfacing effluent, although DOH made clear that they were to be treated separately. In these cases, we rechecked DOH files to make sure that we had not missed the surfacing effluent citing. In addition, many errors were made because collators called normal upgrading of the septic tank or drainfield for a home expansion or remodel a failure.

In general, the County survey was inadequate because the collators misunderstood the set criteria and called storm damage, a few greywater systems, and additions "drainfield failures" even though they that had nothing to do with surfacing effluent. Whatever the truth or falsehood of DOH claims, it is obvious that the 1988 DOH survey does not substantiate claims. The study cannot be used to judge the comparative success or failure of on-site systems along the beach or inland.

A few additional comments are necessary. The study called "functional failure" rate what many wastewater managers usually call "repair" rate. This is a less loaded term that indicates how frequently an on-site system needs repairs, replacements or additions. The only hypothetical "total failure" for the beachfront would be a situation in which no new septic tank or drainfield could be installed. This might occur when the intricate machinery of the biological mat clogs and causes the drainfield effluent to surface. In Malibu, when clogging of the biological mat occurs, the contractor digs out and removes the old beachfront drainfield (including the clogged mat) and replaces it with new imported gravel and sand. In short, almost all drainfields can be upgraded or replaced (see below). If drainfield longevity is short, the question becomes one of recurrent cost of repairs and better design.

"Repair" rates always occur in an older community like Malibu with on-site systems of different ages, built under different codes, by contractors with varied ability, and with varied histories of use and abuse. Winneberger (1984), Warshall (1973) and Wert (p.c.) found that during home-site surveys, repair rates average between between 15 and 20% in most towns (no matter what the soils) because of ignorance about good design, installation, and maintenance. For instance, Paradise, California is an old community like Malibu and repaired 150 systems in 10 years. Accepting the DOH "functional failure" rate as a 22 to 33% repair rate would indicate that Malibu is only slightly worse off in its neglect and abuse than other towns. With more accurate data, the repair rate might be a lot less than other areas. Keller (1989) removed storm damage from the DOH data and found a 2% repair rate over a 20-year period.

With proper care and management, there is no reason to assume the repair rates would not drop to below 5% per year and longevity increase to 35 to 50 years per system. In other words, there is reason to be concerned about the neglect, ignorance, and lack of proper agency management. There is no reason to use these data as an excuse to abandon on-site systems. When the baby has measles, you treat the malady. You don't throw the baby away. If a management agency wishes to do so, it can help with both the longevity and repair rates of systems.

If we eliminate the vacant lots, 89% of the addresses reviewed in the home-site survey were functioning. These systems showed no signs of septic or drainfield dysfunction and homeowners expressed no complaints. Only about 1% were in truly terrible shape, with surfacing effluent, and in need of immediate attention. About 8% (N=16) were marginal. That is, a "marginal system" was a system whose homeowner was worried and we thought had a real concern but, at the moment of the survey or in the recent past, there had been no emergent effluent or back-ups of household plumbing. In general, from our limited sample, which was biased toward problem systems, no more than 9% of the addresses visited required were "problems" or "marginal". This survey is closer to Keller's data than to that of the County's.

VI.5 Survey Results for Wastewater Loadings and Water Conservation

As explained in Chapter III, the determination of wastewater loadings from water use data can be unreliable. In order to increase accuracy, we selected a sample with only year-round residents. Year-round residency smoothed the ups-and-downs of water use by weekenders and seasonal or mixed users (Table VI.1). We selected only those homes with minimal irrigation (e.g., potted plants on the patio, less than 100 square feet). But, there were still the wide variations in water use between homes: pressure and diameters of the water lines, selective use of bathrooms with water conservation fixtures, decorative pools and fountains, and subtle differences of water conservation fixtures (i.e., few residents knew whether the toilets were low flush, ultra-low flush or pneumatic). For these reasons, the standard deviations were very large and the data did not fit a normal distribution. In these cases of skewed distributions, medians become better estimates of the mean than the arithmetic average.

The low-irrigation single family residences (SFR) had an average water use of 342 gpd per dwelling for 2.43 occupants (Table VI.1). The median was 305 gpd per dwelling. Low irrigation SFRs generally irrigated about 25 square feet of potted plants and pockets of vegetation. About 20% of the homes had greywater systems, although the sample showed a large standard deviation. If 80% of the water entered the septic tank system (the low-irrigation scenario), then about 244 (median) to 274 (average) gpd per dwelling is the wastewater loading. If "design wastewater loading rates" for SFR are set at 250 gpd per

Table VI.1
Water Use in Malibu: SFR with "No" Irrigation*

Variable		Average	S.D.	Median	N	Min	Max
S91	GPD	312	174	270	51	59	809
W91	GPD	351	287	256	50	34	1484
S89	GPD	416	276	350	49	49	1426
W89	GPD	273	212	245	46	0	1306
S91	GPP	144	101	117	51	23	552
W91	GPP	153	112	115	50	12	561
S89	GPP	189	143	151	49	16	713
W89	GPP	130	128	102	46	0	653
Total	GPD	342	173	305	46		
Total	GPP	157	96	142	46		
Occupants		2.43	0.96		51	1	6
Bedrooms		3.14	1.11		51	1	6
Bathrooms		3.06	1.32		51	1	7
Irrigated Area		23.60	33.60		51	0	100
Greywater		19.6%	40%		51	0	1

*Year-Round Occupancy, <100 square feet of irrigable surface.
S = Summer W = Winter 91 = 1991 89 = 1989

dwelling, then Malibu is normal to slightly higher than the design criteria (Chapter II). Very generally, an average of 10 to 15 percent more water conservation would bring interior use (wastewater loading) in line with standard septic tank system wastewater loading design criteria. From the wastewater loading point of view, this level of water conservation is a lot more feasible than the 20 to 60% stated by the County (Chapter II). It should be remembered that there is wide variation. Some homes are very water conservative and some are below the 250 gpd per dwelling wastewater loading because of greywater diversions. Since there are no car washes in Malibu, many homes may use more water for car washing than in other communities. Nevertheless, these data indicate that, with exceptions, Malibu is not doing an exceptional job of conserving water resources.

There were no statistically significant differences among the low irrigation homes before or after rationing (Technical Memo 11). Water conservation came from conserving on outdoor uses or substituting greywater for imported water for irrigation. About 20% of all homes surveyed had greywater systems. There were more greywater systems inland because of larger lots, more landscaping, and fewer effective DOH inspections. A total of about 12% of all the homes surveyed used greywater systems for irrigation and only 8% were greywater disposal systems with no reuse goals.. The greywater systems significantly reduced (- 30%) the wastewater loadings to the drainfields.

We sorted the water use data for all residences (SFR, multiplexes and apartments) where all wastewater-related data could be compiled (Table VI.2). This group averaged 6,748 square feet of irrigation (again with wide variation) with about the same percentage of greywater diversions. An average of 664 gpd per dwelling reflects the increase in irrigation and an average number of residents of 3.15. The median was 372 gpd per dwelling, again reflecting that homes with very large irrigated areas can skew the average data. The median water use per person per day was 152 gpdpp, about the same as the median for SFRs (142 gpdpp).

Surge loadings (peaks) in wastewater production occur among businesses and during residential parties. This momentary phenomenon is known as "Super-Bowl" syndrome, because all over America citizens use their toilets simultaneously at Super Bowl half-time, creating a difficult to handle flood of sewage into treatment plants. In Malibu, sunny weekend summer days create peak surges at businesses and public rest rooms. Any day that is party day can create a surge flow in SFRs. These surges can push suspended solids into drainfields and create an excessive biological oxygen demand that can damage drainfield function.

We questioned 109 "party homes," homes in which at least 1 party of any size is given each year. The average size of a party was about 6 guests. 38% of the party homes gave these "average" parties (1 to 11 guests) from once a year to once a week. Homes with these more intimate parties averaged about 14 parties per year. About 25% of all the party homes gave parties with 12 to 21 guests (a maximum of 2 per month with an average of about 1 every other month). About 35% of the party homes gave bigger

Table VI.2: Water Use in Malibu: SFR with Little to Large Irrigation*

Variable		Average	S.D.	Median	N
S91	GPD	607	930	380	91
W91	GPD	656	971	337	89
S89	GPD	892	174	442	87
W89	GPD	441	643	255	80
S91	GPP	254	302	162	91
W91	GPP	267	344	154	89
S89	GPP	345	499	175	87
W89	GPP	187	231	117	80
Total	GPD	664	1007	372	80
Total	GPP	267	333	152	80

S89	Summer 1989	GPD:	Gallons per dwelling per day
W89	Winter 1989	GPP:	Gallons per person per day
S91:	Summer 1991		
W91:	Winter 1991		

*Year-Round Occupancy. All levels of irrigation. Single family residences with single on-site systems.

parties (22 to 51 guests) and more of them. The maximum number of these bigger parties was 60 per year (5 per month). The average was about 7 bigger parties per year. Finally, the BIG parties (50 to 250 guests) are given in about 3% of the party homes. Each home averages 1 Big Party per year with a maximum of 3.

While we cannot claim an "unbiased" sample, it is clear that homes with frequent bigger parties and any home with a Big Party need to become aware of how to protect their drainfields (Chapter XI). None of these homes had over-sized septic tanks or drainfields or special baffling or holding tanks for the surge flow. Only one had a special "water conservation" or "party" bathroom with an air-assisted (less than 2 quart) toilet. None had spring-loaded faucets.

For design purposes, the UPC designs by the number of bedrooms, not by the wastewater loading rates (Technical Memo 11). In order to verify the usefulness of bedrooms for design purposes and in order to determine what were the best correlations between design variables in on-site systems, PEWARA performed a series of statistical analyses (see Technical Memo 13 and Glossary for details). For the low-irrigation/SFRs, the number of bedrooms was not correlated with the number of occupants. Out of 4 seasonal water uses (2 before and 2 after rationing), only the summer of 1989 had a low correlation with bedrooms (Table VI. 3). Average gpd per person did not demonstrate a correlation to bedrooms. On the other hand, the number of bathrooms strongly or moderately correlated with all the seasonal water uses (except the winter of 1991), the average gpd per person and per dwelling, and the number of bedrooms. For Malibu, bathrooms (not bedrooms) may be better related to wastewater loading. Neither bedrooms nor bathrooms, even for the highest values of the t-test, were correlated with the number of occupants, even for year-long occupancy. Many Malibu homes had many more bedrooms than were actually utilized.

VI.6 Overall Survey Results: Single Family Residences

The survey generally looked at on-site systems by inland vs. beachfront vs. commercial categories. Multiplex residential will be discussed under commercial. As stated, these are not hard-fast categories.

Septic tanks are useful passive structures for reduction of suspended solids and biological oxygen demand in the in-coming sewage. They require "extra" storage space for the settled sludge and floating scum and extra capacity for the party surges. From the practical point of view, there is a need for, at least, 1 day of retention within the tank for the sewage to achieve settling (Winneberger, 1984). Greater holding capacity can be balanced against the efficiency of the tank's baffling, flow-through design, and storage capacity. Increased size rarely increases costs in significant increments. Many authorities use 3 days or a detention time that accounts for 3 times the wastewater load entering the tank daily. For instance, a home of 3 producing a total volume of 250 gpd would have a septic tank of 750 gallons for a 3-day holding capacity, which decreases when parties or sludge/scum accumulation has reduced the tank's effective volume. The same tank would accommodate a party of 50 people using 10 gallons each (500 gallons) plus the 3 residents for a1 day

Table VI.3: Correlations--Single Family Residences with Year-Round Occupancy, Low Irrigation and Seepage Beds

Variable #1	Variable #2	Correlation	Significance	N
S91 GPD	Bathrooms	0.45	**	31
S91 GPD	Drainfield area	0.61	**	20
S91 GPP	Occupants PD	-0.39	*	31
S91 GPP	Bathrooms PD	0.51	**	31
S91 GPP	Drainfield Area	0.53	*	20
S89 GPD	Bedrooms	0.45	**	31
S89 GPD	Bathrooms	0.62	***	31
S89 GPD	Drainfield Area	0.75	***	20
S89 GPP	Bedrooms	0.40	*	31
S89 GPP	Bathrooms	0.66	***	31
S89 GPP	Drainfield Area	0.65	**	20
W89 GPD	Bathrooms	0.61	***	29
W89 GPD	Drainfield Area	0.71	***	20
W89 GPP	Occupants	-0.38	*	29
W89 GPP	Bathrooms	0.60	***	29
W89 GPP	Drainfield Area	0.61	**	20
XGPP	Occupants	-0.40	*	29
XGPP	Bathrooms	0.61	***	29
XGPP	Drainfield Area	0.62	**	20
Bedrooms	Bathrooms	0.64	***	31
Bedrooms	Irrigated Area	0.40	*	31
Bedroom	Septic Tank Size	0.59	**	24
Bedroom	Drainfield Area	0.47	*	20
Bathrooms	Mean GPD	0.59	***	29
Bathrooms	Drainfield Area	0.64	**	20
Septic Tank Size	Drainfield Age	-0.50	**	24
Drainfield Area	Drainfield Age	-0.43	*	20

GPD:	Gallons Per Dwelling	S91:	Summer 1991	*0.05 to 0.01 probability
GPP:	Gallons Per Person	S89:	Summer 1989	**0.01 to 0.0001 probability
XGPP:	Average GPP	W89:	Winter 1989	***0.001 or less probability
				Non-significant t-test correlations not shown

detention time. If one-third filled with scum and sludge, the detention time would be 2 days, instead of 3. In Malibu, SFR septic tank volumes have an average of 3.2 days holding capacity compared to household wastewater use (gallons per day per dwelling).

The minimum is 1 day; maximum 10 days. The average size of a tank is about 1,000 gallons, varying from 750 gallons to 1,500.

The tanks are usually 2-chambered with inlet/outlet "T's". This baffling and flow-through pattern as prescribed by the LAC codes are not the best design (Winneberger, 1984). In Malibu, septic tanks are predominantly concrete. Including those lost in storms, septic tanks averaged 26 years in age from known installation to replacement. The average age of working septic tanks at the moment is approximately 20 years but many will last a lot longer. Perhaps the most outstanding fact uncovered by the survey was that most septic tanks have only 1 porthole or easy access to 1 chamber. That is, when pumping sludge, the pumper only pumps the first chamber. While the second chamber may accumulate sludge and scum at a lower rate, not pumping the second chamber will contribute to an accelerated release of suspended solids into the drainfield and a shortening of the drainfield's life.

It is harder to generalize about drainfields in Malibu. They are the most ecologically dependent of all parts of the on-site system and given Malibu's variability in soils/bedrock/slopes, it appears that almost each case of drainfield design, installation and repair must be considered individually. This will be the major challenge to improved on-site practices. In addition, there were huge variations in code requirements at installation time, ability of the installers, and subsequent use and care patterns. For example, the codes have changed 3 times in the last 20 years on the subject of groundwater level to the bottom of beachfront drainfields. The codes required seepage pit designs to calculate sidewall area but seepage bed designs to use bottom area. In addition, the codes penalized homeowners for use of the seepage bed bottom area no matter what the pre-treatment. The variable ecology and inconsistency in design standards, installation and maintenance patterns, and the overlapping dates of the work (repair, replacement, and additions) history resulted in non-normal distributions, huge standard deviations or very small homogeneous samples (Technical Memo 13).

The following generalizations from our fieldwork appear to be reasonable. Of the 66 single family residences with accurate data, the average drainfield size was 687 square feet of infiltrative surface (N=66). Because of the variety discussed above, the standard deviation was proportionately high (411 square feet) with the smallest drainfield only 200 square feet and the largest over 2,200 square feet. For homes producing 185 gpd of wastewater, filtered by a biological mat at 0.3 gpd, a drainfield size of 617 square feet would be required. Malibu's average size is amply larger but, as the standard deviation indicates, there are undersized systems. For instance, 5 of 9 problem systems with adequate data were SFRs with undersized drainfields.

The average interval between replacements of old and aging drainfields is not exceptional (between about 23 and 25 years). This is above federal standards (20 years) but could be much higher with proper design and management. Drainfields "killed in youth or adulthood" are predominantly from poor design. They may display problems within a few years (leading to large standard deviations). By 8 to 10 years, they can no longer absorb effluent nor treat it. Beachfront drainfields can require replacement or repair at any age because of storm damage. Nevertheless, the average age of completely replaced storm damaged systems was about 18 years (N=33). This reflects the clustering of "exceptional storm events" in the early 1980s. Since homes destroyed by landslides are not usually replaced, no one has calculated the average interval for drainfield replacement due to earth movement. Fire does not directly impact a drainfield. But, some homes that were destroyed by fire used the opportunity to alter the location or replace their septic tank systems.

Inland, many homes have never "replaced" their seepage pits. When there were problems, they added more seepage pits, stringing them out into open areas. Inland systems on landslides can have "marginal" systems because of local land settling. We saw one house on hydraulic jacks which allowed relevelling each year. This house could no longer use the master bathroom as the flow to the septic tank was no longer downhill. In general, within the life of a house, most homes (70%) have had some sort of work history. But, most known work on drainfields (about 70%) is not problem related. It has been for upgrading, renovations, remodelling or replacing old systems.

Data from the home-site survey showed that drainfield areas varied from 200 square feet to 2240 square feet of potential infiltrative surface for single family residences. Although not normally distributed, the typical drainfield area was between 500 to 700 square feet. Drainfield area was not correlated ($p>0.05$) with seasonal or average water use by persons or dwelling. It was not correlated to occupancy, bedrooms, bathrooms or septic tank size. It averaged about 2 to 3 gallons per square foot of infiltrative surface per day, if discharge is approximately 250 gpd per dwelling. These rates are reasonable for sandy soils but not for clays. From field observations, most inland drainfields are in fractured or transmissive bedrock and have great hydraulic heads, criteria not included in more common design definitions (Chapter XI).

VI.7 Survey Results: Single Family Residences on the Beachfront

This section discusses the details of on-site system components along the beachfront. The same diversity of location, size, installation, and design occurs here as it does everywhere in Malibu. Table VI.4 shows the diverse locations of septic tank installation. Note the large percentage on the street-side of the house or within the house structure (25 to 30%). These are protected from storms by the home itself. The street-side tanks have relatively easy access for pumping. Almost 60% of the homes surveyed had their septic tanks under the raised porch or elevated floor of the house. A few of these homes had poor access because of low clearance. A small number had their septic tanks within the home under the slab floors of the dining or living rooms. Pumping occurred by lifting a rug to access the porthole to the tank.

The beachfront homes average slightly larger tanks than Malibu as a whole. Averages are about 1300 gallons, indicating a preponderance of 1200 and 1500 tanks. For SFRs along the beach with known water records, there was no significant statistical correlation between the size of the septic tank and any measurement of water use (gpd per person, gpd per dwelling, seasonal, pre- or post-rationing). There was poor correlation between the number of occupants, bathrooms, bedrooms, irrigated area or drainfield area. Two strong correlations appear to be the result of code changes (Table VI.3). Recently installed seepage beds along the beachfront have both larger drainfield areas and larger tanks compared to older systems.

Drainfield designs are a peculiar mix of County Codes requirements and practical additions by contractors or designers. The beachfront drainfields are predominantly seepage beds (69%) with a substantial number of seepage pits (16%) located between the house and the street. There are a few redwood boxes that simply seep the effluent, a few trenches, and a few hybrid systems. Less than 10% of the systems investigated utilized pumps to move effluent around their lots.

The beachfront homes are situated on small lots. The home owners have been restricted by County codes to utilizing only half their available property area for the drainfield. The other half is a "future area" even though it is usual practice to remove the drainfield and replace it with engineered fill. The drainfields for which accurate data could be found averaged about 590 squre feet (SD=352 square feet) with a minimum of 200 square feet and a maximum of 1,967 square feet (N=67). This is about 30 square feet

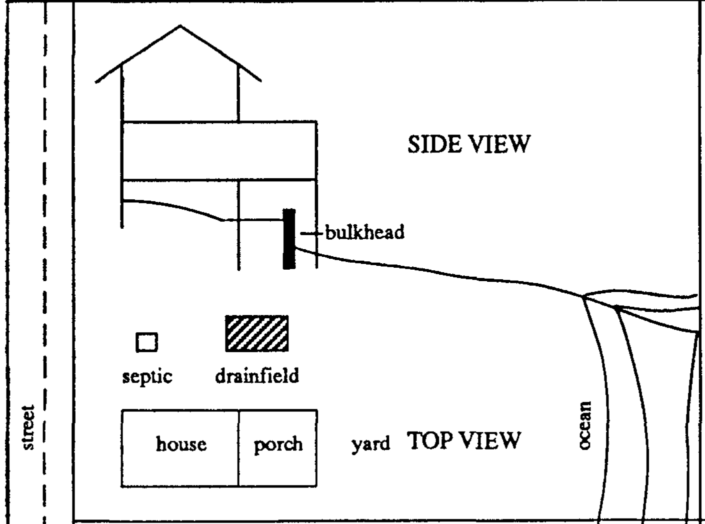
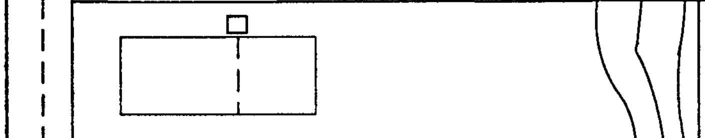
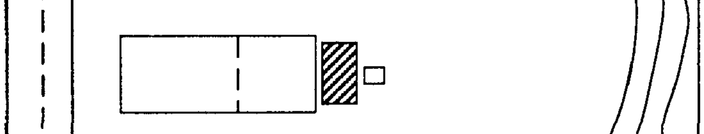
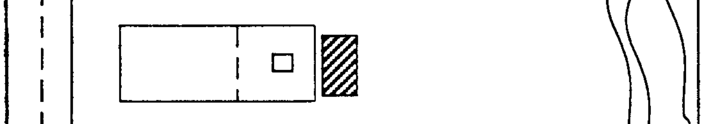
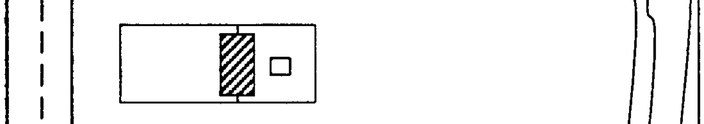
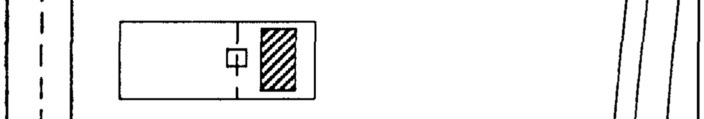
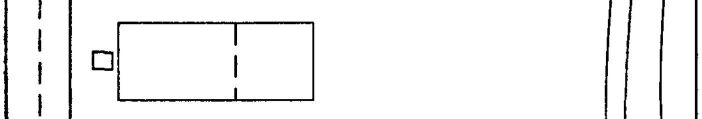
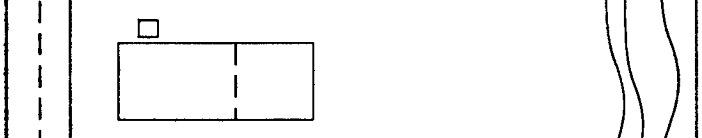
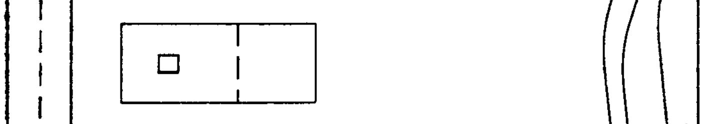
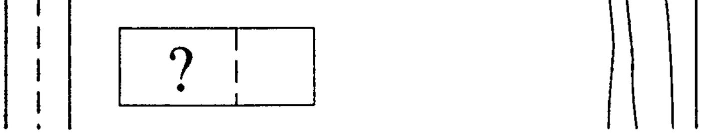
LOCATION OF SEPTIC TANK	DESCRIPTION	TYPICAL ACCESS	% OF SURVEY	NO.
	On-site system under house or porch. Home elevated.		100	118
	Side of house Closer to ocean	Blue-sky or patio	5	6
	Beach-side of drainfield	Blue-sky (yard/garden) or patio	0	0
	House-side of drainfield	Blue-sky (garden/yard) or patio	3	3
	Beach-side of drainfield	Under elevated porch or floor	19	23
	Street-side of drainfield	Under elevated porch or floor	38	44
	Between house and street	Below driveway or yard	19	22
	Side of house closer to street	Yard, below wooden walkway or stairs	5	6
	Within structure of house	Through floor of a room	7	8
	Unknown	Unknown	5	6

Table VI.4: Location of Septic Tanks Along the Beachfront below the "typical" engineering rule-of-thumb described above. The survey showed that proper sizing, more efficient use of the land available for renovated systems or legal greywater disposal, and intermittent sand filters on tight lots would all provide more sustainable systems (Chapter XI).

The location of the drainfields (seepage beds or pits) is as diverse as the location of septic tanks (Table VI.5). In the PEWARA survey, about 60% were under homes with elevated floors and porches. These had relatively easy access for replacement or repair. About 13% were on the street-side of homes, usually seepage pits under pavement. A very small percentage (we searched out worst-case situations) were within the perimeter of the home, where drainfield replacement would require tearing out the floor. 77% of the beachfront homes had no problems with installation and repair access. 22% had clearance problems for back hoes and would probably require hand labor (see cost discussion). The lack of equipment paths (about 10 feet wide) along certain sections of PCH and Malibu Colony Drive can increase time and expense, especially if the equipment needs to work from the beach between high tides.

Many of the gravel filled seepage beds along the beach are rapidly in-filled by surrounding sand, greatly reducing the "pore space" in the seepage bed. In rarer instances, the sand enters the distribution pipe. The County only gives credit for the bottom area of seepage beds but most designers realize that sidewalls are important if not better surfaces for infiltration. They make the beds deeper than credited by the County in order to increase sidewall area. Sand filters, used in adjacent counties, are unknown in Malibu.

The soils in which the beds and pits are placed are not uniformly sand. Areas such as Malibu Colony were an old delta with layers of silts, sands and clays that strongly influence the performance of drainfields and groundwater. Old photos show that part of Malibu Road was vegetated coastal dune. The soils were landslide debris with a jumbled profile of clays, silts, and sands. Seepage pits and effluent from some seepage beds enter these deposits. Other drainfields were installed in imported or re-arranged soils from the construction site. Below the layer (either imported or natural) in which the seepage bed or seepage pit is located, there may be layers of cobbles and large gravel (e.g., towards the east end of Malibu) rather than bedrock. Lack of surface runoff management and consequent elevated groundwater was noted at Malibu Colony and the north side of PCH. Increasingly, high groundwater along parts of Malibu Road (despite years of drought) was also a repeatedly voiced concern by homeowners interviewed.

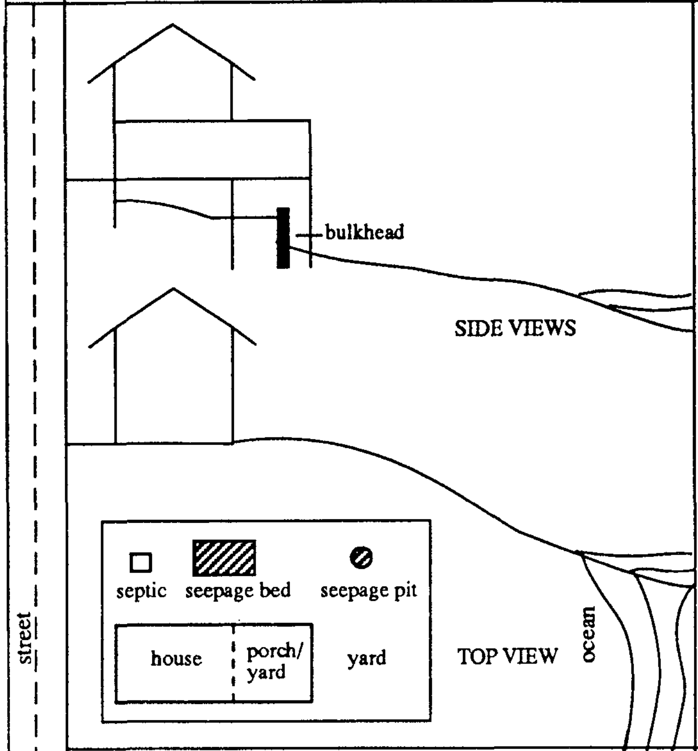
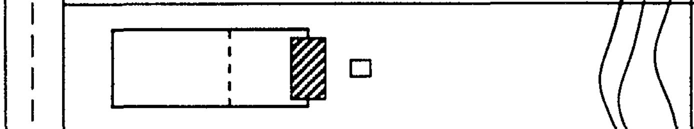
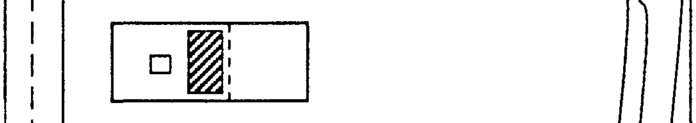
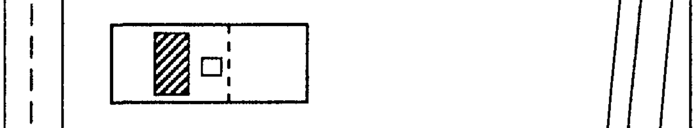
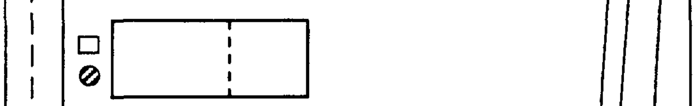
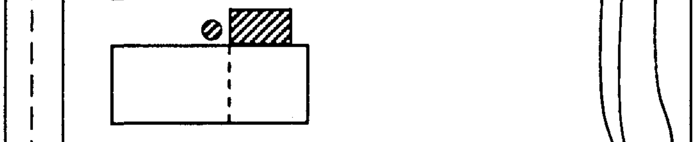
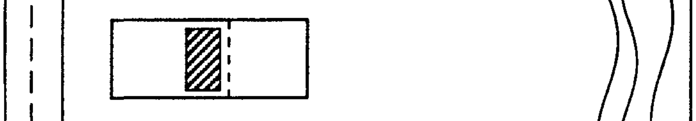
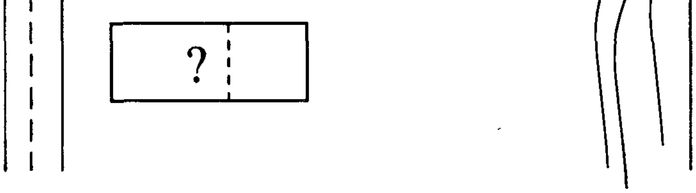
LOCATION OF DRAINFIELDS	TYPE	DESCRIPTION	% OF SURVEY	NO.
	A B	On-site system under home or porch. Home elevated. Home on beach surface.	100	118
	B	Ocean-side of house	9	11
	B	Beach-side in yard or patio	3	3
	A	Under house's elevated floor	36	43
	A	Under house's elevated floor	23	27
	A or B	Street-side of house	13	15
	A or B	Side of house	5	6
	A	Under house No access withoutbreaking out floor	3	4
		Unknown	8	9

Table VI.5: Location of Drainfields Along the Beachfront

The very complex flow and dispersion of drainfield effluent into the subterranean tidal flux or the floating freshwater lens is, in part, governed by the depth of sand, groundwater, cobbles, or bedrock (see Table IV.1). As a first estimate, the depth to sand behind the protective barrier was deep (greater than 8 feet) in 58% of the drainfields encountered; shallow (less than 6 feet) in 14% of the beachfront drainfields; and unknown or indeterminable for 27%. The average depth to watertable or bedrock was equally difficult to define as it changes with tidal flux, wind-stressed surges, distant storm waves, and the seasonal height of the freshwater lens and the sand covering. On most DOH schematics, the height of the drainfield was estimated by drawing a line for the Mean High Water or a line for the height above "average sea level." From the technical point of view, the accuracy or meaningfulness of these lines is questionable (Chapter IV). Few DOH dossiers explained how they arrived at the line and very few gave the NGVD elevation (land-based location for sea level). From the survey questionnaire and selected soil borings, homeowners gave us a feel for the depth to watertable or bedrock. It averaged about 13.2 feet from the sand covering or about 8 to 9 feet from the drainfield bottom. This was more than anticipated.

77% of the beachfront septic tank systems surveyed had some type of constructed wall (cement bulkhead, rip-rap, cement bags, retaining wall, wooden wall, with or without footings) for protection against storms or the highest tides. Twelve percent had drainfields on the inland side of the house. That is, 89% of the homes surveyed had some sort of protection. About 8% had no protection and 3% were undetermined. A subarea of concern was the very east end of PCH where the older homes had fewer protective barriers and the mean high water line cuts across one-third to one-half of 15 parcels. But a telephone survey, DOH file survey and an interview with 6 homeowners with “worst case” tidal intrusions showed that these homes did not stand out as suffering storm damage or drainfield problems.

Behind the sea wall protection, 81% of the homes surveyed had allocated areas for future drainfields equal in size to their existing drainfields. About 4% did not have any such room. By interviewing homeowners and contractors, it was discovered that when a new field was needed in areas without a "future area," the contractor simply removed the old drainfield and imported sand and gravel for a new one. There was hardly any reason for the future areas along the beach. Future reserve areas unnecessarily restricted the design and longevity of the on-site system. A good single design for a larger area functions better and for a longer period. Using a larger area may have allowed a shallower seepage bed, placing the drainfield higher above the first layer of groundwater (fresh or saline). These reserve areas can be used for subsurface disposal of greywater, if the homeowner feels it would help the existing on-site system.

As opposed to other areas and drainfield types, the area of the seepage beds along the beachfront (low to no irrigation, year-round occupancy, a single system per home) was strongly correlated to seasonal and average water use (per person and per dwelling). Seepage bed area was strongly correlated with the number of bathrooms and weakly correlated with the number of bedrooms (see Table VI.3). The homogeneity of the sands, year-round bedroom/bathroom use, and water use established the greater correlations.

VI.8 Survey Results: Single Family Residences for Inland Homes

Inland residences discharged into septic tanks with capacities about equal to those in the rest of Malibu (a volume of about 1300 gallons). However, slightly more than one-third of the homes visited diverted part of the wastewater to a greywater system, decreasing daily wastewater loads entering the tank. This may have reduced the amount of soluble BOD entering the drainfield. Almost all inland systems had seepage pits with disposal into transmissive or fractured bedrock or, occasionally, deep soils. Roy Brothers, the main installer of on-site systems in Malibu, estimated that 90% of the inland systems utilize seepage pits. From limited data, these seepage pits have about 200 square feet more infiltrative surface than the seepage beds.

For inland homes, a review of DOH files, discussions with contractors, and interviews with homeowners, revealed that about 65% of all drainfield repair work was the addition of more pits. Because of larger lots and the relatively small surface area required by seepage pits, homeowners simply added one or more additional seepage pits, either in a series or parallel to already existing pits. No distinction seems to have been made between series and parallel installation, although the difference can be crucial to flow equalization and other hydraulic properties of disposal (Technical Memo 3). Seepage pit area and age were not correlated with seasonal or average water usage, occupancy, bedrooms, bathrooms, or septic tank size. Since pits are simply added to marginal systems, it is difficult to calculate an "average lifespan" for on-site systems utilizing pits for disposal.

Seepage pit installation is done primarily by machine. The use of a bricking machine to line the pit or a crane to set precast perforated concrete rings are the most common methods. The inside of the pits are hollow and have no distribution pipe. They are covered with a flat concrete lid or a concrete dome. They are capped with a steel manhole cover. The hollow center has a higher risk of collapsing than pits filled with gravel and a distribution pipe (Ventura County). As slopes become steeper than 2:1, back hoes cannot be used and either benching or the use of special drill rigs is required. Liability increases with the steeper slopes which can discourage drillers.

Pits are usually 5 feet in diameter. Their depth varied from 10 to 60 feet. The average area of an inland drainfield (over 90% are pits) was 951 square feet (SD=465) with a range from 255 to 2240 square feet (N=33). It is difficult to interpret these figures because it could not be determined how much of the pit sidewalls were non-transmissive. The main limitation on depth was meeting the County requirement that the bottom of the pit be 10 feet above groundwater. The depth to groundwater, of course, will vary depending on the season of year, the total annual rainfall, and the previous history of rainfall. Digging pits in some types of hard sandstone and lava (basalt) is limited by the expense and difficulty of excavation.

VI.9 Multiplex Residential Buildings

The data on multiplex residences come from small samples (Technical Memo 13). Duplexes and triplexes were essentially designed and installed with the same size and scale as single family residences. From survey data, duplexes had 1 to 4 residents (mean of 2.6) and triplexes 3 to 5 (mean of 4.2). Septic tank volumes are on the large end (1,500 gallons) with distinct exceptions. One duplex had a 750 gallon tank. The maximum size of a triplex septic tank was 1,650 gallons. Quadruplexes had from 4 to 10 residents (mean of 6.6). The septic tanks ranged from 1,000 to 2,600 gallons. Quadruplexes had larger drainfields. The smallest drainfield had 353 square feet of infiltrative surface. A few of the quadruplexes had greywater systems to relieve the surge flow from the communal laundry and, perhaps, protecting the undersized drainfield.

Apartments varied from 5 to 16 occupants in buildings with 5 to 22 bedrooms and bathrooms. During the survey period, the average number of occupants was 9 per apartment complex. Apartments had septic tanks from 1,800 gallons to 6,000 gallons and larger drainfields (about 1,500 square feet). Although the samples are small, we note that the average age of working apartment drainfields was half that of duplexes. The age of working drainfields decreased as the number of units increased. This appears to indicate that the multiplexes with larger numbers of units may not be adequately designed. The data are ambiguous because of small sample, construction dates, and recent conversions of some buildings to different multiplex scales.

VI.10 Survey Results: Commercials

PEWARA studied 22 commercial establishments (16 from the DOH study; 6 volunteers). The 22 addresses included about 40 on-site systems though some were such complex "Rube Goldberg" machines that we cannot be sure of the total number. They included restaurants, office/shopping complexes, RV parks, motel/hotels, condos, mobile home parks, and a large community center. In general, DOH files for commercial establishments were much less accurate than for residences. Many schematics and violation or complaint notices were missing or out of date. Many of the DOH claims proved mistaken. Such a large percentage of the commercial parcels had changed ownership, users, and design that we did not feel it worthwhile to pursue a comparison of our results to those of the County.

The most salient observations concerning commercial systems made by PEWARA investigators were:

-- Compared to residential uses, many more systems were marginal (no surfacing effluent but operational difficulties expressed by the owner) or were true problem cases with surfacing effluent. About half the commercial addresses and systems reviewed were marginal or were problem situations. Less than 10% actually showed surfacing effluent but many survived by cartage (sometimes called in northern California, “haulaway”). Longevity of the commercial systems, especially restaurants, is about half that of a single-family residence. Restaurants have the shortest-lived drainfields, which is typical everywhere (Went, p.c.).

-- Ownerships and occupancies changed rapidly. However, the systems had been designed to receive and had received County approval based on the uses of the occupant of the moment. Dry cleaners become oriental fast-food restaurants; gourmet lunch shops become computer stores. The design and the size of the on-site and wastewater loading rates were rarely adjusted to meet these significant changes in use. The failure to adjust systems for new uses has proved harmful to many of them. Shopping centers that do not permit restaurants with large grease loadings have survived better than more "liberal" shopping centers where restaurants come and go.

-- The County did not custom-design or insist on custom-designed systems (Technical Memo 3). The systems followed the UPC "cookbook" for residential usages, incorporating a few adjustments from general engineering texts (e.g., grease traps for restaurants) to accomodate wastewater loadings. Systems were not designed with surge flows in mind. For instance, restaurants had "cookbook" systems with 2,500 gallon grease traps and 7,500 gallon septic tanks, which were not designed for the different qualities (especially high BOD that characterize many fast-food and restaurants). Large volumes generated by some commercial establishments are handled by installing groups of smaller tanks in series, or parallel, or both. Tanks in series offer a multiplicity of lids to a pumper and, generally, some of the chambers remain unpumped. Tanks in parallel do not display good flow equalization or flow-through design.

-- Storm runoff was not considered in the designs nor was management of groundwater tables. Water conservation is haphazard and reuse systems do not exist. In one case, the County insisted that air conditioning condensate water enter the septic tank rather than having its own reuse or disposal system.

The poor County design standards, installation, and maintenance requirements appear to be the major reason for system troubles. Many business operators are desperate for an off-site sewer because they have been burdened with on-site "lemons." Some have spent tens of thousands of dollars to meet codes that only led to increased problems. With cartage, sewage costs can exceed $70,000 per year.

-- Many of the businesses have their drainfields under pavement, especially in parking lots. The County and UPC have never designed for paved-over drainfields, although this knowledge has been available and used in other areas for over a decade. The result has been shortened life spans for drainfields and very costly replacements, and cartage repairs (Technical Memo 6). Proper design can overcome many of these concerns (Chapter XI).

-- Odors, a secondary nuisance, have resulted from the poor design and poor maintenance practices. Odors can be controlled with inexpensive additions to on-site systems. No one seems to have helped businesses plan for odor control.

-- Proper maintenance has rarely been performed. Two restaurant managers who personally oversee pumping of septic tanks and cleaning of their grease trap had working systems. Another restaurant, owned by a foreign multinational, is considered investment property only and the owner refuses to pay for maintenance check-ups. This commercial area has almost daily difficulties, cartage, and odors. Still another restaurant did not even know where its grease trap was located or who collected the grease. Another restaurant, which did not pump its grease trap, lost its pump and disposal field in 3 months.

-- The restaurants are served by rendering plants which pick up grease and oils on a scheduled basis. One of the rendering plant companies offered a grease-trap cleaning service. With the use of vegetable oils and detergents in many restaurants, more oils may be passing through the septic tank. This potential problem needs more thought and design by the wastewater engineering community.

--Most of the septic tanks did not have two risers. Pumping emptied half the tank's sludge accumulation.

-- About one-third of all the businesses we visited have utilized all their drainfield area. Owners are concerned about their future options, even if the present drainfields last another 10 years. Two commercials had already obtained an easement (lease) on adjacent property for installation of additional drainfields. Others were considering this option. A few businesses occasionally used chemicals such as sodium hydroxide or sulfuric acid to "revive" drainfields before they permanently clogged. Depending on the soil type, this chemical treatment can prolong drainfield life.

-- Because the systems were larger and more complex, questions of hydraulic head, flow equalization, and uniform flow distribution took on special importance. About one-quarter of the businesses included pumps. Condominiums, RV parks, and mobile home parks had from 30 to 55 seepage pits. The maintenance of these pits requires good maps, monitoring ports, and labor time. One caring operator had plugs to shut off various lines between the septic tanks and various seepage pits in order to force more equal usage of the pits, to give some pits a seasonal rest, and to prepare for the Memorial Day/Labor Day rush.

-- A few businesses and cluster developments are dependent on daily or weekly cartage (Chapter X). They have prevented any health hazard from occurring by carting the contents of their septic tanks or, less often, their seepage pits.

We regret that the confidentiality clauses do not allow us to praise the ingenuity of many of the commercial establishments. They have "made do" in a world that provides little or poor technical assistance. Of all the developed parcels, their claim, in particular situations, for an immediate and viable wastewater management solution has the most urgency.

VI.11 Septage and Cartage

Malibu produces around 14 million gallons of pumped water and solids from septic tanks and seepage pits each year (estimates courtesy of discussions with Tom Lubisich). This liquid and solids is called "septage". It is carted by truck to dump stations near LAX or Van Nuys and eventually is treated and disposed of at the Hyperion treatment plant. The field survey and discussions with pumpers resulted in the following conclusions:

-- Many tanks had only one riser to the first chamber. An inadequate job of pumping occurred because the second chamber was never or rarely pumped. This practice has shortened the life span of some drainfields. The city should start a program of two chamber pumping as soon as possible.

-- Some homeowners pump too often and some pump too rarely. There is no need for single family residences to pump every year or even every three years, under normal usage (Chapter XI). On the other hand, for long-term use of on-site systems, a monitoring program would ensure that tanks are checked or pumped as needed.

-- The cost of pumping is high, in part, because pumpers must travel long distances to dump septage and LA Hyperion requires a "tipping" fee for each load. Closer locations for treatment and disposal are worth considering.

-- None of the hauling companies make use of the most recent cartage technology (e.g., the "Hamstern"). The Hamstern removes the solids (the job of pumping) but returns the liquid to the tank. The selective removal of solids allows trucks to cart septage from more tanks per round-trip. This reduces travel time and costs.

The scarcity of Hamsterns in Malibu may be because some cartage is a form of sewage disposal for inadequate or overloaded drainfields, rather than for solids disposal as intended. Should Malibu consider a septage treatment plant, this distinction will become crucial. Solids pumping is a form of maintenance, while pumping of overloaded drainfields is done for survival and health protection. In addition, the City will eventually require a policy that either accepts liquid cartage as a legitimate form of sewage disposal or a situation requiring another solution.

-- During the home-site survey, there were some complaints that pumpers have not been educated on the purposes of pumping. We heard complaints that they "skimmed" the water out and left the sludge. A code of ethics for all pumpers operating in the city is warranted.

-- There has been much discussion of the metal contents of septage. There is little doubt that metal concentrations in septic tank sludge can be high. But, it is equally true that they are unpredictably high. The metals usually found in high concentrations are iron, copper, and aluminum. Arsenic is the only toxic metal of concern. Nevertheless, treatment plants with relatively low flows are concerned about the lack of dilution of septic sludge by their own flows. In general, the total amount (pounds) of septage sludge metals is miniscule compared to other sources in medium to large treatment plants. A comparison with Tapia's total sludge intake at varied amounts and concentrations would be useful. This is suggested for Phase 2 in order to determine if, in fact, Malibu's sludge would harm the treatment processes or violate any regulations.

-- Malibu has large areas of earth subject to settling, deformation, earthquake vibration, rupture, soil creep, and mass movement. In addition, many areas are undulating with only short flat areas. These environmental conditions are similar, in many ways, to Japan and parts of Europe which have chosen to transport sewage by truck (cartage) rather than pipes. Wastewater managers consider it safer and more cost effective to cart sewage than run pipes up and down unstable hillslopes to small neighborhoods with few homes. From our review, it appears that, in the United States, only the San Lorenzo Valley On-Site Wastewater Management District has adopted a policy in which cartage is considered an equal option to on-site or off-site sewers. The cartage option is appropriate to Malibu's environment. Isolated commercial or residential systems may be more cost-effectively served by cartage than a conveyance system. The choice between cartage, on-site or neighborhood systems, and off-site sewerage raises financial equity questions beyond the scope of this report (Chapter X).

VI.12 Conclusions

Despite County assertions, the City of Malibu does not have an exceptionally high repair rate for on-site systems. The city contains a diverse assortment of systems built in different decades, some before codes and many under a series of changing codes and waivers. Many have been poorly designed. Some may have been poorly installed. The majority have been poorly maintained because only one chamber has been pumped. The home-site survey showed that:

-- Upgrading of design and installation would greatly increase the longevity of on-site systems.

-- Commercial systems need the most help.

-- Reuse of greywater for drought irrigation has been relatively common

-- Storm damaged systems are not particularly shorter-lived than the national "norm".

-- More recent systems have bigger tanks and larger infiltrative surfaces.

-- Recent technology for everything from odor control to intermittent sand filters is virtually unknown in Malibu.

-- Interior water use is about average for high-income communities.

--Serial distribution and pumps for uniform flow distribution are also rare and not carefully planned.

-- Techniques for sizing seepage pits and safely designing them could use vast improvements.

-- The design for below pavement installations is totally inadequate.

These and other insights will allow Malibu to write and manage a custom-designed, on-site wastewater management ordinance for on-site systems with longevities comparable to, or better than, other areas which use modern and thoughtful design. Systems with a service life of up to 50 years can be expected. Some engineers feel that with proper care, on-site systems can last even longer.

CHAPTER VII: PACKAGE WASTEWATER TREATMENT PLANTS WITHIN THE CITY

There are 5 "package" or pre-engineered treatment plants within the city: the Latigo Bay Shores, Point Dume, Trancas Canyon, Malibu Mesa and Maison de Ville wastewater treatment plants (WWTP). These package plants have multiple names (e.g., the Malibu WWTP is also called the Maison de Ville WWTP). This has led to some confusion about the number of actual plants. Hughes Research Lab also has a pre-engineered plant for its industrial waste. This plant was not included in the survey because it is presently undergoing re-design. Its domestic-type waste is treated by a septic tank/drainfield system.

This chapter is a preliminary inventory of the package plants, primarily to inform the city of what exists. Package plants play an important role in any overall wastewater management plan. Some plants discharge into soil and bedrock. Should the soil absorption system fail, the WWTP might be forced to request a discharge permit to nearby streams or switch to permanent cartage until new drainfields can be constructed. For those plants with subsurface disposal or irrgation re-use, concerns have been voiced about possible rising groundwater elevations even in the drought. Should a nearby on-site system be unrepairable, the on-site system might be able to connect to package plants that are still below design capacity. If subareas require or wish to abandon on-site systems, then new custom-designed or prefabricated small volume plants are an option. The new WWTPs could use existing locations. This study will not address these questions, but suggests them as options in the chapter on subareas of concern (Chapter IX).

This chapter locates the WWTPs and describes them on an "acquaintance" level. It reviews relevant portions of past reports (Montgomery, 1986; ES, 1988; Coastal Application, 1990), some material made available by package plant owners and operators, and the WWTPs themselves. Each tour was accompanied by 1 or 2 of the most knowledgeable persons involved with the plant (see Further Acknowlegments and List of Contacts), but was cursory, lasting only several hours per plant.

VII.1 Latigo Bay Shores Wastewater Treatment Plant (Tivoli Cove)

The Latigo Bay Shores WWTP has been in service since 1973 (Montgomery, 1986). It was originally planned to be used for a limited period, to be abandoned when

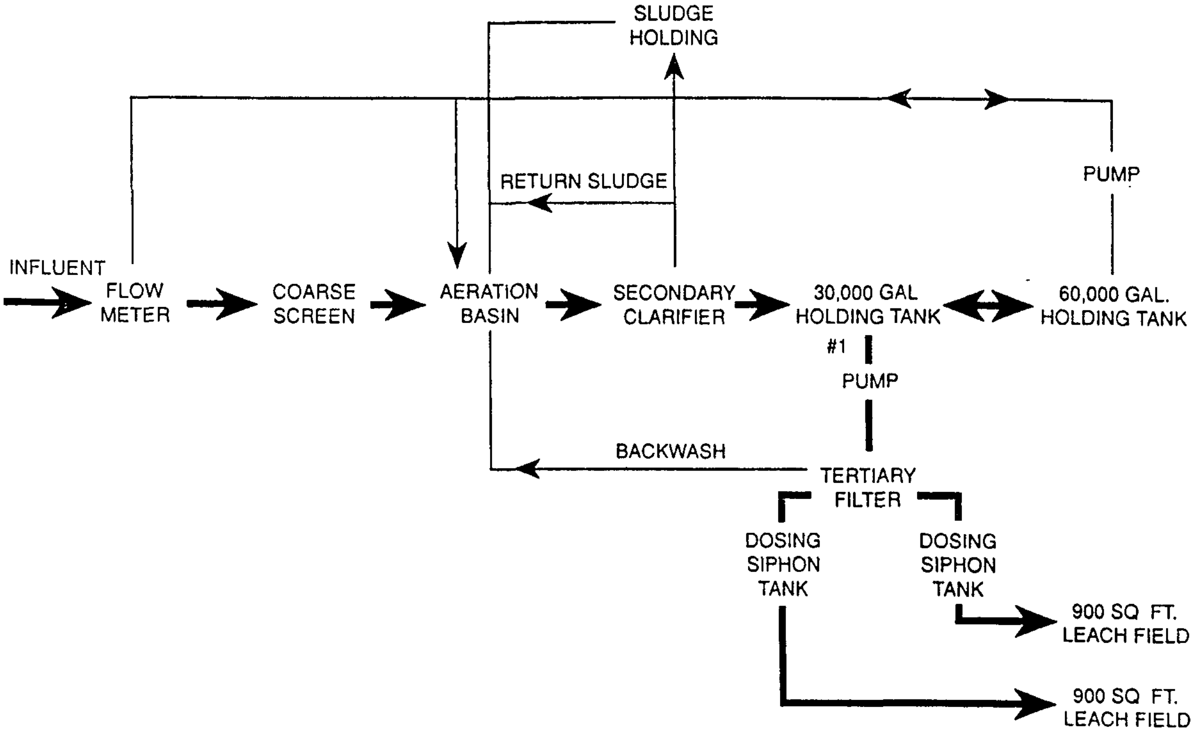
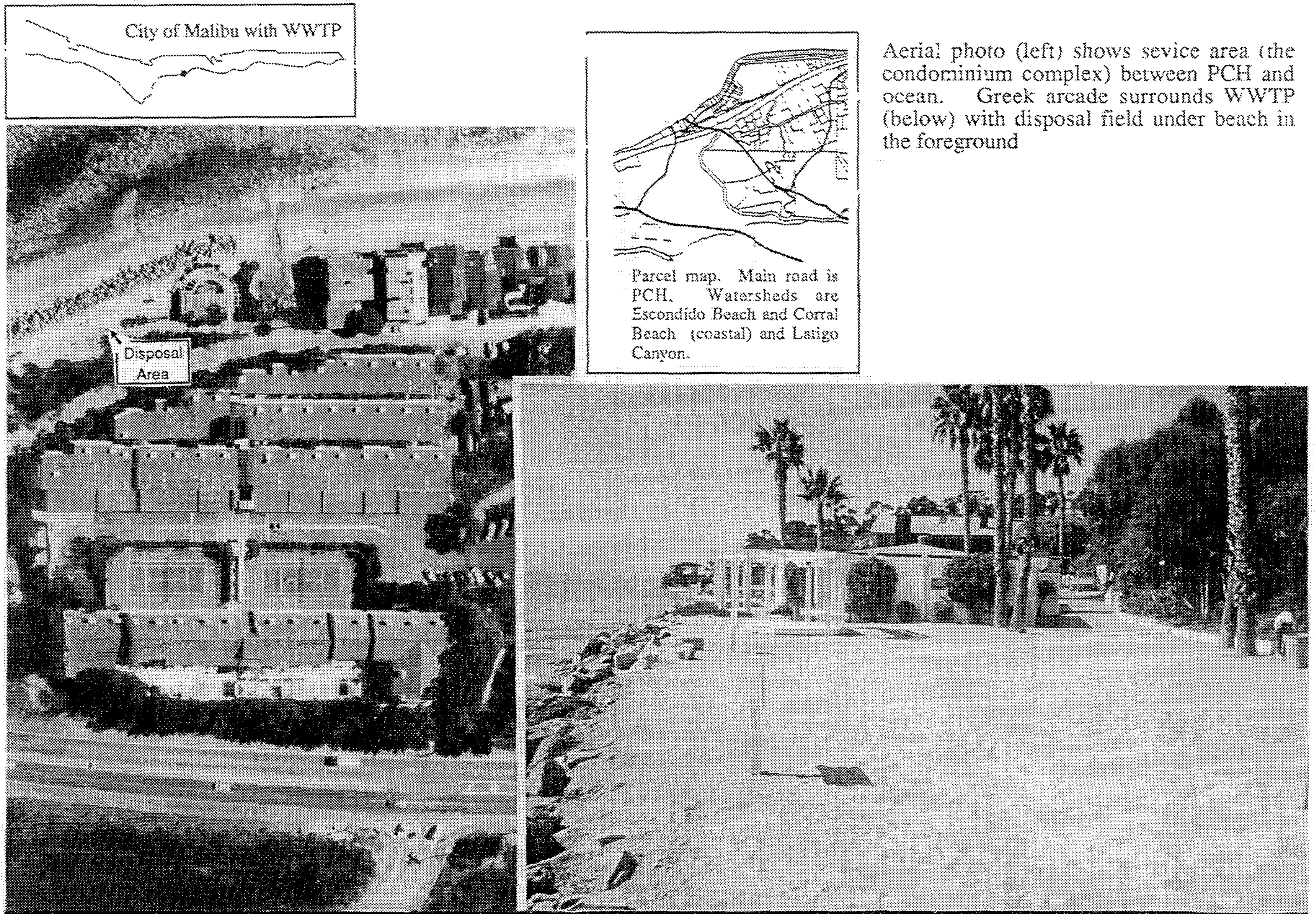


Figure VII. 2: Flow Diagram, Latigo Bay WWTP

regional facilities became available. The report stated that adequate treatment was provided by the plant, however sometime in the early 1980s leachfield clogging occurred which was successfully corrected by treatment with hydrogen peroxide.

The plant serves the Latigo Bay (aka Tivoli Cove) condominium complex of about 120 units. Treatment plant design was reportedly based on an occupancy of 224 persons, and a flow allowance of 125 gallons per capita-day. Maintenance requires 4 full time equivalent (FTE) workers per week and a minimum of 3.5 hours per day.

The plant is a Smith and Loveless Addigest extended aeration plant, serial number 46-0301, with tertiary filtration and having a design capacity of 28,000 gallons per day (gpd). Present flows are reportedly about 20,000 gpd. The flow diagram is shown as Figure VII.2. Influent enters the plant via a Palmer-Bolas flume where flows are measured with a Manning flow meter. The influent then passes through a coarse screen to the aeration chamber, to the secondary clarifier, and then to a 30,000 gallon holding tank which dampens peak flows to the tertiary filter. Effluent then flows to two siphon tanks which dose two, 900 square foot leach fields. The leachfields are located in beach sand in an area about 40 feet by 180 feet, lying east of the plant (Figure VII.1).



Parcel map. Main road is PCH. Watersheds are Escondido Beach and Corral Beach (coastal) and Latigo Canyon.

Aerial photo (left) shows sevice area (the condominium complex) between PCH and ocean. Greek arcade surrounds WWTP (below) with disposal field under beach in the foreground

Figure VII. 1: Latigo Bay Shores Package Plant

In the event of plant malfunction, flows can bypass the plant and be retained in a 60,000 gallon holding tank which is sized to accept approximately 2 days' flow. Waste sludge is stored in a 6,000 gallon wet well originally planned for a future pumping station. About 2,500 gallons is trucked monthly to a designated manhole on a sewer tributary to the Hyperion treatment plant.

The plant is attractively screened from view, and no odor problems were reported despite the proximity to the condominiums. Treatment seemed to be adequate, to the best of our knowledge from the brief visit. General upkeep and repair maintenance were judged to be adequate, considering that maintenance is provided only 3 times per week for about 1 or 2 hours per visit.

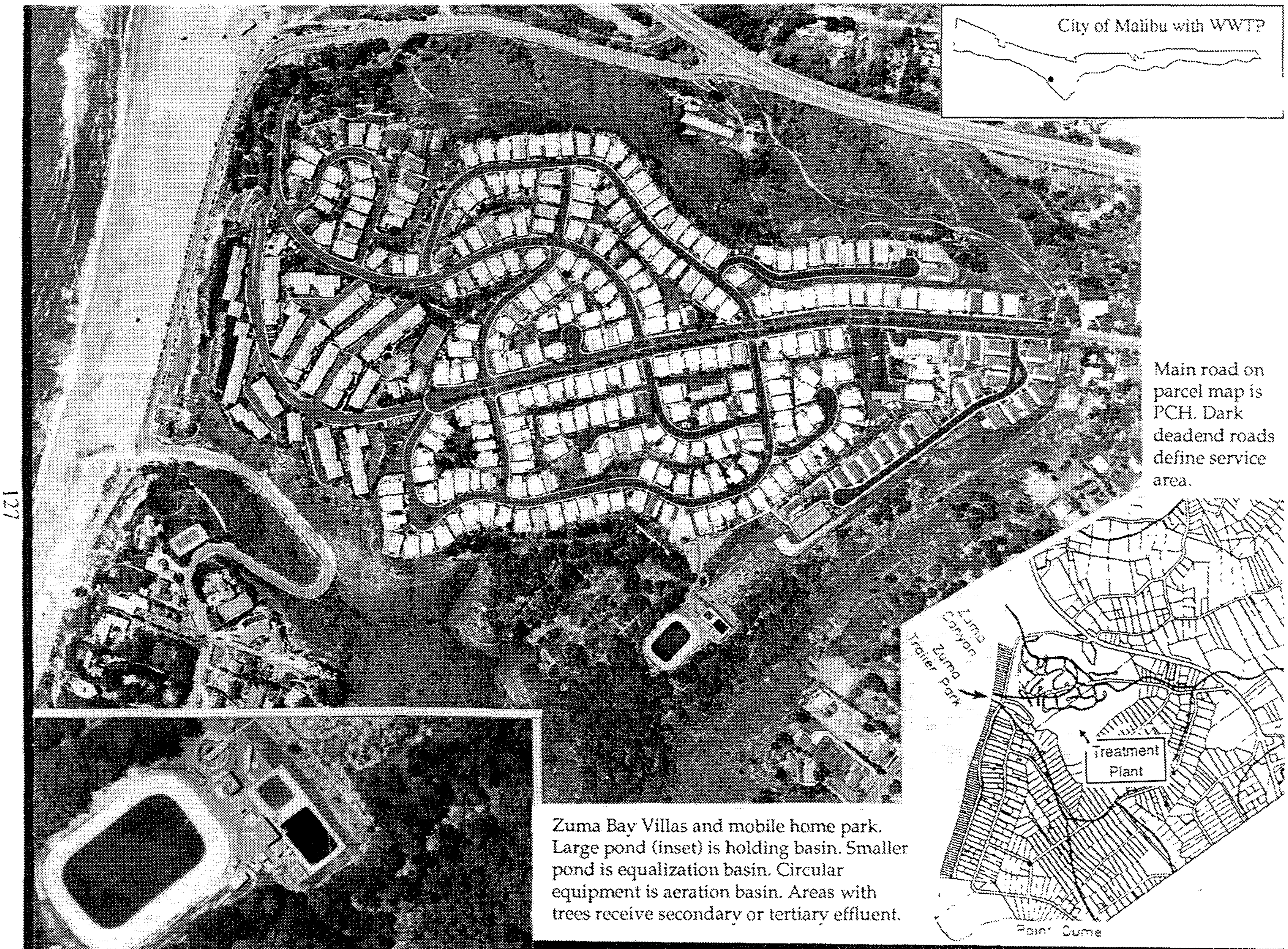
Limited room for expansion was seen, but neither did there seem to be much apparent reason to expand this facility.

VII.2 Point Dume Wastewater Treatment Plant

An extended aeration type facility, this package plant was constructed in 1969, with tertiary filters added in 1983. Two levels of treatment and disposal were described in the Montgomery report: about 40% of the effluent receives secondary treatment and is spray irrigated on adjacent foliage (about 6 acres) while 60% receives tertiary filtration and is used for landscape watering inside the Point Dume Moble Home Park and Zuma Bay Villas condominium development (about 4 acres). Additonal land is available for spray irrigation reuse. The Coastal Commission permits maximum flows of 22,000 gpd for secondary effluent. The Water Quality Control Board permits 50,000 gpd for tertiary.

Flows reported in 1986 (and presently unchanged) were about 45,000 to 60,000 gpd, with plant design capacity being 70,000 gpd. Labor requirements are 7 days per week, 80 man-hours per week.

The plant serves 297 mobile homes within the Point Dume Club of Malibu, and 90 condominiums at Zuma Bay Villas (Figure VII.3). The population reported is a maximum of 630 people. The facilities and mobile home park land are privately owned by the Adamson Company. The 92 acres include parcels 4468-013-011 and 4468-022-002 to --



Main road on parcel map is PCH. Dark deadend roads define service area.

Zuma Bay Villas and mobile home park. Large pond (inset) is holding basin. Smaller pond is equalization basin. Circular equipment is aeration basin. Areas with trees receive secondary or tertiary effluent.

Figure VII. 3: Point Dume Reclamation Plant

091. There is no separate charge to the Mobile Home Park. The condominiums pay $1,410 per month for all 90 units.

A Smith and Loveless extended aeration package plant is used together with coagulation, flocculation, sedimentation and filtration. A holding basin is provided which offers about 15 days emergency storage, and standby power generation is provided. A flow diagram of the plant is shown as Figure VII.4

The operators report that good quality effluent is being consistently achieved. About 13,000 gallons per month of waste sludge is trucked to the Tillman treatment plant for disposal. Tillman is connected to Hyperion. The cost of cartage is about $10,000 per year.

There appears to be room for doubling the capacity at this plant site. The reported 8.5 acres of foliage that is spray irrigated and the estimated 10 acres of landscape in the park may be able to accept more reclaimed water than is presently supplied. Potable water is now added to the tertiary effluent during drought periods to meet the irrigation demand.

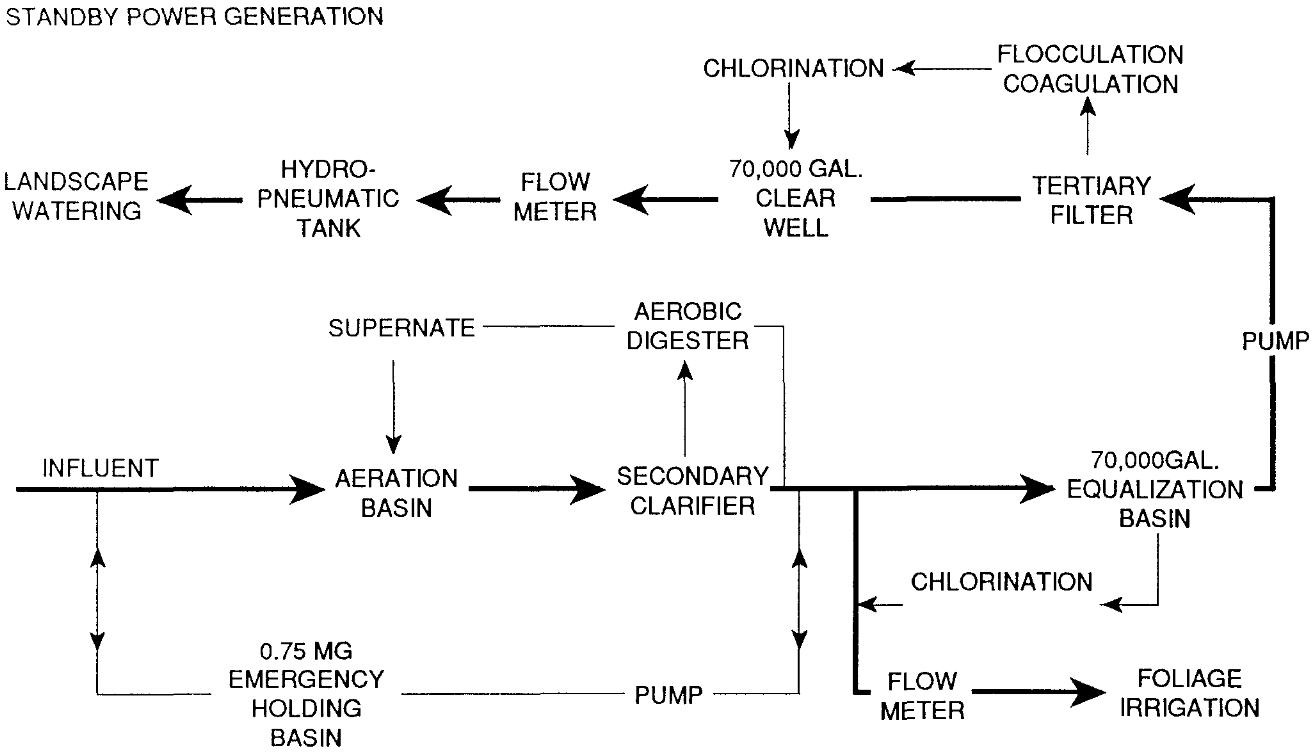


Figure VII.4: Point Dume Reclamation Plant Flow Diagram

VII.3 Lechuza Point Wastewater Treatment Plant (now defunct)

This was a small privately owned package extended aeration treatment plant which was located entirely underground (Montgomery, 1986). It was installed as a temporary facility in the mid-1960s, and effluent was disposed to a leachfield located so near the ocean as to cause concern. The plant consisted of an aeration basin, a secondary clarifier, and a sludge storage tank.

Flows in 1986 were estimated at about 10,000 gpd. The plant showed signs of deterioration due to age. It was replaced by pumping stations to the Trancas WWTP in 1987.

One pumping station is located on Broad Beach Road. A second pumping station is located near Sealevel Drive. Thirty-six homes along Sealevel Drive, Point Lechuza Drive, Victoria Point Road and 6 lots along Broad Beach Road are connected to a force main. A 4-inch ductile iron force main conveys the wastewater to the Trancas plant. The pumps and force mains are owned and maintained by Los Angeles County. See Figure VII.5.

VII.4 Trancas Canyon Wastewater Treatment Plant

The Trancas WWTP at 6338 Paseo Canyon has 2 parts. The easterly part is 2.76 acres with all the treatment plant facilities and some of the subsurface drainfields (parcel: 4469-045-900). It is owned by LA County. The westerly parcels (4469-36-56 and -57) add up to about 0.8 acres and are owned by the Jewish Community Foundation. The westerly parcels have additional disposal fields.

The Trancas Plant has a long history, dating from 1964, when it was first built. Following nuisance odors and operational problems, 2 large fields were reconstructed in 1977 and a rotating biological contactor (RBC) plant began operation in 1978. In 1983, after major storm damage, the County declared an emergency and connected 36 additional homes to the Trancas Plant. These homes fed the plant through the conveyance system that replaced the Lechuza Point WWTP. In 1989-90, 7 laterals from Broadbeach homes were added to the system. Flows in 1986 were reported at 50,000 to 65,000 gpd. The plant design flow of 75,000 gpd. Peaking days can reach 105,000 gpd.

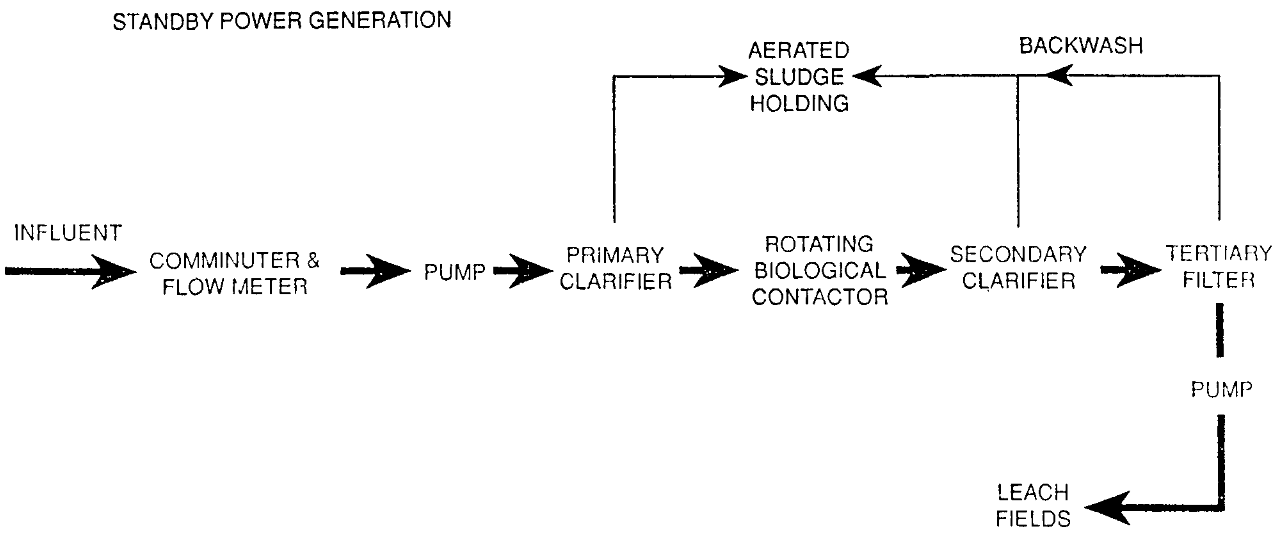


Figure VII.6: Flow Diagram, Trancas Canyon WWTP

In 1986, the Montgomery report stated that there was room available for an approximate doubling of the treatment plant and leach field. The Trancas Canyon area is reportedly located in an "Area of Special Biological Significance" (ASBS) which does not allow wastewater discharges that are tributary to the ocean, so any expansion will rely on continued practices of subsurface disposal and a design that will prevent premature surfacing of the effluent into the creek. The Montgomery report projected a need for a seven-fold increase in plant capacity at Trancas (to 750,000 gpd), which in reality may not be achievable or desirable.

Caption, Figure VII.5: Parcel map shows service area including force main. Lower aerial shows pump stations from Lechuza Point to WWTP. Upper left aerial shows WWTP and the two separated subsurface disposal areas. Cylindrical building is the rotating biological contactor. Upper right is an aerial of immediate service area with PCH shown in lower lefthand corner.

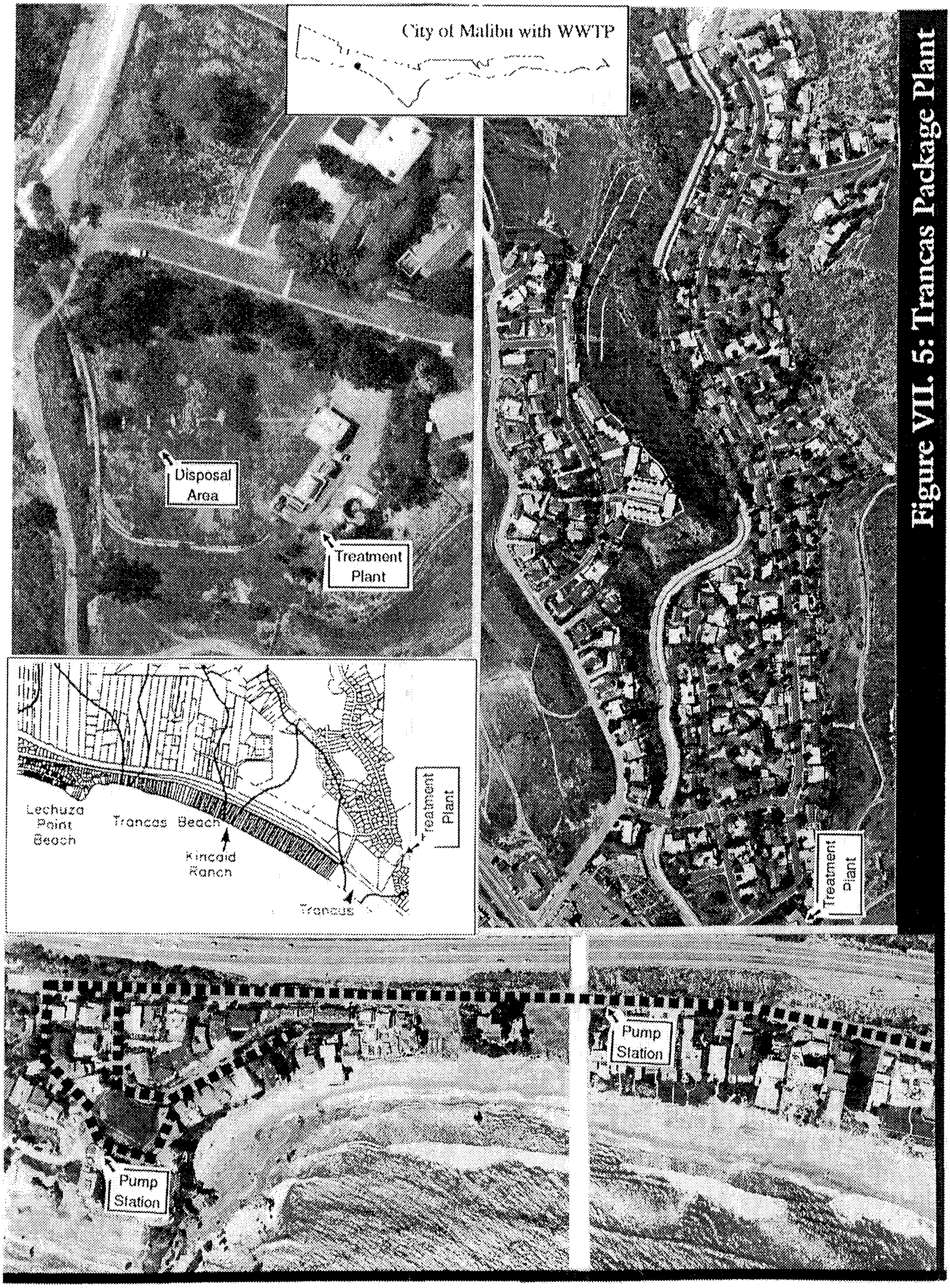


Figure VII. 5: Trancas Package Plant

The plant is owned by Los Angeles County and operated by the Consolidated Sewer Maintenance District (Figure VII.5). The plant is attended 7 days per week, 8 hours per day, and serves the residential subdivision within Trancas Canyon, east of Trancas Canyon Road, as well as the area described under the Lechuza Plant. The residential subdivision is represented by the Malibu West Community and has an agreement on operation, connections and charges with the County. Charges of about $700 per year appear on tax bills. The charge has more than doubled in the last decade. The original hook-up fee was about $10,000.

A Bio-Surf rotating biological contactor (RBC) provides secondary treatment. Clarifiers were custom built following Los Angeles County Department of Public Works design, and tertiary filtration is provided by Hydroclear filters. An abandoned plant has been converted to an aerated sludge holding facility. The flow diagram is shown in Figure VII.6.

This plant replaced a Spirogester primary plant constructed in 1964, with final improvements completed in December, 1979. The Spirogester, a device similar to an Imhoff tank, was replaced due to odor problems and poor treatment quality. It had caused clogging of some leachfields, which were also reconstructed.

Design is for 75,000 gpd. Present flows are reportedly about 60,000 gpd, from an estimated population of 660 (263 dwelling units). All users are single-family residents. After a program of collection system rehabilitation by grouting, little infiltration into the collection system has been reported. The site offers room for plant expansion. Except for the assimilative capacity of the leachfields, effluent disposal options appear limited.

No permit violations were reported, nor were there any apparent needs for modification to the plant. It appeared well maintained, although some unavoidable corrosion is occurring, especially to the filters. The plant is located in proximity to homes, making it a candidate for odor complaints, but no objectionable odors were observed during the visit. According to the operators the plant functions well and consistently provides over 90% removal of BOD (biological oxygen demand) and suspended solids.

An average of 5,000 gallons of waste sludge at about 5% solids content is trucked from the plant weekly, and deposited at a designated manhole on a sewer in Los Angeles tributary to the Hyperion plant.

According to the interviews, the main leachfield beds located adjacent to the plant contain twenty-five 210 foot long laterals. Another site located across Paseo Canyon Drive contains sixteen 140 foot long laterals plus ten 120 foot long laterals. These westerly fields are believed to be partially damaged. They have been raised to avoid groundwater problems. The leachfields are believed to have capacity in excess of the flows now received.

VII.5 Malibu Wastewater Treatment Plant (Maison de Ville)

In 1966, the Masion de Ville plant was built. In 1986, the Montgomery report stated that the Maison de Ville plant was a package extended aeration plant discharging to local seepage pits. It was reportedly running at design capacity of 37,500 gpd. The plant was probably not intended as a permanent installation, however a good level of treatment was provided. Due primarily to corrosion, plant components were described as approaching the end of their service lives.

This plant is located at the intersection of West Civic Center Way, Vista Pacifica and de Ville Way (Figure VII.7). It is owned by Los Angeles County and operated by a Consolidated Sewer Maintenance District. The plant sits and partially disposes of effluent on 1 parcel owned by Los Angeles County. In addition, it leases land (about 1 to 1.5 acres with easements) from the Santa Monica United School District (across de Ville Way) for additional disposal. The area is controlled by the County through dedicated easements for sewerage purposes on Tract 28992. The Malibu Land Use Plan shows the land as zoned for residential and neighborhood commercial. The parcels involved are 4458-021-012 and -013 (easterly) and 4458-027-904 (westerly).

The plant is attended approximately 4 person-hours per day, 7 days per week. It serves the existing condominiums on de Ville Way and Vista Pacifica Street. Plant capacity is reported by the Waste Discharge Requirements Order at 55,000 gpd, and present flow received from the 170 dwelling units served is about 30,000 gpd. The practical design capacity was about 37,500 gpd. Sufficient room is available for an approximate doubling of plant size.

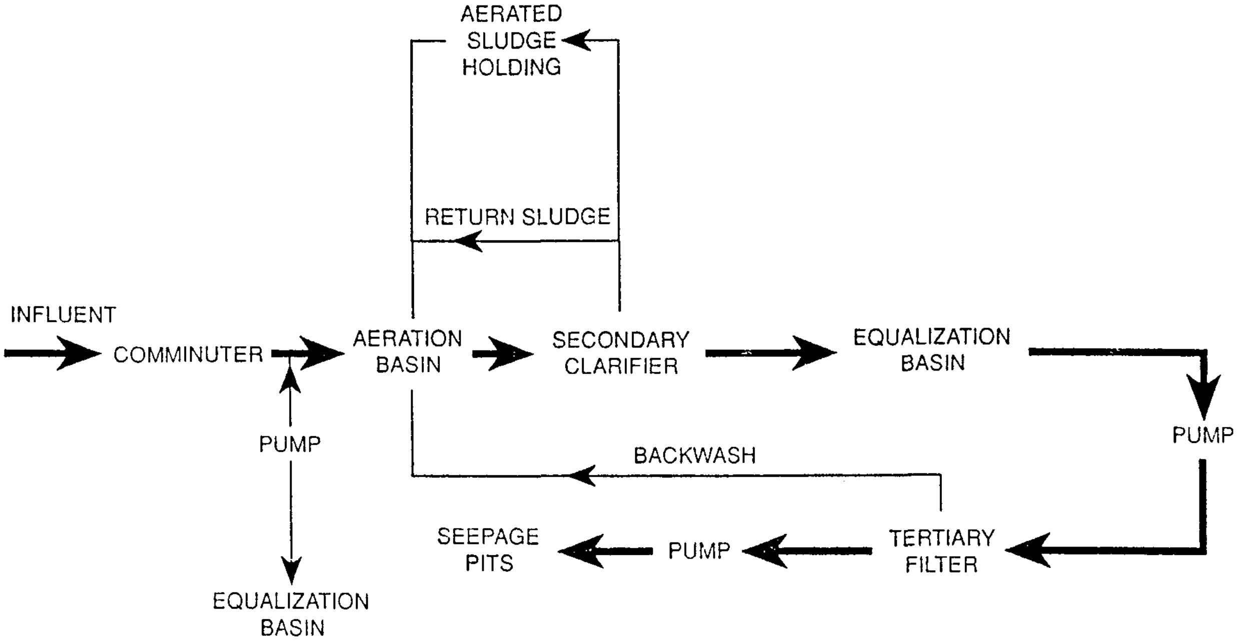


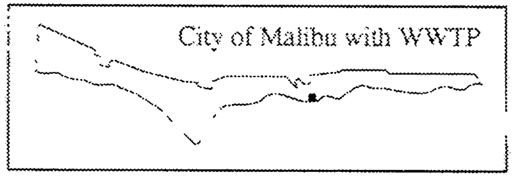
Figure VII.8: Flow Diagram, Malibu (Maison de Ville) WWTP

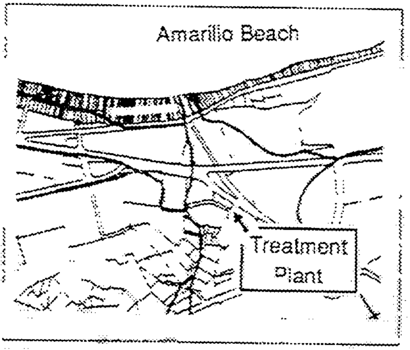
This extended aeration plant uses a Chicago Pump SL-131 brand. The flow diagram is shown as Figure VII.8. Treated effluent is disposed to 9 adjacent seepage pits of 4-foot diameter perforated concrete pipe, 40-feet deep. The nearest creek is in Marie Canyon. Approximately 5,000 gallons of waste sludge is trucked from the site weekly and discharged at a designated manhole on a sewer tributary to the Hyperion plant.

No permit violations were reported. The plant appears to perform well and to be well maintained, but corrosion is evident and the plant will likely be in need of rehabilitation soon. Annual service charges were reported at $875 per dwelling unit.

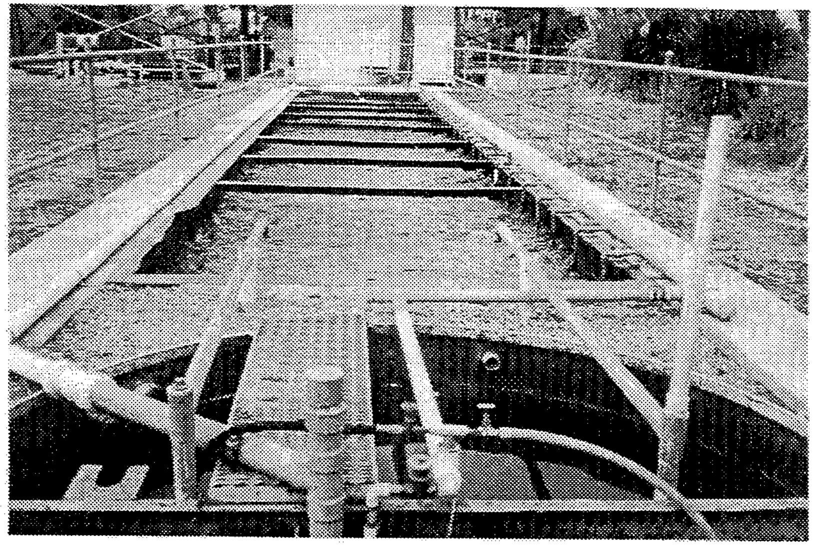
VII.6 Malibu Mesa Wastewater Treatment Plant

This is the largest treatment plant within Malibu. It occupies 2.64 acres (parcel: 4458-030-900) and serves Pepperdine University (outside city limits) and Malibu Country Estates (within city limits). Its address is 3863 S. Malibu Drive near John Tyler Road and Pacific Coast Highway. A package unit is part of the facilities, but remaining portions are of custom design. The plant was first placed in operation in 1978. Tertiary effluent is spray irrigated on the Pepperdine campus. The Malibu East report (Engineering Science, 1988) states that use of reclaimed water by the university is approximately 485,000 gpd from Malibu Mesa, the Tapia plant, and domestic supplies. There has been some concern





Parcel map shows location of WWTP relative to beach and PCH (largest road shown). Aerial photos shows service areas with three multiplexes that generate wastewater. Subsurface disposal occurs on two separate parcels. Upper right shows aeration basin.



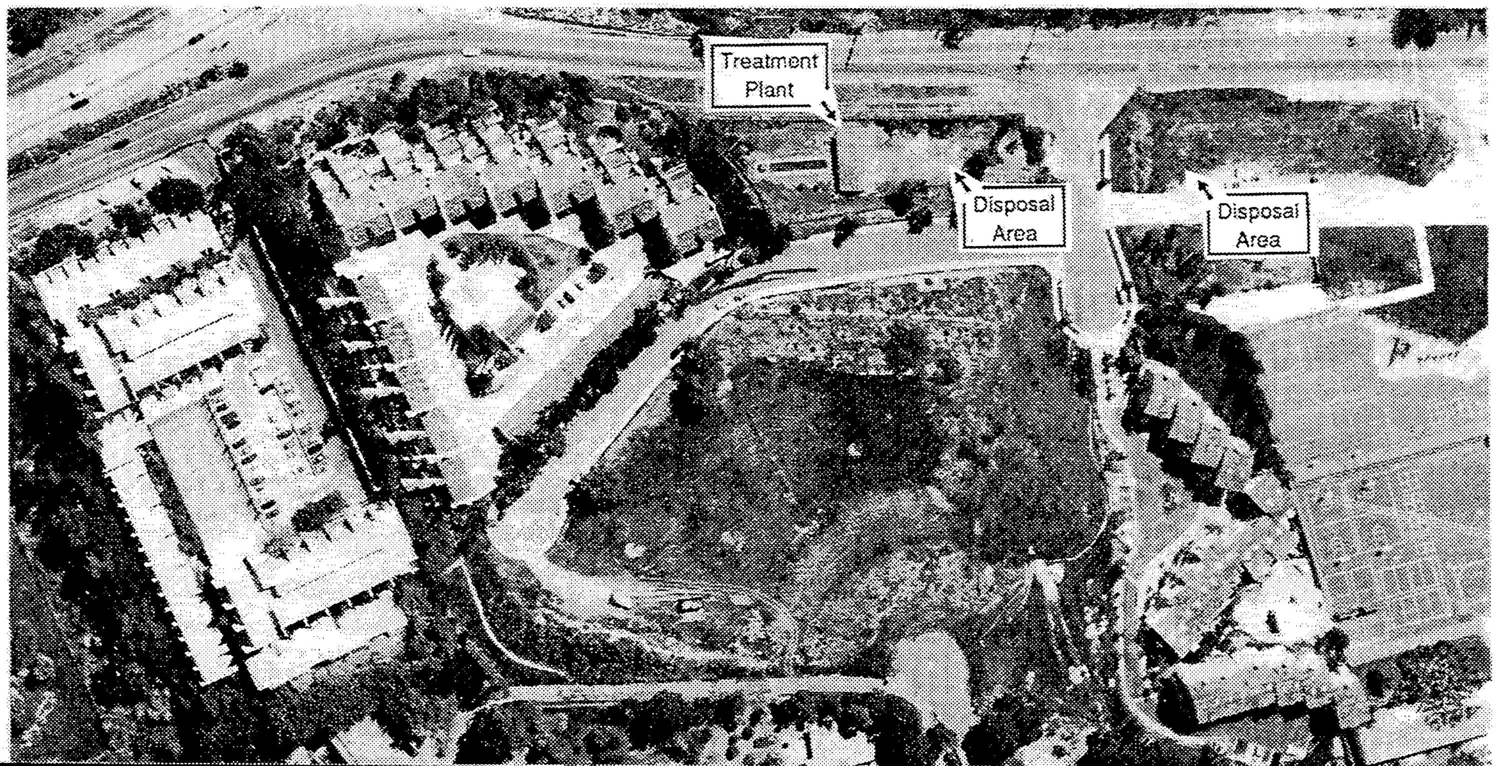


Figure VII.7: Maison De Ville Package Plant

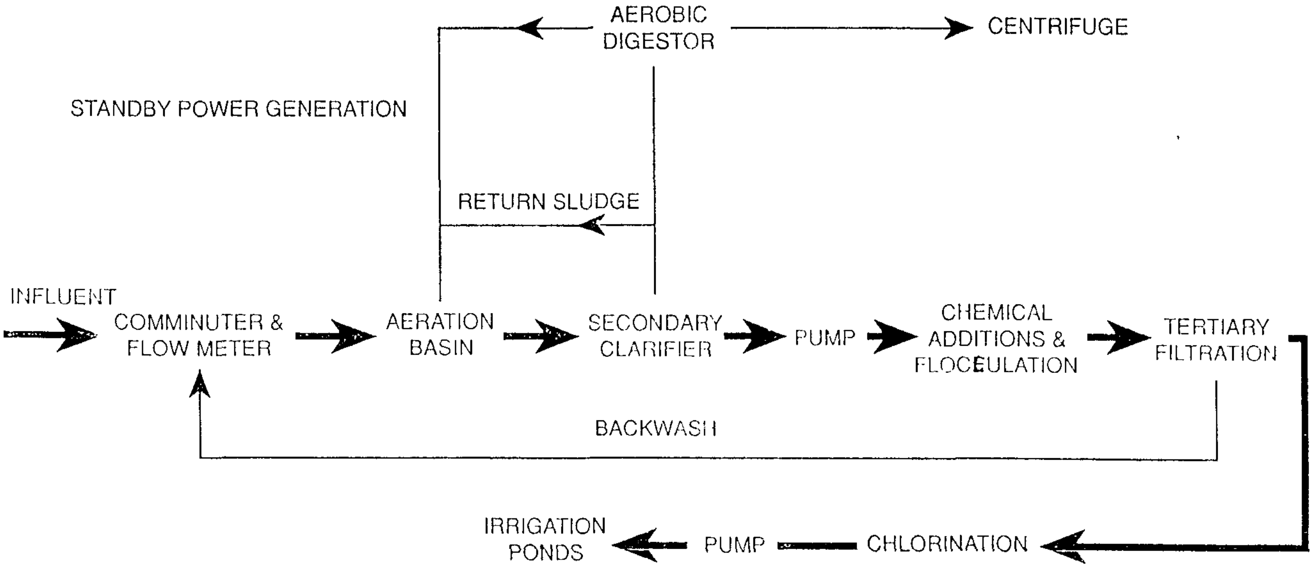


Figure VII. 10: Flow Diagram, Malibu Mesa WWTP

about rising water tables downhill from the spray irrigation fields by Malibu Road residents. The source of the groundwater remains unresolved.

The Montgomery report (1986) described the plant as having a design capacity of 200,000 gpd. Current flows were 180,000 gpd during the school year and 90,000 gpd during the summer. Those flows remain unchanged. The population equivalents (PE) served are 1,450 PE (including Pepperdine students and faculty), or 800 equivalent dwelling units (EDU), with 107 connections in Malibu Country Estates. Operators gave plant capacity as 300,000 gpd, but the SWRCB permit limits flow to 200,000 gpd. The County performs replacements, repairs and additions. The plant operational services are provided by JMM. The plant has personnel 7 days a week working about 10 hours each day in the plant. There is 1 FTE for 6 days and 2 FTE for 1 day.

Caption, Figure VII.9: Dense parcels on the parcel map and in lower left corner of aerial photograph are the in-city service area (Malibu Country Estates). Pepperdine University is the out-of-city service area. Discharge is to spray irrigation areas including lake storage (lower right). Or, effluent can be sent to Tapia by force main (not shown). Bottom photo shows aeration basin (circular equipment) and small spray irrigation area surrounding treatment plant. PCH is large horizontal road at bottom of photos.

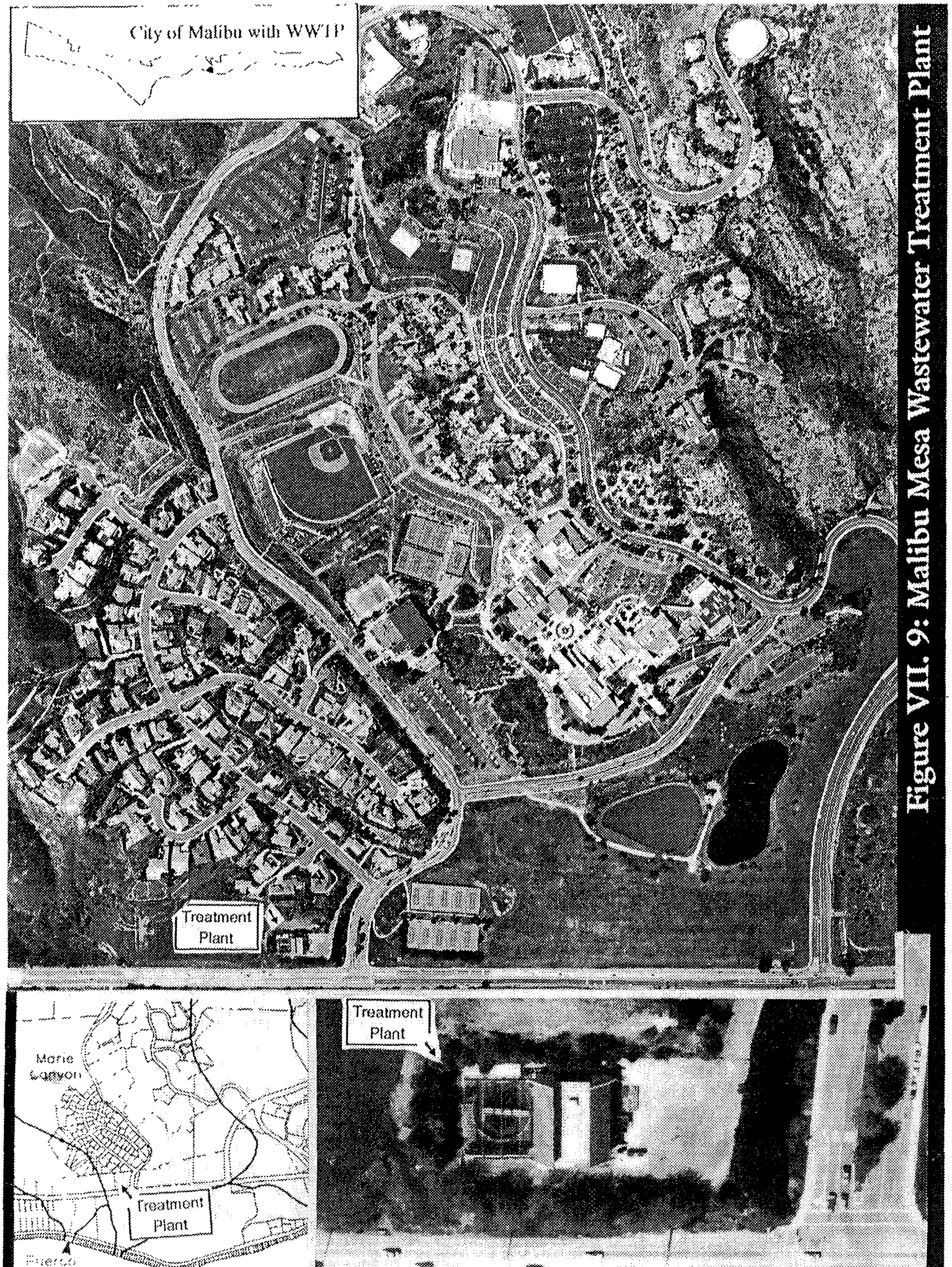


Figure VII. 9: Malibu Mesa Wastewater Treatment Plant

There is some confusion over ownership that is important to the city's understanding of jurisdictional authority. Pepperdine and the Malibu Country Estates believe the plant to be jointly owned by Pepperdine University (83%) and Malibu Country Estates (17%). From discussions with representatives of Malibu Country Estates, the County appears to believe that it owns the plant. Tax assessment records show the land to be owned by Los Angeles County.

This is a Walker Process size 3.0 Swirlmix package conventional activated sludge system. Chemical addition and new Parkson upflow sand filter units are of custom design and were added in 1991. The plant flow diagram is shown in Figure VII.10. Flow from Pepperdine enters six 10,000 gallon underground holding tanks located about 200 yards from the plant, then is pumped to the Malibu Mesa plant.

Flows in excess of about 150,000 gpd are pumped through a 6-inch force main to the Tapia plant for treatment. This force main can receive part of the flows normally directed to Malibu Mesa, which provides a partial fall back position for Malibu Mesa in the event part of that plant has to be taken off line for maintenance. The force main and pumping facilities are owned by Pepperdine University. Since the force main is long (about 5 miles), the pumpage becomes septic and odorous at Tapia, but because of the large assimilative capacity of the Tapia plant, this is not a major problem. The centrifuged sludge is trucked to Hyperion or County JWPCP plant.

An agreement between Tapia and Malibu Mesa requires that Malibu Mesa receive reclaimed water in equal volume to the wastewater they may discharge to Tapia (Dave Kaschalk, P.C.). This agreement was made at a time when reclaimed water was regarded a liability, but at Tapia today the demand for reclaimed water reportedly exceeds the supply. Two irrigation ponds on the Pepperdine campus have a combined capacity of 12.5 million gallons. Irrigation of the 200 acre area is applied throughout the year.

As best as could be determined during the brief visit, the plant is well maintained and reliably produces quality effluent. Sufficient property is available to accommodate perhaps a doubling of plant capacity.

Homeowners within Malibu Country Estates report that annual charges are $333 for plant maintenance, $313 for an upgrade bond, $15 for sewer maintenance, and $75 for the new plant proposed by Engineering Science, for a total of $736 per year (Aristid Berk, p.c.).

In the Montgomery report, the "multiple local plant" alternative would have required a doubling of plant capacity. The Engineering Science Report advised against expansion of this plant due to local opposition, but proposed continued use of the plant in conjunction with a new 1.8 mgd (million gallons per day) plant located on the adjacent Adamson property. Together these plants were to serve the area between Puerco Canyon and Malibu Creek (the Civic Center), and the east end from Malibu Creek to near Topanga Canyon.

VII.7 Conclusions

Most plants in Malibu are small, aging package plants, though a few (e.g., Malibu Mesa) are partially prefabricated and have new additions. None had any serious violations of RWQCB standards at the time of visit. The property on which the facilities are located appears to be more valuable than the plants themselves. Perhaps the greatest value is the de facto public acceptance of the sites' long established use for wastewater treatment and disposal. Consequently, greater attention was given to the plant itself and the disposal sites than the equipment or process.

In examining the plants, the issue of reliability came to attention. Often WWTPs have dual or redundant facilities so that any one item can be taken off line for repair. In Malibu, there were few instances of equipment redundancy. At Point Dume, there was a huge holding basin that could store up to 15 days' flow while repairs were made. At Malibu Mesa, the fallback position is the plant's ability to pump part of its flow to Tapia and to do repairs in the non-school seasons or holidays when flows drop by 50%. Trancas has an aerated sludge holding facility that could be used in an emergency with daily cartage. But Trancas, Latigo Bay Shores and Maison de Ville WWTPs have very few options if shutdown is required. It is speculated that these plants may have less concern for reliability since they discharge into soil absorption fields where additional treatment is provided and health concerns caused by brief and occasional decreases in effluent quality from the WWTP might be tolerated. It may also be speculated that these plants were under less strict regulations when built (about 20 years ago). These WWTPs would be built differently if they sought permit acceptance today.

The WWTPs that discharge to soil absorption systems should be of primary concern (Latigo, Maison de Ville, Trancas). Continued operation relies on their ability to assimilate treatment plant effluent. Two of the plants (Maison de Ville and Trancas) have leased lands not belonging to them for subsurface disposal. No efforts to document the state or probable longevity of these soil absorption systems appeared during the survey. The Malibu Mesa WWTP also discharges to soils by way of spray irrigation. There is some concern over the effect of spray irrigation on the groundwater table.

Finally, many of the treatment plants could be easily upgraded to handle larger volumes of sewage. The limit to these plants appears to be disposal (either subsurface or spray irrigation), not the plant or the processes and equipment that are part of the plant. The Latigo Plant, Trancas, Maison de Ville, and Malibu Mesa all reported to be operating below capacity. But without further study of the equipment capacities, peak surges, and the state of the soil absorption capacities, no major increase in service area or numbers of connections should be considered.

CHAPTER VIII: NONPOINT SOURCES

Water borne pollutants or residuals originate from point and nonpoint sources. The most common point sources are sewage treatment outfall pipes into the ocean or a creek. Malibu has no point sources. Nonpoint sources include residuals carried to streams, lakes, estuaries by surface runoff and to groundwater by infiltration and percolation of runoff. A parking lot is a common nonpoint source. Since nonpoint sources do not originate from a pipe or channel and are not continuous or direct releases, they can be difficult to control. In Malibu, the main concern for potential nonpoint pollution has been storm runoff, upstream contributions for watershed lands inland from the City of Malibu, and dispersed contributions of pathogens from septic tanks along the beachfront (Chapter IV) and within Malibu Lagoon.

Storm runoff from Malibu's 62 watersheds carries a load of pollutants to Malibu Lagoon and to Santa Monica Bay. These pollutants include trash and debris, oil and grease, nutrients (nitrogen and phosphorus), hydrocarbons and other organic matter, heavy metals, bacteria, and suspended sediment. At the moment, none of the storm runoff receives deliberate treatment, though certain marshes probably treat particular storm flows through natural processes. The contributions of freshwater to Malibu Lagoon from upstream and in-city stormdrains may distort the natural salinity balances within Malibu Lagoon. In these cases, freshwater is a pollutant (a substance causing harm). This chapter focuses on estimates of the water quality impacts of developed areas throughout the City with a special section on Malibu Creek and Lagoon.

VIII.1 Watersheds and Stormdrains

Watersheds focus the storm runoff from hillslopes and canyons into Malibu's creeks. As portions of the watershed are paved over, as traffic increases, as dogs and horses become more common, and as the vegetation changes from natural to landscaped plants, the water quality that runs off the hillslopes changes. When culverts and stormdrains become part of the landscape, they are constructed for the purpose of flood control without thought to water quality, seasonality, and destination. However, in addition to carrying rainfall runoff, these stormdrains carry "nuisance" waters such as excess irrigation water with fertilizers, crankcase oil, animal droppings, chemicals from car exhaust and polluted dust, commercial discharges and street washdown water. The stormdrains in southern California have occasionally transported toxic and sewage wastes resulting from illegal connections. In serious storms, sewage pump stations have used stormdrains as "fail safe" overflows. Because stormdrains do not necessarily follow natural runoff channels, the rain-derived and nuisance runoff can enter creeks at new locations or even discharge to a different watershed. Because of the smooth open channels, pavement, and pipes, the storm waters can gather together more rapidly and dose the creeks with potential pollutants more intensely. Any discussion of nonpoint sources becomes a discussion of changes in land use.

VIII.2 Water Quality Parameters of Concern

Limited data on storm water quality are available for the Malibu coastline area. These are currently being evaluated in a study by the UCLA Department of Civil Engineering (Michael Stenstrom, p. c.). Until these data can be evaluated, we will have to rely on general information on the quality of urban runoff. The primary concerns for urban runoff water quality in Malibu center on the following pollutants:

1.Trash and debris. Trash is a ubiquitous product of land development and beach parties. Although primarily an aesthetic beach problem, plastic trash has been shown to choke, entangle and block the digestive tracts of fish, birds and marine mammals. Control strategies generally focus on anti-litter campaigns, highway pickup programs and proper maintenance of debris screens at stormdrain inlets.

2. Oil and grease. Hydrocarbons are contributed by runoff from streets and parking lots, especially in the "first flush" of runoff following a dry period. Oil and grease at high concentrations may be directly harmful to aquatic organisms, and indirectly harmful at low concentrations by contributing to biochemical oxygen demand (BOD). Oil and grease are difficult to measure directly, and are included in measurement of BOD, chemical oxygen demand (COD), and total organic carbon (TOC). Control strategies include use of first flush collection basins, and programs aimed at increasing the recycling and careful handling of waste oil.

3. Nutrients. The primary nutrients of concern are nitrogen and phosphorus. Nutrient sources in surface runoff include fertilizers applied to lawns and golf courses, nitrous oxides from automobile exhaust, and animal waste and surface soil erosion. In Malibu, the eutrophication of Malibu Lagoon has focused attention on the nutrient problem.

4. Heavy metals. Zinc (Zn), lead (Pb), copper (Cu), mercury (Hg) and cadmium (Cd) can be harmful to aquatic organisms and to humans at very low concentrations. These metals are more likely to be associated with runoff from industrial areas than from residential areas, although leaded gasoline used to be a major lead source. The toxicity and bioavailability of the heavy metals depends largely on other water quality parameters, such as pH, sulfide, carbonate and chloride concentrations. In surface runoff, heavy metals are generally adsorbed onto sediment and transported in the particulate load.

5. Bacteria. Fecal coliform bacteria often show up in stormwater runoff. They are an indicator that some animal sources (dogs, horses, birds, and occasionally leaking sanitary sewers) may be contributing disease-causing organisms. Recent studies by Heal The Bay have shown high bacterial levels in stormdrains feeding Santa Monica Bay.

6. Suspended sediment. Sediment originating from land development is thought to be adversely affecting rocky subtidal habitat in Santa Monica Bay (Fay, 1991). Orme (1991), however, notes that the Malibu Coast east of Point Dume is sediment starved as a result of dams and reduced cliff erosion. Possibly the damage to subtidal habitat is associated with fine sediment that moves quickly offshore, and the input of which has not been reduced.

VIII.3 The Storm Runoff and Water Quality Model

PWA used a USGS planning model (Driver and Tasker, 1985) to determine mean annual loads of potential pollutants for undeveloped, residential, and highly developed areas of the city. The model used in this study cannot be applied to some of the important water quality parameters, including suspended sediment, bacteria, oil and grease, and trash, which require site-specific monitoring. The contributions were only measured for the in-city portions of Malibu's watersheds which can be quite miniscule compared to upstream areas and contributions. Figure I.1 displays the watersheds. Table VIII.1 gives the total watershed drainage area, the proportion within the city, and the percent impervious surface within the city portion. Table VIII.2 shows the estimated annual loads of various potential pollutants from within the city. Methods and assumptions for these map areas and estimates

Table VIII.1: Drainage Basins & Percent Impervious Surface Area

Drainage Basin	Total Watershed Drainage Area (mi^2)	Watershed Area w/in City of Malibu (mi^2)	Percent Impervious Area (%)
Nicholas Beach W.	0.32	0.32	0.69
San Nicholas Canyon	1.47	0.96	0.18
Nicholas Beach E.	0.38	0.38	10.41
Los Alisos Canyon	1.50	0.63	0.42
Los Alisos Canyon E.	0.02	0.02	72.73
Lachusa Canyon	1.75	0.47	0.74
Piedra/Pescador Beach	0.93	0.92	7.20
Encinal Canyon	2.50	0.51	0.50
Lechuza Point Beach	0.20	0.20	40.64
Steep Hill Canyon	0.45	0.18	2.79
Trancas Beach W.	0.25	0.25	22.01
Kincaid Ranch	0.21	0.25	8.21
Trancas Beach E.	0.14	0.14	35.68
Trancas Canyon	10.00	0.72	0.57
Zuma Beach A	0.37	0.37	11.76
Zuma Beach B	0.49	0.44	21.44
Zuma Beach C	0.24	0.24	24.10
Zuma Beach D	0.19	0.19	20.99
Zuma Canyon	8.75	1.40	2.13
Zuma Bay Villas	0.07	0.07	44.00
Zuma Trailer Park	0.27	0.27	28.18
Point Dume	0.40	0.40	23.03
Malibu Riviera S.	0.20	0.20	28.37
Malibu Riviera N	0.43	0.43	28.63
Walnut Canyon	0.55	0.55	20.78
Paradise Cove	0.27	0.27	30.47
Ramirez Canyon	4.50	0.79	1.94
Fouquier	0.39	0.39	23.01
Escondido Beach	0.22	0.22	39.78
Escondido Canyon	3.25	0.84	3.07
Escondido Beach E	0.21	0.21	31.91
Latigo Canyon	1.25	0.42	0.79
Corral Beach W	0.09	0.09	2.18
Solstice Canyon	4.50	0.63	0.07
Corral Beach E	0.11	0.11	6.25
Corral Canyon	3.75	0.33	0.00
Puerco Beach	0.49	0.44	15.67
Puerco Canyon	1.00	0.23	0.70
Puerco/Amarillo Bch W	0.02	0.02	29.09
Marie Canyon	0.88	0.14	3.93
Amarillo Beach E	0.15	0.15	20.81
Winter Canyon	0.40	0.17	9.19
Malibu Creek A	0.25	0.25	22.78
Malibu Creek B	0.07	0.07	31.43
Malibu Creek C	0.09	0.09	61.75
Malibu Creek D	0.65	0.65	19.79
Malibu Colony	0.05	0.05	80.00
Malibu Pier	0.07	0.07	34.76
Sweetwater Canyon	0.64	0.17	5.47
Carbon Beach W	0.37	0.35	21.36
Carbon Beach Mdl	0.10	0.09	9.18
Carbon Beach E	0.10	0.10	33.06
Carbon Canyon	3.25	0.31	1.21
La Costa Beach	0.20	0.20	36.83
Las Flores Canyon	4.75	0.31	0.44
Malibu PO	0.24	0.18	7.37
Big Rock Beach	0.48	0.48	23.95
Piedro Gorda Canyon	0.75	0.22	0.35
Las Tunas Beach W	0.20	0.20	12.46
Pena Canyon	0.88	0.11	0.29
Las Tunas Beach Mdl	0.09	0.09	17.33
Tuna Canyon	1.50	0.11	0.08
Las Tunas Beach E	0.06	0.06	19.51

Table VIII.2: Estimated Annual Loads - Watersheds, Existing Conditions

Drainage	Mean Annual Load (lbs/yr)										
Basin	COD	SS	DS	TN	TKN	NO3-N	TP	DP	CU	PB	ZN
Nicholas Beach W.	3,960	877	3,888	111	9	102	4	7	2	5	8
San Nicholas Canyon	78,388	9,386	173,111	1,266	95	1,171	79	53	31	79	156
Nicholas Beach E.	5,602	1,054	5,223	154	12	142	5	8	3	7	11
Los Alisos Canyon	83,404	9,837	186,632	1,333	100	1,233	84	55	33	84	167
Los Alisos Canyon E.	1,245	179	306	59	5	54	0	2	0	2	3
Lachusa Canyon	131,760	14,091	331,823	1,939	145	1,794	135	75	49	130	266
Piedra/Pescador Beach	27,300	3,811	40,885	552	42	510	24	24	11	30	55
Encinal Canyon	433,372	36,286	1.5E+06	5,120	377	4,744	465	173	146	401	890
Lechuza Point Beach	3,592	559	1,894	122	10	112	2	4	1	5	8
Steep Hill Canyon	6,704	1,305	7,348	172	13	159	6	9	3	8	13
Trancas Beach W.	3,747	688	2,638	117	9	107	3	5	2	5	8
Kincaid Ranch	2,636	592	2,076	82	7	76	2	5	1	3	5
Trancas Beach E.	2,439	431	1,248	87	7	80	1	4	1	4	5
Trancas Canyon	6 5E+08	1.2E+07	1.6E+10	2.0E+06	133,552	1 9E+06	911,775	27,818	113,675	410,888	1 5E+06
Zuma Beach A	5,559	1,035	5,069	154	12	142	4	8	2	7	11
Zuma Beach B	9,418	1,436	8,588	247	19	227	7	10	4	12	20
Zuma Beach C	3,757	676	2,566	118	9	109	3	5	2	5	8
Zuma Beach D	2,759	545	1,816	90	7	83	2	4	1	4	6
Zuma Canyon	2 6E+08	5 6E+06	4 8E+09	944,087	64,019	880,068	342,423	14,432	48,117	172,108	587,274
Zuma Bay Villas	1,651	293	672	66	5	60	1	3	1	3	4
Zuma Trailer Park	4,357	732	2,913	136	11	125	3	6	2	6	9
Point Dume	6,965	1,114	5,705	194	15	179	5	8	3	9	15
Malibu Riviera S	3,212	574	1,973	106	8	97	2	5	1	4	7
Malibu Riviera N	8,461	1,321	7,088	234	19	214	6	9	3	11	19
Walnut Canyon	10,980	1,747	11,089	279	23	256	8	11	4	14	23
Paradise Cove	4,476	784	3,073	140	12	128	3	6	2	6	10
Ramirez Canyon	5 3E+06	280,964	3.8E+07	40,091	2,999	37,092	6,507	981	1,468	4,381	11,514
Fouquier	6,765	1,166	5,802	190	16	174	5	8	3	9	14
Escondido Beach	3,944	650	2,278	132	11	120	2	5	1	6	9
Escondido Canyon	1 2E+06	87,493	5 8E+06	12,249	935	11,314	1,413	352	384	1,104	2,629
Escondido Beach E	3,540	683	2,234	116	10	106	2	5	1	5	8
Latigo Canyon	51,159	7,572	105,297	896	75	821	56	39	22	54	102
Corral Beach W	1,150	369	835	41	4	37	1	3	1	1	2
Solstice Canyon	5 2E+06	298,573	3.8E+07	39,055	3,074	35,981	6,867	981	1,468	4,379	11,164
Corral Beach E	1,466	431	1,070	51	4	46	1	3	1	2	3
Corral Canyon	2.2E+06	151,727	1 3E+07	18,428	1,546	17,882	2,831	542	674	1,945	4,681
Puerco Beach	8,846	1,641	9,097	229	20	209	8	10	4	11	18
Puerco Canyon	29,622	4,914	52,699	573	48	525	32	27	13	32	58
Puerco/Amarillo Bch W	746	204	323	32	3	29	0	2	0	1	2
Marie Canyon	22,827	3,879	36,084	470	40	430	23	22	10	26	45
Amarillo Beach E	2,273	533	1,502	77	7	70	2	4	1	3	5
Winter Canyon	6,091	1,296	6,240	164	14	150	6	8	3	8	12
Malibu Creek A	3,864	796	2,860	120	11	109	3	5	2	5	8
Malibu Creek B	1,366	322	672	53	5	49	1	2	1	2	3
Malibu Creek C	2,371	376	861	96	9	87	1	3	1	4	6
Malibu Creek D	15,341	2,443	17,206	365	31	333	13	14	6	19	33
Malibu Colony	2,012	279	533	91	8	82	1	2	0	4	5
Malibu Pier	1,421	322	672	56	5	51	1	2	1	2	3
Sweetwater Canyon	12,511	2,374	16,441	290	25	265	12	14	6	15	25
Carbon Beach W	6,148	1,166	5,287	174	15	159	5	8	3	8	13
Carbon Beach Mdl	1,341	391	915	48	4	43	1	3	1	2	3
Carbon Beach E	1,796	394	928	67	6	61	1	3	1	3	4
Carbon Canyon	1.2E+06	92,976	5 8E+06	11,932	958	10,974	1,491	352	384	1,104	2,549
La Costa Beach	3,463	641	2,019	117	10	106	2	4	1	5	8
Las Flores Canyon	6 9E+06	369,412	5 3E+07	48,885	3,835	45,049	9,075	1,182	1,875	5,683	14,757
Malibu PO	3,087	769	2,706	93	8	85	3	5	2	4	6
Big Rock Beach	9,501	1,607	6,803	251	22	229	7	10	4	12	20
Piedro Gorda Canyon	15,884	3,009	24,021	344	29	315	17	17	7	18	31
Las Tunas Beach W	2,686	657	2,103	85	7	78	2	5	1	4	5
Pena Canyon	21,871	3,879	36,084	447	38	409	23	22	10	24	43
Las Tunas Beach Mdl	1,459	387	901	53	5	48	1	3	1	2	3
Tuna Canyon	83,079	11,193	196,873	1,327	110	1,217	93	55	34	86	166
Las Tunas Beach E	1,171	319	660	45	4	41	1	2	1	2	2

are discussed in Technical Memo 9. The results indicate that in many cases, the predicted increase in load is very small. This is because the developed areas are averaged over an entire in-city catchment, so that the percent increase in impervious area is relatively small. Also, many of the developments in Malibu are of low density, and probably do have relatively little effect on the quality of storm runoff (compared to heavily commercial and industrial areas). In the highly developed small watersheds, however, the percent increases predicted by the model are large. For example, both Los Alisos Canyon East and Malibu Creek C (the service area of the Malibu Colony drain) show increases over 100% for all potential pollutants.

To put the model results in perspective, we calculated the increase in loads for different levels of development in a hypothetical 0.5 square mile catchment with typical Malibu storm characteristics. Table VIII.3 shows the percentage increase in loads for three cases: (1) completely undeveloped, (2) residential development throughout the basin, and (3) high density residential and commercial development throughout the basin. These results show increases of 40 to 60% due to residential development, and 150 to 277% increases due to commercial development.

Table VIII.3
Percentage Increase in Loads for Different Levels of Development

	Percent Increase in Loads					
Percent Imperviousness	COD	TN	TKN	NO3-N	PB	ZN
0 (Undeveloped)	0	0	0	0	0	0
30 (Residential)	42	52	56	52	62	64
80 (Commercial)	156	208	225	206	263	277

The model predictions are for total mean annual load of the various constituents. Even if the percent increase in annual load is relatively small, one cannot conclude that there is no problem. Transient short-term pulses of contamination at the beginning of a storm could be ecologically significant in receiving waters, even if the annual average is only slightly increased. In semi-arid climates, the "first flush" of runoff (defined as that produced by the first 1/2 inch of runoff) carries most of the pollutant load.

Not all of the load that is generated from the landscape necessarily reaches Santa Monica Bay or Malibu Lagoon. Some of it may be stored at least temporarily in channels. The relatively steep topography, however, would not permit much channel retention.

VIII.4 Sediment and the Malibu Coast

Of all the processes that take place in Malibu, movement of sediment plays the largest role in connecting the land to the sea. In Malibu, most of the geology was formed under the sea and much of the rock, by landslides and erosion, is returning to it. Technically expressed, erosion indices relating rainfall energy and sediment production on the land show direct correlation with suspended sediments along the coast. High magnitude floods in erodible basins deliver large volumes of sediment to the coast where materials are sorted out and redistributed by waves and currents. The land provides sediment for beach regeneration but, in excess, can destroy the tidal pools along the coast.

Sediments come from rivers and sea cliff erosion. Prior to human interference with the coastline, the ratio of river to seacliff sediments was about 80:20. Over the last century, the total quantity of sediment from both sources has been reduced. The seacliff contribution to coastal sediments comes mostly from landslides on and above the cliffs and marine erosion at cliff base. Technical Memo 10 gives the details of the undercutting of these bluffs for the construction of the Hueneme, Malibu and Port Los Angeles Railroad (later the Roosevelt Highway and PCH). In the 1920s, 2,600,000 cubic yards (2 million cubic meters) of rock debris were removed from the cliff base from Point Mugu to Santa Monica Canyon for road bed and seaward protection. Twenty groins and more rip-rap using local materials created several seawalls. The net result is a disequilibrium. The shoreline bluffs are armored by PCH, seawalls, revetments and retaining walls and cannot produce beach materials.

The production of sediment from rivers comes from both within and without Malibu. Outside the city, three rivers provided sediment to the ocean that was brought to the Point Sequit to Point Dume beaches by currents. The Ventura and Santa Clara rivers and Calleguas Creek fed the beaches of the Zuma Cell (Chapter II). Because of dams, flood control structures, and gravel mining, Ventura River now contributes less than one-third its natural contribution of sediment to the Zuma Cell. Some of the sediment has been intercepted by Santa Barbara's jetty. The city will need to cast a wide net to protect and manage its upcoast sediment budget.

Within the city, Malibu Creek is the most important contributor of sediment. Since little marine sediment passes east of Point Dume, Malibu Creek was the major source for the beaches from Point Dume to Topanga (the Santa Monica Cell). Sediment production has been reduced drastically because of upstream dams, especially the larger grains such as sands and gravels. The presently non-functional Rindge Dam testifies to the amount of sediment each dam can trap. (The Santa Monica watersheds and smaller basins throughout the city produce only 30 to 50% sands in their sediment. This rest is silt and clay.)

In Malibu, nature is the main governor of sediment production. During droughts it decreases. From the point of view of the beach, there are a few years of plenty (1969, 1978, 1980, and 1983), separated by long periods of relative famine (the 30 years preceding the 1969 floods and the period since 1983). Sediment quantities are also tied to wildfire and large storm events. Following a wildfire, the process of dry ravel delivers fine sediment (up to small gravel in size) to stream channels. Intense and infrequent storms trigger landslides on steep hillslopes with enormous quantities of relatively coarse sediment.

This general starvation of the beaches should not be an excuse for poor land use management. First, the beaches cannot utilize the fine silts and clays which are the major sediments produced by exposed work sites and which overflow dams. It is these "fines" that harm tidal pools and have an unknown impact on the food production of Malibu Lagoon.

Sediment production is greatest during and just after development. Once the development process is complete and landscaping in place, sediment production usually drops, with the exception of sediment production from maintenance.

VIII.5 The Water Quality of Malibu Lagoon

The City of Malibu includes the lower reach of Malibu Creek (approximately 0.9 miles to the beach), Malibu Lagoon (approximately 13 acres), and the nearshore waters. This in-city portion of the Malibu Creek's 105 square-mile watershed is especially important to the city as one of the few remaining tidal estuaries in Los Angeles County, a major migratory bird habitat, fish migration and spawning habitat in the tidal prism, a site designated for the preservation and restoration of various endangered species, and a major focus of water-based recreation, especially surfing and nature study. It passes west of the Serra Retreat development, east of one of the city's major commercial developments, continues under PCH into an embayment surrounded by a park, the Rindge Historic Estate/Museum, Malibu Colony housing development, and a golf course. The creek periodically is trapped behind the world-famous Malibu Beach, a beach visited by thousands each year. Periodically, the embayment opens to the ocean from creek flows or from excavation of the sandbar. The lower creek/lagoon is part of the City of Malibu's largest floodplain area which includes the civic center, an area in which much of the future commercial development of Malibu has been targeted.

This section reviews the literature and adequacy of coverage of water quality problems for Lower Malibu Creek and Malibu Lagoon. However, to address the relative importance of various sources of pollution, the whole watershed must be considered. The major water quality concerns for the embayment area have been pathogens and health risks, nutrients and eutrophication, pH, seasonal salinity gradients, sediment, temperature, and toxic chemicals (organochlorides, heavy metals).

The Malibu Lagoon Stormdrains

The locations of the stormdrains feeding lower Malibu Creek and Malibu Lagoon were mapped in the field, and the contributing area for each drain determined on the 1:7200 aerial photography. Figure VIII.1 shows the locations of the drains. The Malibu Colony Drain deserves special attention. This drain appears on no City or County map, although a manhole cover labels it as belonging to the L.A. County Flood Control District. The drain originates at the corner of Webb Way and Malibu Road. It passes beneath the Bank of America parking lot, and thence east along the northern edge of Malibu Colony, and under the southern edge of the golf course. It terminates in an open box at the southeast corner of the golf course. A weir controls outflow from this box into a 36 inch diameter concrete pipe, which conveys water under an unpaved access road to a channel in the Lagoon. The drain has been observed to carry water at times during summer months, and the discharge from the pipe is malodorous. From field observations, filamentous bacteria characteristic of anaerobic conditions are sometimes present where water flows from the pipe to the Lagoon.

The Civic Center Drain is the largest stormdrain emptying into the Lagoon. It receives runoff from much of the flood plain (Figure VIII.1), as well as the steep hillslopes between the Civic Center and Malibu Canyon Road.

A third pipe, the Cross Creek Drain, drains the area between the Civic Center Drain, PCH and the Lagoon. At present, it receives groundwater that is pumped from Texaco's groundwater contaminant remediation project and conveys that effluent to the Lagoon.

A fourth pipe drains surface runoff from PCH directly to the Lagoon. The pipe outlet is obscured by brush and partially blocked by sediment (not shown).

A 12 inch diameter corrugated metal pipe also enters the lagoon near the footbridge to the beach from the parking lot. This pipe conveys surface runoff from a yard and tennis court in the Colony, and is relatively insignificant.

Nutrients and Water Quality

A major water quality concern is eutrophication, a term commonly applied to algal or planktonic blooms caused by high loads of inorganic nitrogen and phosphorus. Eutrophic embayments can be cultural (man-made) or natural. A major concern for Malibu lagoon is defining the natural seasonal cycle of nutrient loading and the frequency of natural blooms. There are, at present, no standards or goals for the seasonal loading and variation of nutrients for the embayment. There have been no historical reconstructions of Malibu lagoon under "pristine" conditions that address the question of natural vs. cultural algal blooms. Other analogous estuaries need to be compared to Malibu lagoon in order to set these goals.

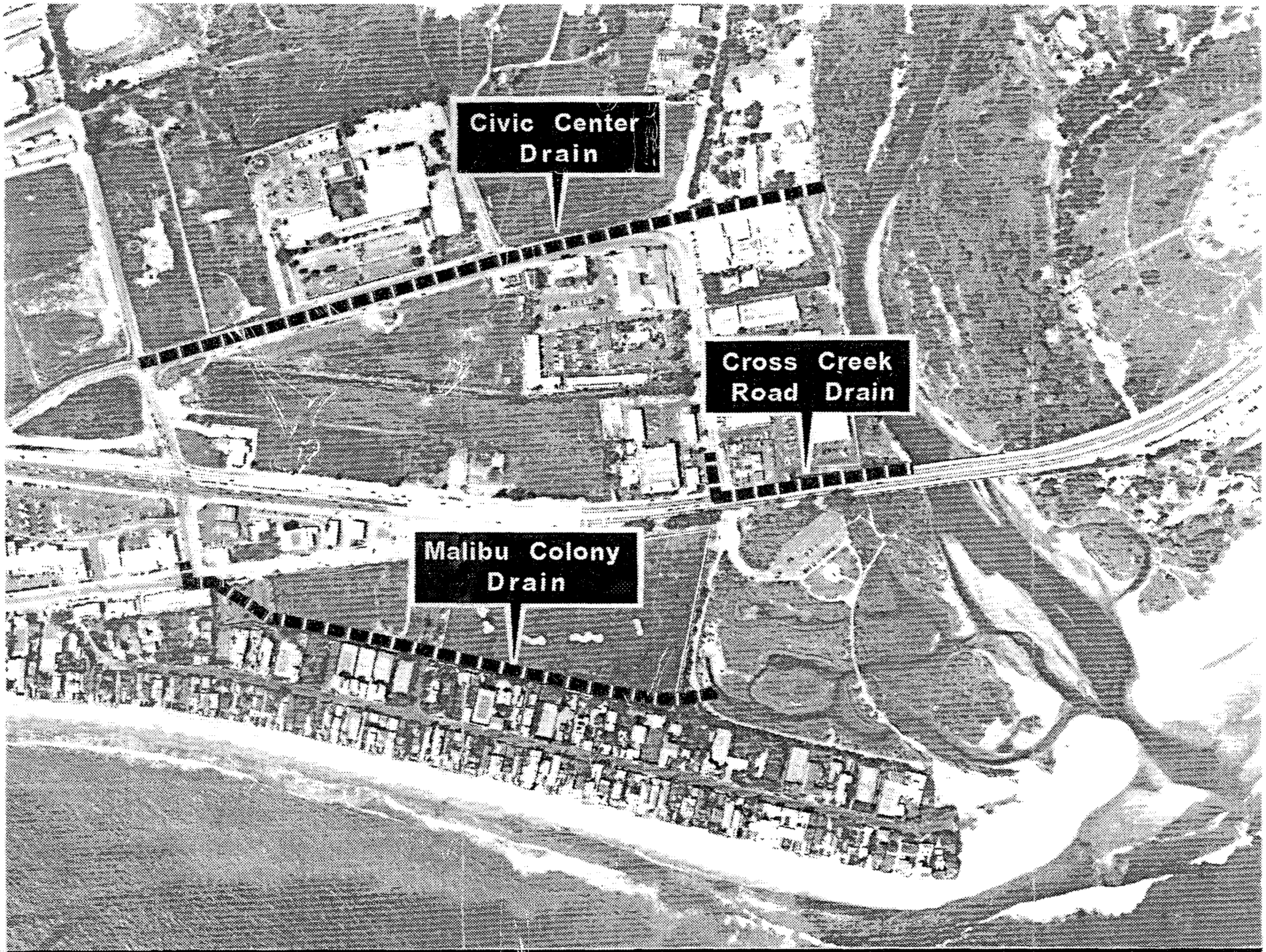


Figure VIII.1: Malibu Lagoon Storm Drains

Nevertheless, some biologists believe that the embayment suffers from an extraordinary number and areal extent of algal blooms (Gearhart and Waller, 1989; Dillingham and Manion, 1989; Harris, 1991). These blooms are considered negative impacts because humans tend to favor clear water over waters that may attain the consistency of thick pea soup. Eutrophic embayments have low dissolved oxygen which, in extreme, can kill fish but more frequently emanate foul odors. Persistent eutrophication can lead to changes in the species composition of plants and animals inhabiting the aquatic system. In some cultures that cultivate fish, this is considered an advantage due to higher productivity and select food harvest. In Malibu Lagoon, this shift is considered negative to the extent that it reduces biological diversity. For instance, the lagoon's erratically high pH is significantly influenced by algal blooms and may be depressing the jacknife clam population.

To reduce algal blooms, the most practical steps include changing the nutrient loading, changing the internal circulation pattern within the lagoon, and changing the flushing pattern (the opening of the sandbar). Along with recording the location and events surrounding each algal bloom, a "nutrient budget" for Malibu Lagoon is the first step in understanding the relative importance of various "deposits, savings, and withdrawals" of nitrogen and phosphorus from the lagoon account. It is an essential step in reducing human-caused eutrophication and returning the lagoon to a frequency and scale of natural eutrophication events. The accounting will be difficult because certain deposits and withdrawals cannot be measured accurately and others have not been measured accurately.

Nitrogen and phosphorous are not necessarily of equal importance in cultural eutrophication. The atom ratio of nitrogen:phosphorus required to sustain non-nutrient-limited phytoplankton growth is considered to be 16:1. For instance, the N:P ratio at the Tapia discharge point during 1990 averaged 6.6:1. The average ratio exceeds 16:1 in the summer. This means a phosphorus limitation is possible during the summer. But, many algae are capable of absorbing phosphorus in excess of their nutritional requirements. This excess phosphorus can be used at times when phosphorus is scarce from environmental sources. Because of this ability of algae to assimilate excess phosphorous, it is probably more practical to focus on nitrogen contributions to the lagoon.

The major sources and sinks of nitrogen and the state of our knowlege concerning them includes the following 8 issues:

1. Natural nitrogen additions to water bodies. Some forms of blue-green algae (Anabeana) do not need nitrogen to bloom. They fix nitrogen. Their presence and impact on lagoon algae blooms is unknown.

2. Natural nitrogen additions and subtractions from the land-based plantlife. Nitrogen is naturally accumulating in the watershed from nitrogen-fixing plants like lupines and alders. Some is stored in the soil and in plant and microbial proteins. Some returns to the air (denitrification). The amount of fixed nitrogen depends on the species, cropping, fire responses, and the percent of the watershed covered by plants. Accumulations can range from 2 to 500 pounds per acre (1 to 250 kgs per hectare). The storage in soil and by plants is an area of massive ignorance for chaparral areas of the southern coast. In brown forest soils, up to 3.5 tons/year can be stored in the top 40 inches. Denitrification (the return to air of gaseous nitrogen) requires high organic pockets that are anaerobic. This is another unknown withdrawal from the watershed account.

3. Airshed (rainfall, smog, fog) contributions of nitrogen. Rainfall contains appreciable concentrations of ammonium and nitrate forms of nitrogen. Nitrate is related to air pollution for automobile exhaust. Concentrations of inorganic nitrogen in Berkeley (1978-79) averaged 0.3 mg/l dissolved inorganic nitrogen (McColl, 1980). (Data are available from the Los Angeles Basin but would exaggerate the actual air quality found in Malibu.) With an average annual precipitation of 18 inches, rainfall would contribute 1.4 kg/ha/yr (0.5 lb/acre/yr). This does not include the smog/fog inclusion. In other areas, with either more lightning or dusts, 4 to 12 pounds nitrogen per acre have been estimated (Winneberger, 1982). For a 105 square mile watershed, this is 39 metric tonnes (17 tons) of inorganic nitrogen. Depending on the amount of hardened surface and plant needs (both unknowns), the amount could be much less entering the creek and still less entering the lagoon. The contribution might be 10% of the total watershed collection or 3.9 metric tonnes (1.7 tons) per year. This is a very preliminary guesstimate of "background" levels.

4. Domestic and natural animal sources: birds, dogs, horses, and fish. The contribution of nitrogen and phosphorus to the lagoon from domestic and wild animals has not been attempted, yet these contributions may be significant in the total nutrient budget. These difficulties arise because fecal nutrient contributions vary (1) with mammal species and some of the species of birds and fish have unknown but large seasonal fecal contributions to the lagoon and creek; (2) with the age, condition, and individuality of each animal; (3) with the food consumed; (4) with the litter used for horses,

Eutrophication: A Complex Phenomena in Malibu Lagoon

Eutrophication is a complex phenomenon. Many factors modify the extent to which nutrients become amplified into plant growth. These include:

(1) Amount of light available to green plants (from the sky, filtered by suspended clays or dissolved coloring matter in the water).
(2) Concentrations and rhythm of supply of nutrients (varying with the nature, location, and frequency of discharges).
(3) Form and depth of the embayment (Malibu Creek and Lagoon have been greatly modified by channelization, flood control projects, bridge and road construction, and sandbar stabilization which impact water circulation).
(4) Temperature of air and in-coming water.
(5) Sedimentation of algae and nutrient-coated clays (turbulence and particle size).
(6) Removal of nutrients and algae to the ocean ("flushing time").
(7) Grazing activities of filter-feeder zooplankton, bottom-dwelling herbivores, and fish (algae reduction).
(8) Parasitism by bacteria, fungi, and other microbes (plant death by disease).
(9) Regeneration of nutrient supply from decomposition of plant and animal remains in water and sediments.
(10) Mixing caused by wind.

A complete study of Malibu Lagoon needs to keep all these influences in mind.

its handling, storage, and disposal. All aspects of the nutrient budget are unknown. For instance, a horse might produce about 9.5 tons of manure (weight of excrement plus weight of bedding) each year. This might include 40 to 90 lbs/horse/year of nitrogen (48 to 110 kg/horse/year). It must be remembered that these numbers are extremely variable. Additional literature and fieldwork to define the magnitude and seasonality of nitrogen and phosphorus inputs from wildlife (especially birds) and domestic animals is required.

5. Human instream and surface sources. Human influences on eutrophication from instream and surface sources include the Tapia discharges (outside of city), the Texaco discharges (in-city), and urban storm runoff (in and out of city limits).

The Tapia discharges are point sources from a direct outfall into the creek and percolation beds. The Tapia discharges have varied widely from season-to-season and year-to-year (Harris, 1991; Gearhart and Waller, 1989). For instance, during 1990, 52.6 metric tonnes of nitrate-nitrogen and 17.7 tons of phosphate-phosphorus were released from the Tapia Water Reclamation Facility at Calabasas. This was a low release year because the Las Virgenes Water District sold all of its discharge for July, August, and September. (In 1986, the total point discharge was on the order of 135 metric tonnes, assuming 4 MGD discharge for the whole year.)

The nitrate-nitrogen reaching the Lagoon is modified by the time of passage to the city (streamflow from all sources); the self-purification abilities of the creek, microbes and plants; and the extent of the sandbar. The amount of nutrient reaching the lagoon requires measurement of the amount of instream and subsurface flow arriving upstream of the Tapia outfall, adding the Tapia discharge, adding any non-Tapia flows below the Tapia outfall, and subtracting concentration losses from stream purification processes. A preliminary calculation estimates that between April and November 1990, the watershed upstream from the Tapia outfall added about 0.6 metric tonnes of nitrogen and 0.2 metric tonnes of phosphorous. As noted, the Tapia outfall added 53 metric tonnes of nitrogen and 18 tonnes of phosphorous. The total reduction of nitrogen load (denitrification, transformation into microbial and plant biomass, deep groundwater losses) below the Tapia discharge point is also unknown. The reduction is not believed to be very large. Concentrations of nitrogen at monitoring stations between the outfall and lagoon do not differ greatly. Based on the above, nearly all the total nitrogen output from Tapia eventually reaches the Lagoon. These calculations need to be made for wet season flows and other years.

In remediating for a gas storage tank leak, **the Texaco Co.** is pumping shallow groundwater from several wells between Cross Creek Road and Malibu Lagoon. This in-stream discharge needs to be made from estimates of water volume, seasonal variations, and nutrient concentrations. No data are available as Texaco does not monitor nitrates.

Urbanization of the Malibu Creek watershed (and, in particular, the floodplain) is increasing the load of nutrients to the lagoon during storms. The nitrogen-compounds accumulated in the soil may be released ("breaking the savings account") by natural soil disturbances (erosion, landslides), natural leaching of the soil, and human-caused disturbances (grading, road building, excessive irrigation, etc.). Part of the accumulated nitrogen will wash from the disturbed soil or travel by underground to the lagoon (see below). No direct data are available to quantify this surface runoff load, but it is possible to make a rough estimate from the literature of contributions from the immediate civic center area.

The estimates of in-city contributions for nitrate-nitrogen load to Malibu Lagoon (Malibu Creek A, B & C) provide an interesting comparison with load estimates from other sources (Table VIII.2). The Driver and Tasker model provides an estimate of mean annual nitrate-nitrogen load of about 0.1 metric tonnes per year from the 3 major drains. The amount of nitrate-nitrogen released by the Tapia Water Reclamation Facility in 1990 was

52.6 metric tonnes. The stormdrains may, however, carry nitrogen to the Lagoon from fertilizer, but the stormwater runoff nutrient contribution appears to be insignificant relative to the Tapia discharge.

6. Septic tank contributions. Septic tank effluents have been thought to influence nutrient loadings in the lagoon, especially during high water levels. These occur when the lagoon fills to above the 3.5 foot level or when the lower creek area floods. Malibu Colony, Serra Retreat, and Cave Creek Plaza, effluent infiltration into stormdrains, and cross-connections to stormdrains have been mentioned as possible nutrient sources.

The total quantity of nitrogen that could be contributed from the Colony is not large. The septic tank system of an average home (3.7 persons per dwelling) contributes about 24 lbs/yr (10.9 kg/yr) of nitrogen to groundwater (Winneberger, 1982). The 10 homes nearest the lagoon could conservatively account for about 109 kg/yr (91 lbs/yr).

7. Other human-related surface or groundwater contributions. Some nutrient contributions may come from sources that, in part, come from subsurface flow and, in part, from surface runoff. These inputs include contributions from fertilizers, horse manure (described above) and pets, and ground disturbances.

Fertilization of lawns and a golf course occurs throughout the Malibu Creek floodplain. A 6.5 acre golf course is located adjacent to the lagoon. The fertilizer application is not known, but 200 lbs/acre/year would not be unusual. The soils underlying the golf course are not known. If they are sandy, we can only guess that half the nitrogen is leached from the soil (Winneberger, 1982). This would add about 0.3 metric tonnes per year from the golf course to the shallow groundwater. Additions from homes in Malibu Cove Colony, Serra Retreat, and other areas of the floodplain cannot be calculated without additional fieldwork.

To determine the output of nutrients from the shallow groundwater, it is necessary to know the direction of flow, concentrations, and amount of flow. There is little available data on this subject. Several wells were at one time drilled near Cross Creek Road to depths of 100 feet or more. Concentrations of nitrate-nitrogen varied from 0 to 13 mg/l (DWR, n.d.). In another study, the hydraulic gradient and elevation of groundwater have been determined by Texaco. But, concentrations of nitrate-nitrogen and hydraulic conductive (K-values) have not been made publicly available. From current literature, estimated values for hydraulic conductivity (K values from 1 to 10 m/day), concentration of nitrates (25 mg/l), and the measured slope of shallow groundwater (0.0016 slope) indicates a rough estimate of 1 to 10 metric tonnes of nitrate-nitrogen per year. The calculation needs to be done with real data.

8. Sediment storage and release. The sediment in the Lagoon is both a source and a sink for nitrogen and phosphorous. The sediment on the bed of the main lagoon comprises mainly small cobble, gravel and sand. Clay and organic matter dominate in the side channels, especially in the restored areas of the lagoon (Manion and Dillingham, ibid.) The fine-grained organic-rich sediment provides a potential source of nutrients to the water column. There is no simple way to estimate exchange of nutrients between sediments and water column. Release of nutrients from sediments may continue for some time even if the nutrient inflows from Malibu Creek are reduced.

Summary: The nitrogen budget for Malibu Lagoon cannot be described because of too many unknowns. These include: additions from blue-green algae, wildlife and domestic animals, disturbed/paved/natural soils in the whole watershed, and the Texaco outfall; soil and biomass storage; fire impacts; losses from soil denitrification; and the sediment/water column interchange. Preliminary estimates show that Malibu Colony septic tank discharges of nutrients are minor. The most important appear to be Tapia discharges, possibly the golf course, and the combined sources from the shallow groundwater of the lower civic center area. How these contributions compare to the unknowns cannot be determined at this time. The location and extent of algal blooms need to be mapped and related to flushing time, berm closure, and the internal circulation of water within the lagoon and in-city portion of the creek.

VIII.6 Health Hazards in the Lower Malibu Creek, Malibu Lagoon, and Nearshore

The number of possible sources of bacterial indicators of health risk in the in-city area of Malibu Creek is enormous. Ducks, shorebirds, upstream contributions from Tapia, in-city stormdrains, cross-connections, horse corrals, vegetation piles, dogs, rodents (rabbits, mice), homeless camps, after-growth blooms, and ocean influxes can all contribute to unwanted microbial life. But, the risk of health hazard is unknown and poorly documented. The reader is referred to the introduction to shoreline health hazards (Chapter IV). There we explain the complications of sorting out indicators from pathogens, minimal infectious doses, exposure, and confounders. The state-of-the-art has huge gaps of knowledge and understanding. In addition, in Malibu Lagoon, widely varying water quality (pH, dissolved oxygen, water temperatures, nutrient loads) means that wide variations in results will be the norm. The discharge and receiving water standards for freshwater cannot be reliably used to assess health risks for estuarine and seawater habitats. The freshwater samples need to be separated carefully from the saltier samples in the presentation of data.

The non-human sources of coliforms, fecal coliforms, and streptococci need emphasis. There are about 100 ducks and coots living near the bridge. In any 1 day, a single duck produces about 5 times the total coliforms and 5 times the fecal coliforms as a human and 300 times the fecal streptococci (Geldreich, 1966; Crane, 1983). The coliform numbers for shorebirds are not well studied. Even in much lower numbers than ducks, the population of terns, gulls, pelicans, and fall migrant shorebirds would easily overwhelm any other source. The increase in coliforms near the creek's connection to the lagoon give added validity to the importance of waterfowl contributions. In addition, horses and dogs contribute roughly equivalent orders of magnitude in coliform, fecal coliform, fecal streptococci, and enterococci.

The lagoon and surfzone water samples for total coliforms, fecal coliforms and enterococcus have been collected weekly by the County, monthly by Tapia Water Reclamation Plant (TWRP), monthly (dry weather only) by Los Angeles County Department of Public Works (LACDPW), Tapia-Las Virgenes Resource Conservation District (TLVRCD) and the Regional Water Quality Control Board. A special summer study by TWRP and the year-long RWQCB study have not been released to the public. The coliform data from the Texaco outfall study is also unavailable to the public. Heal the Bay is collecting human specific viral samples. The frequency and location of any positive virae results will be a vast improvement over bacterial data.

The sampling program to determine health risk in the in-city creek, lagoon, and surfzone is inadequate. The sampling station used by the County is between the lagoon entrance and the pier. This is too far to determine surfzone health risk near the lagoon mouth. TWRP station R-11 has been moved (without change in NPDES permit) and long-term sampling results are not comparable. The County station and DPW overlap for coliforms which is not cost-effective. The samples are rarely coordinated with other biochemical influences such as pH, salinity, water depth, algal blooms, and numbers of birds. These skew the data and have created the extremely wide variability found in the results.

The question is not frequency of sampling but creating a testable hypothesis which the sampling can answer. For instance, short intensive studies on conditions before and after breaching the sandbar would be more important than poorly located samples at widely separated time intervals. There is a definite need to coordinate the multiple agencies and private organizations so that financial resources can be conserved and monitoring data mutually contribute to greater understanding of the health risk situation.

There is no strong evidence for health risk. There has been no cohort study of beach users (surfers, waders, swimmers) comparing it to a more pristine beach (e.g., Leo Carillo). There have been no case history studies in which clinical symptoms are traced to sources. There have been no "before-and-after" studies for sandbar breaching in which the clinical symptoms of disease within the lagoon and nearshore waters have been tracked.

The more indirect studies (i.e., studies that describe potential exposure but not dosages) do not exist or could not be obtained. These include hydraulic gradient, movement of groundwater or stormwater by dye studies, movement of seeded bacterial or viral indicators, and culturing of human specific viruses. It is believed that Texaco has some data on hydraulic gradients but there has been difficulty obtaining well locations and hydraulic conductivity data from them. There have been no studies of shellfish tissues.

This leaves only the weaker studies from the point of view of assessing health risk. Dr. Jeff Harris collected anecdotal evidence from sports shops and talks with life guards. The survey has no frequency data and no particular health risk and no source of the health risk can be implied from this survey without more rigorous sampling.

Dr. Harris (Harris, 3/91) also collected non-random samples from the sediments at various points in Malibu lagoon. It is difficult to draw health risk conclusions from sediment samples. Nevertheless, *Pseudomonas aeruginosa* (a cause of swimmer's ear) and *Citrobacter freudii* (a cause of sinusitis and gastrointestinal illnesses) have been found. All the other bacteria found could be non-pathogenic members of a larger group of bacteria. Dr. Harris has shown that two pathogens are present and others could be present. But, no risk can be assessed from these observations.

In summary, there is a need for better coordination among the monitors of in-city health risks associated with the lower creek, lagoon, and nearshore waters. The studies no longer need to be general surveys but very specific and carefully designed to discover sources of bacterial and viral pollution. The major difficulty is separating out non-human contributions from human sources. Because non-human sources will overwhelm coliform, fecal coliform, fecal streptococci, and enterococci counts, these tests are not cost-effective. The highest priority study would track human-specific bacterial and viral pollutants and clinical disease frequencies before and after sandbar breaching.

Salinity. Release of Tapia effluent, the frequent closure of the Lagoon entrance and stormdrain contributions are the major human-related hydraulic factors affecting the salinity of Malibu Lagoon. Low salinity contributes to bacterial growth and stressed alkalinity (i.e., high pH, lower salinity, increased primary productivity). These high and very irregular fluxes of freshwater from Tapia and perhaps some local sources, in turn harm various species and create an unnatural salinity gradient for the marsh/lagoon. The freshwater inputs during the summer and fall months are particularly contrary to natural seasonal fluxes. A sudden breach of the sand barrier can also result in a total loss of juvenile steelhead, prematurely exposed to high salinities. Other impacts on the food web, especially of food available to migratory birds, have not been studied.

There is little work (Soltz, 1986) on proper salinities, tidal prism, and lenses of freshwater for Malibu lagoon. Water standards for "indicator" or preferred species need to be analyzed. The shock loading of artificial breaching needs to be studied as it impacts fish within the lagoon. These studies are beyond the scope of this report. To manage salinity levels will require a joint powers agreement with Tapia or a revision of the NPDES permit and cooperation with various agencies on beach breaching.

Sediment. The sediment samples taken off Malibu Lagoon show sediment types which are finer than most other sample points (Gearheart and Waller, 1989). This could be a result of entrapment of larger particles by upstream dams. The metals associated with these sediments have shown higher values than other parts of the bay. There is some indication that these are transported to the Malibu shelf from other outfalls and creeksheds. This concern is outside the scope of our work. Nevertheless, stormwater drainage should be occasionally tested for metals.

The sediment input to Malibu Lagoon is of concern for species distribution and productivity. Different types of substrate support different species complexes. This distribution has not been studied for the Lagoon or related to sediment inputs from the creek. The sediment inputs to the lagoon are dominated by highly episodic events which are influenced by storm magnitude, fire, and exposed surface. Fires accelerate the input of finer sediment to the stream channel. The fate of fine sediment depends on the opening or closure of the Lagoon. Closure may temporarily increase cloudiness and sedimentation. Extreme storm events may generate large debris flows (Florsheim, et al., 1991). Since 1925, all the large debris generated above Rindge Dam has been trapped. Fine sediment from disturbed surfaces, transported in urban runoff, has not been measured in Malibu. They include slope sloughing, landslides, grading, dirt roads, and debris piles.

Other water quality parameters. Concerns include changes in the temperature of Lagoon waters from out-of-city waters (Tapia), in-city contributions of oil and grease, heavy metals, and pesticides. EPA's water quality data base (STORET) indicate occasional and sporadic spikes of pesticides and heavy metals in the lagoon, but persistent levels have not been indicated. UCLA's report will hopefully contribute to our knowledge of these parameters from stormwater runoff.

VIII.7 Conclusions

The goals of a storm runoff program for Malibu are to reduce pollutant loadings to Santa Monica Bay from runoff (including stormdrains), to prevent degradation of the marine ecosystems, to minimize risk to human health, and to protect the beaches. In Malibu, the general goals can be implemented through the following measures:

(1) An ordinance to manage runoff and sediment production and prevent discharge of contaminated runoff. This ordinance would include goals set by "water quality zones" and surrounding buffer zones with standards for the percent of impervious surface allowed within the zone, percent of total runoff allowed from any particular parcel, receiving water standards, discharge standards for particular stormdrains, and requirements for recycling and/or disposal of oils/grease, trash/debris, and hazardous wastes. For instance, Malibu Lagoon and Lower Creek would have a set of standards that differ from Zuma Creek or Winter Canyon.

(2) A series of joint-powers agreements with upstream users to do their part in reaching the receiving water standards and help mitigate beach losses.

(3) An educational pamphlet on best management practices to retain or retard runoff and sediment with incentives such as reduced building permit fees for those who follow or improve upon practices.

(4) A catch-basin cleanup schedule that applies to all four jurisdictional owners of stormdrains within Malibu.

In particular, the following tasks appear to be of highest priority within the city:

--The establishment of receiving water standards for the Creek and Lagoon will inform dischargers what treatment levels they need to accomplish. The priority water quality standards required are seasonal salinity and nitrates. Once standards are set, they can be incorporated into service area land uses, discussions of stormwater management in Malibu Colony, and the possibility of an overflow pipe to regulate lagoon levels (Chapter IX).

--The use of wetlands for urban runoff water quality control has gained considerable attention in recent years (Stockdale, 1991). At Malibu Lagoon, an opportunity exists to create a small designed wetland to receive the first flush and "nuisance" water from the Malibu Colony drain and, with considerably more investment, a small wetland to receive and treat stormwater from the Civic Center drain.

-- A joint agreement with Texaco or revision of NPDES permit to monitor water levels and nitrates.

-- A thorough study of the nitrogen budget of the lagoon with particular attention to upstream sources of nitrates from Tapia and NPDES requirements.

-- A joint agreement with Tapia to time releases and volumes to meet salinity needs of the Lagoon.

-- Determination of the responsibility for the Lagoon stormdrain with careful study of contributors.

-- Mapping of areal extent and magnitude of algal blooms within the Lagoon. Goal: correlation with water quality, depth and form of Lagoon, and water circulation within and in-and-out of Lagoon. The configuration of the Lagoon and its circulation are one of the many factors creating wide variation in monitoring data. A study of circulation patterns and salinity, water temperature and pH would be useful for background understanding of bacterial survival, viral sources, and nitrates. The ultimate goal is the best hydraulic circulation pattern, breaching management, and water quality for humans and Lagoon species.

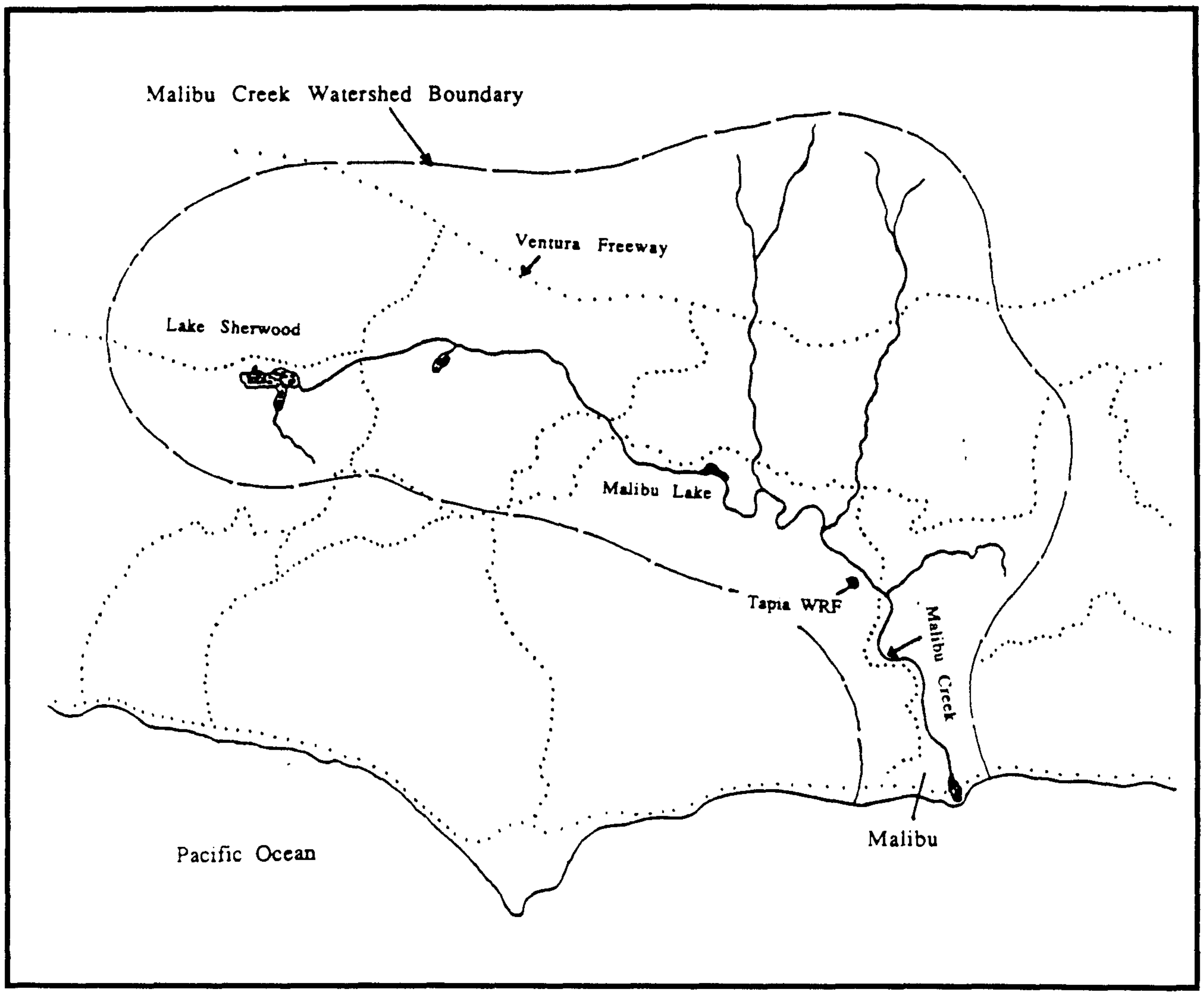
-- Consideration of the removal of Rindge Dam in order to restore natural flow regimes and sediment production to the Lagoon and adjacent beaches.

-- Should human specific viral samples show significant risks, an epidemiological study (a cohort study or a follow-up case history study) of waders, surfers, swimmers, and non-water contact beach goers before and after the opening of the Lagoon.

-- If bacterialogical samples continue, coordination of bacterial sampling with other water quality parameters and a joint meeting with all monitors to ensure more cost-effective and better designed monitoring program. Intensive monitoring at breaching events would be informative.

-- If Texaco data appear suggestive, a single year study of groundwater movement and quality inputs from the Malibu floodplain. Piezometers should be placed along 2 transects across the hydraulic gradient. Water levels measured periodically and samples of nitrate, ammonium, and pathogens collected.

-- If the UCLA study indicates the need, a statistical review should be conducted of STORET water quality data pertaining to Lagoon nutrients, heavy metals, pesticides, salinity, etc. The goal is relating concentrations to discharge data and creation of a history of water quality changes, land use developments, and the discharges of treated wastewater from upstream sources.



The Malibu Creek Watershed sends good news or bad news to the city by way of Malibu Creek. Managing potential nonpoint sources of pollution, sediment for beach replenishment, and Tapia discharges of will require long-term upstream/downstream cooperation.

CHAPTER IX: SUBAREAS OF CONCERN

Malibu's wastewater management goals and policies are in a transition period. Many homeowners and commercial enterprises need to know the direction of city planning before they will make long-term investments for sustainable on-site practices. Many are worried that they will find themselves in a double financial jeopardy: paying for an upgraded on-site system and then an off-site sewer. Many commercial owners want to be clear on future zoning before they commit themselves to a particular style of wastewater management. They do not like the poor practices that presently give them maintenance costs and headaches, but they have never been presented with the opportunity to design and install a better management system.

During our survey, certain areas appeared to have greater difficulty with decision-making than others. This chapter describes some of their options. But, because of confidentiality conditions, in certain cases, we cannot go into details. In other cases, we are limited because of other pending studies (e.g.,the Bing Yen study on Big Rock). In still others, the on-site solution would be easy, if the subarea remained at approximately the same population density and wastewater loading. If major density or remodel changes will occur, then some sort of collection system may be warranted. Since the general plan that sets zoning and remodelling conditions has not been written and we were instructed to look only at existing conditions, we can only give tentative scenarios for many subareas. In effect, much of this chapter is premature. It requires a resolution of County/City disputes, the creation of a city administrative structure to review and regulate on-site systems, and a clear land use plan for the future. Then and only then will property owners feel comfortable making the financial investments required for superior on-site waste management.

IX.1 Approach to Subarea Wastewater Management

This chapter has four basic approaches:

-- handle the situation on-site with improved practices or
-- have a small decentralized sewage treatment plant and disposal/reuse site or
-- connect to an existing plant or
-- find a neighborhood parcel that a group of property owners are willing to share for treatment and/or disposal.

In addition, area-wide consideration should be given to:

- -- water conservation as a method of reducing wastewater loadings;
- -- reuse systems, especially for irrigation of landscapes, as ways of both reducing deep percolation of effluent into unstable hillslopes, and increasing the longevity of the existing drainfield;
- -- surface runoff diversions away from particular drainfields;
- -- groundwater diversions to lower water tables in particular instances;
- -- special design considerations for paved over areas;
- -- use of pre-treatment systems on specific lots (Chapter XI);
- -- custom-designed renovations that decrease wastewater loads for new commercial systems;
- -- additional actions, unrelated to wastewater management, in slide areas but integrated with it (see below);

In short, Dr. Winneberger stated that there was no inland site that he reviewed that could not remain on an on-site system. Since beachfront systems could be completely replaced on site, these systems (with few exceptions) are a matter of cost and access, not impossibility. It was generally agreed that all systems in all areas need upgraded design, installation, and management practices. The difficult areas are high density commercial.

IX.2 Paradise Cove

Note: We would like to thank Mr. Harry Lee Kissler for allowing us to print the following information about a private development.

Location: At the mouth of Ramirez Canyon. Figure IX.1

General: Paradise Cove has 32 on-site systems and drainfields with varying numbers of units (three to twelve) per drainfield. The area is 76 acres. There are separate laundry rooms, though a few mobile homes may have their own washing machines. Paradise Cove also includes the Sandcastle Restaurant which has its own system including grease traps. There is an "overflow" system on the flat areas to the west which is used for problem tanks or seepage pits. Usually units are pumped about twice a year with about five trips per month to Hyperion to discharge septage.

Aerial photo shows Paradise Cove (the area below the main road which is PCH). Condominiums north of PCH are separate from Paradise Cove. Near pier is restaurant on its on on site system In upper left is overflow system used to dispose of carted septage and effluent. Ramirez Canyon creek flows through subdivision. Open areas on both sides of mobile home parks can be used for a small treatment plant.

Figure IX.1: Paradise Cove

Paradise Cove is one of the subareas in a state of transition. The ownership of the land or part of the land or facilities on the land may be changing. The future land use practices and zoning may be changing. The ownership, financial and maintenance responsibilities for the existing on-site systems may be changing.

Reasons for inclusion as a subarea of concern: Paradise Cove has changed from seasonal to year-round use. The number of persons per mobile home and the water using fixtures (e.g., some washing machines) within mobile homes have increased. In 1964, there were seventy units with ten permanent residents. Now, there are about 292 units with about 10 non resident homes. The volumes of wastewater have increased and the soils have had shorter, if non-existent, periods to re-aerate. The codes have changed.

Where septic tanks and drainfields could be under mobile homes in the past, County regulations now prohibit these sites. This has cramped the available space for seepage pit installation. Some pits are pumped and carted to a large "overflow" drainfield on the property which has septic tanks and additional seepage pits. While absolutely no health hazard can be documented, the need to pump seepage pits indicates that some of the on-site systems are marginal in that the soil cannot assimilate the wastewater loads. There have been concerns that the groundwater is elevating (despite the drought) and interfering with on-site drainfields. Two reasons have been offered: (1) The long-term understanding that since water has been imported, irrigation water no longer comes from local wells and the effluent is adding to the recovering groundwater table. (2) The condominiums on the north side of PCH are recharging the groundwater table. (The lower part of Paradise Cove is in the Ramirez Canyon floodplain.)

Options: There is no reason why Paradise Cove cannot handle all its wastewater on the acreage available. This can be done by a package or preferably a custom-designed plant, continued cartage, upgraded "neighborhood" systems with greywater recycling, water conservation, irrigation reuse or/and rejuvenation of wells. At this time, the present owner is not interested in inclusion of the condominiums across PCH or other private land owners in any wastewater arrangements. The groundwater situation needs further consideration within the wastewater design process.

IX.3 Point Dume Highlands and Plaza

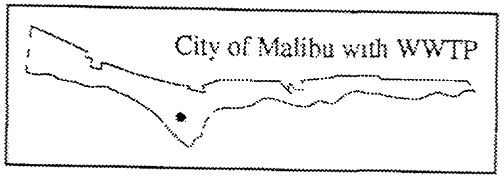
Note: Because of confidentiality promises, this discussion is kept on a general level.

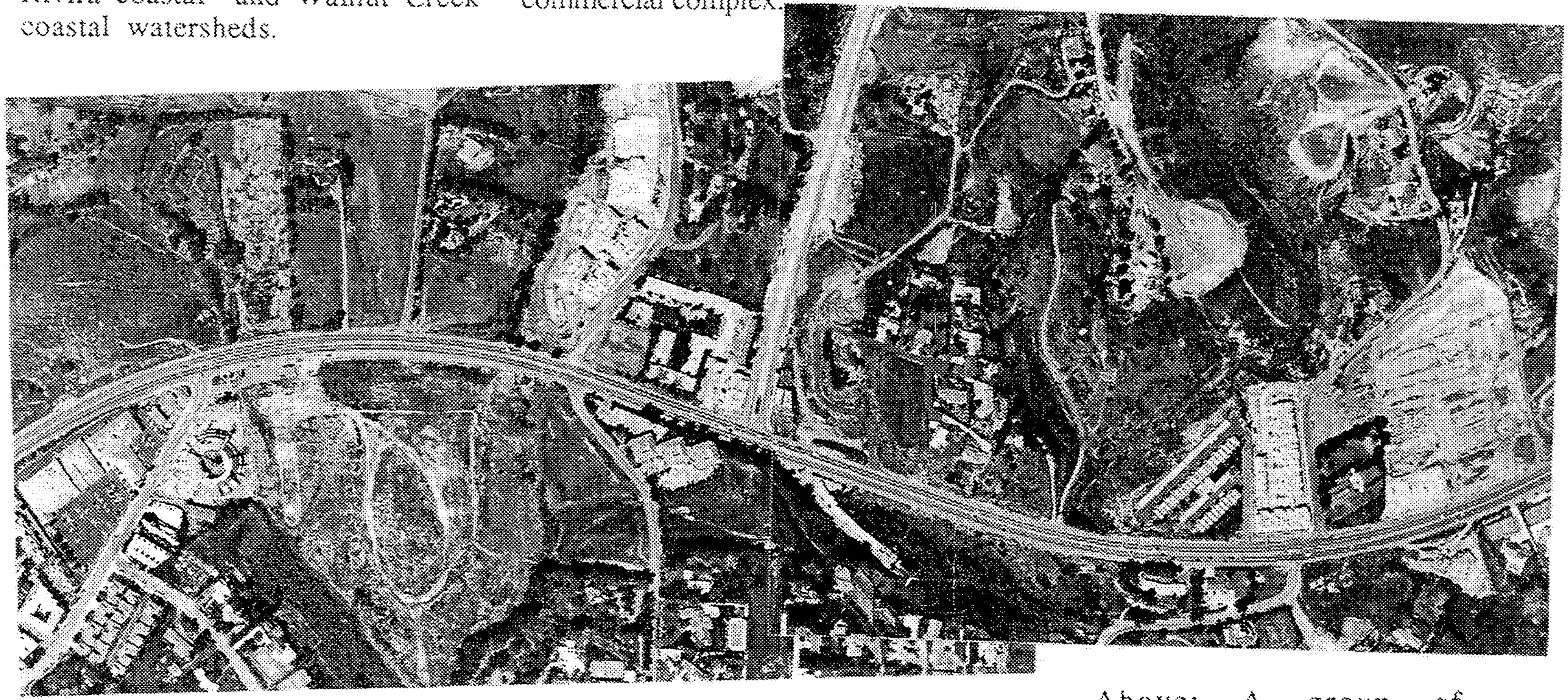
Location: Figure IX.2. There is no easily defined area. The Point Dume Plaza and amenable condominium developments shown in the area are included for this discussion.

General: This area is the secondary commercial and population hub of the city. With the number of condominium developments and commercial developments, it is the west end's equivalent to the Civic Center hub. There is a need to consider future densities and plan for any off-site sewerage at an early stage (i.e., before land and reuse possibilities disappear).

Aerial photos of the ill-defined Point Dume Highlands area. Major road is PCH. To the left and downhill is Zuma Creek wetlands (not shown), an area propsed for wetland restoration. Area includes Malibu Rivira coastal and Walnut Creek coastal watersheds.

Below: A series of condominium complexes and. south of PCH. a small commercial complex.





Triangular area is Point Dume shopping plaza. Across street are commercial complex and a dense series of resdiential buildings. Open areas are available for neighborhood systems and park reuse.

Above: A group of condominium complexes built and under construction.

Figure IX.2: Point Dume Highlands Subarea

Reasons for inclusion: In addition to future densities, various condominium complexes have marginally operative wastewater management. Particular condominiums either have leased or are attempting to lease additional land for effluent disposal, or have daily or weekly cartage because of soil overloading, or partial water conservation practices directed toward reducing wastewater loads. The costs of operations and maintenance are high. There is no surfacing effluent and no health problems because of cartage. The cause of these problems is similar in all cases: poor design and installation with full County and Coastal Commission approval. In one case, the total number of seepage pits allegedly dug have never been re-located. The soils and geology work were obviously inadequate. Much of the area is on Monterey Shale which is variably transmissive. There are locales where transmissivity changes drastically in five feet. The type of geotechnical work to assure the assimilation of effluent in this type of bedrock is expensive and appears to have been incomplete. There was no consideration of pre-treatment or raising the level of treatment to a quality that could be reused either for subsurface irrigation or surface irrigation. Some of the systems are under-designed for peak loading. Given the recurrent costs and headaches of operations and maintenance, some of the condominiums may be open to a new solution.

Options: At this early stage, the inclusion of this area is a strong indication for the General Plan update to include wastewater planning in the area. A series of open meetings with local condominium and commercial owners is required.

Scenario 1: Keep practices as they are. The advantages are that those who are having problems are paying for them directly. The disadvantages include the costs to condominium owners and the inevitable marginality of the sewage system (see Chapter X on pumping management and regulatory powers).

Scenario 2: Try to improve practices on each site. Although some attempt has been made in this direction, the various condominium owners have been without the state-of-the-art advice. A water conservation audit, a study of reuse possibilities, the use of pre-treatment devices, and perhaps the experimental use of some of the newer small treatment devices (e.g., Thetford Corp or Memcor) could be considered.

Scenario 3: A subarea sewer. Should a number of condominium developments wish to join a subarea sewer, there is the possibility of also adding the commercial development around Point Dume Plaza. There is still adequate land within the subarea, especially for a combination park and a no discharge sewerage system. In addition, the Zuma Creek wetlands can be fed by gravity from a treatment facility and have been suggested by the Coastal Commission for a wetland restoration program.

Major questions need to be answered:

-- Can the subarea sewer also include a treatment plant for the city's septage (see the next chapter)? This would spread some of the costs as all city parcels with on-site systems could help pay for the land dedicated to city-wide uses and that part of the system used for septage treatment and reuse. This has been done, for instance, in Bolinas, California. The result should be lowered pumping costs for all on-site systems as the transport distance and time would be enormously reduced. The reuse of septage and green waste compost can be used in erosion control and costs can be partially offset by compost sales.

-- Does the city wish to become a proprietor of a small treatment facility or simply remain as a regulatory body (Chapter XI)? If they do not wish to own a facility, who would become the owner and operator?

-- Can an agreement with the Point Dume plant be made to handle part of the wastewater flow with return line for disposal and reuse in other areas (analogous to Tapia/Pepperdine agreement)?

-- What regulatory control should the city assert for situations requiring permanent cartage or use of leased property for disposal?

IX.4 Landslide Areas

This section addresses the major inhabited and larger slides within the city (Table IX.1). Given the amount of unknown information about each slide, PEWARA has tried to make our assumptions very explicit. In this way, those that disagree can do so on specific identifiable data or issues. The complete description of methods can be found in Technical Memo 4. Basically, whenever it was possible to err on the side of an increased landslide risk, we did so. In other words, we tried to picture "worst case" situations in which septic tank effluent would be most predominant. If a house ambiguously contributed to a slide, we assigned its effluent as contributing. We calculated densities at the time of the slide so that now abandoned houses counted in the density ratings. We compared human vs. natural sources (column 9), listed other slope destabilizers (column 10), researched the stability of the type of bedrock (column 11) but assumed that dewatering would continue in those areas in which it now exists.

TABLE IX.1 THE IMPACT OF

Slide Name	Acres	Houses[1]			Houses[2] Discharging Effluent		Water Loads[3]		
		H	E	D	Number	Density	Effluent Irrig.	Natural Grndwtr	Human v Nat.[4]
Las Tunas Beach (2 slides)	26/15	11	32		8	0.30	L	M	L
Big Rock Mesa + extension	220	147 60 (ext)	61	8		0.94 0.98	M	L (M)	H (E)
Eagle Pass	25	20		2	20	0.80	M	Lo	H
Rambla Pacifico	18	2	4	10	20 (12)	1.25 (0.75)	H(M)	M	H/E
Calle de Barco	9	6	8		20	2.2	H	M	H/E
Carbon Mesa (17 slides)	45 comb	8	12	1	26 (25)	0.60( )	M(L)	L/M	E
Carbon Cnyn	60	6	0	0	9	0.15	L (M)	L	E/H
Malibu Road Amarillo Bch	40	6	71	0	6	0.15	L	H	L
Puerco Bch (5 mapped slides)	40	22	52 on beach	2-3	22	0.55	L	H	L
Corral Beach (RV Park slide)	36	RVs + office	7	0	10	1.38	L	M	L
Latigo Shore	9	12	16	0	12	1.33	H	H	E
Latigo Canyon	10	0	0	0	4?	0.40	L	L	LE
Malibu Cove Colony (Escondido shore slide)	8	15	3	0	12	1.5	H	H	H/E
Lower Encinal Canyon slide complex	120	0	0	0	0	0	O	H	O
Lachusa Highlands	140	53	14 below PCH	1	53	0.38	L	H	L

1: H=houses on slide; E=endangered houses adjacent (above, beside, below); D=damaged, destroyed or condemned houses. Source: aerial photos (3/91).

2: Houses on the upper part of the slide and houses adjacent but off slide mass. Houses in lower parts of slide not included. House just across drainage divide may be counted twice. Number is subject to a better understanding of groundwater movement. House number is projected to the time when slide moved. "( )" for existing houses.

3: H=high water loads; M=medium; L=low; O=no water load. Effluent/Irrigation is considered low (0-0.6 houses/acre); medium (0.6-1.2 houses/acre); high (1.2-2.2 houses/acre). Assumes equal wastewater loadings and irrigation intensity on all parcels. Natural groundwater is considered "low" when slide occurs along a relatively narrow ridge with deep canyons on both sides (i.e., inflow from highlands and impermeable rocks should be low). Natural groundwater is "high" when slide mass is backed by uninterrupted highlands. It is higher when coastal terrace deposits cap local bedrock. Faults, folds and fractures make these estimates preliminary.

4: Relative importance of natural vs human contribution of water to slide mass. H=human more important; E=human and natural about equivalent; L=human less than natural. "LE" or "HE"=equivalence with high or low ratings.

5: Destabilizers include: U=undercutting of toe by road cuts or under-compacted benches may cause additional shallow sliding; C=undercutting by creek or other natural force; B=toe-of-slide at or below sea level (marine erosion and/or saturation).

ON-SITE SYSTEMS ON LANDSLIDES

Other Destabilizers 5	Bedrock 6	In-Place Mitigation 7				Importance Off-Site Sewers 8	Notes
		W	D	O	S		
B	Kt,Tt,Tcob,Qt					None	
B	Ts,Tv,Tt,Ti,QLs	18	30			Small	Assumes dewatering.
C	Kt,Tcc,Qtm,af					Small	Sensitive slide plane
C, U	Tc,QLs	6		23		Small to none	Assumes dewatering. Bing Yen study
U	Tc,af	6	7	9	70	Small	Assumes dewatering.
C	Tr,Tco,Tc,af					None to small	Localized instabilities.
C	Tc,Tv					Small	
B	Tm,Tz,Tr,Qtm,af	30		6		None	
B, U	Tr,Tz,Tm,Qtm,af	7	16			None	
B?	Tm,Tr,Tz,Qt,af					None	
B	Tr,Tm,Qtm	6-10				Small to medium	Dewatering ineffective. Includes some north of PCH homes.
C	Ttue	2-4				None	Some homes outside city limits. Dewatering for road.
U,B ?	Tr,Tm,Qtm,af					Small	
None	Tv,Tmz,QLs					None	
?	TtLs,Tmz,af,db, QLs					None	Consider dewatering

6: Bedrock. Kt (Tuna Canyon Fm); Tt (Topanga Fm); Tcob (Conejo Volcanics); QLs (Quaternary landslide debris); af (artificial fill); Tc (Calabasas Fm); Tm (Monterey Fm); Tr (Trancas Fm); Qtm (Quaternary marine terraces); Ttue (upper Topanga Fm); db (instrusive diabase).

7: W=dewatering wells; D=horizontal drains; O=monitoring (e.g., piezometers); S=structural re-enforcement. Source: Bing Yen (Letter, 10/91).

8: Based on source and size of water loads, other destabilizers and bedrock type. Assumes dewatering continues.

Slide Reference Numbers in Figure III.1: Las Tunas Beach (T 21, 31); Big Rock Mesa (T 1, 2); Eagle Pass (MB 97); Rambla, Pacifico (MB 95); Calle de Barco (MB 94); Carbon Mesa (MB 74-90); Carbon Canyon (MB 91); Amarillo Beach (MB 50); Puerco Beach (MB 36-41); Corral Beach (MB 3); Latigo Shore (PD 87); Latigo Canyon (PD 64); Malibu Cove Colony (PD 83+); Lower Encinal Canyon (TP 15+, PD 1); Lachusa Highlands (TP 11-14). USGS Maps: T=Topanga quad; MB=Malibu Beach quad; PD=Point Dume quad; TP=Triunfo Pass quad.

The main focus of the table is the water budget within a particular slide. This is the concern of on-site system management. Other concerns are as important (buttressing, recompacting) but are not part of this report. The table compares an approximation of the relative inputs of artificial recharge vs. naturally recharged waters. The artificial recharge is estimated by a count of extant homes on, or directly adjacent to, the slide mass, divided by the acreage of the slide mass, assuming about 250 gpd of effluent discharge per household. Except for Rambla Pacifico, it does not include differences in irrigation recharge nor differences in surface runoff recharge that might result from housing development.

The relative natural recharge of groundwater within the slide mass is more difficult to gage given existing data. The relative amounts have been estimated by a topographic-based argument and the geologic connection of the slide mass to uninterrupted highlands, the presence or absence of deep canyons, and the presence or lack of blanket deposits of Marine or "spongy" fluvial terrace deposits that can transmit infiltrated waters toward the coast. The Table does not include an analysis of perched water tables which may cause local slippage such as the Brown house on the Rambla Pacifico slide. In other words, homes that might move from an internal reconfiguration of the slide or at the edge of a scarp or toe are considered endangered but the influence of the water budget on their stability cannot be determined without additional fieldwork.

The next to the last column shows that off-site sewering would have no impact on the Las Tunas, Carbon Canyon, Amarillo Beach, Corral Beach, Latigo Canyon, Lower Encinal, and Lechusa Highland slides. Assuming dewatering continues, sewering Big Rock Mesa and extension, Calle de Barco and Puerco beach will have small to negligible impact on the safety factor. The impact of sewering on Eagle Pass, Rambla, Pacifico (some dewatering), Carbon Mesa, and Malibu Cove Colony would also be small. That is, no engineer, agency or tax assessor is likely to change the safety factor or value of the land with installation of an off-site sewer that would guarantee an acceptable standard of public safety. The impact on Latigo Shore could be significant but the situation needs more study. The dewatering system there seems ineffective. An effective dewatering system is needed at Latigo Shore as we believe there is substantial natural groundwater compared with effluent.

In short, the installation of sewers by themselves does not appear to provide much benefit within the city. *Increased safety would still require other technical interventions.* Homeowners within specific slide areas may want to remove septic tank effluent as an option to potentially decrease frequency and magnitude of sliding. It cannot hurt to do so.

But, the need for a large, centralized treatment plant to accomplish these subarea choices is not demonstrated. In fact, given the numbers of slides the conveyance system will have to cross, it may be asking for high maintenance costs and sewer pipe breakages. We provide a few examples of particular slides with possible scenarios.

Example 1: Rambla Pacifico

The Rambla Pacifico slide (Figure IX.3) is actually an 18-acre slide mass with three recorded shear zones on a steep, east-facing slope above Las Flores Creek. It has been studied by Bing Yen (1991) for the purposes of increasing slope stability and restoring a road.

There are only two houses left on the slide. Eight houses have been completely destroyed. One residence is severely damaged. Parts of Rambla Pacifico road have been completely destroyed. The lobes of the slide have continued to move, even during the drought years of the 1980s. The slide has reduced the channel capacity of Las Flores Creek and increased the chances for destructive flooding to creek-bottom homes. The report lists 21 houses contributing artificial recharge to the slide in 1980; 12 houses in 1990. Ten are not directly on the slide.

The Bing Yen report redflags the following concerns in landslide stability:

-- reactivation of pre-existing slide plane failures;
-- exceptionally high rainfall, especially after a series of high rainfall years;
-- the undercutting of the slope and removal of slide debris by Las Flores Creek;
-- infiltration of surface runoff;
-- slope angle;
-- roadcuts that were cleared of debris and caused local steepening (e.g., the Brown house slide);
-- earthquake events;
-- artificial recharge from irrigation waters, and
-- artificial recharge from on-site disposal systems.

The report emphasizes the overwhelming importance of consecutive years of heavy rainfall which elevates the groundwater and increases submersion of the shear zones. Bing Yen suggests that subsurface flow takes three years to traverse the slide. Rainfall is the

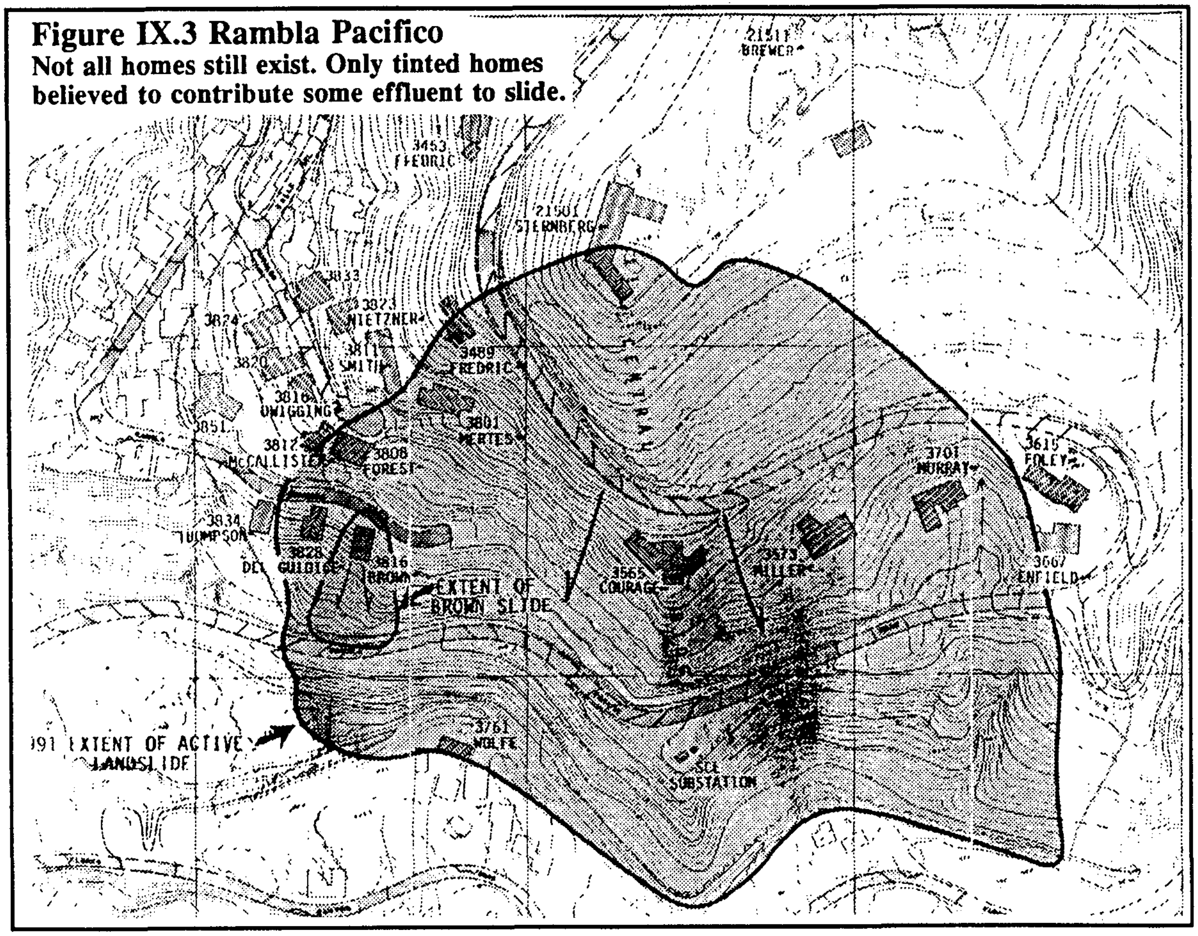


Figure IX.3 Rambla Pacifico
Not all homes still exist. Only tinted homes believed to contribute some effluent to slide.

only possible contributor to the shallow slides with perched watertables because septic tank effluent enters the slide mass below the slide plane.

The possible interventions suggested by Bing Yen include buttressing the slope, channelizing Las Flores Creek, managing surface runoff to reduce infiltration, passive hydraugers to dewater the slide mass, removal and recompacting part of the slide mass, and off-site sewering. The only changes in safety factor provided are for buttressing, retaining walls, and partial channelization of Las Flores Creek. No increase in safety factor associated with off-site sewering and reduction of surface runoff was provided. Conspicuously missing from the possible interventions are intense water conservation to reduce indoor and outdoor contributions to the groundwater table, and on-site designs that maximize the reuse of wastewater for irrigation and disposal of wastewater by evapotranspiration.

From conversations with Bing Yen (Glen Toffani, p.c.), the slide would continue moving even if all the water were drained from the slide. Therefore, the crucial intervention must be buttressing to stop the slide movement.

The most cost effective reductions in groundwater levels come from water conservation and surface runoff management. After the installation of buttresses to prevent ground deformation, then passive dewatering of all types of groundwater (effluent, irrigation, natural) is the most cost effective on a per home basis. The Bing Yen report explicitly states "the most feasible means of controlling groundwater levels would appear to be thru implementation of surface drainage improvements and installation of horizontal drains..." Sewerage with long conveyance lines is considered a fourth level priority in terms of cost and benefits because it only prevents effluent recharge, not irrigation nor natural recharge. Any installation before buttressing encounters the same problems as dewatering lines -- frequent breakage. The Rambla Pacifico slide has well-documented cases of utilities breakages. We would not recommend any sewer laterals for a centralized or local sewerage system until this stabilization is accomplished.

The overall importance of septic tank effluent to the slide's groundwater is difficult to determine. First, both natural and artificial recharge leads to a non-uniform distribution of groundwater. For instance, the north lobe of the slide has three or four uphill homes that might contribute some artificial recharge. The north lobe appears somewhat independent of the denser housing recharge area above the south lobe. Second, the report contained no data directly addressing how many feet of elevation of the groundwater table were caused by artificial recharge. Bing Yen (Toffani, p.c.) felt that artificial recharge of 2 MGY and a three year retention time elevated the water table a maximum of twenty to thirty feet which decreased the safety factor by 10 to 15%. Since artificial recharge is half septic effluent and half excess irrigation water, off-site sewering might lower the groundwater level by 10 to 15 feet and the increase the safety factor by a maximum of 7.5%. This needs to be verified by more detailed analysis because the report uses some unexplained data (e.g., contributing watershed area, three different artificial recharge quantities, no 1990 water use data) which would significantly change the relative importance of septic tank effluent. A detailed review of these data is beyond the scope of this report. But, PEWARA feels that the groundwater levels and safety factor influences are maximal and could reasonably be considered half of those reported. That is, off-site sewering might lower the groundwater table only 5 feet and change the safety factor by less than 3.5%.

In Rambla Pacifico, the majority of homes that may contribute to the slide's groundwater receive no benefit to themselves by off-site sewering because they are not located on or directly adjacent to the slide mass. To involve them in sewer financing with no obvious benefits raises questions of equity. On the other hand, the implementation of an intense water conservation and reuse program can begin immediately at relatively little cost for all twelve homes. Intense water conservation requires a home owner organization willing to help homes off the slide, police water use records for compliance, and set up a meter or alarm-system for early detection of water line breaks. In addition, increased management of the surface runoff can also be installed immediately without great cost and without waiting for the buttressing project.

The above summary is of crucial importance to homeowners on the slide, in homes safe from the slide but contributing artificial recharge to the slide, for homes at the toe of the slide and within the Las Flores Creek floodplain, and homes cut off from a short route to Malibu. They must decide if off-site sewers provide a reasonable increase in safety to the two homes on the slide, the homes at the toe of the slope, and the homes impacted by continued slide movement into the creek. Given limited funding, what is the best choice of expenditure?

Scenario 1: Intense Water Conservation. Given the area's high water usage (Appendix H in Bing Yen, 1991), the cheapest and most practical intervention is an intense water conservation and reuse program with monitoring. This alternative addresses the equity question. Homes off the slide would not be levied high costs for allegedly contributing to groundwater levels within the slide mass. For much lower capital and operations cost, 50% of the indoor flows could be reduced for all homes possibly contributing to the slide mass. Timed irrigation with line-emitters and greywater reuse would reduce summer irrigation. Assuming accurate analysis, the stated gains within the Bing Yen report do not require off-site sewering.

Scenario 2: Water Conservation plus recycling systems. For those homes that might contribute to a perched water table or the two homes located within the slide mass, a site specific design for a shallow, recycling system and irrigation system for combined wastewater (black and grey) would effectively eliminate any significant artificial recharge. This alternative would eliminate the possibility of pipe breakages from local surficial deformation and could be implemented before the buttresses or retaining walls have been built. Not all homes will need this extensive a conversion of their on-site systems.

Example 2: Big Rock Mesa

A number of exhaustive technical reports are written on the area, including Evans (1986), Michael (1988) and references therein, Bing Yen and Assoc (1991). *The Bing Yen final geotechnical report for the 1987-1991 time period was not released in time to include results in this report.*

The Big Rock Mesa slide complex is the largest recognized landslide in the city. Its slide plane is generally planar and it is classified as a translational slump. The slide mass is now known to have a long period of prehistoric development. At least six episodes of prehistoric (pre-twentieth century) slide movement are mapped. The multiple flat areas on the slide where most homes have been situated are eroded old slides from multiple prehistoric sliding events. Clearly, the slide mass contains several, perhaps many, extant and fossil coalescing slide surfaces buried in the hillside. Several north-plunging faults (Los Flores faults of Yerkes and Campbell) seem to define the aerial shape of much of the main slide mass. Its toe is thought to be virtually at the beachline, not extending offshore. Resistant volcanic rocks that exist under shallow sand just offshore are thought to impede the slide by buttressing and to force the toe end upward as the mass moves seaward; thus PCH and environs are seen to periodically raise slightly.

The slide mass with monitored slide movement contains 147 homes, and endangers another 60 in a newly suspected "western extension" area, and another 65 structures along PCH below the slide mass. Movement of the slide following heavy rains in 1983 initiated the current level of interest, but earlier movements had been noted (1972). During the late 1980s, new structural cracks on the northwest corner of the slide appear to be defining a new potential problem area that is called the "western extension" of the slide. Additional cracking has been noted in the western slide as of November 1991.

Big Rock supports a medium density of homes. They are distributed in the head scarp area, the main mesa or near the bluffs. Each position has different safety factors and contributes different percentages of artificial recharge (irrgation and septic tank effluent) to the slide mass. The total contribution to the slide mass of effluent (house density) is medium compared to such places as Latigo Shore or Rambla Pacifico. Compared to estimates of natural sources of groundwater, human water inputs may be comparable to Eagle Pass. Nevertheless, the natural groundwater inflow to the mesa has never been directly measured, and is an unknown in water budget calculations. Similarly, the transmissivity of the slide planes itself is not well understood. Even though the current sliding episode was triggered by 1983 rains, and an earlier smaller one possibly by early 1970s heavy rains, the current hypothesis for slide instability is what the County calls "excess groundwater" due to irrigation and drainfield effluent. Evidence for this includes a previous 1800 year-long period of apparent slide stability. But, the situation is not clear as this area supported a water company until the 1960s and the amount of human-derived water actually encountering the slide plane is not easily calculated. For instance, the number and discharges of seeps and springs from lateral flows is not known.

Extensive geotechnical work since 1965 has been aimed at stabilizing sliding by dewatering the slide mass using dewatering wells, horizontal drains, and channelized runoff, with results monitored by laser surveying along PCH and various kinds of implanted movement indicators. It is instructive to look at dewatering data reported by Evans and Bing Yen Associates. Total dewatering rates (output of wells plus horizontal drains) have decreased from an all-time high rate of 300,000 gpd for a brief time in late 1984, to about 100,000 gpd in late 1986-early 1987, down to about 50,000 gpd for most of 1991. However, peak summertime water use and low wintertime water use by homeowners have both increased overall by about 25-30% during the years 1985-1990, as gaged by master water meter readings. Likely, this is because of the protracted drought since 1984, and perhaps some increased infiltration because of overwatering. Michael (1988) suggests in a water budget calculation that a long-term dewatering rate of about 30 acre feet per year (27,000 gpd) is minimally necessary to achieve long-term hillslope equilibrium, assuming 1988 water use practices in effect. He also calculates that in 1988, deep percolation below the root zone of irrigation on the mesa accounts for nearly 38 af/yr (34,000 g/d) of infiltrated water and deep percolation of septic tank effluent at about 30,000 gpd (500 people X 60 gpd each). The irrigation assumes the postulated ET rate for the area. The septic tank rate assumes no ET. Infiltrated rainfall may be about 20% of total rainfall (0.2 X 15, or 3 inches/yr), and would also theoretically average about 30,000 gpd. Each of these additions to groundwater in itself is near equal to the equilibrium dewatering rate. We are not particularly comfortable with these numbers. Bing Yen will produce a new set in the next few weeks. The alternative scenarios may be modified depending on their results or our analysis of their results.

Scenario 1: Dewatering only. This appears the most practical technical intervention. It is in part in place and paid for and requires no conveyance systems, special treatment and disposal processes. It removes irrigation recharge, rain and surface runoff recharge, and natural groundwater inflows as well as on-site effluent. The dewatering appears effective and could be somewhat increased at a smaller cost than a off-site sewage system. Its effectiveness in wet years needs to be monitored.

Scenario 2: Dewatering plus regulated water conservation and reuse management. While no detailed study is available, it is easy to cut interior water use 10 to 20% and thus reduce deep percolation from the seepage pits. More intense water conservation (Chapter XI and Technical Memo 11) could decrease wastewater loads by 40%. The use of greywater systems with near surface irrigation would reduce both the amount of deeply percolated irrigated water and wastewater loading. In summer months, there is no reason to assume that a 70% or greater wastewater loading reduction could not be achieved with careful planning and management (Chapter III). Proper irrigation management could effectively reduce deep percolation from lawns, exotic shrubbery and trees by 60% or more. At that point that about half the septic tank effluent and about half the deep percolation from irrigation has been eliminated, the purpose of a sewer becomes very questionable as long as dewatering continues. This scenario requires the Big Rock homeowners to monitor water use and reuse practices and to include water use/reuse regulations on property deeds.

Scenario 3: Dewatering plus conversion of septic tank systems to recycling systems. This much more aggressive action would not only work on conservation of water but would rehabilitate the existing seepage pits. The deep-seated pits (those below the root zone) would remain as an emergency overflow devices. But, intermittent sand filters with either a UV attachment for surface irrigation, pressure dosing to shallow trenches, or line-emitters for near surface irrigation would be part of the technical interventions. If desired, winter time effluent or treated greywater could be stored for summertime fire protection either on the property or for neighborhoods. This scenario would require the establishment of a management program and careful description of options and costs for individual parcels. It relies heavily on high-quality micro-management. It would effectively eliminate the need for an off-site sewer probably at lower capital costs and definitely at lower operations costs.

Scenario 4: Dewatering plus a Big Rock sewer. This scenario allows for a conveyance system for just the Big Rock area (one hundred fifty plus homes). The conveyance system has the same difficulties as all the pipelines running around Big Rock.

The choice between septic tank effluent pump sewers, small diameter grade sewers or vacuum sewers is premature at this time. The treatment system is not the obstacle. A recirculating sand filter with disinfection could fit into a space of about 150 feet by 150 feet. The obstacle is local disposal. Here, the options include (1) a disposal bed on the beachfront which would require a combination purchase for public open space and a high quality subsurface disposal area; (2) a creek outfall to any of a number of canyons and creeks; (3) near surface irrigation reuse on publicly purchased green areas; or (4) near surface irrigation reuse on private land in agreement with the nearby Las Tunas area landowners. There is also a potential site for a treatment plant at Las Tunas.

Scenario 5: Dewatering plus a sewage conveyance system out of city limits. The sewering of Big Rock with a sewer running east to Topanga has two possibilities for treatment and disposal: (1) in Topanga; (2) at Hyperion. Both alternatives would probably include the homes along the extreme east end of PCH in order to make the project economical. Besides identifying that lands in Topanga exist and some property owners might be interested, no pre-feasibility study was attempted. The connection to Hyperion was originally the County's suggestion (Montgomery, 1986). Careful assessment of Hyperion capacity would be required.

Example 3: Puerco Beach -- the Westernmost Slides of Old Malibu Road

Western Puerco Beach slide contains 22 homes on the slide and a total of 52 homes possibly endangered. Most of these homes are along the beach above or near the toe of the slide. Two to three houses have already been destroyed. The density of houses relative to the size of the slide is medium and the natural groundwater input is considered high (see Table IX.1, footnote 3). For wastewater planning, there are really two rows of houses at issue. The lowest row are beach houses below Malibu Road . They cannot hydraulically contribute any significant effluent to the slide plane. Another row of house sits above Malibu Road on a moderately steep slope. Access to these upper homes is along a road between the homes and a 40 foot bench composed of artificial fill. PCH sits on the top of this bench. The upper houses themselves are partially situated on artificial fill. As mentioned in Chapter III, this situation of unstable slopes and artificial fill is commonly associated with slides.

In 1944, an aerial photo shows that slides already existed in this exact area. Cut-and-fill and unstable benches could only contribute to an already pre-existing condition.

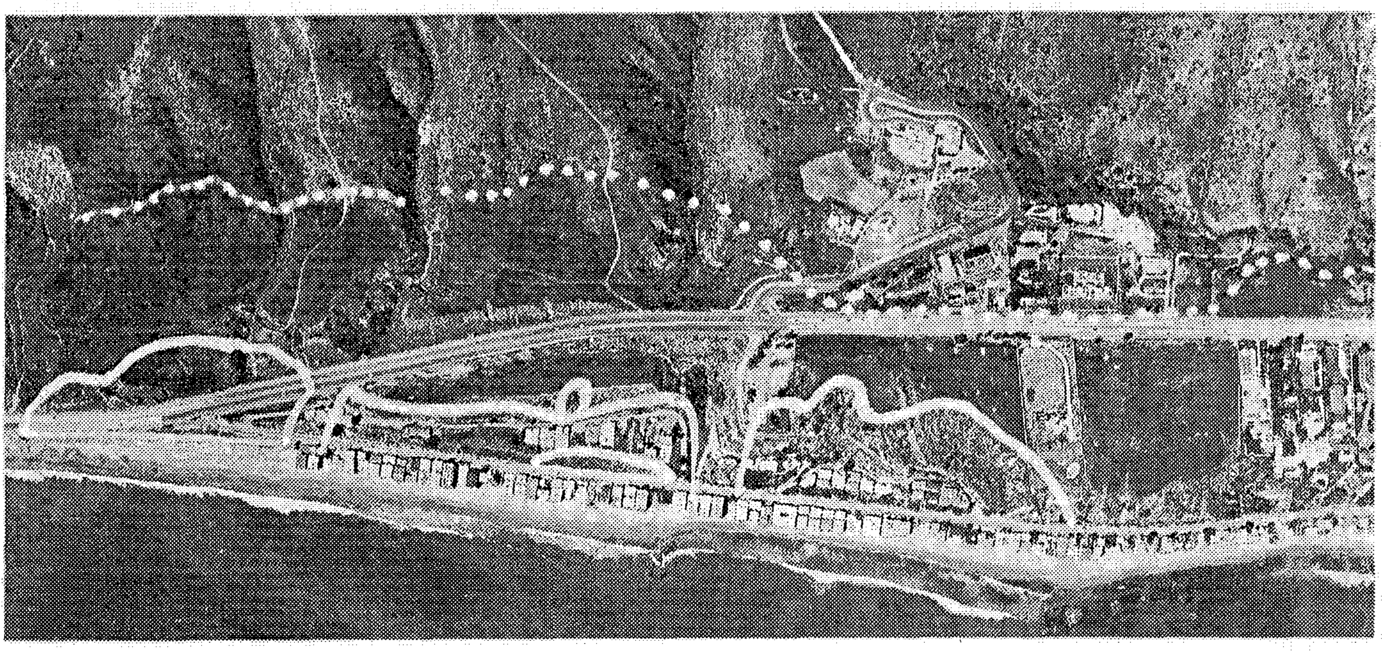


Figure IX.4 The Puerco Beach Slide Complex.

Dotted line shows the border of the terrace deposits -- considered a major source of groundwater to the Puerco Beach slide complex. Three major slides and two smaller slides in the central slide are shown.

By 1960, law suits about house cracking had begun. By 1985, the County had installed dewatering wells and horizontal drains in an attempt to stabilize the slope and bench.

Along this stretch of the beach, there is a continuous stretch of very transmissive marine terrace deposits that lie as a spongy blanket directly north and above the slide that, in all likelihood, effectively conducts water to the basal shear zone (Figure IX.4).

Superficially, the upper row of houses could be called the culprits in the recent slides. The slide headscarp runs through a line about where seepage pits and foundations occur. But, this would be superficial. The renewed cracking is now occurring above the row of twelve houses and, given the probable uphill groundwater contributions, the deeper (marine influenced?) slide plane(s), the infiltration from runoff from PCH and other impervious surfaces, and the artificial fill, these twelve homes cannot be singled out as the major cause.

Scenario: strict management of wastewater quantities and irrigation could help make the slide less unstable but **the crucial needs are an improved dewatering system** to intercept the downhill flows and a review of the stormwater runoff, impervious surfaces, and cohesive strength of the artificial fill. A collector sewer appears irrelevant.

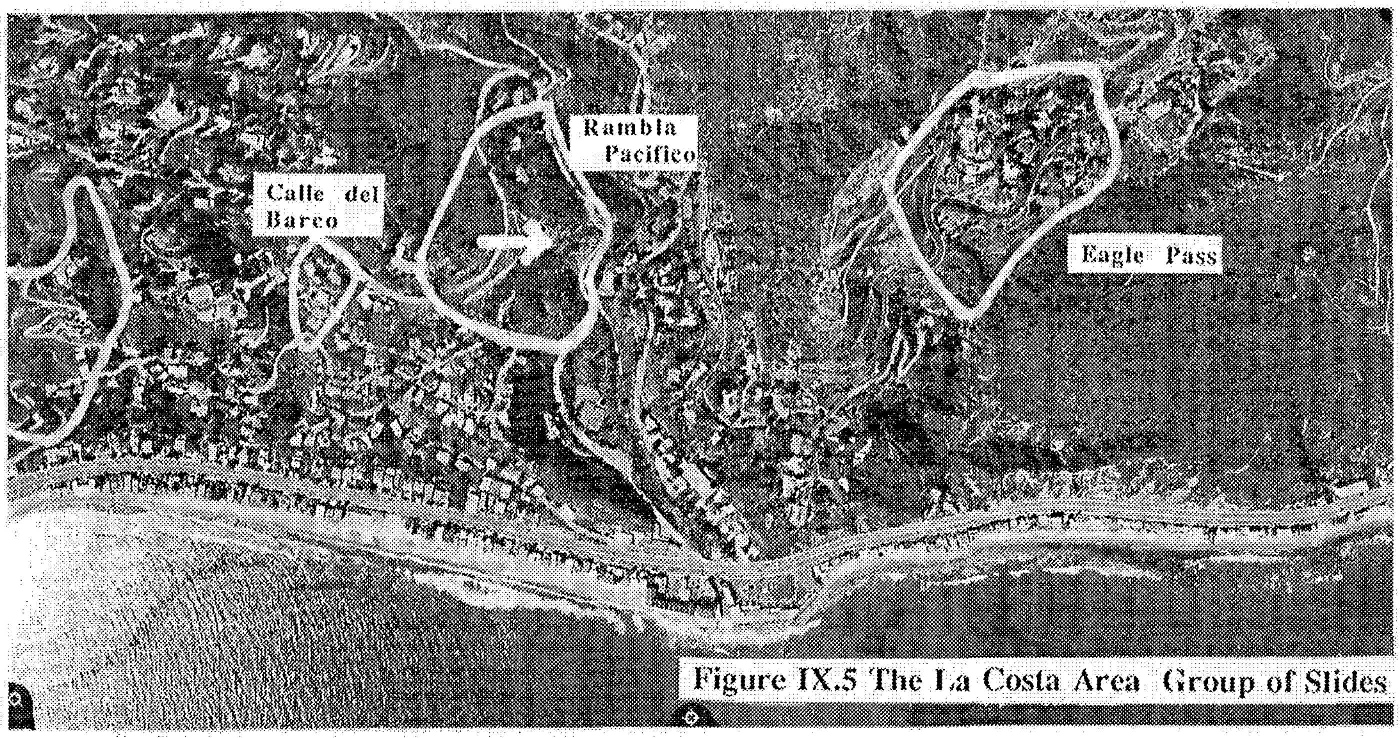


Figure IX.5 The La Costa Area Group of Slides

Example 4: Calle del Barco

The Calle del Barco area lies along a headland of a small, steep-walled canyon that joins Santa Monica Bay about 1,200 feet south of the trouble area (Figures IX.5 and IX.6). Slopes in the canyon vary from 28 to 50%. These slopes have been cut away for roads so that many are over-steepened. Even without septic tank effluent, Calle del Barco is red flagged as risky; steep slopes, cut away roadbanks, slide prone bedrock, ancient slide debris, some natural groundwater, and a large percentage of impervious surfaces that increase the storm flood peaks and erosive power. The Calle del Barco area is a landslide superimposed on an older landslide (s) developed on extreme slide prone Calabasas rock.

Calle del Barco slide (in the narrow sense) is about 9 acres with only six houses (Figure IX.5). But, houses contributing to groundwater houses could number as high as 22. If all these homes do contribute wastewater effluent, this would be the highest density contributions to a defined slide mass in Malibu. The Calle del Barco subdivision began in the 1930s. By 1978, a stabilization district was formed. Seventy deep caissons were sunk to try to hold the slide mass in place. One of the concrete retaining walls has seven hydraugers. Six dewatering wells are scattered throughout the neighborhood. The area has been plagued by mishaps.

In the 1979-80 storms, an unstable, poorly buttressed slope slumped into the feeder road (Rambla Vista) and closed one lane of the road. It has not been reopened. In 1980, a

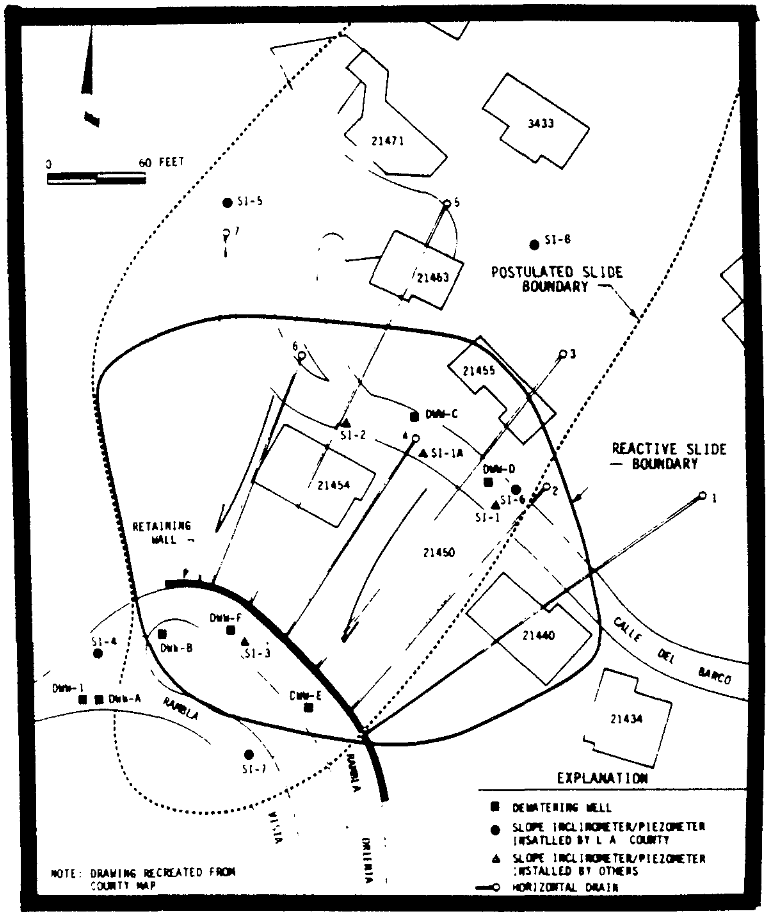


Figure IX.6 Calle del Barco (From Bing Yen, 1991)

clogged storm drain diverted additional runoff into the canyon which, overloaded from rains and runoff from impervious surfaces, cut the slope causing soil and trees to slump into the canyon. When fixing the slope, seepage was noticed percolating downslope at the base of the soil. Traced backwards, the seepage came from a broken water main. There is a high equivalence of human and natural contributions to the slide mass (see Table IX.1).

Given all these influences, there remains the question of how much sewering could actually reduce risks. The first understanding is that buttressing and dewatering should be the priority technical interventions. The assertion that dewatering should probably be reviewed, a topic beyond the scope of this report. That dewatering <u>plus</u> sewering would increase the safety factor of properties within the Calle del Barco area (especially with the likelihood and recurrent history of pipe breakages, washouts and electric failures) is doubtful. Should subsequent studies change this evaluation, very careful consideration should be given to the conveyance system and the choice between vacuum, small diameter sewers, and STEP systems.

Scenario: Intense water conservation program to reduce effluent contribution by 40% or more. Formation of a homeowners group for landslide to monitor water use. Inclusion on deed of water conservation requirement. Consideration of greywater reuse systems in irrigated areas.

In summary, the use of off-site sewering to benefit home stability and stabilize home values appears doubtful. Other technological interventions seem more appropriate. Water conservation, water reuse, and re-design of on-site systems appears to be the most cost-effective approach. Dewatering makes more sense in that it removes all sources of deep percolated and subsurface water, not just disposed effluent. Dewatering and surface runoff management more clearly address the goal of lowering the groundwater table. To be effective, the implementation of a water conservation and reuse program will require a neighborhood monitoring program supported by the city's enforcement authority.

IX.5 The Civic Center Area

NOTE: Confidentiality clauses have somewhat limited the discussions of existing on-site systems.

Location: Figure IX.7. The "Civic Center" area has been defined and re-defined by many agencies and organizations. It always includes the complete "flats" from the alluvial flats on the east side of Malibu Creek to the bluffs that separate Malibu Creek from Marie Canyon and south to Malibu Road. Sometimes it includes the highlands (e.g., the Hughes Research Center), sometimes Malibu Colony, and sometimes an extension area toward the pier.

General: PEWARA's contractual scope of work was limited to existing conditions. In the Civic Center area, there are about 52 footprints for structures. But, the majority of the land remains open and is owned by a relatively few larger owners. Of all the subareas, this area is the most premature to discuss. Its future has not been shaped and many changes of direction could occur. There are over thirty agencies involved with the planning process and land use priorities are still under early scrutiny.

There is the usual engineering caveat that engineers are supposed to find the best design for a prescribed series of zoning designations and their accompanying wastewater loadings. In the case of the Civic Center, this is not the case. At least some of the proposed sewage treatment designs will influence the location and shape of the zoning. They need to

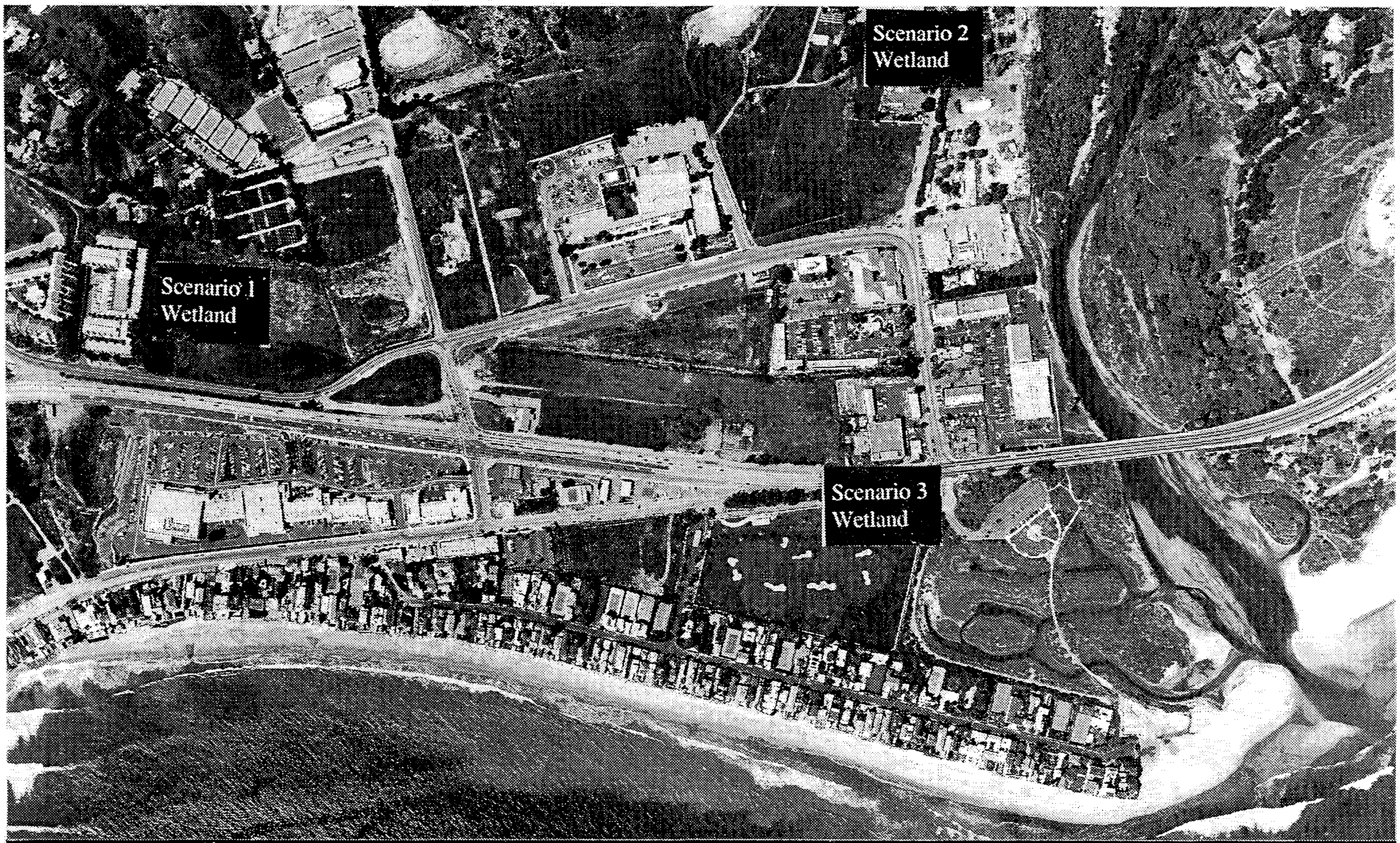


Figure IX.5: Constructed Wetland Options for the Civic Center Subarea be considered along with the land use planning, not after it. The main reason for this side-by-side discussion is the desire to treat and/or polish with constructed wetland systems and the need to integrate wetland systems into the recreational, traffic (especially pedestrian traffic), stormwater, and commercial goals of the General Plan Task Force, lower Malibu Creek and Malibu Lagoon. To this end, we have included "ideas for thought." They are based on our discussions with a highly diverse group of individuals and, even then, we were unable to meet with some with whom we wanted to share our thoughts. At this stage, PEWARA has no strong preferences among the ideas presented.

Reasons for Inclusion: Besides becoming the commercial, governmental and recreational hub of the city, the Malibu delta has certain ecological characteristics that need to be considered in wastewater treatment. These are the high groundwater levels that occur toward the beach end of the delta; the highly varied depth to groundwater depending on season and consecutive years of drought or rainfall; the destroyed nature of the many of the upper soils which have been replaced by artificial fill; the relatively permeable loams, sandy loams and clay loams underlying the area; the problem of seismic liquefaction that will influence the construction of any structures, especially below ground pump stations; the extent of the floodplains as defined by LA County, the Federal Emergency Management Agency, and historical photos and documents; and the requirements of Malibu Lagoon as a central location for recreational activity and biological diversity.

The need for a subarea sewer is not yet obvious. If no more increase in wastewater loads occurred, the on-site or neighborhood option would remain strong. Only when the final land use plan is apparent can the final choice be made. But, given previous plans and the water table in the lower areas, there would minimally be a need to pump some of the effluent to communal drainfields or neighborhood sized systems. In fact, this is already in process.

Subarea Collector Sewerage and Constructed Wetlands

This section presents three scenarios for a collection-type conveyance system with a treatment plant attached to a multiple-use constructed wetland. The treatment plant is not any obstacle at this scale. It could be confined to an area about 150 by 150 feet (not including maintenance buildings and driveways), such as recirculating gravel or sand filters. We would not recommend a package plant. The major obstacle is reuse and seasonal disposal through the marsh system. The other obstacle is acquiring the land necessary for a constructed wetland and obtaining permits for reuse and constructed wetland treatment from regulatory bodies. While northern California has three coastal constructed wetlands involved in sewage treatment, southern California has little knowledge or experience with them. Before giving the scenarios, we list the assumptions behind our choices and some of the obvious concerns:

-- There are no receiving water quality standards set for Malibu Lagoon and the lower creek. Setting these standards is the first step in defining the nature of the treatment process and the ability of any treated effluent to return to the creek for beneficial purposes. The lack of receiving water standards will confuse any future wastewater planning for the Civic Center area that considers a fall, winter, or spring discharge to Malibu Creek or Lagoon. The standards may require a standard for the "breached" vs. closed sandpit and a standard for out-going vs. in-going tide.

-- The quantities of effluent produced are also crucial and depend of the final definition of the Civic Center area. Smaller quantities can be more easily recycled. If they also follow stricter water conservation methods, more facilities can use a treatment plant. A nursery, the Hughes Plaza, the Civic Center, and street landscaping all could reuse treated wastewater. In summer months, there should be a no discharge system to Malibu Creek (total reuse) if this will help restore its natural flow regime. This requires a certain amount of land without impervious surfaces that is zoned to be landscaped and accept treated effluent. In winter or transition periods, the major in-stream and in-lagoon water quality concerns are erratic acceleration and deceleration of temperature and salinity from discharges.

-- Any discharge must meet the highest standards of bacteriological and viral counts because of human uses. The use of chlorine is discouraged because of organochloride production and toxic impacts on fish. The use of ozone and the more difficult use of UV (requiring < 2 NTU, turbidity units) would be encouraged.

-- The intermediate or final form of treatment would include constructed wetlands in order to help increase the viable habitat size of Malibu Lagoon and Creek, possibly restore steelhead or other native fish nurseries, for nature and walking recreation and a more beautiful "downtown" area. The size and species mix of these wetlands will depend on overall intent of land use planning.

-- The ability of the city to discharge even a small volume of effluent in particular months comes into direct conflict with Tapia discharges because they are additive. At the moment, Tapia's discharges are market driven (how much reclaimed water they can sell), not biologically regulated. The size and design of any city sewage treatment facility must reconcile Tapia's direct and indirect discharges with Malibu's.

Scenario 1: Restoration of the 1902 mapped marsh. On a USGS map from 1902, a marsh is apparent right near the present location of Civic Center Way running parallel to PCH (Figure IX.5). This marsh was restudied and determined to have been partially saline. It was probably part of the wetland system of Malibu Creek when its channel was further west than today's. The restoration of this marsh and its use for effluent polishing would require great imagination, technical expertise, and cooperation between property owners and administrators. The goal would be a stream that returned to Malibu Creek and traversed the complete Civic Center providing a walkway, trees, reuse of treated effluent for tree (artificial riparian?) irrigation, and even such additions as a constructed steelhead runway and nurseries. Artificial fish nurseries and fish runs are popular tourist destinations. The treatment plant could be either a renovated Maison de Ville or a separate facility.

Scenario 2: Riparian and wetlands in lower Malibu Creek. The treatment plant and marsh would be upstream on Cross Creek Road on a property presently owned by the Adamson Company. The advantages of this site are the discharge to a freshwater marsh and riparian and a logical extension of wetlands along proposed Malibu Creek trail network. Similar steelhead or other nurseries safe from non-native predatory fish are possible. The location is somewhat uphill from PCH commercials and would require pumping.

Scenario 3: Restoration of Malibu Lagoon from oldest maps. This design is based on reconstruction of the lagoon from oldest maps available. The treatment plant might be located near the entrance to Malibu Colony and the constructed wetland would be an extension of existing restored lagoon. This logical extension would require close negotiations with the owner and major land development swaps and land purchases. It would require the excavation of the present golf course. It could be combined with an increased circulation of tidal waters by creating a salinity adjustment pipe through the colony. This would help restore the saline nature of the original lagoon while maintaining freshwater and saline marsh as part of the polishing treatment. This location would be the most difficult to negotiate but also have the most positive impact on recreation and lagoon restoration. The site is basically gravity fed.

Scenario 4: Connection to Tapia. This scenario does not necessarily include a wetland restoration project. The sewage generated would be pumped to the force main now connecting Pepperdine to the Tapia WWTP. This scenario requires extensive jurisdictional, ownership, discharge permit, and cost negotiations. For instance, Pepperdine owns the force main but Tapia owns the treatment plant; capacity of the force main is perhaps 300,000 gpd; Pepperdine is required to take back as much reclaimed water as it sends to Tapia; Tapia discharges in Malibu Creek; and Tapia will not accept Malibu septage.

IX.6 The Beachfront Subareas

The predominant reason for residential beachfront homes to sewer up was the claim that their effluent created a health hazard to beach visitors. Without this claim, the situation becomes a design question and a question of drainfield protection (costs) for extreme storm events that have about a once in 25-year statistical probability of occurring. The major concerns have been the small size of lots and the custom-designing of technical options to the lot (Chapter XI). Certain coastal areas continually re-appear in these discussions: Malibu Colony, the east end of PCH and, less frequently, Malibu Road and other stretches along PCH. This section addresses our findings on these areas.

Malibu Colony is a very dense series of homes with very high value. There is a tendency to want to maximize the use of each square foot. Drainfields and septic tanks can reduce the amount of square footage converted into living space. Remodels with additional bedrooms or bathrooms or people can overload the existing system and, indirectly, drainfield capacity can become a limit on "vertical" development. In addition, high groundwater plagues certain homes near the lagoon and lenses of "blue clay" can be found in specific locales. In specific instances, access to homes from the beach or inland is difficult because there are no equipment passage ways. A combination of real estate, groundwater and blue-clay concerns were energetically expressed to us during the home-site survey. We were, at times, gracious guests and, at times, unwanted surveyors to various Malibu Colony residents.

The concern for groundwater occurs because of the low elevation above sea level and an extraordinarily poor stormdrain/stormwater drainage system. Small elevational difference and the continuing expansion of impervious and raised building platforms shifts surface runoff to a small number of lots. There are homes with sump pumps that feed various stormdrains during major storm events. PEWARA recommends a thorough evaluation, design and installation of an adequate stormdrain system for the area. The major obstacle is discharge points for the stormdrains. Because of the need to manage salinity in Malibu Lagoon, discharge should be direct to the ocean. The on-site system groundwater concerns may be relieved by these drainage works.

The Colony has been the alleged source of pollution to the Lagoon. As a source of significant nitrates, these claims appear false or terribly exaggerated (Chapter VIII). The drainfields have not been studied for any hydraulic connection to the lagoon. Our survey showed that some of the drainfields were closer to the street (not lagoon) and probably never drain to the lagoon. Our soil bores showed a complex interlayering of clays, silts and sands which historically derived from receding oceans and delta muds. The combination of sands and clays is actually ideal for treatment of potential bacteriological and viral pathogens (Chapter IV). When the lagoon was flooded, it appeared from cursory field observations that the flow was actually away from the lagoon and toward the ocean. Although no hydraulic dye tests have been made, these preliminary investigations indicate that neither nutrient (Chapter VIII) nor pathogen pollutants (Chapter IV) are likely to have their source in Colony drainfields.

The individual problem of blue-clays requires a site-specific design -- typically an intermittent sand filter, water conservation, and specially adapted drainfields. The problem appeared localized and individual and could be a part of Phase 2 considerations for volunteer demonstration systems.

Option 1: Custom-designed on-site systems, curtain drains plus major storm drainage works.

Option 2: Eastern part of Malibu Colony joins to Civic Center sewer. Stormdrains become secondary priority.

The East End beachfront homes along PCH has always be sited as a "worst case" situation because a majority of the systems are old, most lots are small (<1/8 acre), there are two stretches of beach where the mean high water line actually cuts across the toe of the property (about fifteen homes in total); the beaches tend to be cobbly (not sandy); and some of the older homes have never built seawall protections.

There is no real boundary to the "east end of PCH" but it is typically defined as east of Las Flores Canyon Road to the city line. Each of the major beach areas has between sixty (Las Flores) and 105 (Big Rock) homes. Since there are no identifiable health concerns, the choice between off-site and on-site is a choice of costs. Competing costs include (1) the construction of Las Tunas groins which will increase protection and the time of passage between drainfield and possible surfzone emergence of treated effluent; (2) the County assessment for an off-site sewer vs. costs of upgrading on-site systems over the next twenty years; and (3) the parcel-by-parcel assessment of bulkhead requirements with either on-site or the proposed sewer. The County requires a bulkhead for any septic tank damaged by storms, including STEP system septic tanks.

Many residents of this area have been waiting to receive final directions: If there will be a sewer, they do not want to upgrade their system. In other words, they are postponing repairs. It was beyond the scope of this study to compare the financial costs (bulkheads, protected vs. unprotected septic tanks, electrical systems vs. passive systems) on a neighborhood level of detail.

Option 1: Remain on-site and upgrade systems as they become marginal or damaged by storms. This is probably a ten to fifteen year planning horizon.

Option 2: A joint purchase agreement with State or other authorities to reserve open lots for beach access and neighborhood drainfields. At the moment, the long-thin beach access paths could be used for disposal in conjunction with an intermittent sand filter (ISF). Short conveyance lines for ten to fifteen homes would be very feasible. A brief overview of open lots along the beach between Topanga Beach and about 23000 PCH found about 20 open areas along the beachfront. The purchase of a few of these areas would be mutually beneficial to the public (access to beach) and might, if the costs were reasonable, provide a fall-back position for the east end. If the drainfield and ISF was off-site, it would allow full use of the property.

Option 3: Combine with other subareas and convey sewage to possible Las Tunas site, Hyperion, or possible Topanga site. This option could include anywhere from about 300 homes (Big Rock Mesa plus all beachfronts and inland PCH to the east) to 550 homes.

Neighborhood Reserves. Malibu Road, Latigo Shores and other areas of PCH have no need to join an area-wide sewer. Occasionally, a single parcel will run into extreme difficulties trying to repair a marginal or old system. The decisions on costs and technical options are presently limited. In some areas, it may be profitable to set-aside "reserve" areas for multiple purposes on-site reserves, fire protection areas, access to the beach, homeowner beach use areas, neighborhood mini-parks, removal of upslope geo-sensitive parcels that might increase slide risks if built upon, etc.. The purpose promoted by this report is a neighborhood drainfield "reserves" for the installation of systems that are so expensive to repair that the homeowner wants to consider using another site. Malibu Road, for instance, has, at present, enough open parcels that if one or ten homes should find it impossible to repair their systems, a short conveyance system with an intermittent sand filter and drainfield is possible both on the inland side or the beachside of Malibu Rd. Home owner associations might want to consider a joint agreement with the Coastal Conservancy, city or other authority.

IX.7 Northside of PCH

It was the opinion of Dr. Winneberger that the north side of PCH was simply poorly designed and could accommodate on-site systems, if properly designed and maintained. The land area constraints were at times severe and commercial clustering systems with high levels of reuse are potential solutions. There is irrigable area along many areas of PCH and a need to define possible reserve areas along the beachfront or inland for long-term on-site practices with increased development.

Option 1: Careful site-by-site design of commercial systems.

Option 2: City coordinates a meeting of northside PCH to cluster commercials for economical small-scale reuse systems (e.g., Thetford, Memcor, Cycle-let), water conservation, and land-use planning.

Option 3: Determine a buy-in cost to future subarea sewer near Civic Center for those in the extension area just east of the creek. If capacity allows, build a conveyance system.

IX.8 Conclusions

No area-wide sewer appears necessary at the existing levels of development. Certain areas should compare costs of upgrading on-site practices with neighborhood or subarea collection systems, if there is interest. There is no problem with *treatment* either on-site or by small-volume collection systems. The only constraints will be disposal or reuse and regulatory requirements. In Malibu, keeping volumes small and decentralized will increase the possibilities of reuse. The Civic Center and the Point Dume Highlands subareas should discuss options. The landslide areas need an overall management plan to reduce deep percolation. It appears that water conservation, re-design of on-site systems, water reuse, surface management, and in special locations, the continuation of dewatering is a more cost-effective option than off-site sewers. Construction of off-site sewers in slide area does not address the question of other water sources in the slide mass which can only be mitigated with dewatering. Before financing off-site sewers, property owners on slides should be convinced that a significant, cost-effective increase in the safety factor will result.

CHAPTER X: MANAGEMENT OPTIONS

The management of on-site wastewater systems for the city requires actions in the combined fields of policy and administration. It includes all the people who provide the decisions and the supervision necessary to implement on-site wastewater management objectives in a fair and equitable manner. Management requires the formulation of policies for the short-term (the initial or start-up period in which the city writes its ordinances, joint-powers agreements, land use plans, and designs its administration) and the long-term (especially design, maintenance and supervision procedures) that will provide for on-site systems with long service lives.

This chapter addresses the administrative and policy aspects of on-site wastewater management. The next chapter addresses state-of-the-art technical options. The two are inseparable. No matter how good the equipment, the quality of the supervision, the accuracy of the site evaluation, and the regulation of design, installation, and maintenance will ultimately determine the viability and sustainability of on-site and subarea wastewater systems.

X.1 Legal Issues

Previous unincorporated areas (e.g., Stinson Beach) and private developments (e.g., Auburn Lake Trails) have been required to form an on-site waste water management district. This process does not appear to be necessary for a municipality and, as far as we can tell, Malibu will be the first incorporated city to regulate on-site systems. We understand that a municipal government such as Malibu has broad regulatory and enforcement powers (Jenkins, 1992). The regulation and enforcement can be handled within existing departments or with the creation of a new department.

There are 3 basic options for ownership, design and operation: (1) privately owned/privately operated, (2) publicly owned/privately operated, and (3) publicly owned/publicly operated (Lombardo, n.d.). The city will need to consider these proprietary, as opposed to regulatory policies. There is neither reason nor advantage for the city to own on-site systems on private property. We recommend against it. Instead, the City should regulate, apply standards, and review privately owned and privately operated systems.

Currently, it appears that site design and regulation are under the jurisdiction of the city. Health enforcement appears to remain in the hands of the County. Procedures for coordinating health concerns (e.g., abatement notices based on nuisance or potential health hazard) have not been clarified and could lead to legal disputes. The city has the right to form its own health department or inspector.

There appear to be few obstacles for the city to adopt its own on-site regulations (Jenkins, 1992), although the legal connection to the State Water Resources Control Board (SWRCB) and Coastal laws for municipalities have not been settled in detail. The authority of the city with respect to the existing package plants should be investigated. The city may want the authority to connect non-functional on-site systems to package plants. Its ability to require monitoring or review of the subsurface disposal systems needs clarification. The city should also clarify its ability to form local assessment districts within the city for the purposes of intense water conservation and surface runoff management on landslides.

In the event of new construction of package or custom-designed subarea treatment plants, the City will have to determine the ownership relations. Does the city want to own the plant and run it itself? Does it want to have the plant owned privately and regulate it? These situations can become quite complex as shown in our chapter on package plants with dual-ownerships of the plants, a third ownership of the land, and leased lands for disposal fields. The Regional WQRCB and CC have taken an active interest in allowing small volume wastewater treatment plants if careful regulatory oversight is provided. There may be some interest in switching regulatory governance from LA County to the city for certain package plants. This would better implement RWQCB policies of clustering package plants under a single entity.

The other serious private/public legal issue involves greywater systems. A good case can be made for allowing on-surface irrigation of greywater in restricted or out-of-the-way areas of private property. Although pathogens may be present in greywater, the health risk appears extremely low given its widespread use throughout California. At some point, the cost of a simple on-surface line-emitter system must be weighed against the more elaborate and energy-intensive pumped and subsurface systems. The combination of low health risk, private property, and no off-property discharge makes it unclear how much intrusion the public regulatory bodies should be allowed. For instance, public authorities have very rarely been able to quarantine homes from visitors in which a resident has been diagnosed with a potentially contagious disease. The dosage, exposure and concentration of pathogens to visitors in such a situation are obviously much riskier than an on-surface greywater system from a washing machine.

Because Malibu tends to be a litigious community, the ordinances should pay careful attention to liabilities. When the possibility of a lawsuit looms large, many highly qualified experts shy away from jobs or consultancies. The seller, developer, civil engineer involved in design, the site evaluator for soils, the contractor, broker, and the sanitarian or city plan checker can all become part of a dispute over the functioning of an on-site system. Cronin (1991) has written on, a least, one geotechnical lawsuit for unethical conduct in Malibu. PEWARA became involved in two legal disputes concerning on-site system functioning in its short period of fieldwork. To establish accountability in on-site wastewater management, PEWARA has suggested a "peer review" committee for the first two years of city administration (see below). The legal department will need to write careful wording to protect itself, employees and outside contractors from expensive litigation.

The major legal tasks during the start up phase of city administration will be writing ordinances for on-site regulations, site evaluation, greywater regulation, water conservation, and geotechnical regulations related to on-site systems. These ordinances will include permits, licenses, procedures, certifications, and instructional pamphlets. Requirements for an on-site ordinance and regulations are listed in Tables X.1 and X.2. This on-site manual will be the foundation that provides guidance on how to evaluate soils and match them to appropriate systems. Maine, Oregon, Wisconsin, North Carolina, and West Virginia have good guidelines, especially for the use of soils as the basis for in-site design. Some of the unique reuse aspects of Malibu's systems (e.g., shallow reuse to minimize deep percolation) will require new state-of-the-art guidelines, not found in other states. The on-site and greywater ordinances should be priorities for Phase 2.

Good water conservation ordinances are available from other cities (Technical Memo 11). A joint-powers agreement or, at least, a city-agency coordination agreement needs to be written with Waterworks District 29. They are the most appropriate agency to provide incentives to increase water conservation (Table X.3).

TABLE X.1: Probable Requirements for City Ordinance on On-Site Systems

101 Enumerated powers under municipal law.
102 Boundaries.
103 Compliance with federal, state, etc. law or regulations relating to water pollution and health.
104 Abatement for public nuisance, pollution or health powers. Procedures, especially for unlawful disposal.
105 Billing and collecting powers: billing, collecting, penalties, interest, suits, use of tax roll, attachment to other bills, etc.
106 Use of revenues by city for designated purposes only.
107 Manner of effecting annexation of adjacent lands for purposes of water pollution management.
108 Powers to issue permits, fees, licenses and special assessments requirements.
109 Violation fines.
110 Powers of inspection and access.
111 Variances for design and installation.
112 General requirements for regulations for site evaluation, component design, installation, operations, and maintenance for repairs, additions, replacements and new systems. Regulations are an appendix to ordinance.
113 General compatibility and relation to water conservation, greywater, grading, geotechnical, stormwater or other ordinances.
114 Designer qualifications: certification or equivalence.
115 Qualifications for contractors (construction, installation) and right of home owner to build their own system.
116 City peer review process.
117 Emergency authorities for acts-of-God (storm damage, landslides, fire, earthquake).
118 Required licensing of pumpers to operate within the city and disposal requirements.
119 Relief from Inequity: by application or by Council motion, appeals to Board.
120 Application of rules to dual- or multiple-ownerships of same on-site systems and to systems located on two separate properties.
121 Application of rules to neighborhood systems using on-site treatment and disposal.
122 Authority to connect defective on-site system to existing wastewater treatment plant.
123 Authority to form assessment districts within or partially without city boundaries for subarea wastewater treatment.
122 Effective date.
123 Projects or actions in progress before effective date: authorized by County, Coastal Commission, City.
124 Separability.

TABLE X.2: Probable Regulation Requirements for a City Ordinance for On-Site Systems

200 Short title.
201 Definitions.
202 Sewer not available.
203 Permit required (permit form).
204 Application and issuance of permit procedures.
205 Building permit and on-site permit procedure and requirements.
206 Water service and on-site permit procedure and requirement.
207 Inspection requirements.
208 Design requirements (refer to appended pamphlets, peer review, plans, regulations, and final City Council authority).
209 Alteration, repair and replacement requirements.
210 Maintenance and monitoring requirements.
211 Certificate of Inspection requirements for proper maintenance.
212 Rates and charges for permits, licenses, certification, taxes or other sources of revenue.

Table X.3: Summary of Water Conservation Options to be Coordinated with Waterworks District 29

Rate-structure changes, surcharges and metering.
Leak detection and repair.
Pressure reduction.
Ordinances: new construction, remodels, and additions.
Feebates, rebates, giveaways and free installation.
Education and propaganda.
Required water conservation audits for multiplexes, commercials, and additions and landslide areas
Agreement with Waterworks to enclose information in their mailing of bills.

X.2 Management Organization

In modern management terminology, the previous management of on-site systems can be characterized as "punitive-authoritative." That is, there were a series of "cookbook" regulations that had to be followed. If not, permits were denied or home owners brought to court. With the formation of the city, an opportunity exists to change the management style to "consultative-democratic." In this style, the city would emphasize its role as an extension service that provides educational material and services and financial incentives to design, install and maintain high quality on-site systems. As explained below, the "consultative-democratic" approach would allow more custom-designed systems, include a non-punitive peer review process of plans and installation, encourage cost-saving technologies such as greywater reuse systems for irrigation, coordinate city regulatory responsibility with neighborhood groups, and provide information about the condition of the on-site system for potential buyers and sellers.

Bureaucratic procedures: Table X.4 lists the tasks required to start up and administrate on-site systems. Figure X.1A shows the bureaucratic path for an applicant seeking a simple, washing-machine-only greywater license. Table X.5 shows the management needs for greywater and water conservation. Figure X.1B shows the bureaucratic path for an applicant seeking a new or renovated on-site system, an experimental system or a multiple-fixture greywater system. These procedures are for the first two years of management. The first two years are the start up period for the city and we would expect details to change as experience is gained.

The greywater license parallels the current purchasing of a driver's license and carries similar responsibilities. The applicant would be required to read a pamphlet which details the standards for the fixtures involved and methods of installation and use and includes a questionnaire at the end. The license is conditional on proper construction, installation and maintenance. The city has the right to inspect construction, installation or maintenance if it wants. No special certification is required for the designer and installer.

The more complex permits are for new and renovated on-site systems, multiple fixture greywater systems, and experimental systems. The permit includes a series of questions to "red flag" the most important design concerns for both the builder, the hired designer, and the city staff (Chapter XI). The red flagging is also a form of consumer protection. In the escrow stage, potential purchasers can have access to the data base and

TABLE X.4: Tasks to Be Performed

General Tasks

Initial: Establishing friendly, high quality procedures and educational materials.
Initial: Reconciling County and City responsibilities.
Initial: Determining requirements and procedures with CC and RWQCB and SDH.
Initial: Designing and implementing on-site record keeping.
Initial: Writing on-site, greywater, water conservation, and geotechnical ordinances related to on-site systems(see accompanying tables).
Initial: Writing permits, procedures, instructional pamphlets, licenses for ordinances, pumping ethics codes and certification requirements.

Coordination with other departments and agencies (CC and RWQCB).
Consideration of annexes to city for the purposes of on-site wastewater management (LAFCO).
Coordination of private sector and public sector for maintenance of passive systems, operation of systems dependent on electricity, and pumping.

Wastewater Staff Tasks

Inspections.
Site validation.
Responses to complaints.
Construction and installation validation.
Spot-checks for greywater licenses.
Operations of pumped systems.
Plan-checking and coordination with peer review processes.
Permit processing and scheduling.
Initial on-site form entry into data base.
Addition of new activity to initial entry form.
Meeting w/Wastewater Committee: plans, & issues to be resolved by City Council.
Establish coordination between licensing, fees, and general fund revenues.
Attend workshops to keep up with changing administrative and technical aspects of on-site systems management.

Private Sector Responsibilities (under regulatory rules)

Permit application and processing.
Design of plan and necessary fieldwork.
Construction and Installation.
Scheduling inspections required under permit.
Maintenance and/or operation.
Water quality sampling and testing, if required.
Septic tank pumping, hauling, storage and disposal.
Operations of pumped systems with more frequent maintenance and monitoring.
Peer review of design and installation work.
City contracts with outside private consultants to review ordinances, licensing, design, and installation and help with public education.

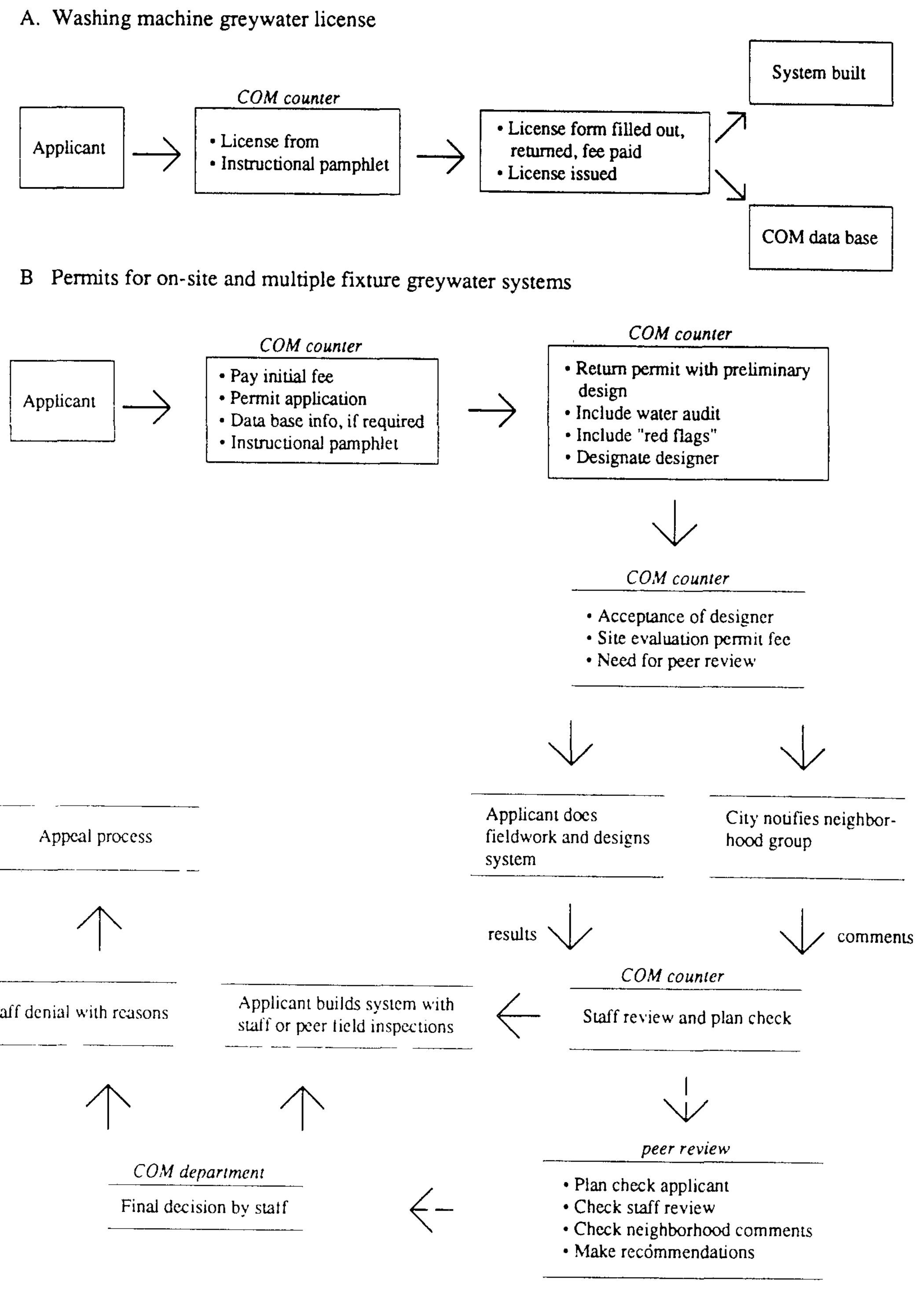


Figure X .1 Flow Diagrams for Applicant Process

Table X.5 Summary of Management Needs for Greywater and Water Conservation

Greywater educational pamphlet for washing machine disposal/reuse.
Permit or license for home construction of washing machine greywater system.
Greywater educational and instructional pamphlet for more elaborate greywater systems.
Permit and license for construction of multiple fixture greywater systems.
Oversee demonstration projects for greywater reuse.
Legal review of conditions for on-surface disposal or reuse.
Coordination with waterworks on management options.
Water conservation ordinance and regulations.
Greywater ordinance and regulations (option requirement in new plumbing).
Workshop on wastewater reuse technologies (both combined and greywater).
Spot check washing machine greywater systems. Field check more elaborate systems.
Design data entry form for wastewater management records.
Custom-designed for Malibu,a water conservation catalog of best fixtures and practices for subareas.
Water conservation audit form for remodels, commercials and slide area homes.

determine the age, repair history, and condition of the on-site system. Depending on the renovation and type of new construction, the plan check may be subject to a peer review by an outside consultant. This ensures that the design meets the highest standards, allows the city to remain knowledgeable of the best technologies available, and allows the department staff to improve their plan-checking abilities.

A new department: The supervising department is presently Building and Safety. We recommend consideration of a new department which would explicitly integrate previous functions with permits for water conservation efforts, greywater systems, surface runoff, geotechnical issues related to wastewater and home owner protection, on-site wastewater management, and off-site and cumulative impacts of systems in landslide areas. In addition, a member of the new department staff would coordinate with the homeowner, neighborhood or watersheds groups in cases where a permit action might impact a neighborhood. For instance, in landslide areas, water conservation options as well as the monitoring of water conservation and surface runoff management are neighborhood actions to increase stability of the slide mass. The landslide area neighborhood groups play a particularly important role. In the experience of many on-site designers, water conservation fixtures are replaced with water-consumptive fixtures or changes in habits and usage which override the water conservation program. If water conservation is going to become a viable method to reduce wastewater loads then review of water bills or special metering of indoor usage is necessary. The participatory (vs. authoritative) approach is the most practical method in terms of incentives, insurance, and legal liabilities. Participatory responsibility by landslide groups is a "preventative" action that can reduce post-crisis lawsuits. The new department would include Building and Safety and might be called the Department of Environmental Management and Consumer Protection.

Start up Tasks: The labor needed for the first two years will include: a data entry person who will design and begin initial entry forms; a part-time staff to process permits and oversee the shape of the management program; a part-time person to plan, field check and coordinate plan checking with PEWARA; a major effort to write regulatory ordinances and accompanying permits and background pamphlets; a major legal effort to clear up unresolved legal areas with the county and other agencies; an in-house or private consulting project to write certification program requirements; a consulting group to write instructional pamphlets and license for greywater licensing; a staff and legal counsel to write septic tank pumper and operators licensing; and a joint-powers agreement with Waterworks District No. 29 to coordinate water conservation programs (Table X.3).

Data Base Records: Minimally, data base records will be required for applicants for pipeline projects, all repairs/additions/replacements of existing systems, and new accepted permits. Additional time could be granted for higher priority systems (e.g., commercial). As revenues or volunteers permit, the remainder of single family residences could be added from County files. Stinson Beach Water District has a computerized data base that could be modified for use in Malibu.

Part-Time Staff: The organization of the on-site administration could take quite a bit of time. It may be required that a new full-time person be employed as part of the new department or staff. The time cannot be estimated because legal questions and agency coordination (two major tasks) cannot be predicted. The number of permits processed for new, pipeline, and remodel systems might reach 50 for 1992. Hours are difficult to estimate until an established procedure has been tested. Licensing for greywater, operators, pumpers, and certification of designers within the city should be a priority (Phase 2). It might be anticipated that beachfront homeowners will want to use part of their future reserve area for the legalized greywater systems. Staff inspectors may become involved in spot-checking pumpers to assure removal of sludge from both chambers and annual checking of pressure dosed systems. The inspection of pressure dosed systems could be privatized with an appropriate license.

City Council Action: Passage of ordinances for on-site systems, greywater, water conservation, and landslide geotechnical requirements are all intertwined. These ordinances (or interim ordinances) will be written in 1992. Legal tasks have been described above. Many of the incentives for water conservation are out of the city's hands because the regulatory authority rests with Waterworks District 29. To institute rate-structure, rebates, leak detection of waterlines, pressure reductions, low-use installment programs, conservation audits and education programs will require some sort of joint powers agreement (Tables X.3 and X.4).

X.3 Accountability

Malibu is empowered to regulate the design, installation, maintenance and operation of on-site systems as well as the hauling of septage. With this responsibility comes the opportunity of improved on-site management. Previous management has been characterized by inadequate design features, inadequate modification of those design features for particular sites or situations, and inadequate maintenance. As mentioned, these have been major causes of shortened life spans and high costs of some on-site systems. At two stages in the process, human weakness can cause poor management: the designer can produce a substandard design and the staff reviewer or overseeing agency (e.g., Coastal Commission) can let it go by. Insufficient time and funding as well as internal politics are the usual reasons for the inadequacy of a review of a design or field inspection.

The funding issue is important. It is generally agreed that a permit fee should pay for all steps of the process. The permit fee for new systems will need to be carefully set by a detailed step-by-step estimation of the hours. In order to produce the highest quality on-site design and installation, the individual requesting the permit must be made aware in advance that extra fees may be required and under what circumstances. Insufficient funds (and staff) have chronically led to cursory and inadequate reviews of the design, a predilection for cookbook designs such as UPC, and the use of inexperienced or under-educated staff who are unaware of local field conditions and hence lack the skills to recognize poor design.

On the other hand, the fee to the homeowner must not discourage the use of the highest qualified consultants. If the fee becomes too high, the applicants look for low bidders of questionable qualification or ethical standards. A question of general funds vs. permit fees arises when efforts are made to set upper limits to fees.

Political interference in permit processes is infamous. A Council member or series of Council members may apply pressure to the staff to let an applicant through. This leads to the all-too-common pattern: designer and installer cut corners in order gain a reputation as a less expensive consultant; local officials look the other way or give tacit approval to avoid a threatened suit or just to get the job done; and Council members either never hear about it or feel the threatened suit is not worth the bother or are glad to help an ally. To achieve accountability at the various levels of government and private sector, we have attempted to outline a procedure of checks and balances. This is a preliminary and, as far as we know, completely innovative approach to on-site design and installation within city government. As such it will go through many changes and, unfortunately, cannot be considered a "recipe" for honesty and competence in the private and public sector.

The organization consists of:

(1) Certified and approved on-site designers who can lose certification without a major lawsuit should they present substandard designs or false information.

(2) A peer review from outside the city that reviews plans parallel to those being reviewed within the city.

(3) A format that makes a designer state explicitly why he/she has chosen a particular design and what is not known (at risk) within the design.

Certification of on-site designers: The state of on-site management is in transition. Many engineers understand the hydraulics of on-site systems but not the biological, horticultural, or water quality concerns within the soil/drainfield interface. Many fine soil scientists know how to judge soils but are weak on the small engineering items that make the difference between a good system and the best system. Other excellent designers come from multi-disciplines and are essentially self-taught in both engineering and soil sciences. Still others have been trained as health officers but, through experience, become on-site designers. Very few universities give much attention to on-site systems and there are very few seminars of worth that occur annually. It is not uncommon to have an on-site designer who is not an engineer do most of the designing which, for a fee, is then signed by an acceptable engineer. For instance, Stinson Beach allows the following qualified professionals to design on-site systems: registered civil engineer, registered geologist, certified engineering geologist, registered sanitarian, or a certified professional soil scientist.

To overcome this diversity, Malibu can implement its own certification program based on experience (previous projects and the number of years an individual has been working), educational background, and/or attendance at a special seminar course with a final Malibu-oriented test. This will ensure that private sector designers have the ability to install the more recent innovations in on-site technology, can accurately judge site conditions and know the particular goals of water quality management for each subarea of the city. It is our hope to help the city "de-program" many designers and installers from the cookbook practices that have hurt the city in the past.

The peer review: The peer review is simply a check-and-balance process. It checks the designs about to be implemented and the skills of the city's staff in reviewing the designs. The peer review process will probably become reduced as the peer review committee finds fewer and fewer comments on designs by both certified designers and experienced reviewers. The minimum time for an active program is two full years, at which time the process should be re-evaluated. This two year period should also include field installation reviews and, if necessary, reviews of field practices for assimilative capacity or infiltration measurements.

If successful, the process will not be punitive but educational. For instance, if a peer reviewer notices that a designer has weaker skills in soils or hydraulics, the reviewer could recommend particular readings or courses designed to increase these skills. Hopefully it will weed out the unethical and "quick fix" designs of the past.

Initially, the number of peer reviewers should remain flexible. It may be useful for the city to see what it gets from peer reviewers (do two peer reviewers come up with opposite opinions?) and at what cost. The process has begun somewhat with PEWARA reviews of pipeline projects. The peer reviewers might be consulted on certification requirements for Malibu on-site designers and a potential seminar that could result in certification.

Accountability Formats and Questions: A questionnaire will accompany a permit and will require the designer to justify the design. First, the concerns that are red flagged must be addressed (see Table XI.4). Second, the soil inspection and testing results from site evaluation must be listed. Third, each item (wastewater loadings, septic tank, venting, baffling, uniform flow options, pre-treatment options, drainfield treatment and disposal options, vertical and horizontal setbacks, pump choices) will require some amount of explicit reasoning. Fourth, the staff reviewer must be given immunity from political influences under the civil service code.

X.4 Funding

Administrative costs or funding sources were not included in PEWARA's scope of work. Until the departmental structure and revenue sources are determined, the division between general fund taxes, licensing fees, special assessments, and permit fees is highly speculative. No details are available on the amount of funds possible from each source or the legal ramifications of choosing between them. Funding maintenance and pumping will require careful expense accounting which is beyond the scope of this report. Private vs. public sector financing needs to be defined.

The best analogies available are Stinson Beach, San Lorenzo Valley and Sea Ranch. However, the size of these communities and revenue sources are quite different. San Lorenzo Valley is closest to Malibu and should be consulted in setting up financing. In general, a staff member or an outside consultant will spend about half-time for one year to set up the initial organization, procedures, permits, licenses, state agency coordination, legal review of ordinances, hiring of special consultants (especially for start-up of the records data base), the writing certification program and peer review. Other labor tasks cannot be predicted as they could be achieved through agreements with the private sector (e.g., pumping inspections).

For simple greywater systems (see Figure X.1), we propose a "licensing fee" similar to the fee paid to obtain and use a driver's license. No inspections would be required. The homeowner would be required to follow the "cookbook" designs in the instructional pamphlet and fill out a form with an informal map. Design variations would be encouraged. Costs to the City include writing an instructional pamphlet, explaining procedures, and recording results in the new wastewater data base. The licensing fee should cover these expenses. The city has the right to spot-check these systems and withdraw the greywater license.

Permit fees for new or remodel on-site systems could be in the form of a "licensing fee" or a single fee. As explained, the fee will need to have a flexibility clause because, under special situations, city staff or the peer review group may require additional work. The fees could also be scaled to encourage water conservation and simple greywater systems to reduce irrigation with imported water.

X.5 Pumping Management

The periodic removal of septage from the septic tank is necessary to prolong the lifespan of the drainfield (reduce TSS and BOD). The management of pumping and cartage requires revisions in Malibu. First, a program for the installation of risers on all portholes has been suggested. Second, an ethics code or licensing for pumpers which requires pumping of all chambers (portholes) and, of course, all sludge should be written. Third, if it becomes possible, negotiations with Tapia for use of their facilities for processing septage would be ecologically and economically superior to dump stations feeding Hyperion. The heavy metals concentrations can be erratically high (Wastec, p.c.; Metcalf and Eddy, 1992), but the total mass contributions are believed to be very low compared to other sources in Tapia (Tchobonoglas, p.c.). The city might request a joint-study with Tapia to resolve this question. Fourth, the responsibility for cartage should remain in private hands. At this stage in the city's development, the responsibility for actual organization of pumping and cartage would be overwhelming and financially unfeasible. Fifth, to promote long-term or sustainable on-site practices, a series of meetings with local private pumpers should be arranged to promote mutual beneficial organization and cooperation between the public and private sectors.

Sixth, the city must determine its attitude toward pumping and cartage. As stated, in other parts of California and in other countries, pumping and cartage is culturally acceptable as a "pipe on wheels." It solves the equity issue in that only those who use pumping pay for it. On the other hand, American attitudes have, until recently, considered daily or weekly pumping as an indication of a problem that requires an alternative solution. The new attitudes toward cartage, or haulaway, can be found in the San Lorenzo District, which allows complete haulaway, haulaway of just blackwater with greywater reuse, or seasonal or peak load haulaway permits. All permits require water conservation and can even require "intense" water conservation. In extreme, the San Lorenzo District has regulations limiting the number of occupants or units until adequate on-site, leased land, or new land has been obtained for disposal. For instance, the Point Dume highlands bring into question whether on-site disposal from one parcel should be allowed on another. If so, what should be the nature of the permit in order to ensure safe and long-term disposal. If an overloaded disposal field is not allowed daily cartage and has no additional land, what are its options?

The organization of pumping management may be difficult: Who will install the risers for the portholes? How will this be coordinated with the pumpers? Should the pumping be a rigid requirement or based on need? Who will decide and pay for the determination of need? Should the city put any regulation on fees for pumping? Should it try to encourage the use of "Hamsterns" which would reduce road traffic and eventually reduce round-trips to dump stations?

In many districts, inspections and suggested pumping for single-family residences varies from once every two years to once every six years. In PEWARA's experience, Malibu is the only city where some homes pump every year.

Scenario 1: City sets up a rule that the tanks must be pumped every set number of years and licenses pumpers to perform pumpings and record date with the city. Each time the tank is pumped, the home owner pays a fee. This scenario probably will overpump many homes.

Scenario 2: City requires pumpers to measure sludge and scum levels before pumping and only pump when necessary. This is an ideal but could be expensive adding the in-and-out cost of the inspection to the in-and-out cost when actual pumping is needed. A cost comparison is required.

Scenario 3: City hires staff to routinely measure scum and sludge. Working full-time, the employee might be able to inspect 25 tanks per day or all the tanks in one year with administration. The employee would then instruct various pumpers on some pre-arranged basis as to who required pumping. Commercials and parcels with cartage would have separate schedules. Citizens would pay for salary through general funds or it would be included as part of licensing fee to the pumper.

A critical choice for Malibu is what to do with its septage. The options include: (1) keep trucking to Hyperion; (2) work out an agreement with Tapia; (3) build a Malibu facility. The first option appears the most likely for the next few years as Malibu writes the plan for its future. An agreement with Tapia would require overcoming years of mutual suspicion. There is nothing technically special about Malibu septage as indicated above. Tapia septage treatment would greatly reduce travel time costs. Option 3 would make sense as a combination green waste/septage composting process in order to recycle both green wastes and septage for fertilizers. But, the septage facility would only make economic sense if combined with another subarea facility such as a facility near the Point Dume highlands. These decisions are beyond the scope of this report.

X.6 Conclusions

The proposed wastewater management program has a two-year start-up phase and a long-term component. The administration includes a new department combining various aspects of environmental management and consumer protection. The major goal in 1992 is the writing of various ordinances, guidelines, permits, certifications, licenses, and accountability agreements to ensure viable on-site systems for the diverse conditions of the Malibu ecology. 1992 will also see a "test run" of the peer review process to ensure accountability in on-site design. Because various legal and agency issues have not been resolved, this process could be delayed. However, there appear to be few legal obstacles to the city writing its own ordinances and regulations.

CHAPTER XI: FUTURE TECHNICAL OPTIONS

Technical options for on-site wastewater management are improving at a rapid rate. The quick pace of change includes new water conservation fixtures, designs for greywater recycling, pretreatment devices, reuse systems for combined black/grey wastewaters, waterless toilets, alarm systems, drainfield aeration systems, near surface irrigation systems with "smart box" (computer controlled) distribution, and the manipulation of microbial biology.

Nevertheless, there is a tendency to want a device or design to automatically substitute for thought, experience and paying attention to careful site evaluation of soils and bedrock. Unless the administrative atmosphere is educational and provides incentives for high quality implementation, rather than a code-driven and punitive approach, none of the technical options will accomplish their potential. This chapter presents the technical options that best apply to Malibu and the ecological circumstances within Malibu for which they are, in general, custom-designed.

The wastewater management goals include: improved site evaluation, installation and maintenance; and custom-designing to reduce effluent strength and loading rates and to increase soil aeration. The technological interventions described will increase the long-term soil acceptance rate and abilities to transform "wastewater" into a "resource" for plant growth. From this longer-term perspective, if the soil mass surrounding the drainfield might limit dispersal or assimilation of the effluent, then it must be considered in the design phase. With proper design and maintenance, there is no reason to believe that drainfield life spans cannot extend beyond 35 years. Because the relative benefits of different technologies have not been thoroughly studied, recommendations will not rely on only one intervention (e.g., water conservation *or* ET disposal). The systems can be designed with redundancy (e.g., water conservation *and* ET) and with conservative sizing. This approach can only help to increase life spans.

XI.1 Water Conservation In Malibu

Water conservation in a wastewater management program is directed toward reduction of wastewater loadings (Table XI.1). The recent work on septic tank systems shows that minimal use of faucet aerators, showerheads and low-flow toilets will not

Table XI.1 Summary of Water Efficiency Options

- Indoor
  - Ultra-low-flush, dual-flush toilets
  - Low-flow showerheads
  - Low-flow faucet aerators
  - Leak repairs
  - Instant tankless water heaters
- Intense Indoor
  - Horizontal drum washing machines
  - Rinse-cycle washing machine reuse
  - Treated greywater and/or blackwater reuse
  - Party "high conservation" bathroom
  - Waterless toilets
- Outdoor
  - Xeriscaping
  - Greywater reuse
  - Treatment with line-emitters and timed watering
  - Storage for fire protection and irrigation

greatly benefit the septic tank system (10% water savings). Only moderate (20%) to large (40%) use of water-saving fixtures will significantly reduce wastewater loads and increase aeration within the drainfield (Sharpe, 1984). The "intense" water conservation effort utilizes instant water heaters, horizontal drum washing machines, a special "party-time" bathroom with pneumatic flush toilets and, perhaps, spring-loaded faucets, and greywater reuse. Experimentally, the approved SunMar composting toilet could be installed.

With water conservation, the concentration of the wastewater will increase, but the effluent maintains the same ratio between various parameters. For instance, a 40% reduction of wastewater leads to about a 67% increase in any given pollutant (Siegrist, 1983). Until a 50% concentration from water conservation is reached, there appear to be no problems with the performance of drainfields and the quality of septic tank effluent (Siegrist, ibid.). Some evidence indicates that organics removal (TOC and TSS) is actually improved with high levels of water conservation. As opposed to simple water conservation, greywater systems and compost toilets both change the quality of influent to the septic tank (see below).

With water conservation, effluent levels within the drainfields ("ponding") are significantly lower, though they vary with rain, sunlight (evapotranspiration), and local drainage conditions. Water conservation reduces all peak loading rates. In one study, homes with the highest levels of water conservation stayed more consistently below peaking points (Sharpe, 1984). Water conservation can reduce or eliminate occasional surfacing of effluent caused by erratic water table highs. If wastewater reduction volumes can be "guaranteed," then drainfields could be downsized.

There is no reason to discard the existing toilet, if a reliable dual-flush system can be installed and home residents feel they can learn to use the dual-flush mechanism (one direction for urine, the other for feces). The use of front-loading washing machines has greatly reduced the water levels in the drainfields studied. They (or the European models that are top-loading but with a horizontal drum) are necessary for success in the water conservation approach to drainfields. Alternatives include disconnecting the washing machine from the drainfield and treating it as greywater and/or using the rinse cycle for the next wash cycle. In addition, instant tankless water heaters greatly reduce the "clearwater" (water that is wasted while waiting for the hot water to arrive). They are not commonly installed in the United States but should be included in any intense water conservation program.

The problem with water conservation as a technological intervention is that some homeowners remove and replace low flow fixtures. If water conservation is a crucial technological intervention, then neighborhood or city monitoring of water bills will be required.

XI.2 Greywater Systems

Greywater has no rigid definition. It is not toilet wastewater and rarely does it include kitchen sink wastewater. Washing machines, bathroom sinks, baths and showers, dishwashers and utility sinks are sources of greywater. Surge flows are typically considered 1.5 times the daily flow. New soaps and cleansers are rapidly entering the market to protect plants irrigated with greywater and to improve the balance of plant nutrients in the effluent (Technical Memo 7).

As mentioned in Chapter VI, 8% of the beachfront homes and 33% of the inland homes surveyed had greywater systems . About 60% of the systems disposed of greywater above-ground. These are "outlaw" systems because homeowners could receive County violation notices for a wastewater discharge (Figure XI.1). Many homeowners find their simple and low-cost systems acceptable on their own property. Recently, some agencies have new regulatory changes that accept "inlaw" systems (Figure XI.2). However, some of these systems are duplicate septic tank systems with a price tag that discourages homeowner installation. There are many unresolved health and legal questions (Technical Memo 5 and Chapter X).

In Malibu, the importance of a greywater system as a technical option includes:

(1) Reduction of wastewater loads to drainfields or septic tanks, especially restaurants, remodelled homes, multiplex apartments, condominiums, and commercial establishments on small lots. Greywater systems can be a cheaper method of reducing wastewater loads to undersized or overloaded systems. Greywater systems can prolong the life span of the blackwater drainfield.

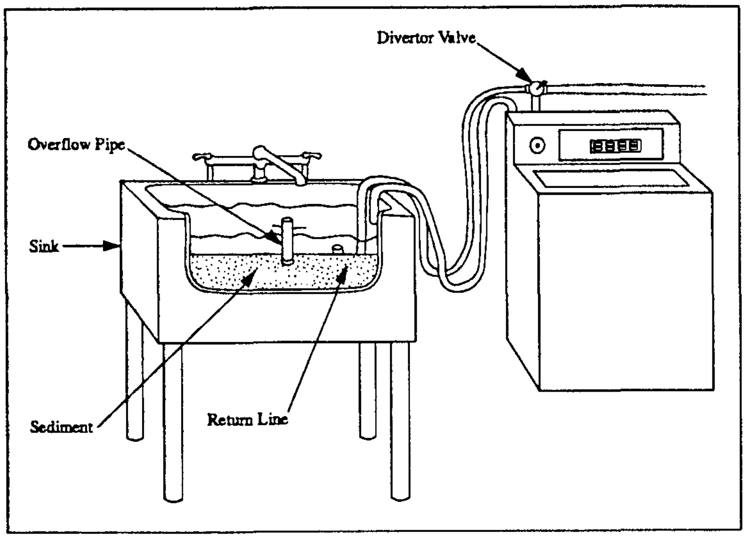
(2) An approximately 60% reduction of deep percolation of wastewaters into slide masses (see below).

(3) Better distribution of wastewater effluent disposal on parcels with difficult soils or geometry.

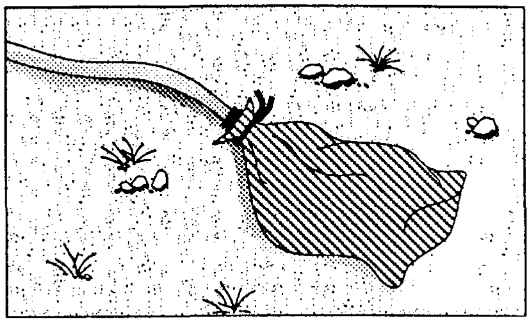
(4) Reduction of wastewater loads (design capacity and performance) to existing package plants or projected treatment plants, especially those with subsurface disposal.

In addition, benefits not directly related to wastewater management include reuse of greywater to reduce water bills, irrigation water, and fertilizers, especially during periods of drought. In terms of cost, the more elaborate the greywater system, the closer it duplicates the system for reuse of combined wastewaters. At a certain point, the reuse of combined wastewaters (black/grey) is comparable to the reuse of greywater alone.

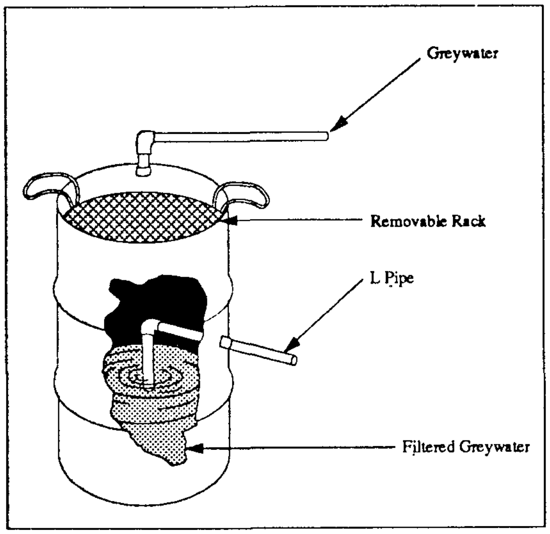
Greywater technical options are in a rapid state of change, especially with valving and computer-controlled irrigation scheduling. The peer review process in Chapter IX and a two-year update of any ordinances are recommended to keep Malibu from installing



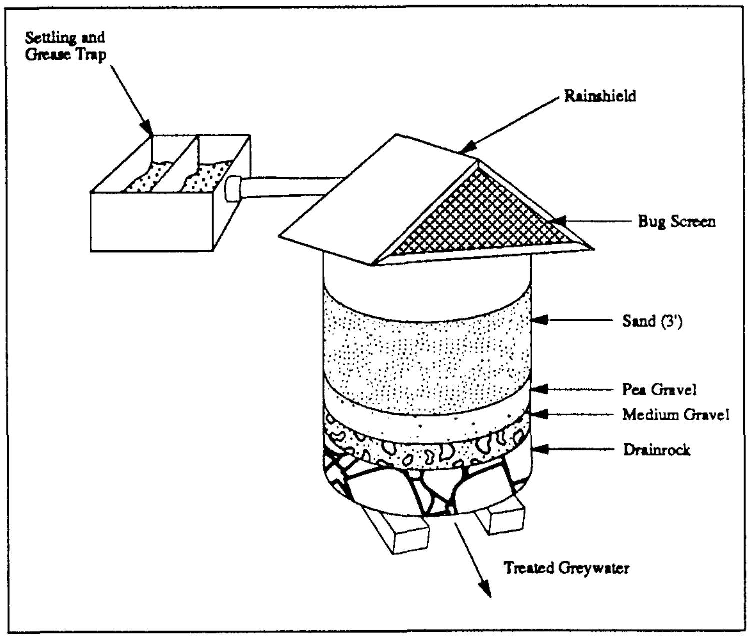
"Outlaw" Suds-saver: Recycles Rinse Water



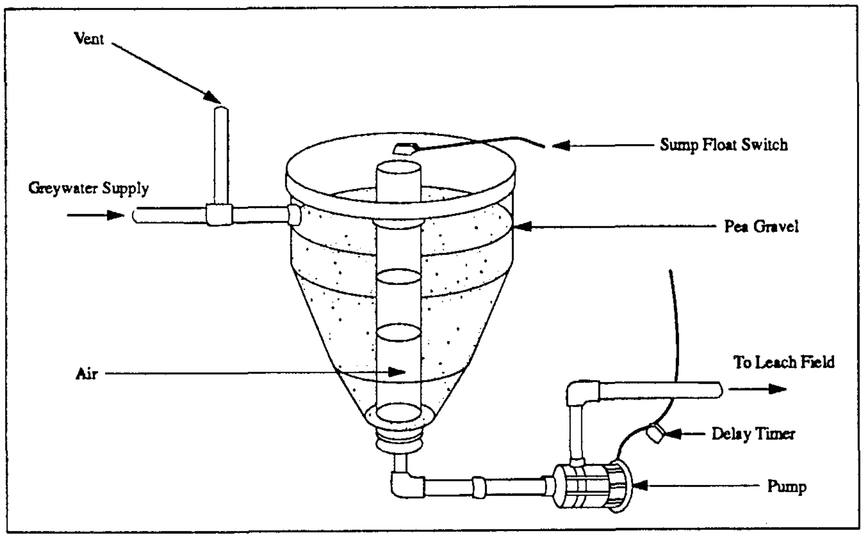
Outlaw System: Hose With Nylon Stocking for Irrigation



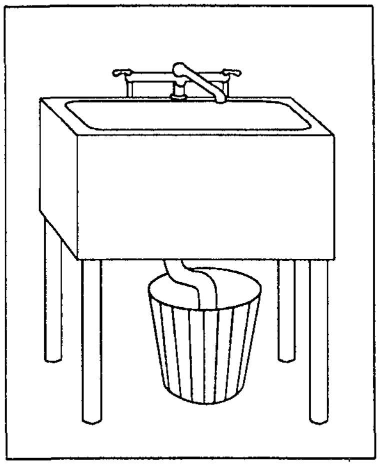
Outlaw System: Rack Filter



Outlaw System: Grease Trap, Sand Filter, and Above-ground Irrigation

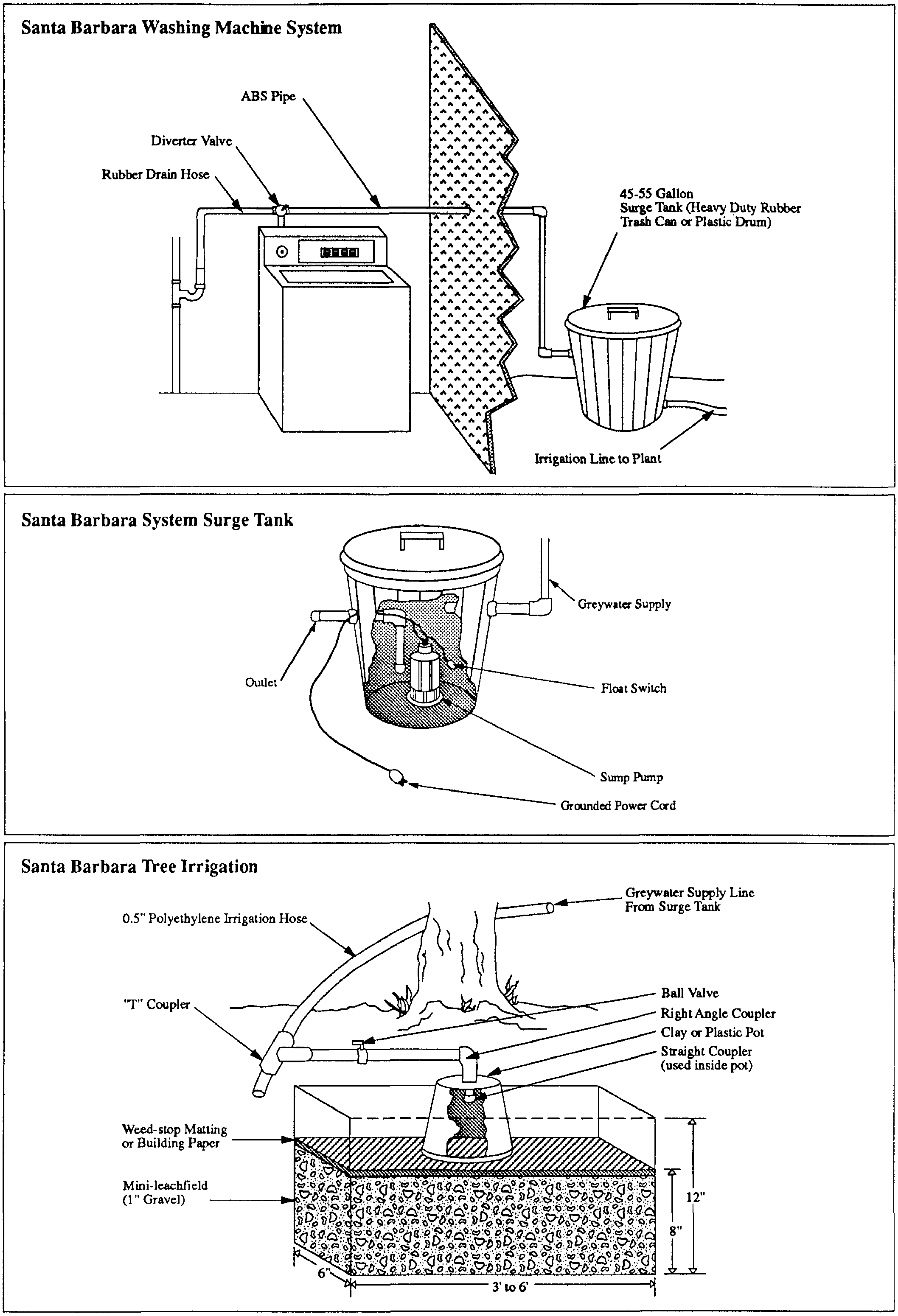


Aerated Filter by Clivus Multrum



Outlaw System: Bucket and Above-ground Irrigation or Use to Flush Toilet

Figure XI. 1: Outlaw Greywater Systems (Karpiscak)



Santa Barbara Washing Machine System

Santa Barbara System Surge Tank

Santa Barbara Tree Irrigation

Figure XI.2: Santa Barbara Greywater System (Karpiscak)

outdated technologies. Greywater systems include use of washing machine water or multiple greywater fixtures for subsurface irrigation (Figure XI.2), reuse of washing machine rinse water for the next wash cycle, or upgrading greywater for reuse in toilet flushing or surface irrigation (Table XI. 2). To accommodate greywater systems, all new homes and buildings should include diversion valves and dual-plumbing to centralize greywater for reuse.

Table XI.2 Criteria for Greywater System Design

Production
Interior use of soaps and cleansers, fixtures involved.

Plumbing
Dual-plumbing, diversion valves or rinse-cycle plumbing for washing machine.

Filters
Outlaw systems include a nylon stocking and or sand/gravel bed. Cycle-let markets a cloth filter, still experimental. Fixed media anaerobic upflow filters for larger flows. Do not use swimming pool filters. For irrigation, see XI.3.

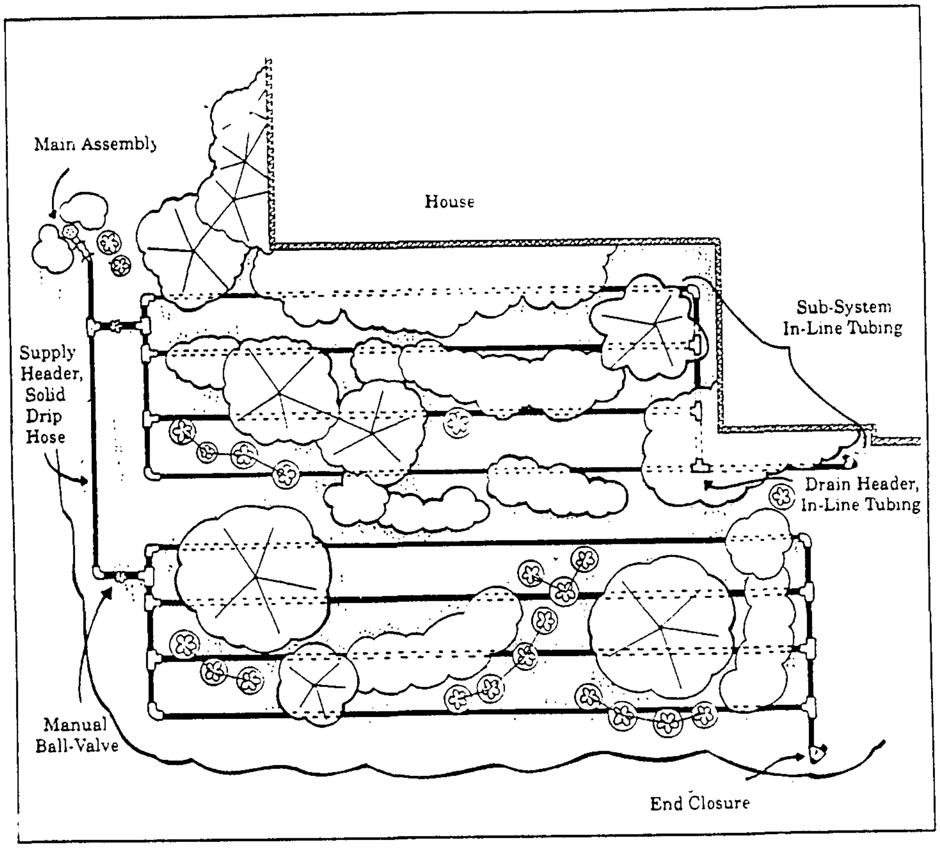
Surge/Sedimentation Tank
For kitchen and dishwasher grease to cool-down influent. For high peak loads. For coupling with a pump. To reduce suspended solids and soluble BOD for subsurface disposal.

Disinfection
Only with above-ground use or long-term storage.

Disposal
Surface disposal is illegal but widespread in out-of-the-way areas of private lots. Acceptable disposal may include under mulch, near surface (2 to 3" below surface), mini-leachlines for trees (12" to 60" deep), or planted drainfields.

XI.3 Reuse for Irrigation and Fire Protection

The reuse of effluent is an important aspect of managing deep percolation in landslide areas. It can also save on water bills and allow more irrigation in drought periods. About 80% of irrigation water is evapotranspirated and about 20% percolates below the root zone. On the other hand, various documents (e.g., Bing Yen, 1991) state that on-site systems discharge 80% below the root zone and only dispose of 20% by ET. The conversion of an on-site system into an irrigation reuse system would prevent 60 to



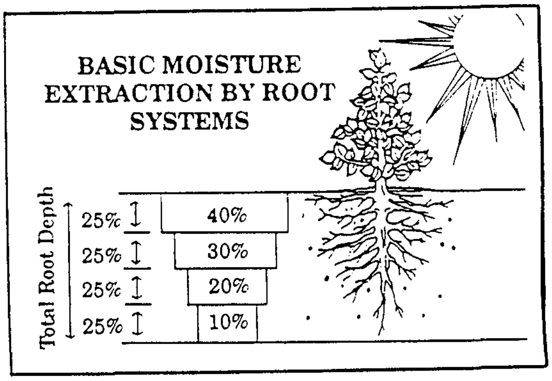
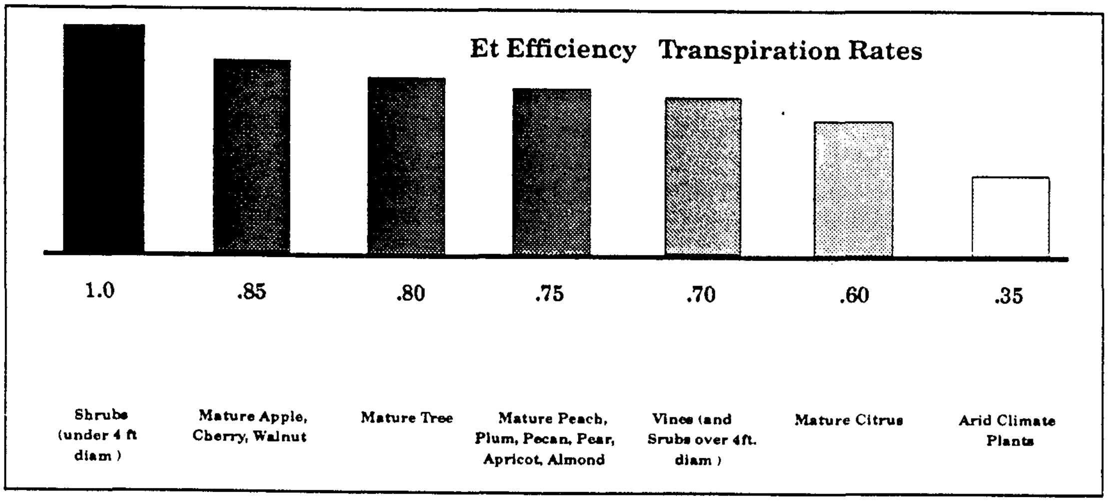


Figure XI.3 Irrigation Reuse of Effluent

Upper drawing shows sub-system appraoch to distributing effluent with ball-valves to divide sub-systems and a drain header for easy flushing and cleaning. Middle drawing illustrates the need to design trenches by root zone utilization of effluent for ET. Bottom drawing gives some of the ET efficiencies of common plants. Illustrations from Drip Irrigation (1991), courtesy of Robert Kourik



70% of the effluent from percolating below the root zone. With no field studies available, 60% is a reasonable goal.

The technical options to increase ET disposal and reuse are: (1) simple greywater recycling from the washing machine or more elaborate recycling; (2) drainfield designs with shallow trenches vs. deep seepage pits; (3) sand filters with low-pressure distribution of effluent near the surface; (4) shallow in-trench sand filters or (4) most elaborately, treated wastewater with disinfection for surface irrigation. Promising designs include many narrow trenches installed with a "ditch witch" trencher all over a lot. The treated effluent is distributed evenly to all trenches by pressure.

ET can be increased by proper selection of plants to maximize year-round disposal (non-deciduous), by combining ET disposal near the surface (grasses) with ET disposal from deeper soil layers (trees), and by aerating the soils with plant species that "pump" air into the soil through special root channels. ET can be increased by mechanically dosing the treated effluent to the plant or landscaped areas in order to increase soil aeration and to allow a period for the soil to dry. Small constructed backyard wetlands with subsurface flow are experimental systems on homesites. The technical features for design concerns are shown in Table XI.3 and Figure XI.3.

TABLE XI.3: Design for ET Disposal

Design Goals
Maximize ET disposal of effluent and reuse of "wastewaters" for gardens.

Special Criteria
Maximize near surface irrigation in landslide areas by spreading effluent. Maintenance required to clean irrigation pipe orifices once a year.

Design Criteria for sizing irrigation reuse system
Wastewater loads, slope, aspect, shading, soil intake rate, permeability rate, available water holding capacity, soil depth, hydrologic soil group, runoff (from spray irrigation only), plant species choice and ET efficiency, estimated monthly ET, climate moderation adjustment, distribution system efficiency factor.

Design elements
Collected wastewater or divided wastewater plumbing, pre-irrigation filter, holding/pump tank, back-up irrigation filter, pressure regulator, A-B irrigation zone switching (includes valves and smart box scheduler), line emitters or pressure dosed piping, irrigation system (under mulch, near surface, mini-leachline or mini-pit), pipe-end cleanouts. Optional UV or ozone for surface disposal.

Winneberger (1984) and others have warned against relying too heavily on ET for disposal and the need to carefully plan for partial ET disposal in an area of erratic fog and marine moisture. The technical expertise to produce the best custom-designed system for Malibu for ET disposal is not usually found in the engineering professions and may require cooperative work by agricultural agents, soil scientists, horticulturalists, botanists and self-taught experts like Robert Kourik and others in Phase 2. There is a need for annual maintenance of pressure dosed distribution lines or the orifices will clog.

Reuse of Effluent for 4 Trees in the Month of May (modified from Kourik, 1991)

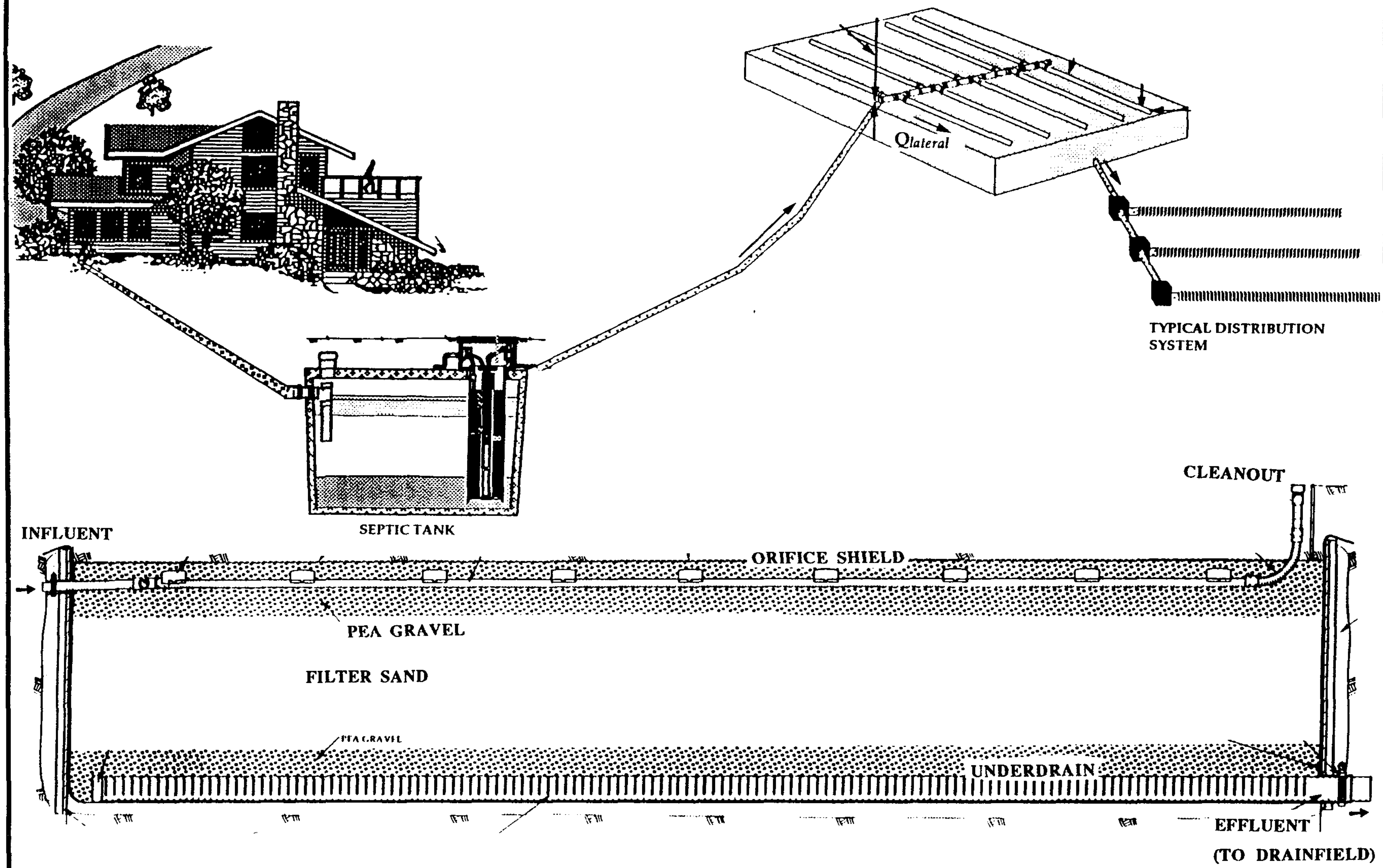
After pretreatment with a sand filter, the effluent from a single family home could be distributed through irrigation filters to 4 mature apple and walnut trees. (Mature trees will use more water than young trees.) The trees might be on 20' centers, forming a square with roots that cover 60'x60' (3,600 square feet). The pressure dosed irrigation lines or line-emitters will irrigate this square. The "plant factor" (efficiency of a particular species in absorbing and transpiring water) is 85% for walnuts or apples. The month is May (about 6" per month or 0.2" per day of evaporative demand) which requires about 0.125 gallons per square foot of root zone. The efficiency of line-emitters is about 90% in the moderate, maritime climate of Malibu. (Pressure dosed 1.25" pipe will give a slightly different rating.) A constant for converting square feet of root zone into gallons of ET is 0.623 (Kourik, 1991). Using the formula for daily needs of the 4 trees,

$$\frac{0.623 \times \text{Area of the Root Zone} \times \text{Plant Factor} \times \text{ET Rate}}{\text{Efficiency of the Line-Emitters in Malibu's Climate}}$$

the total requirement is 424 gallons per day. This is double the production of effluent from a household without water conservation. If the home had a storage area for winter time effluent, then it might use 200 gallons from storage and 224 gallons for its daily flow. The month-by-month calculation with various plant species can be done for existing landscaping as well as landscaping designed to reuse effluent.

XI.4 Pretreatment and Dosing

The intermittent sand filter (ISF) is proposed as a major addition to the "tools" available for on-site management in Malibu (Figure XI.4). They are a pre-treatment device (i.e., they treat the septic tank effluent to a level that increases the number of options available for reuse or disposal). For instance, ISFs reduce BOD by 99% compared to septic



Overall view showing septic tank with filter and pump, dosing line, 19' X 19' sand filter with its distribution system, and drainfield with its distribution system. Sideview showing influent and effluent pipes, pea gravel and sand filter, orifice protective covers. Sand filter can be covered with soil or used as planter.

Figure XI.4 Intermittent Sand Filter (courtesy of Orenco, Corp.)

tank effluent. They reduce suspended solids (SS) by about 93% and fecal coliforms by 99% (3 logs) compared to septic tank effluent. The dissolved oxygen (DO) in sand filtered effluent is about 8 mg/l vs. 1 or less in septic effluent. It is this reduction in the strength of the effluent that allows ISFs to increase loading rates to a soil and/or use the effluent in irrigation systems.

ISFs are used for shallow soils, soils with seasonal water tables, under pavement, and for easier reuse with subirrigation systems. Special considerations in Malibu include their use on the beachfront where they can drain vertically with no need to recapture the effluent and convey it to a drainfield (the "bottomless" sand filter). The ISF plays an important role in landslide areas where a goal of disposal is to maximize evapotranspiration (ET). Septic tank effluent without filtration is not suitable for line-emitter or drip irrigation because it clogs the water lines and may emit odors. Pre-treated effluent can be applied to shallow soils by line-emitters or in low-pressure pipes. The pre-treated effluent enters a holding tank and a pumping vault where it is pressure dosed to shallow irrigated areas.

Intermittent sand filters are not "new" or "alternative"--they have been in use since the 1850s. There are thousands of ISFs in other parts of the United States. They are "new" to Malibu and require a period for the technology to be transferred to local contractors. We had a hard time finding any civil engineer in southern California with enough experience to bring us comfort. ISF installation will require careful monitoring by the city and annual maintenance by an operations manager and, in this sense, are considered special systems. ISFs are a primary reason for a certification program, a training course, and peer review (Chapter X).

Dosing is the periodic application of effluent to the drainfield or subirrigation system. The most important goal of dosing is maintaining aerobic conditions and “resting” periods where the drainfield is dry enough to slough off some of the biological mat. This sloughing prolongs the ability of the soil to infiltrate treated effluent. Aerobic conditions benefit plant uptake for ET disposal and create an microbial species mix that more rapidly processes organic matter and nutrients in the waste stream. Dosing can be used for: (1) poor soils which require longer non-saturated flows; (2) tight areas where the amount of infiltrative surface may be marginal; (3) hillslopes, especially with marginal soils, to achieve equal flow distribution to all seepage pits or to all laterals and along all laterals in trench geometries; (4) under pavements where it is important to maximize the flow of soil air; and (5) as part of the irrigation system to control soil moisture.

Dosing is accomplished by a siphon or pump. Technical details are provided later in this chapter. Dosing is not a new technology but will become a more important tool in Malibu in the design of sustainable on-site systems.

XI.5 Application of On-Site Technology to Malibu

As mentioned throughout this report, it is hard to find a general ecological situation for wastewater management in Malibu. General site suitability situations and other special ecological criteria for drainfield design, installation and construction are given in Table XI.4. The table provides a preliminary "checklist" for an applicant who will custom-design their on-site system for a new, remodeled, or renovated home or for a commercial establishment. A system can fall into two categories. For instance, a home could have both "inland" and "floodplain" concerns. Most homes, however, will fall under one of the following categories for design, installation, repair, and maintenance:

A. New and renovated systems on mapped landslides.
B. New homes, remodels or renovations for single family residences with a new bathroom, bedroom or potential bedroom. These can be broadly subdivided into coastal or inland SFRs.
C. All new and renovated commercials, including changes of use within a commercial complex.
D. All multiplex residences, including condominiums or existing buildings that remodel to contain more units.

The new and repair designs and options for on-site systems are summarized in Table XI.5. Given the wastewater loads and ecology, Table XI.5 contains the vast majority of custom designs. This list includes wastewater load volumes and wastewater reuse, allows for cartage under special circumstances, designates groundwater and surface runoff control when necessary, and makes allowances for experimental and neighborhood systems.

TABLE XI.4: Sites and Design Concerns

A. Floodplain (100 year)
  - High groundwater table
  - Inundation of drainfield during flooding
  - Distance before possible daylighting

B. Beachsite (not yet shown to be actual constraints)
  - Median High Water Line
  - Seasonal beach profile
  - Uphill freshwater sources
  - Depth of sand to fresh or saline groundwater
  - Height (ASL) of bottom of drainfield
  - Type of bulkhead installation
  - Depth to bedrock, cobbles or non-sandy layer
  - Soil inclusions in dispersal area below and around drainfield
  - Initial high rates of percolation

C. Inland (non landslide)
  - Bedrock transmissiveness
  - Relation to groundwater
  - Shallow soil qualities
  - Slopes over 25%
  - Artificial fill and benching
  - Slow permeability of earth materials

D. Commercial/Institutional
  - Peak flow day(s) and flow equalization
  - Peak flow season and adequate rest periods
  - Periods without inundation (dosing, pressure pumping, and dual-field potential)
  - Changing users who discharge different qualities and quantities of waste water
  - Unique wastewater characteristics (e.g., grease, food solids, dry cleaner condensates).
  - Paved surfaces
  - Groundwater sources and surface runoff infiltration
  - Uniform flow distribution
  - Lack of future or dual-drainfield area
  - Proper management of system

E. Landslide
  - Location within slide mass
  - Cumulative impacts: housing density, buffer-zone contributions,
  - Uphill watershed contributions
  - Other groundwater sources
  - Subarea wastewater loads and water conservation
  - Slope
  - Bedrock type
  - Depth of any proposed seepage pit
  - Bedding planes and slope
  - Artificial fill and benching
  - Hillslope cutting: meandering stream or engineered
  - Previous history of slides
  - Dewatering locations, effluent plume and discharge points
  - History of previous legal actions on slide
  - Smaller landslide features: soil creep, terracettes, slumps, settling

F. Under pavement or other non-permeable surfaces

G. Removeable groundwater

TABLE XI.5: Technological Options

A. Wastewater loading reduction by interior water conservation (25%)

B. Wastewater loading reduction with intense water conservation (40%)

C. Wastewater loading reduction as above with cartage

D. Wastewater loading reduction + greywater system

E. Wastewater loading reduction + greywater system + cartage of blackwater

F. Wastewater loading reduction + winter-only cartage

G. Septic tank and trickle flow drainfield

H. Septic tank and dual drainfields

I. Pressure distribution to drainfields

J. Intermittent sand filters (contained and bottomless)

K. Pressure distribution with ISF + sump + pressure distribution for subirrigation

L. Recirculating gravel filters

M. Mounds

N. Experimental systems (e.g., waterless toilets, constructed wetlands)

O. Neighborhood systems (less than 50 homes)

P. Subarea systems (100 homes or more)

Curtain, interceptor or perimeter drains

Surface runoff control

XI.6 Mapped Landslides: Single Family Residences

The major concern of this group of homes is disposal and subsequent deep percolation of effluent to the slide plane. The major strategies are reduced wastewater loadings and maximum reuse of wastewater. Design concerns center on the need to (1) spread effluent so it can be best utilized by plants vs. concentrating effluent in one deep seepage pit, (2) determining the infiltrative capacity of transmissive bedrock; and (3) a high quality effluent that will not clog irrigation systems. Operational concerns include maintenance of sludge build-up, pumps (where applicable) and irrigation systems.

Hydrological interventions must be broader than wastewater only. A"menu" of possible neighborhood interventions could include:

- -- Interior water conservation to reduce wastewater loads and percolation below the root zone.
- -- Exterior irrigation control to reduce percolation below the root zone.
- -- Diversion of runoff to streams from hard surfaces (roofs, patios, streets).
- -- Reuse of household wastewater (grey or combined) for irrigation.
- -- Reuse of household greywater within the home.
- -- Storage of runoff or treated effluent water in sealed tanks for fire protection and irrigation.
- -- Movement of sewage flows to a part of the slide mass where percolation has less impact (the neighborhood drainfield) or off the slide mass.
- -- Dewatering wells.
- -- Dewatering hydraugers.
- -- Sealing swimming pools.

All options require mandated water conservation: The water conservation options are listed under "Indoors" in Table XI.1. These options include water conservation to reduce surplus irrigation water descending below the root zone; substituting treated wastewater for imported irrigation water; and partial use of arid-adapted plants. The "stop deep perc-ing program" should include prohibition of runoff drywells and neighborhood review of stormwater runoff patterns. Through consensus between hydrogeologists and local homeowner groups, the strategy could insist upon the "intense" water conservation scenario with quarterly review of water usage bills for those homes contributing to the slide. The water conservation program must include all the homes contributing effluent to the slide plane. This may not include all the houses within the slide and may include some in the buffer zone (Chapter IX).

Partial Disposal by Evapotranspiration (ET) Options: Ideally, on landslide parcels, the on-site system should be designed for maximal disposal by ET and incorporation of effluent into plant biomass. Tree biomass can hold significant amounts of water, and grasses can be cut and removed or dried further removing water.

Simplest Option 1: Shallower drainfields with some landscaping to increase ET disposal. The technical goal is to dig trenches or seepage pits within the root zone instead of deep seepage pits below the root zone (i.e., 15 feet) and spread the effluent among many pits or trenches to allow greater water absorption rather than concentrate disposal at one point. Trenches are probably more cost-effective for the equivalent amount of seepage pit infiltrative area (see "Costs"). Shallow pits or other drainfields (e.g., ditch witched trenches with pressure dosing) should be required for all renovations and new homes on landslides. This option does not calculate additional ET disposal but simply tries to maximize it at some undetermined level.

Option 2: Specialized septic tanks with an intermittent sand filter (ISF) and shallow subirrigation. This option plans directly for a specific amount of wastewater disposal through plant ET. It hopes to attain the 60 to 70% water reduction explained above. This option requires determining the soil/fractured bedrock parameters, the area to be set aside for subirrigation, and the use of specific existing or purchased plants. The amount can be compared to wastewater loading rates to determine the reduction of effluent seeping below the root zone.

In large lots, shallow trenches or seepage pits can be placed where most convenient to maximize ET. Proper flow distribution may require pumping to drainfield. On smaller lots, this option requires the use of a septic tank with a pumping vault to an ISF with a holding tank for irrigation dosing to varied laterals. Each system has an overflow to existing or installed seepage pit.

For winter use, seepage pit or trenches as in Option 1, or winter-time cartage if the situation is considered extreme, should be considered. During dry winters or long inter-storm droughts, a valve can allow use of the irrigation system between November and March.

Option 3: Specialized septic tanks with intermittent sand filter and post-treatment disinfection for surface irrigation, reuse or storage. This is the most complex technical intervention. The septic tank with a pumping vault feeds an intermittent sand filter. The "pre-treated" effluent is collected in a holding tank where it is pressure dosed through a UV filter to a series of near-surface (2" below surface) irrigation laterals. A pre-UV filter is sometimes employed to reduce turbidity. Steve Wert has designed a similar system for $18,000. The only parts requiring replacement would be the UV filter and the pump. They could be part of the demonstration projects of Phase 2.

Option 4: Waterless toilets and other experimental systems. The new SunMar composting toilet has received approval from the National Sanitation Foundation. This composting toilet should not be confused with experiments in the 1970s which had no fail-safe features such as heating mechanisms to control moisture. The Earth Trust Foundation on Big Rock has offered to demonstrate the use of the SunMar in Phase 2. This seems an ideal locale, situated on a well-known landslide and under the auspices of an environmentally conscious organization.

Corporations involved with ultrafiltration reuse systems, such as Thetford Corporation or Memcor, have volunteered demonstration projects. A Thetford system is operational in Santa Monica. The water produced by this system can be used for toilet recycling or irrigation.

XI.7 Inland: Single-Family Residences

The goal is to upgrade remodels and renovations as well as design new systems for sustained use and to prevent accelerated clogging of the drainfield by lowering the loading rates and/or reducing the strength of the effluent. In addition, dosing can increase periods of non-saturated flow and soil aeration.

Option 1: Water conservation. A remodel may increase wastewater loading rates. In addition, the home may already be experiencing overloading. Step 1 of a permit procedure would require a water conservation audit based on water bills, fixtures, occupiable rooms, and bathrooms. If overloading is probable, the homeowner can choose between greywater reuse, low-use fixtures (horizontal washing machine, ultra-low flush or dual-flush toilets, removal of garbage grinder) or a re-designed system. A"party bathroom" with air-assisted and spring-loaded faucets is also an option. The goal is to harmonize wastewater loads with the existing system or to improve the system.

Option 2: Balancing intermittent sand filter pre-treatment with water conservation. Sand filters with dosing are the most accepted method in areas with limited lot size and poor soils for reducing effluent strength and allowing increased loading rates. ISFs can be added between the septic tank and existing drainfield. Unless the drainfield is shown to be marginal or a problem, the drainfield can remain as the disposal device. ISFs can be used with water conservation.

Option 3: Additional area available. To achieve long-term systems, an area with large lots can use (1) a dual-drainfield system as long as enough sidewall area can be found; or (2) an ISF pre-treatment with disposal or subirrigation. The choice is site-specific. Many designers feel that one good system is better than two alternating ones. Dual-drainfields are crucial in difficult access areas where it is important to put in one system and "never" come back.

Option 4: Waterless toilets and reuse systems. As above, reasonable experimental systems should be allowed.

XI.8 Beachfronts: Single Family Residences

We are currently unaware of any general treatment and disposal problems for the beachfront. The alleged goal is to reduce possible pathogen concentrations. If further studies should indicate that this is, in fact, a necessity in certain areas of the beach, then technical options are available. At the moment, there is no such evidence.

On the other hand, most beachfront systems can be improved and their life span prolonged. Some homes are below the postulated minimum of about 620 square feet of infiltrative area (Chapter VI). Upgrading should be required if remodelling increases wastewater loads on tight lots, and at the end of an existing system's life. ISFs can be beneficial on small beachfront lots because post-ISF disposal does not require additional area and a 2 to 3 log reduction of indicator bacteria occurs during pre-treatment. Disposal can occur vertically through the bottom of the ISF (the "bottomless sand filter"). Additional technical options include: specifying and inspecting high quality fill material for seepage beds; using intermittent sand filters on very tight lots; raising drainfields to a higher elevation in areas with significant landward intrusion of tidal surges; meeting County bulkhead requirements and employing greywater systems and water conservation to reduce loads to existing seepage beds or drainfields. The problem of "sand creep" into the drainfield gravel will be discussed in section XI.13

Many of the beachfront homes have "reserve areas" which do not need to be reserved because drainfield construction removes all the old sand and gravel, replacing it completely. These reserve areas could be used for simple greywater systems at very low cost (e.g., the Santa Barbara greywater system).

XI.9 Commercial On-Site Systems

All commercial buildings require custom designing. Unique quality discharges (e.g., photochemicals) require careful planning. Using cookbook codes would increase the chances of a poorly designed system. To remain with on-site practices, the city needs a knowledgeable person(s) to constructively review commercial wastewater plans. The most important concern is the strength of the effluent.

Option 1: On-Site System. Since most commercial systems are under pavement, *aeration devices* are a necessity (see below). *Pressure dosed ISFs* would seem beneficial for flow equalization, uniform flow distribution, dosing/resting periods (increased aeration), and reduced suspended solids in the drainfield.

A *holding tank* for peak flows and *better grease traps* are a necessity for restaurants. *Nuisance odor control* is easy and should be available in any design. BioSolutions has started an experimental program in Malibu with special strains of bacteria in order to maximize the beneficial bacteria concentrations and improve grease and odor control (BioSolutions, p.c.)

Because of limited lot size, seasonal peak flows may require *cartage.* The choice between full cartage vs. winter cartage vs. peak season cartage vs. blackwater cartage with greywater disposal or reuse should be available in the permit.

Option 2: Neighbor Reuse Systems. On parcels without room for expansion or repairs, the existing on-site system may eventually require complete replacement, including the soils. In these circumstances, cost comparisons with some of the newer reuse systems should be required. On a certain scale, reuse systems (e.g., Thetford Corp. or Memcor Corp.) with ultrafiltration and recycling of highly treated water for use in toilets, on-surface irrigation or washing machines become a viable economic alternative. These systems may be particularly appropriate for the inland side of PCH where a series of commercials are clustered and would prefer an alternative to cartage or shorter-lived drainfields.

XI.10 Multiplex On-Site Systems

Small multiplex buildings should have designs similar to single family residences but with septic tanks at the large end of the scale (1,500 gallons) to handle peak loads, especially washing machines and dinner parties. Quadruplexes and larger require special attention. Community laundries require attention to lint and should install an effluent filter on the outlet.

There are some condominiums that appear to have ruined their drainfields through overloading. There may not be room to rehabilitate these systems on-site. These condominiums have the following options: (1) a greywater reuse system with blackwater haulaway; (2) total cartage; (3) purchase or long-term lease agreements with nearby properties for additional drainfield area; (4) a high-tech reuse system, usually an ultrafiltration system, that would allow recycling to toilets and washing machines and near-surface irrigation; and (5) a subarea sewer. The subarea sewer for multiplex buildings need only be considered in the Point Dume highlands area as explained in Chapter IX. In the interim, the city should require permits for haulaways and an intense water conservation program as a condition of the permit. The water reduction should reduce haulaway costs.

XI.11 Other Special Ecological Design Constraints

Slopes: Slopes up to 30% can be handled by backhoes and most drilling equipment. After 30%, special equipment is needed and special thought must be given to the geohydrology, especially on landslide areas. There are no rules. The designer must answer questions about day-lighting, foundations, water flow, location of future additions, and uniform flow distribution.

Artificial or regraded fill: There is nothing automatically wrong with artificial fill. Problems of compaction, preferential flow, decayable organics (sticks), and impervious inclusions (a railroad track was found in one Malibu drainfield excavation) must be addressed. Actual drainfield materials need to be carefully addressed and fieldchecked by staff. Site preparation, use of dry materials, good artificial fill materials (uniformity, correct and effective grain size), and bulk density tests at field capacity checks are required.

Pavement: As explained in Technical Memo 6, although long-term data are not available, drainfields beneath pavement should be discouraged. Damage to drainfields commonly occurs from heavy vehicles. Adequate pavement strength is a necessity. Breezers should be required for single family homes and all commercials with paved-over drainfields.

More elaborate interventions are worthwhile considerations for many commercials. They include pre-treatment with an ISF and dosing the drainfield. The addition of plant life around paved-over drainfields should be a requirement. For instance, small trees or deep-rooted grasses can be placed at the common "+" intersection of four cars in a parking lot without losing significant parking space. If the paved over area eliminates trees from an area near a seepage pit, the pavement has essentially eliminated the use of ET for effluent disposal. Either planters cut through the pavement or careful spacing of trees near seepage pits should be considered.

If necessary, technical interventions for drainfields under pavement may include parallel aeration lines with breezers. Venting and cross-flows are important. Fans might be used. The technology is not developed and some peer reviewed aeration experiments are a worthwhile goal.

Floodplain: The minimum setback for intermittent streams is usually definable by hydrologists. In Oregon, for instance, the minimum setback is the 5 year floodplain. The goals of floodplain design generally revolve around removal of nitrates and possible pathogens. These decisions depend on soil and soil depth, groundwater level, and level of treatment. Options under high groundwater are similar to floodplain systems. If the 10 year flood line is known, it is also a reasonable setback. More distant setbacks are management risk decisions to keep drainfields out of a particular occurrence of flood: 10, 25, 50, or 100 floodplain.

Poor drainage, high groundwater: The technical interventions include:

(1) A review of neighborhood surface drainage and home impervious surfaces to see if cause could be stormwater runoff

(2) Determine if groundwater is seasonal or year-round.

(3) Determine if soil is drainable. If drainable, use a perimeter drain on slopes less than 12%. If steeper, use a curtain drain.

In all cases, the "intense" reduction of wastewater loads will help increase resting periods. The planting of winter active trees near the drainfield can reduce groundwater levels. For chronically high groundwater, determine among the following options: shallow, sand-filled trenches that are pressure dosed; intermittent sand filter with shallow conventional drainfield; ISF with shallow conventional drainfield but pressure dosed; raised flower-box ISF or pressure dosed mound sitting on permeable soil.

Nuisance odors and nuisance flies: The technical options for odors are charcoal filters on vents, lifting vents to a greater altitude. The usual sources of flies are cracks or poor fits between the septic tank lid or the seepage pit porthole lid and the base it sits on. Less frequently, vents and breezers can cause nuisance fly outbreaks. To keep flies out of the tank, many sealants are available to fill the cracks. Mesh screen on the vents or on top of the inlet tee is advisable. Odors may be controlled by weekly additions of particular bacterial strains (BioSolutions, p.c.).

XI.12 Component Details

This section provides a discussion relevant to the new set of codes to be written by the COM in Phase 2. The UPC may be useful for such items as watertight septic tanks, but it is less useful, if not damaging, for items such as pump choice or setbacks. Phase 2 will consider what, if anything, can be used from the UPC sections on on-site wastewater systems.

Wastewater loadings: The "typical" Malibu residence could be designed with 300 gallons per dwelling per day. To cover the possibility of large users moving into a home, probably 350 gpd per dwelling could be designed into certain design features (covering about 90% of all users). These volumes do not include water conservation. Other designers prefer 55 to 75 gpd per bedroom. We have shown that bedrooms do not correlate well with water use. In certain circumstances, bathrooms were more closely correlated with internal water use. Multiplex or community systems can use 200 gpd.

The practical result of these estimates is that the larger the septic tank, the fewer the possible problems. Given costs, a 1,000 to 1,200 gallon septic tank is reasonable for a four bedroom house. Multiplexes should start with 1,500 gallon tanks. Some designers (after seven bedrooms or units) calculate multiplex septic tank requirements by the US Public Health Service formula: 75% of expected daily flow + 1175 gallons.

In Malibu, any home with a switch of residents or ownership could become a party home. A rule of thumb from barrooms is: each party guest will produce 20 gallons per chair. This includes washing the dishes after the guests leave. For private homes with even minimum water conservation fixtures, a load of 20 gallons per guest appears reasonable. When parties begin to exceed one-third to half the volume of the tank, pre-party pumping, chemical toilets or an installed holding tank are options.

Setbacks: Setbacks can be horizontal (the distance between part of the on-site system and another point on the landscape) or vertical (the distance between the top of the on-site system and another point above or below it.) Setbacks have been the centerpiece of cookbook on-site design. They make little wastewater engineering sense (Technical Memo 3). The goal of setbacks is to ensure that there is enough saturated and unsaturated flow, as well as proper filtering by rock/soil, to treat the effluent before it re-enters the water cycle (groundwater, stream, surfzone). The setback should be determined by the intervening soil but is not. In addition, setbacks are a "safety" space between neighbors. Where everyone wants to build in small lots (the beachfront), the setbacks to property lines diminish to below 5 feet. Where a neighbor can place a swimming pool, cut a road or bench near a property line, the setbacks are usually 10 feet to the drainfield.

Some setbacks useful to on-site practices are never specified (e.g., room for equipment access). Some setbacks had a meaning (broken septic tanks and drainfields might make house footings unstable) but they are not applied with the type of house footing or its location in mind. Other than a reasonable distance from a neighbor, which could be waived by mutual agreement, there appears to be no need for horizontal setbacks except in floodplain, creek, and cliff edge situations. In these situations, the setback should be determined by conservative hydrology.

Two vertical setbacks are commonly established: the vertical clearance above the on-site system, which is called the "blue-sky" requirement, and the vertical distance between the bottom of the drainfield and a water table. Only a small vertical clearance is necessary for air flow. As explained in Technical Memo 6, paving over a drainfield (zero clearance) should be discouraged. The vertical clearance below elevated porches and floors are cost considerations, not safety or health considerations. Low clearances will require hand labor or, in some cases, removing the porch or patio for access to the drainfield. The homeowner should be required to attach to the house deed that this higher cost situation exists and should be required to assure reasonable hand labor access. Situations which require tearing out a floor or patio are reasonable to prohibit.

The distance to groundwater is to ensure that there is an unsaturated zone for the effluent after it leaves the drainfield. The unsaturated zone need not be present every day of the year but should be violated only in wet years or exceptional tidal storm surges. The distance is debatable. Most designers contacted by PEWARA felt that 2 to 4 feet of unsaturated soil or sand was sufficient. Four feet of unsaturated sand between drainfield and a water table is enough. Inland, soil mottling and wet season water tables should be taken into account in making this judgment. If saturated conditions are expected to persist longer than 2 weeks, then additional design is necessary. These rules of thumb should not be mistaken for gospel.

Septic Tank: Table XI.6 lists design criteria, special cases, engineering factors to be considered, and the "menu" of various septic tank types. Many of the design features have not been studied carefully. For instance, the actual release of suspended solids from septic tank types is not well known. Some will argue that single-compartments (with an effluent filter to stop cigarette filters and such) are actually better than multi-compartment tanks. The single compartment tank prevents unequal sludge accumulation which, when deep, can be stirred up by surge flows. Others argue that the best flow-through pattern requires long runs with turns. From theoretical studies, the meander tank appears the best. However, no specific data on suspended solids or BOD is currently available. Most usual installations have two chambers, but the arguments go on about proper depth, volume distribution, etc.

TABLE XI:6 Septic Tank Design

Design Goals
Wastewater/day for settling; peak surges; solids/scum storage; reduced suspended solids and soluble BOD.

Special Criteria
1. Commercials or any building that produces a water quality different from domestic wastes (e.g., grease, food wastes, photo chemicals).
2. Any multiplex, condominium or institution with erratic peak flows (e.g., churches).

Types (see Figure XI.5)
A. Gravity/conventional two compartment
B. Gravity/conventional three compartment (meander tank)
C. Gravity/conventional with effluent filter
D. Septic tank with dosing chamber (siphon)
E. Septic tank with dosing chamber (see "internal pump" and "external pump")
F. Custom-designed receiving tank for special purposes or experimentation

Design Criteria
Volume; compartments and flow-through design; volume distribution; proportions; surface area to depth (length to width; minimal depth; minimal length); clear space above liquid; depth of water below inlet; materials; structural strength; water tightness.

Septic Tank Appurtenances
Ports (location, diameter, seal); Risers (materials, manhole); Inlets; Compartment baffles; Outlet; Gas Baffles.

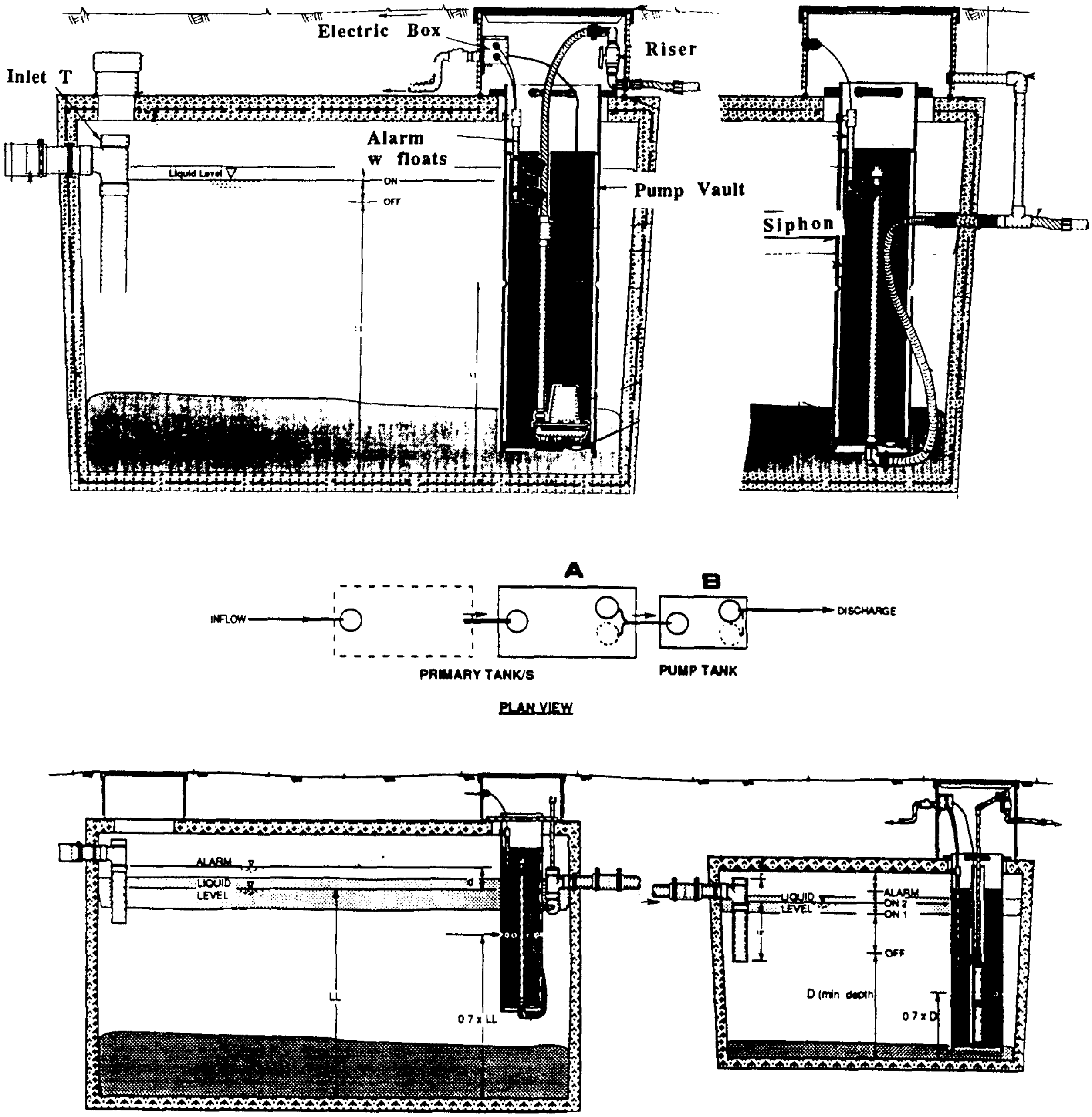


Figure XI.5 Septic Tanks (courtesy of Orenco, Corp.)

Upper left view shows typical 1,000 gallon septic tank with an effluent pump for dosing sand filter, sewer, or drainfield. Upper right (cut off view) shows a dosing siphon in place of an electric pump.

Lower diagram shows arrangement for commercial or multiplex buildings with large flows (1000 to 10,000 gallons per day). Tank A has effluent filter. Tank B is high-head pump.

All designers agree that an inlet "T" and double "T" for the compartment wall and a "T" at the outlet are useful precautions. They also agree that the data on gas baffling (preventing gas bubbles from lifting solids to the inlet) is weak, but since gas baffles are inexpensive, they use them whenever practicable.

From the city's point of view, two portholes (or as many portholes as needed to access all chambers), risers to the surface of the ground, minimal diameters of 18" for the portholes and preferably 22", and good sealant or fit between the porthole caps and the tank top and riser top are required. There are many possibilities, including importing plastic risers from companies like Orenco or making them locally. Good seals are important for septic tank lids and risers. We found many blackflies entering and leaving through small crevices.

Commercial tanks need special design. Parallel tanks to one drainfield should be prohibited unless completely justified. Single tanks are preferred over tanks which are in series because some chambers tend to be skipped in maintenance. Risers with marked portholes and a written agreement with the pumper should be required to insure proper pumping. It is too site-specific to detail grease traps, holding tanks, and other items that may be useful for commercial systems.

Material and structural standards for reinforced concrete and fiberglass septic tanks, California manufacturers, and access risers are well established and can be incorporated into the city's proposed ordinance without extensive revision.

Intermittent sand filters have been proposed earlier in this chapter as a major addition to the "tools" available for on-site management in Malibu. Special considerations in Malibu include their use on the beachfront where they can drain vertically with no need to recapture the effluent and convey it to a drainfield (the "bottomless" sand filter), and on landslides to increase reuse and reduce deep percolation. Because of outages, special attention needs to be paid to the size of the dosing tank volume. The sources of high quality sand (Table XI.7) need to be established.

Drainfield: The drainfield is the most site-specific part of the on-site system. Tables XI.4, XI.5 and XI.8 and Figure XI.6 list major site-suitability categories which are recommended parts of a check-list for each drainfield to be installed. They "red flag" major design concerns for the staff and peer review. The criteria provide a clear method to judge the ability of the designer to assess site suitability. Choices include: narrow trenches, in-trench sand filters with pressure dosing, seepage pits, conventional trenches, seepage beds, and (not our favorite) mound systems.

Table XI.7 Intermittent Sand Filter

Goals
Especially suited for tight areas (small lots) and sites with slow soil permeability. Special uses in Malibu include use for effluent quality for subirrigation reuse on landslides and for drainfields under pavement. Can be used for normal site conditions, for high groundwater tables, and shallow soil over impervious rock.

Design Criteria
Filter medium (material, effective size, uniformity coefficient, depth); Underdrains (not for beach, possible for recycling for subirrigation); Pressure distribution (pump type, pipe size, orifice size, head on orifice, lateral spacing, orifice spacing); Design process parameters; Hydraulic loading; Organic loading; Dosing; Frequency (drawdown, uniform flow distribution); Dosage volume (drawdown); Dosing tank volume (safety if electricity fails).

"Typical" Design for a Single Family Residence
Area: 360 to 400 sq. ft. for SFR. Experimental versions are much smaller.
Filter loading: about 0.6 gpd/sq. ft.
Internal pump with effluent screen or external pump vault.
Dosing: usual is twice daily, each dose about 90 gallons. Should be custom-designed.
Filter media: 0.33 mm or 0.35 mm sand with a uniformity coefficient of 4. Requires highest quality.

Table XI.8 Drainfield Design

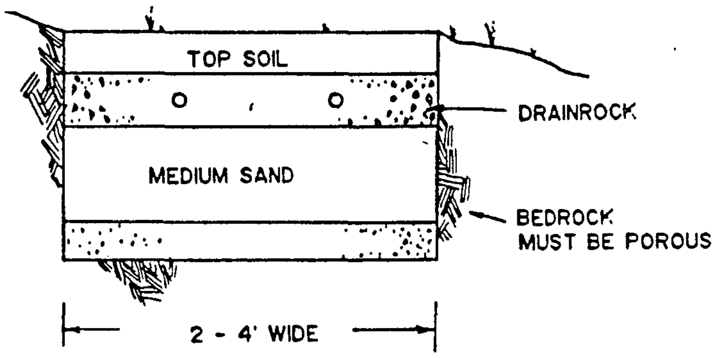
Special Criteria:

1. Reduce effluent to slideplane (landslide areas)
2. Use transmissive rock for dispersal (hill areas)
3. Serial or dosed distribution and depth considerations (slopes)
4. Aeration (under pavement)
5. Initially rapid infiltration (beachsands)
6. Pretreatment with special drainfield design (shallow depth to bedrock)
7. Pretreatment with special drainfield design (slow permeability)
8. Artificial and regraded fill (engineered fills)
9. Drainage and period of inundation (groundwater and/or floodplain)
10. Experimental system

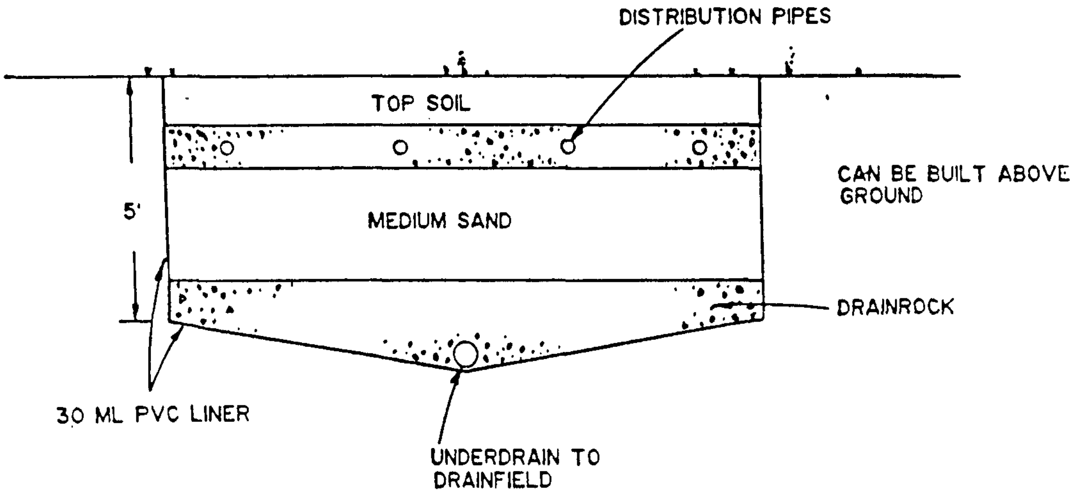
Design Criteria:

Sizing of the infiltrative surface
Geometry (beds, trenches, pits, narrow sand-filled trenches, etc.)
Configuration: dual, parallel, serial.
Fill materials
Separator between fill and soil cover
Pipe material and size
Orifice spacing
Soil aeration (breezer and/or aerators, fans)
Monitoring well
Reserve area
Curtain drain

In-trench Sandfilter



Sandfilter with Underdrain for Collection and Possible Conveyance to Subirrigation System



Bottomless Sand filter

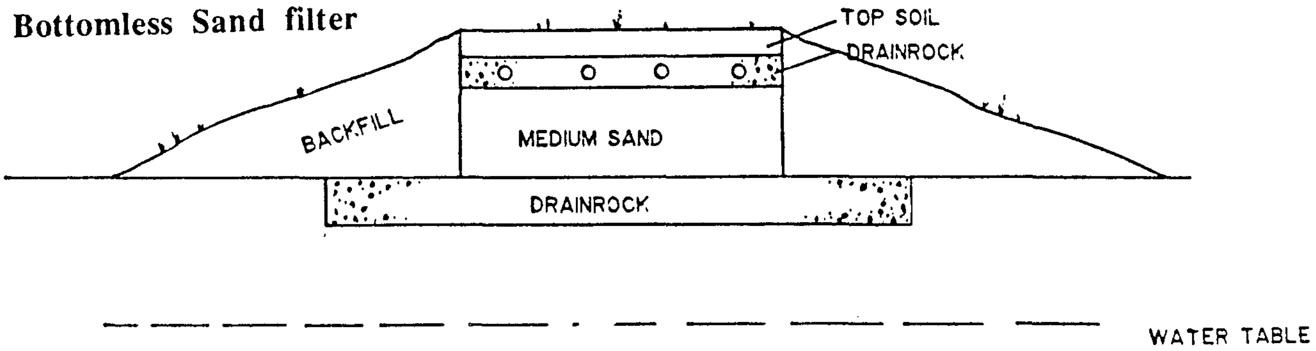


Figure XI.6: Drainfield Types (Courtesy of Steve Wert)

The first step in the permitting process will specifically list the design goals (e.g., reduce effluent movement to landslide plane). It includes a preliminary site inspection to determine "red flagged" criteria, adding any further design constraints discovered, and determining which system the designer prefers and why. The first step will also include a method to determine sidewall infiltrative capacity, a judgment on long-term capacity, and any problems in assimilative capacity (see section XI.13).

The second step will perform all fieldwork and design for final plancheck. If the fieldwork relies of percolation testing or bedrock basin tests or any other hydraulic test, then the staff will be informed of the day and time.

Malibu rock types need to be defined for long-term acceptance rates. If they are deep, the combination of hydraulic head should be combined with trickle flow infiltration rates. The "hydraulic" vs. infiltration situation is probably impossible to define without immense cost.

In digging deep seepage pits, the contractor usually makes a small diameter hole to explore the soil and bedrock layers. We recommend that the test hole (usually 1 to 2 feet in diameter) be converted to a monitoring well for both landslide risk and long-term effluent acceptance rate assessment.

Seepage pit design in Malibu has included brick or ring-lined pits with hollow centers. We recommend that this design be phased out and replaced with a gravel-filled pit with a perforated pipe down the center. There is a loss of surge flow capacity, but these systems are much safer from collapse and probably less expensive to install. The design is current in Ventura County and well-known to local contractors.

Manifolds: The uniform distribution of effluent has been a major problem in Malibu. The concrete distribution boxes or other plastic manifolds ("wyes" or multiple "tees") tend to settle or clog, producing uneven flow, so that one lateral or seepage pit is used more than another. There is not much that can be done with passive flow manifolds to achieve uniform distribution.

There are many adequate methods for pumped systems and these should be required in hilly country or slopes, especially for condominiums and other commercial buildings. In some cases, a serial distribution is adequate for single family homes. Serial distribution requires using one trench or pit before the next. This method can lead to progressive clogging of the infiltrative surface. The choice between serial distribution and pressure dosed distribution should be made explicit in permits.

Table XI.9 Pump or Siphon Vault Concerns

Internal Screened Vault
Minimum volume between pump on and off levels, manifolds for uniform flow.

External Screened Vault
Liquid volume below septic tank inlet, minimum volume between pump on and off switch, pump setting above bottom, pump type, manifolds for uniform flow.

Dosing: Dosing can be by siphon or electrically-energized pumps. Table XI.9 provides the design criteria and needs for installment within the septic tank or in a separate pumping vault. In Malibu, there will be a need to learn which pumps (head, flow, power) serve best for each condition. Pumps can be internal to the tank (see Figure XI.5) or in their own pumping vault. All pumped effluent should be preceded by an effluent filter or pre-treatment.

XI.13 Installation and Site Evaluation

Installation is both an art and a wisdom derived from experience and training. In Malibu, installers have done their best with poor guidelines and extraordinary terrain. This report cannot possibly include all installation knowledge.

Site Evaluation: The most important addition to Malibu's wastewater management will be improved site evaluation. Besides the insistence on red flagging problems and designing for them, site evaluation should include fieldwork that PEWARA rarely encountered in its review of DOH files.

First, for single family residences, a description of the soil should be required. This is not the description provided by structural engineers. It is a careful description of the soil layer(s) and porosity to be used for the drainfield. If the soil is porous enough and has good soil structure, then no further fieldwork will be required. An applicant's soil description is more easily verified by staff or peer review than percolation tests. Should the soil be red flagged (e.g., high clay content), then the city could require a percolation test.

Second, if the soil layer was shallow above bedrock and the bedrock will play an important role in the dispersal of drainfield effluent, then the bedrock acceptance rate will be required. Verified drainfield sizing in bedrock is not available. The best available method we know for shallow seepage pits or trenches is to backhoe a trench to an area of bedrock to be used. With a geologist's hammer, a shallow basin (1" deep) and about 3 to 5 square feet in area is dug. The area is swept clean and the basin is filled with water. Infiltration is then timed. The basin should accept 5 gallons per square foot per day.

Third, for larger flows, the long-term acceptance rate (Metcalf and Eddy, 1991) should be required unless the soil description clearly indicates that it is unnecessary. Known as the "absorption trench" or the "shallow well pump in" test, the test demonstrates how fast the effluent disperses and where it goes. The detailed descriptions for these procedures are beyond the scope of this report.

Beachfront: A major installation problem has been "sand creep" into the gravel and the drainfield pipes. Three methods have been used to prevent sand creep. The best and most labor intensive method, is to use 2 pieces of plywood to create a "buffer" of pea gravel around the larger gravel of the drainfield. The plywood forms are set and filled with about 6" of pea gravel. The drainfield rock is then backfilled and the forms removed. This provides excellent protection. A second method involves"Infiltrameters", which are 2' wide half cylinders that must be protected by a pea gravel buffer. They protect the drainfield pipes and provide ample room for discharge into the gravel. Hancor and a corporation in Connecticut are the suppliers. A third method, is to use pea gravel instead of drainrock. A 1 1/4" PVC pipe is placed in pea gravel and pressure dosed. We do not recommend filter fabrics.

The procurement of high quality sand and gravel should be under city regulation. Only those businesses that can meet city standards should be able to sell to contractors.

Normal soil installation: The main installation problems have always been smearing the sidewalls, installing too steep a grade on trench bottoms in the wet season, and poor distributions of flow. Smearing ruins the infiltration surface of the drainfield.

Table XI.10: Installed Costs*

Curtain Drains (5 feet deep)	$8/running foot
Leachline (2 feet wide x 2 feet deep)**	$6/running foot
Mounds	$14-22,000
ST + conventional leachlines	$3,500 to $5,000
ST + pressure dose + "Bottomless" ISF (pump in tank)	$7,000 to $9,000
ST + pressure dose + ISF + pressure dose + shallow trenches	$15,000
ST + pressure dose + ISF + UV + pressure + near surface (2") irrigation	$18,000
ST + pressure dose + in-trench sand filter	$5,000 to $6,000
Percolation Test (inland)	$900
Testing Pits for Seepage Pits	$700 to $1,000
External Pump for ST	+ $1,200
Siphons (minimum 15-20 foot elevation)	- $300 to $500 compared to in-tank pump

* Includes 1,000 gallon septic tank, pump inside septic tank, electric and pipe hook-up and installment labor. Permits or special consulting fees not included.

** Labor for hand-dug beach parcel about $1,000 per 100 square feet.

ST = septic tank

XI.14 Costs

The total cost of an on-site system includes permits, design fees, costs of materials, and installation costs. Permit fees are unknown at this time. Design fees are difficult to judge because we could find no civil engineer or equivalent in southern California with extensive experience with intermittent sand filters and pressure dosed systems. Malibu may have to attract outside designers until a local group of professionals can apprentice or learn to install non-UPC designs. This raises homeowner costs for a period of time. The costs of materials and installation can be approximately estimated. But, even in these areas, the installations may require a learning period and it is not clear if there are competent installers of certain types of pumps, filters, and subirrigation lines for treated wastewater reuse. The experience of PEWARA consultants is that many good ideas and designs fall into disfavor from poor installation. Finally, there is the question of "what costs the trade will bear." For instance, prices in Marin County tend to $1,000 to $2,000 more per installation than Oregon because customers are willing to pay that amount without complaint and costs of living are higher. As competent competition enters the market, initial costs of proposed systems will probably decrease.

Table XI.11: Some Unit & Maintenance Costs

Unit Costs	
Aerators	$500
Carbon Filters	$50
Risers	
21" diameter	$21/foot
24" diameter	$24/foot
Lid	$30 to $50
Adapters for Fiberglass	$25
Filter Fabric 4.5 feet x 100 feet	$25
Sandfilter Collector Cloth	0.35/square foot
Dosing Siphons	$200 to $300
External Equipped Pump Vaults	$1,500
Maintenance Costs	
Pumping to Customer	$100 to $200
Pumper's Dumping Fees	0.03 to 0.08 per gallon
Grease Pickup	$25 to $50 (one-time fee)

Tables XI.10 and XI.11 provide rough estimates of costs from discussions with suppliers, contractors, and experience in other areas. There are large discrepancies in costs with the Questa report (1988) which we cannot explain. Questa costs appear to be consistently higher. The cost of intermittent sand filters will drop as they become more mainstream in southern California.

XI.15 Neighborhood and Subarea Systems

William Bowne's Technical Memo 14 discusses the general implications of different types of sewers. In this report, we have suggested the possibility of neighborhood (5 to 50 homes) or subarea (100 or more homes) sewers. Three more recent technologies (pressure, small diameter gravity, and vacuum sewers) may be appropriate in these situations (Figures XI.7 and XI.8). Each of these sewers uses small diameter, lightweight plastic pipe in 20 foot lengths which are shallowly buried. In some cases, they can follow the topographic profile as contrasted to classic gravity sewers which need a continuous downslope. Some do not need rigorous grade control. The 3 alternatives are non-growth inducing and citizens may prefer them because they are not subsidizing future growth. Costs are typically one-half of conventional sewers even after including maintenance.

It is premature to suggest subarea designs. We were not asked to review the proposed STEP system or compare costs and technologies. In Technical Memo 14, observations by sewer dealers and the home-site survey have brought out the following thoughts. The use of polyethylene or polybutylene pipe may be superior to classic PVC in areas with land movement such as Malibu Road or Big Rock or any of the areas with swing joint, surface water lines. In other words, the conveyance system should be chosen for flexibility and shallow burial. An advantage of vacuum sewers (vs. pressure sewer) is that no electric power is required in the home served and standby electric power can be provided at the central vacuum station. There is no interruption of service during outages and the holding tanks needed with pressure sewers could be eliminated. Alarms would not occur in the home but at the vacuum station. With vacuum sewers, there is no sludge or scum generated and no associated pumping costs. The septic tank could be used for a greywater reuse system, an emergency holding tank, or abandoned. The wastewater remains aerobic so that pre-treatment would not be required prior to discharge into a gravity sewer. This may be required in septic tank effluent pumping (STEP) or small diameter gravity (SDG) sewer systems. Sewage spills would not occur if the line breaks as it also breaks the vacuum. On the other hand, careful consideration is needed of vacuum pipe flexibility and the impacts on vacuum seals.

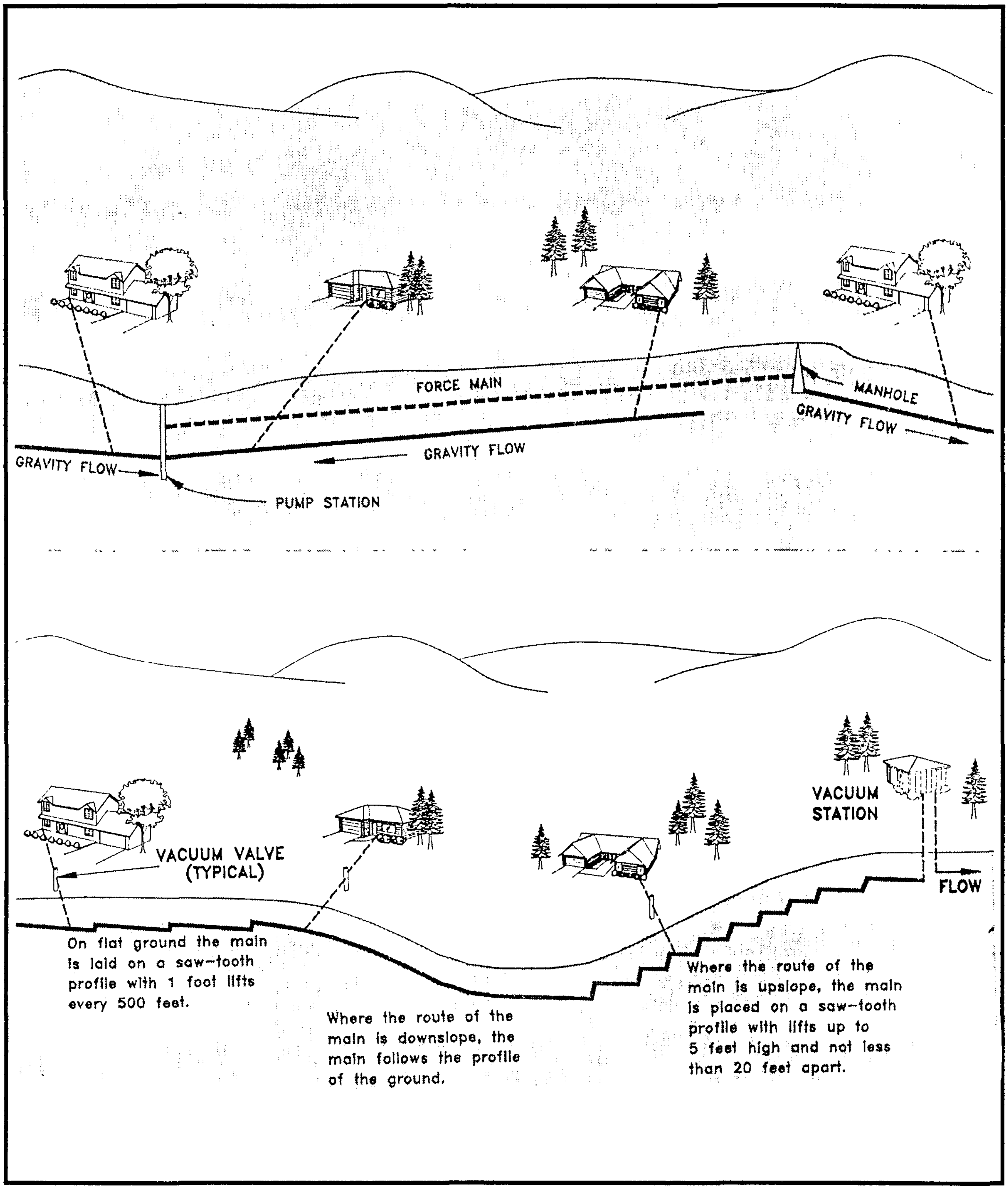


Figure XI.7: Gravity vs. Vacuum collector and conveyance sewers. Gravity sewers show manholes and required pump stations. Vacuum sewers show nighborhood vacuum station. Courtesy of Bill Bowne.

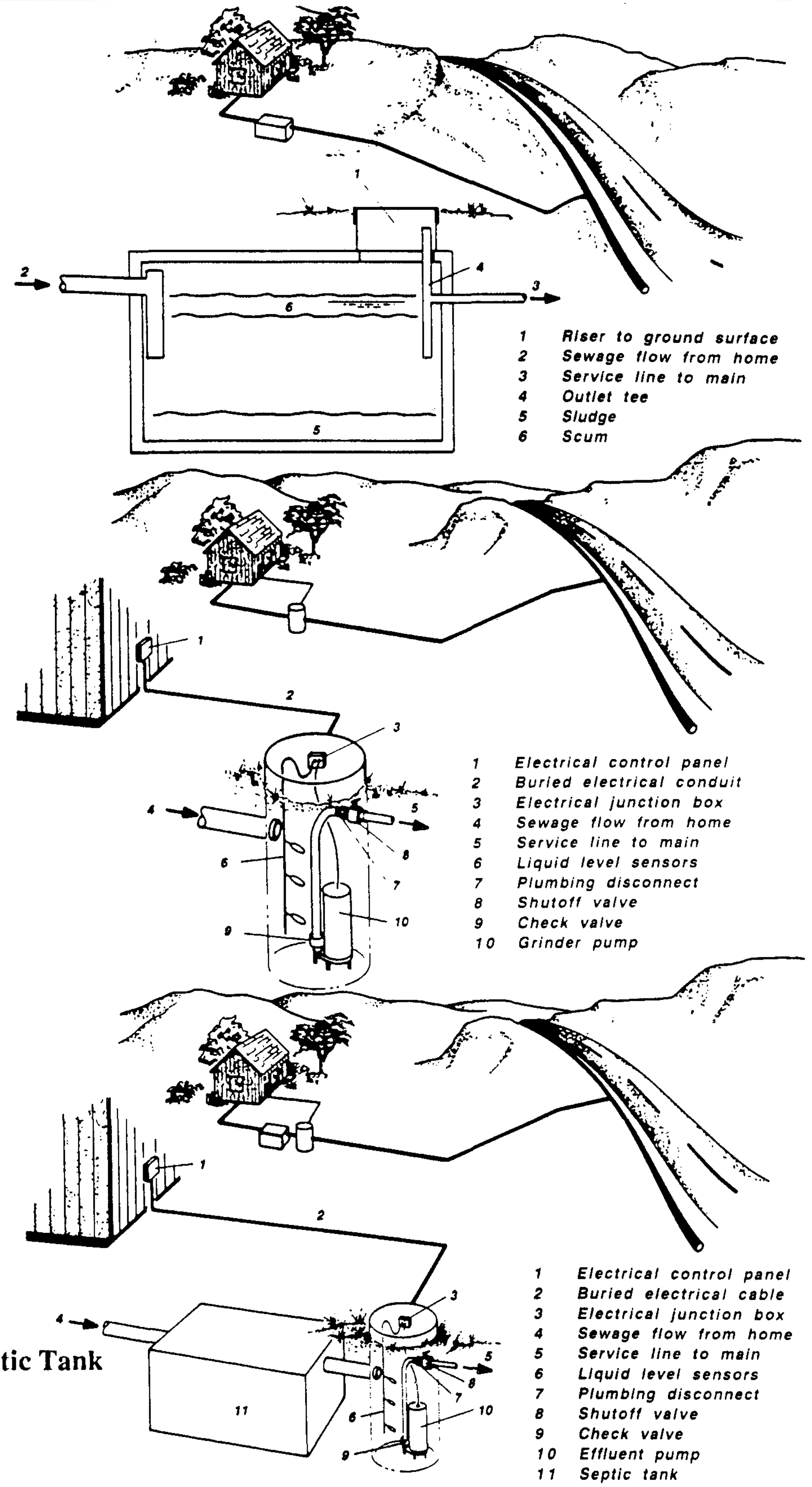


Figure XI. 8: Three types of septic tanks for three styles of conveyance system.

Small Diameter Gravity Sewer

Grinder Pump Pressure Sewer

Conventional Septic Tank Pressure Sewer

Finally, a mix of small diameter gravity sewers and pressure sewers is possible in Malibu because of the varying elevations of home sites. The septic tank removes scum and sediments and then feeds a smaller sewer to a main line by gravity. A home above the hydraulic grade line would use a SDG sewer. A home below grade would use the STEP system. We have visited homes in which the proposed STEP system could have been replaced by a SDG sewer. For neighborhoods in hilly locations, the use of a sewer that requires fewer mechanical parts and lower maintenance is an important consideration.

It is also premature to specify treatment plants. Recirculating sand filters should be given serious thought for subareas, small neighborhoods or commercial clusters. Constructed wetlands (subsurface or surface flow) have been suggested for the Civic Center area. Recirculating sand filters are “modular”. That is, they can enlarge with demand so that initial users do not need to pay capital costs for the whole system.

XI.16 Pumping and Septage Treatment and Disposal

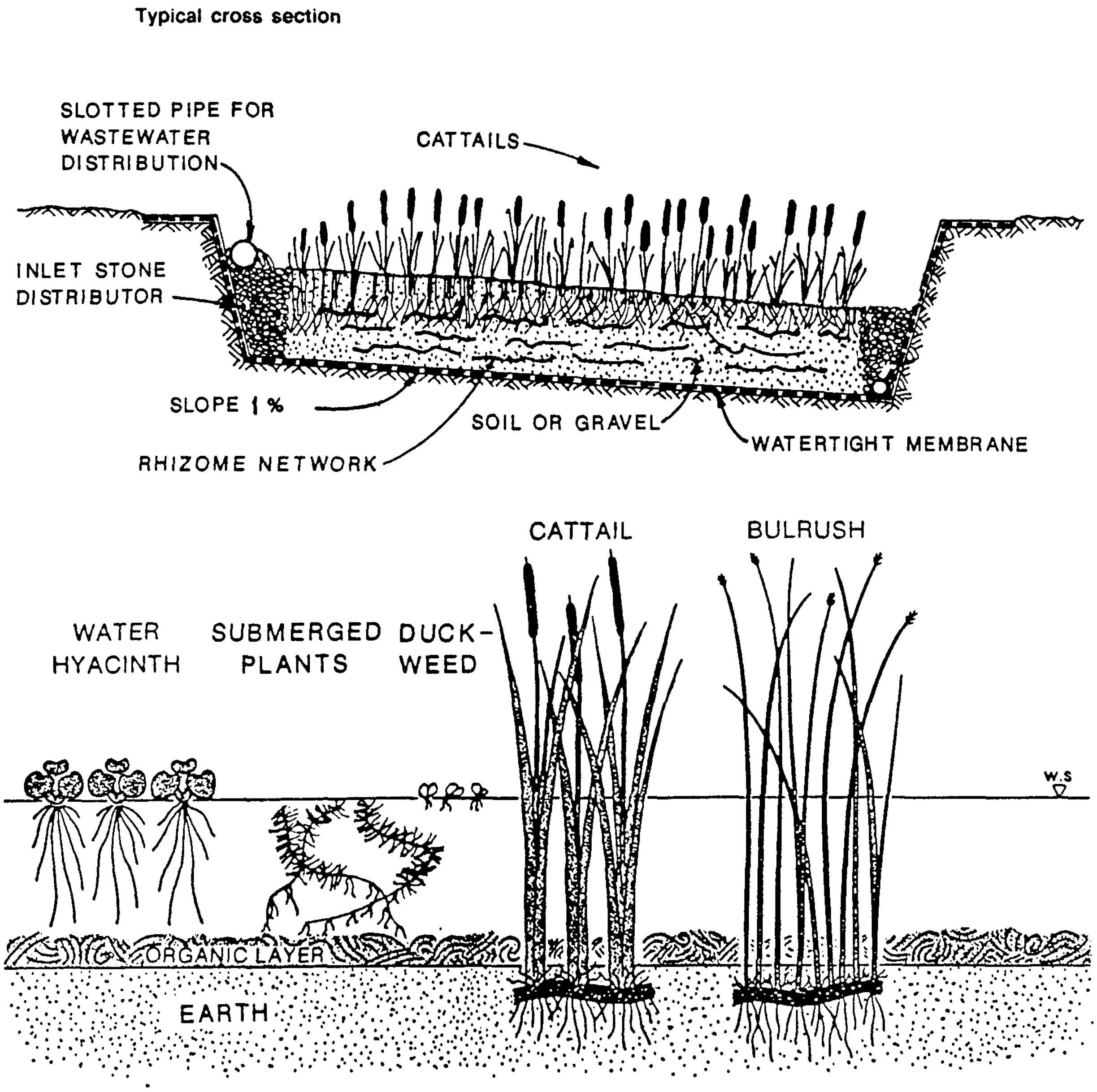
Disposal of the liquid content of effluent can be reduced by "hamsterns" or similar septage trucking. These trucks dewater at the site and return de-sludged liquid to the tank. This allows fewer trips to the dump station and greatly reduces travel and labor costs. In Malibu, a rough guess of 20,000 to 40,000 gpd of liquid requires disposal. The amount of effluent might be considerably reduced if only "solids" pumping occurs (using “hamsterns”).

The sludge and scum build up in single family homes utilizing on-site systems has been studied carefully in Glide, Oregon. Careful curves of build-up were made and a "safety curve" that would pump 99% of the tanks within the right time span was created. The time interval between pumpings was 14 years. If Malibu was to become conservative compared to these data, they might require pumping once every 7 years or sooner (if a homeowner so desired). This would create a rotation of about 600 to 700 single family tanks per year. The number does not include commercials, required cartage or special circumstances. If a still conservative interval of 10 years occurred, then an interval of 10 years for tanks 1,000 gallons or more and an interval of 5 years for tanks of 750 gallons would be reasonable. In all cases, certain homes would be overpumped.

With cartage to Hyperion or Tapia for septage disposal, the city has little control over treatment, disposal and fees. Should the city decide to construct a septage treatment facility, the most likely project would be co-composting with green wastes (garden and food wastes) and septage. The best adapted technique for Malibu (given land costs and the amount of septage and package plant sludge) is called "in-vessel" composting. Green wastes and septage go into a drum or digester. Because mixing, aeration, temperature, and moisture can be tightly controlled, this is the fastest form of composting. Since the vessel is enclosed, there are fewer odor problems. Dewatering the septage and sludge is the major difficulty. How will it be treated? With use of a dewatering septage truck, this problem can be somewhat reduced. Further decision-making is premature and beyond the scope of this report.

XI.17 Conclusions

Malibu will try to establish the best management practices for on-site systems and reuse of treated wastewater in the nation. They are bringing new technological interventions to southern California which will require re-training or new training of the usual professional involved with on-site systems. Because many interventions include reuse systems, there may be a need for two or more workers on a project: one for the hardware and one for the irrigation and plant-use aspects. To design, install and monitor reuse systems will require non-rigid guidelines to allow continual improvement in technical options. For example, Stinson Beach formed an on-site district in the late 1970s and still has not written its regulations in final form. A decade of experimentation has been necessary to avoid cookbook systems. The technological interventions suggested to meet these constraints, such as intermittent sand filters, dosing, charcoal odor controls, and washing machine greywater reuse, are all well-known in other areas of the state and nation. They are no longer "alternative."



Typical cross section

Constructed wetlands, including a restoration of the steelhead nurseries, could be part of the planning for the Civic Center area. Top drawing shows a constructed wetland that can also be used to treat runoff from stormdrains. Bottom drawing shows some of the plants used in constructed wetlands.

CHAPTER XII: CONCLUSIONS AND PHASE 2

To write the first plan for the new City of Malibu, this report inventoried three aspects of wastewater management: on-site systems, package plants, and nonpoint sources of potential pollution. The inventory established the adequacy of the environmental baseline for planning purposes. From that baseline the report provides the administrative and policy options that will help guide the city's future. At this early stage in municipal development, these policies are perhaps more important than any particular implementation action. From our experience with the new city, PEWARA recommends that slow and deliberate care be taken with the ordinances, regulations, and administrative organization which will guide the next decades of Malibu's wastewater management.

During the home-site and commercial survey, it became clear that many property owners have been living in a state of double jeopardy within the County's Malibu Sewer Assessment District. They are uncertain as to what the future will bring. If it brings long-term on-site systems, they are willing to make the required investments in these systems. But, if it brings the proposed sewer, they do not wish to make any further investments in their on-site system. Since the vast majority of on-site systems are within the Sewer Assessment District, the most important goal of 1992 is to resolve the direction of future wastewater management with the County, Coastal Commission, Regional Water Quality Control Board, LAFCO, and other agencies. The question of revenues for the newly proposed COM Department of Environmental Management and Consumer Protection (now Building and Safety) and the salaries for required staff, hinge, in part, on the resolution of this present situation. Taxpayers will rightly protest a double-jeopardy--paying the City and the County to go in two different directions at once.

XII.1 The Environmental Inventory and Wastewater Management

In order to write wastewater guidelines, previous investigations on watersheds, climate, geology (as it relates to on-site sewage systems), groundwater, soils, the coastline, population, parcels, on-site wastewater systems and water usage have all been inventoried. The elongated shape of the COM impacts the cost of transporting pumped septage, the cost and design of conveyance lines, and the time necessary to repair power outages and water or sewer line breaks. There are over 60 watersheds within the city's boundaries, 22 of which extend inland of the city's northern boundary and will require joint-powers agreements with upstream residents and agencies to control nonpoint water quality reaching the coast. Zuma Creek and Malibu Creek floodplains and wetlands have been designated for possible restoration and integration into constructed wetland treatment systems. Riparian and floodplain mapping for Malibu is preliminary. Blueline streams and the boundaries of the various floodplains require redefinition. With the exception of the Malibu Creek delta, the importance of floodplains to on-site systems is small as there are relatively few affected homes . From the nonpoint source management point of view, more work on water quality and vegetation is required before "pocket" wetlands can be constructed to partially treat runoff.

There are no local evapotranspiration (ET) field data. These data are required to properly design on-site systems that partially dispose of effluent through ET and biomass storage. The rain data are better defined, but various rain stations have been closed and elevation records are no longer being kept. The city should take an active role in assuring that at least one monitored gauge is present for every 100 feet in elevation. Fog and wind data have not been well documented.

The geology, geohydrology and soils are so complex that on-site evaluation (and, at times, costly fieldwork) will be required for each individual parcel to ensure proper treatment, reuse and/or disposal. Even though bedrock is the major disposal medium for inland homes, the importance of bedrock transmissivity, movement through fractured bedrock, and de-lithification (return to a "soil-like" condition under the influence of water) has not been summarized nor well studied. Seepage pit sizing has not been based on techniques commonly accepted in other parts of the western United States.

The use of inland soils (porous medium on top of bedrock) is relatively unknown in Malibu. Proper design will require further understanding of soil structure, texture, mottling, shrink/swell clays and other factors to reduce the volume of effluent and irrigation water percolating below the root zone of plants and potentially submersing slide planes. Percolation tests have been performed in a manner unique to Los Angeles County and not verified for their accuracy. The "shallow pump in test" required for larger flows is unknown in Malibu. Engineered fill and artificial soils have not been part of drainfield design considerations.

Groundwater inflows, discharges, movement and quantities are the least known phenomena related to on-site disposal and treatment in Malibu. This ignorance precludes accurate water budgets for landslides and any dogmatic conclusions about the importance of deep percolated effluent to the safety factor on the slide mass.

No collated work has been done and no manual exists on the plants best suited to on-site systems for disposal of treated effluent by ET or plant biomass storage. There is a need to work with nurseries for species or variety selection that will provide year-round ET or large biomass storage as well as have attractive qualities. The on-site manual should list plants by root depth, specific ET efficiency, relative water use, and aesthetic value. Plants that pump oxygen to their root systems would play an exceptionally important role in these reuse systems. It was premature to specify wetland plants for constructed surface or subsurface flow treatment systems. When sites are better specified for treatment of runoff by "pocket" wetlands or small volume subarea treatment, then a list should be carefully compiled.

Non-human animal species are a wastewater concern in Malibu Lagoon and the lower creek because of potential nonpoint pollution and discharges from Tapia. In Malibu Lagoon, no particular animal, plant species or habitat group has been established as the "indicator" of proper water quality management. Salinity fluctuations, nitrates, sediment size and quantities, pH, and dissolved oxygen goals must be established before dischargers will know how to treat wastewater. In the case of salinity, freshwater can be a pollutant if released seasonally or in quantities damaging to local flora and fauna. Previous studies of receiving water quality standards have not been designed with "indicator" species in mind. Steelhead runs or constructed habitats for endangered fish should be incorporated in future designs for wetland restoration and treatment.

The Malibu Coastline

The Malibu coastline is about 25 miles long with a variety of beach types ranging from cliffs to cobbles to sand to landslide debris. This coastline is important to wastewater management because of (1) the asserted health risk associated with beachfront on-site systems; (2) the asserted health risk associated with storm damage, and (3) the combined influences of watershed development, coastal armoring by sea walls and bulkheads, coastal drift, and on-shore/off-shore sand movement on beach profiles. It has been asserted that sand starved beaches may contribute to a greater health risk than sand rich beaches because of a potential shorter detention time of treated effluent within the sand (Chapter IV). In addition, it has been asserted that the frequency of higher sea levels harm the treatment (decay rate) of potential pathogens.

Chapter IV reviewed DOH material and the existing literature on beachfront systems on both the Atlantic and Pacific coasts. DOH assertions regarding a health hazard and critical need for off-site sewers are not supported by the evidence. A critical analysis of health risks by degree of treatment, exposure, and contagion showed that water quality in the surfzone met recreational standards and that the most reliable and mid-level studies to determine health risks had not been performed. Only the weakest studies had been performed and the data for these studies had been neither reliably collected nor appropriately analyzed.

The importance of sub-sand tidal flux and nearshore surges on drainfield functioning have not been studied in the field. In particular, pathogen or indicator organism die-off rates, dispersion, dilution, detention, and retention rates are virtually unknown. There is no information on the impact of salinated (marine) waters on the functioning of the biological mat or clogging surface that provides almost all the treatment. An oversimplified model by DOH of the relation of tidal surges to treatment and exposure possibilities was replaced by a more complete understanding of what occurs to the concentrations of potential pathogens between the drainfield and possible emergence in the surf zone. Further work on the seasonal changes in beach profiles for Malibu's various beach types would increase understanding of both effluent detention times before emergence and potential exposure rates. Water sampling during these studies would increase understanding of dispersion, dilution, die-off rates, and perhaps detention times.

Along the coast, storm frequencies are well-documented. Those that have an impact on unprotected or poorly protected drainfields occur about once every 25 years, although storms may cluster, as they did during the early 1980s. This is a statistical phenomenon. The impacts of storm damage on health are not documented. There are no reliable water quality data and no epidemiological data to document an increased health risk. The average life span of on-site systems damaged by storms and confirmed by the home-site survey was 18 years. This is very close to the County projected life span for systems without storm damage (20 years). There is good evidence that those homes with recently constructed bulkheads suffered no damage or only minor damage to their on-site systems. Homeowners vociferously challenged the asserted claim of damage to some on-site systems and claimed that DOH confused damage to protective barriers with damage to the septic tank system. DOH is in partial agreement with home-owner claims as there were no records kept of the extent of damage.

The management of sediment as both a requirement for beach replenishment, a possible pollutant to Malibu Lagoon and nearshore tidal flats, and as a harmful aspect of hillslope erosion requires both local regulation and joint-power agreements with agencies upstream and upcoast. The sediment and sand budget extends from the Simi Valley to the Santa Clara River. No goals for sediment type and quantities have been set for Malibu Lagoon.

The management of nitrogen-compounds is of particular importance in Malibu Lagoon. The overwhelming loads appear to come from Tapia releases. Given the local hydraulics, the number of homes, and on-site treatment process, Malibu Colony is not making an important nitrogen-compound contribution to the lagoon. From a runoff model (no field data), runoff contributions from within the city are small compared to those of Tapia. The importance of Texaco releases is not known. A carefully defined nitrogen budget study may be necessary to request changes in Tapia's or Texaco's NPDES permits.

The bacterial and possible viral pollution of Malibu Lagoon and nearshore waters has not yet been established. The studies have been confounded by poor sampling choices and procedures, and the "noise" in the sampling results from coliform and other bacteria deposited by birds and non-human mammals. A series of more accurate studies is suggested to pin-point possible sources. Given Malibu Colony's soils and drainfield distances from the lagoon, there is only a small possibility that on-site systems contribute coliform, potential pathogens, or pathogens to the lagoon. To determine sources, local stormdrains, Tapia, and runoff sources should be included in any analysis.

Effluent and Landslides

About 250 landslides have been mapped in the COM. The 15 largest landslides contain 350 homes, although not all of these homes can be considered endangered by earth movement. There are about 285 homes adjacent to these slide areas that might possibly become endangered by movement of the slide mass. In almost every instance of landslide movement, the previous years have contributed above normal rainfall and infiltration to the slide mass. Besides groundwater levels, 15 other factors contributing to landslide movement have been "red flagged." Nevertheless, the Los Angeles County Department of Public Works (DPW) and others have asserted that effluent significantly raises the water level and submerses the shear zone(s) of slide masses, decreasing their stability. A review and water budget risk analysis of the largest landslides in Malibu indicated that the importance of off-site sewers to increased slope stability was minimal. There were no cases where off-site sewering could be shown to make a large difference (Table IX.1). (Bing Yen's Big Rock report was not available at the time of this report's publication.)

Given the irregular groundwater paths in many slides and the uphill groundwater contributions to specific slides, dewatering appeared a more reasonable technological intervention. Dewatering could intercept infiltrated rain and runoff, natural subsurface flows, infiltrated irrigation and other human-related sources of water. Off-site sewering addressed only one aspect of the water budget and, in many instances, did not offer reliable evidence that the deep percolated effluent ever reached the slide plane. Some homes on the slide mass cannot possibly contribute to increased pore pressure along the slippage plane. Others, quite distant from the slide mass, could be contributors. This creates unresolved equity questions. Each landslide within Malibu should be considered unique and other contributors to slide movement should be evaluated before a final cost vs. benefit decision is made.

In conclusion, alternatives to off-site sewers were presented. These included neighborhood wastewater flow reductions by indoor water conservation (10% to 40% decrease in wastewater), a re-design of the on-site systems to dispose of effluent by ET (not deep percolation) with an additional 60% reduction in effluent and irrigation artificial recharge, and a surface runoff management program. These appeared to be less costly alternatives to off-site sewers.

XII.2 On-Site System Design and Function

There are about 4,200 use and part-time use parcels with on-site systems in Malibu and probably about 4,000 on-site systems. About 960 homes are connected to local package plants. There are about 3,800 single family residences, 1,018 multiplexes (including apartments and condominiums), and 140 commercial and institutional parcels that have on-site systems (Chapter II). Malibu does not have an easily defined generation of wastewater because of the wide variety of uses (weekend, year-round, seasonal) and household sizes, peak flows from summer visitors and "party homes," and wide variations in effluent strength among commercial on-site systems.

The city can, for practical reasons, be divided into single family residences, multiplexes (including condominiums), and commercials. The geographic distinction of most importance is inland or beachfront. However, many "beachfront" systems are actually more like inland systems, while inland systems are installed in a wide variety of sites.

PEWARA surveyed 247 on-site systems at 203 addresses. 118 of these homes had been previously considered functional failures by DOH. PEWARA found about 11% of the on-site systems were marginal or had problems requiring immediate attention. This is typical for older communities with systems of varying ages built under varying codes, by various contractors, and with various amounts of use or abuse. Other similar communities have between 15 to 20% repair rates each year.

The DOH claims regarding the rate of "functional failures" over the last 20 years could not be verified. Only 22% of the homes re-visited fit the definition of functional failure without dispute. 37% did not meet DOH's own criteria, apparently because the collators of the information misunderstood the criteria of the project director. 13% were disputed by home-owners. 29% had insufficient information in DOH files or from homeowners to confirm surfacing effluent or chronic system back-up into the home. The 1988 DOH study cannot be used to judge the comparative success or failure of on-site systems in Malibu.

The home-site survey found a large diversity of on-site systems based on varying codes, waivers, designer and installer abilities, use and abuse of the system, added-on greywater systems, parcel size and irregularities, and site characteristics. For instance, along the beachfront, septic tanks are situated between the drainfield and the beach, or between the drainfield and the house foundation, or between the house and the street, or even within the house foundation area. The beachfront drainfields were found within the beachsand, or in imported material, or on old landslide debris. The drainfields display varying depths of sand to cobbles, bedrock, or groundwater.

Both wastewater loading rates and occupancy rates were highly irregular. However, the median loading rate was equivalent to that described for high-income homes in most engineering texts. Commercial systems, especially those on small lots and under pavement, suffered most from poor design, poor site evaluation, lack of consideration of effluent strength, peak flows, non-uniform flows, surface runoff, groundwater movement, poor installation, and poor maintenance. They had the highest proportions of marginal and problem systems. In addition, a few condominium complexes had similar problems. These troubled commercial and condominium systems pumped more frequently for survival rather than maintenance. All single family residences and most small multiplexes pumped for maintenance, not survival. Single family residence pumping was based on a myriad of reasons.

Most septic tanks were above the commonly accepted design standard of 1,000 gallons for a 3 to 4 bedroom home. Some of the septic tanks were undersized (750 gallons) for high-income homes, some could use improved flow-through designs, and a few homes had no septic tank at all. Almost all the tanks had no access to the second chamber for pumping. The inability to pump the second chamber may contribute to the shorter life span (about 20 years) and marginality of some systems. The average age of a septic tank between replacements was 26 years. However, this included replacement of old tanks (e.g., redwood boxes). The presently installed tanks will have longer life spans.

The drainfield types were, with significant exceptions, limited to seepage pits inland and seepage beds along the beach. There were virtually no in-trench sandfilters; no pretreatment by intermittent sand filters; and no narrow, shallow trenching for increased disposal by ET. Seepage pit designs require revision for increased safety and possibly for reduced costs. Some of the older beachfront on-site systems were undersized and required upgrading. Newer beachfront drainfields met reasonable engineering standards for infiltrative surface. Many parcels had not used their beachfront "reserve" areas. The "reserve" areas unnecessarily limited sustainable design. One larger well-designed system was more appropriate than a system with a poorly-designed, sometimes under-sized drainfield. In addition, the reserve area appeared to be unnecessary as repairs and replacement of drainfields removed the whole drainfield and replaced it with engineered fill. "Sand creep" into drainfield gravel and paved over drainfields were important design considerations that had not been incorporated into County regulations.

Water conservation was erratic. The 1991 season demonstrated some increased water use which homeowners explained was to save particular trees. Most water conservation appeared to come from reducing exterior uses. Interior use does not demonstrate any strong conservation incentives. To help prolong drainfield use, the water conservation program for interior uses needs to be much more intensive (20 to 40% reduction). Greywater systems were found in 8% of the coastal homes and 30% of the inland homes. The reasons for greywater systems were predominantly drought irrigation inland. Along the beachfront, there were many reasons for greywater systems. A greywater system would provide a useful intervention to reduce peak loads to drainfields, reduce deep percolation in slide mass areas, and provide irrigation water in dry periods.

The most important report recommendation is the improvement of on-site design, site evaluation, installation and maintenance. Malibu has been living with regulations that are technically indefensible and work contrary to long-term functioning of on-site systems. Poor design is the major cause of shortened on-site life spans. In some cases, procedures and designs were 20 to 30 years out-of-date. There are no pre-treatment devices such as intermittent sand filters; no activated charcoal filters or aeration devices for odor control; no pressure dosed drainfields; and few devices or designs for uniform flow distributions.

XII.3 Subareas and Neighborhoods

Five neighborhoods of Malibu treat their wastewater in package plants or partially custom-designed small volume treatment plants (Trancas Canyon, Point Dume, Latigo Bay Shores, Malibu West, and Maison de Ville). The City has not established any regulatory guidelines for these plants. A preliminary review showed that they have few violations of state standards, are well run, are not operating at over-capacity, but are aging with signs of corrosion. The wastewater treatment plants do not have redundant equipment for breakdowns or maintenance. However, they could use various holding tanks for short-duration shutdowns or, in the case of Malibu Mesa, pump sewage to Tapia. The plants dispose of effluent either through soil absorption systems or by spray irrigation. The life span of the soil absorption systems requires further study. Should they fail, it is not clear what alternatives exist for each package plant. In some cases, the influence of spray irrigation on groundwater needs review. The parcels and their accepted use for sewage treatment are probably the most valuable asset. Some plants have leased land or acquired easements for discharge. The City needs to be aware of all on-site systems and package plants which utilize multiple parcels with different owners.

A review of inland and beach sites showed no subareas requiring off-site sewering at existing densities of development. The two most difficult situations were condominium complexes which appear to have ruined their disposal areas without having extra expansion land and small commercial areas which require replacement of the existing drainfield with imported filter bed material. Planning for increased density and allowances for "vertical" growth of homes to accommodate more bedrooms raises questions about the future in localized areas. We were asked to look only at existing conditions. Our review, therefore, is premature. We have focussed on subareas where homeowners have expressed an interest in off-site sewers or where we felt that it was reasonable to consider such an option Final decisions must be neighborhood, subarea, taxpayer and voter decisions.

The subareas reviewed include the Civic Center, Paradise Cove, the Point Dume Highlands, the major slide masses with significant construction, the east end of PCH, other beachfront developments (e.g., Malibu Road and Malibu Colony), and the north side commercials along PCH. The two areas that should give more thought to subarea sewers are the Civic Center and the Point Dume Highlands. Three potential constructed wetland sites, which have been identified for the Civic Center, should be included in the planning process. The east end of PCH should decide which of the many scenarios they prefer on the basis of cost and neighborhood goals. If they choose to do so, the east end of PCH and the northside commercial area can remain on upgraded on-site systems . The northside PCH commercials may have expensive repairs due to a history of poor design and abuse. But, with these repairs or a small recycling treatment plant, there is no technical reason for off-site sewering. In the case of the northside of PCH, there is room for a small volume clustered commercial system with reuse and disposal.

Malibu Road, the other beachfront residences, and the majority of the landslide area included in the Sewer Assessment District do not require off-site sewers to reduce geohazards or health hazards. A "stop deep percolation" program is presented as an alternative on slide areas. It includes shallow drainfields, reuse of effluent and greywater for subirrigation, surface runoff management, dewatering all sources of groundwater, and indoor water conservation. Along all of PCH and the beachfront neighborhoods, it is recommended that the General Plan Task Force identify parcels that could become "reserve" areas for the isolated on-site system, which may not have room for repair over the next 25 years. These reserves should not be utilized for expansion. They can serve 1 to 20 houses and can double as open space and/or beach access points. Malibu Colony should first construct proper surface drainage before considering any off-site sewerage.

An important element of choice is cost. PEWARA was asked not to review the proposed County sewer costs. Comparisons of unit and maintenance costs for on-site systems produced large unexplained discrepancies with County documents (Questa, 1988). Questa appeared to report consistently higher costs. If many individual parcels in the Sewer Assessment District request exemption from the proposed sewer, the cost to any particular homeowner could change dramatically and funding for the City's on-site wastewater management department will be affected.

XII.4 Phase 2

Phase 2 has three simultaneous approaches: (1) administrative organization, policy implementation and finance; (2) further studies; and (3) demonstration projects.The administrative organization and financial base are the major unresolved questions.

The City has strong authority under municipal codes to regulate and even to own on-site systems. It is recommended that no on-site district be formed. Instead, the City might create a Department of Environmental Management and Consumer Protection which would include on-site wastewater management, regulation of the package plants, nonpoint sources, and the existing duties of building and safety. Within the year, new ordinances for on-site wastewater management, nonpoint pollution, water conservation, and greywater need to be written. The ordinance contains a license for certification of on-site designers within Malibu, a peer review process, licensing or a code of ethics for pumpers, and a license for simple greywater systems.The new regulations will require careful thought. Stinson Beach, another district with on-site management, has taken over 10 years to refine the best on-site practices. The procedures for management include a detailed checklist to "red flag" site constraints and ensure that honest and competent design, field testing, and installation occur.

Unresolved questions include the inspection process for pumping and upgrades. The staff will require one full-time manager until ordinances, regulations, record keeping and procedures are in place. It will be necessary to pay the peer review committee for review of pipeline projects. Training classes and possibly a test for a certificate to practice in Malibu will be required so that there will be no need to import trained engineers. At the moment, the nearest trained specialists in intermittent sand filters appear to be in Marin

County. In addition, training in pressure-dosed near surface and line-emitter subirrigation systems will be necessary, especially for on-site systems on landslides.

It is recommended that the City eventually create its own health department in order to place enforcement under one administration and avoid further City/County conflicts (e.g., greywater management). The enforcement department of the health department should not overlap with the environmental management department which should act more as an "extension" agency.

Other unresolved questions include the city's understanding with the Coastal Commission, LAFCO, and the RWQCB. Strong liaisons with these agencies will be necessary, including on-going briefing of staff regarding on-site regulations and oversight of the package plants.

The question of revenues for the on-site section of the department is unresolved. The City is not yet clear on how much of the Sewer Assessment District, if any, will remain with on-site systems. The number of on-site systems will impact the financial base for managing on-site systems. In addition, some of the taxes that went to on-site administration through the County should now devolve to the City. The City can levee fees, charge for licenses, increase taxes by a very small amount, or form a special assessment district. The initial years will be more costly as ordinances, regulations and procedures are formulated.

A computerized data base will be necessary for record keeping. A potentially useful data base (requiring some modification) is in operation at Stinson Beach. The pipeline and any repair project need to be entered in the newly created data base for on-site systems that will eventually include records on all 4,000 or so systems.

XII.5 Phase 2, Demonstration Projects and Further Studies

Further studies mentioned in section XII.1 are important but will require outside funding. The most immediate study of importance is establishing the salinity and nitrogen-compound water quality standards for Malibu Lagoon. These standards will influence the size and kind of treatment facility that the Civic Center subarea might propose and the management of the opening and closing of the sand pit.

The General Plan Task Force (GPTF) needs to identify mulitple-use reserve areas for the next 25 years as well as the city's ability to use public lands for reserve purposes. The GPTF needs to consider constructed wetland sites and total wastewater loadings in its plans for the Civic Center area.

Should the beachfront health hazard issue remain unresolved, a swept prism and groundwater study for at least four different localities over the course of one year would become necessary.

On-site demonstration projects should include SunMar waterless toilets, simple greywater reuse systems, intermittent sand filters with pressure dosed subirrigation on slide areas, and shallow trench and/or shallow seepage pits designed for disposal by ET. Both Thetford Corporation and Memcor have proposed possible demonstration projects. They should be encouraged to tackle one of the commercial clusters with ultrafiltration, disinfection, and reuse. These demonstration projects should be part of the city's training program for contractors and professional designers interested in the "new" systems and combined on-site/subirrigation systems.

XII.6 Concluding Remarks

In closing, this report has looked at on-site systems that provide sewage treatment for subareas of Malibu and individual parcels ranging in size from one home to a condominium complex or a small shopping center. For these parcels, on-site wastewater systems have many advantages. Soils and plantlife, when properly understood and incorporated into on-site design, remain the best treatment device for the largest variety of potential pollutants and potential pathogens available. Because of the small volumes of wastewater, on-site systems provide greater ease in the treatment and recycling of wastewater than centralized systems. Especially in Malibu, where large volume reuse possibilities are limited by the hilly landscape and landslide potentials, on-site systems are a simpler technology to spread the effluent thinly and reuse it for subirrigation over a large area of the city. On-site systems provide increased equity as the homeowner receives the benefits of irrigation and lower water costs. On-site systems self-quarantine any potential pollution or health risks to small areas rather than concentrate the pollution potential in a large volume at a single location. They prevent the storm crisis sewage discharges that have occurred frequently to Santa Monica Bay. They do not require creek or ocean outfalls with strict discharge requirements that are difficult and expensive to meet and may be inadequate to prevent long-term harm to the environment. In addition, on-site and neighborhood systems avoid repair, surveillance and maintenance costs associated with long conveyance lines over unstable earth. They can avoid extensive pumping in an area of hilly terrain with frequent power outages.

To ensure excellence in on-site treatment and reuse, it will be necessary to custom-design Malibu's on-site systems to the diverse ecological patterns of the Malibu environment and to form a trained, accountable administration and staff. Because many agencies view some of the proposed technical and management interventions as "cutting edge," Malibu will require a certain amount of resolve to actualize its new role as a leader in the practice of high quality on-site sewage treatment.

FURTHER ACKNOWLEDGMENTS

City of Malibu

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  - Mike Caggiano, Walt Keller, Carolyn Van Horn, Larry Wan, Missy Zeitsoff
- Raymon Taylor, City Manager
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- **Malibu Mesa:** Joe Captain (JMM Operational Services), Vince Ferrini, and Jim Mayfield
- **Point Dume:** Michael Vignieri (Adamson Companies), Stu Ebert, and Bob Van Gilder
- **Trancas Canyon:** Vince Ferrini (Plant Supervisor) and Jim Mayfield.
- **Tapia:** Steve Witbeck (Water Reclamation Superintendent)

Los Angeles County

- Harry Stone, Department of Public Works
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- Glen Toffani
- Greg Silver

California Coastal Commission

- Gary Tim
- Madelyn Glickfeld

Caltrans

- Jim Hansen

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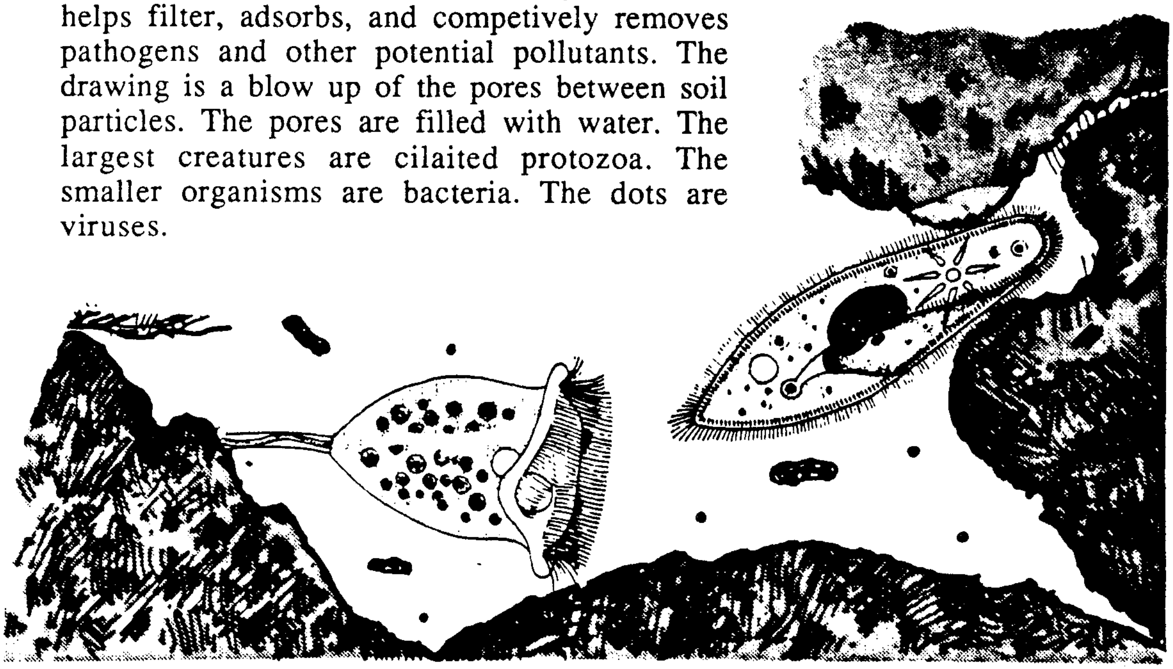
APPENDICES

"A teaspoon of living earth contains five million bacteria, twenty million fungi, one million protozoa, and two hundred thousand algae. This stupendous reservoir of genetic materials has evolved continuously since the dawn of life on eart (about two billion years)." From: **Clean Water** by Leonard Stevens.

It is this living soil that chemincally renovates, helps filter, adsorbs, and competively removes pathogens and other potential pollutants. The drawing is a blow up of the pores between soil particles. The pores are filled with water. The largest creatures are cilaited protozoa. The smaller organisms are bacteria. The dots are viruses.



APPENDIX A: CONSULTING TEAM ORGANIZATION

Peter Warshall and Associates

Consulting Team

Peter Warshall, PhD	Research Manager, Report Writer, and Project Director. Health and geohazard risk analysis, greywater, water conservation, subarea scenarios, watersheds, policy and administrative research and analysis, Malibu lagoon ecology and receiving waters, demography, inland and coastal on-site systems.
William C. Bowne, PE	Package treatment plants, subarea sewers, technology options, commercial water use.
E.D. Michael, RG, CEG	Geology, geohydrology, coastal processes, landslide stability, watershed and surface drainages, on-site management procedures.
Christie Perala	Climate, botany, stormdrains, home-site survey coordinator.
Robert Scarborough, RG	Geology, landslide concerns, watershed morphology.
Joe Tabor, CPSS	Soils, inland and coastal on-site systems, statistical and data analysis, watershed mapping, home-site survey coordinator.
Steve Wert, CPSS	Coastal on-site systems, soils, technology options, ordinance reviews, wastewater loadings.
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Robert Schanz	Nonpoint sources analysis.
Philip Williams,CE	Report review.

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Alyse Jacobson	Finances.

APPENDIX B: TECHNICAL MEMOS

Technical Memo 1: Water Quality Issues at Malibu Lagoon
by Robert Coats, PhD and Peter Warshall, PhD

Technical Memo 2: Potential Health Hazard Data for Malibu Coastline Septic Tank Systems
by Peter Warshall, PhD

Technical Memo 3: A Review of On-Site Sewage Disposal Practices with Special Reference to Malibu, California
by J.T. Winneberger, PhD

Technical Memo 4: The Landslide Map and Discussion of Landslides
by Robert Scarborough

Technical Memo 5: Wastewater Issues and Fieldwork
by Peter Warshall, PhD

Technical Memo 6: The Blue-Sky Amendment
by Peter Warshall, PhD and J.T. Winneberger, PhD

Technical Memo 7: Greywater in Malibu: Where and Why It's Important and Working Toward a New City Ordinance
by Peter Warshall, PhD

Technical Memo 8: Status of Existing Wastewater Treatment Plants
by. W.C. Bowne, C.E.

Technical Memo 9: Nonpoint Source Water Quality Problems at Malibu
by Robert Coats, PhD, Rob Schanz and Christine Perala

Technical Memo 10: The Malibu Coast: a Contribution to the City-Wide Wastewater Management Study
by Antony Orme,PhD, Department of Geography, UCLA

Technical Memo 11: Water Conservation and Wastewater Management
by Peter Warshall, PhD, with contributions by Steve Wert, J. T. Winneberger, W.C. Bowne and G. Tchobonoglas

Technical Memo 12: The Environmental Background to Wastewater Management in the City of Malibu
by Christine Perala, Joe Tabor, Robert Scarborough and Peter Warshall, PhD

Technical Memo 13: Results of the Home-Site Survey
by Peter Warshall, PhD, Christine Perala, Joe Tabor, J.T. Winneberger and Carin Winneberger

Technical Memo 14: Wastewater Collection Alternatives
by William Bowne, C.E.

APPENDIX C: SUMMARY OF PHASE 1 FIELDWORK

Issue	Home-Site Survey/Fieldwork
Property	Recorded property size; additional area within property; additional area nearby (neighborhood system); inaccessible spaces (beachfront only; hardened surfaces.
Costs	Review costs on installing on-site systems with contractors. No "ability to pay" survey.
Power outages	Record review.
Waterline breaks	Review of recent records.
Seismic hazards	No fieldwork. City map meeting.
Piping/lateral flow	No site-specific data available. Case-by-case observations.
Landslide risk	Mapped landslides. City Geo meeting.
Watersheds	Mapped.
Local rock/soil movement	Case-by-case observations. No areawide fieldwork. Breakage information from water and gas department.
Slopes	Case-by-case. No specific fieldwork. Mapped.
Perched water, slowly permeable soils	Case-by-case. No specific fieldwork. No County data. Some soil bores. No percolation tests. Focussed on problem situations.
Excessive percolation	Permeometer tests for beach sands. Some soil testing.
Thin soils	Case-by-case. No mapping.
Artificial soils	Case-by-case anecdotes. No formal study.
Seasonal groundwater	Case-by-case anecdotes. No formal study.
Flooding	Review of FEMA maps. Recorded on survey form.
Microclimate	No fieldwork. Literature review.
Evapotranspiration	No fieldwork.
High tides	Case-by-case anecdotes. Mapped highest. No formal study.
Storm surges	Case-by-case interviews. Recorded on survey form.
Wave damage	Recorded anecdotes on survey form. Recorded type of protection and year of construction. No formal study.
Salinated sands	Literature review.
Sand loss	Recorded anecdotes on survey form. No formal study.
Overloading	Recorded water use and drainfield size. Record number of bedrooms, bathrooms, residences.
Overloading of neighborhoods	No County data on locations. No fieldwork.
Surge flows	On fieldwork survey form when available.
Grease	On fieldwork survey form.
Septic tank systems	Intensive survey of inland, beachfront, and commercial systems.
Greywater	Checked DOH files. Fieldwork. On survey form.
Septage	No fieldwork.
Component design	Recorded components on survey. Interviewed contractors.
Pump longevity	No fieldwork. Proposed commentary.
Drinking water	Partial recheck of DOH claims of setback violations.
Cartage	Part of survey. Wastec records. Discussion with Tapia.

APPENDIX D: CHARACTERISTICS AND QUALITIES OF SOILS THAT OCCUR IN MALIBU*

SOIL SERIES	GEOGRAPHICAL SETTING	EFFECTIVE DEPTH FOR ROOTS	DRAINAGE	SUBSURFACE GEOLOGIC SOURCE	POSSIBLE CONSTRAINTS TO SEPTIC TANK ABSORPTION FIELDS
Calleguas	Steep mountainous upland on eroded south facing slopes, 9-75% slope	8 to 18 in.	Well drained	Shale, sandstone, or mudstone	Depth to rock and slope
Castaic	Very steep to rolling uplands, 2-75% slopes	22 to 40 in.	Somewhat excessively drained	Shale, sandstone, or mudstone	Depth to rock, slow permability, and slope
Corralitos	Marine terraces, alluvial fans, and small valleys. 0-15% slopes	60+ in.	Somewhat excessively drained	Eoluvium or alluvium from sandstone	Fast permeability
Cropley	Alluvial fans and valleys. 0-9% slopes	60+ in.	Moderately to well drained	Alluvium from shale	Slow permeability and wetness
Diablo	Complex, undulating, rolling, to steep uplands, 2-75% slopes	40 to 80 in. to paralithic contact	Moderately to well drained	Cakareous shale, mudstone, or sandstone	Slow permeability and slope
Elder	Alluvial fans and flood plains, 0-5% slopes	60+ in.	Well drained	Alluvium with weak to distinct stratification	Flooding
Gaviota	Mountainous uplands, 2-75% slopes	6 to 20 in.	Well drained	Hard sandstone or granite	Depth to rock and slope
Gazos	Uplands, 9-75% slopes	20 to 40 in.	Well drained	Hard fractured banded shale and sandstone	Depth to rock, slow permeability, and slope
Gilroy	Uplands, 9-75% slopes	20 to 40 in.	Well drained	Igneous and metamorphic rock	Depth to rock, and slope
Hambright	Mountainous uplands, 2-75% slopes	10 to 20 in.	Well drained	Basic igneous basalt	Depth to rock, and slope
Huerhuero	Old terraces, 5-15% slopes	50+ in.	Moderately well drained	Stratified old terrace sediments	Slow permeability and wetness

Appendix D: Characteristics and Qualities of Soils that Occur in Malibu* (Continued)

SOIL SERIES	GEOGRAPHICAL SETTING	EFFECTIVE DEPTH FOR ROOTS	DRAINAGE	SUBSURFACE GEOLOGIC SOURCE	POSSIBLE CONSTRAINTS TO SEPTIC TANK ABSORPTION FIELDS
Linne	Mountainous uplands and foothills, 5-75% slopes	20 to 40 in. to paralithic contact	Well drained	Calcareous fractured banded shale and sandstone	Depth to rock, slow permeability, and slope
Lockwood	Alluvial fans and terraces, 0-15% slopes	40+ in.	Well drained	Alluvium	Slow permeability
Los Osos	Uplands, 5-75% slopes	20 to 40 in. to paralithic contact	Well drained	Hard, banded sandstone and shale	Depth to rock, and slow permeability
Malibu	Foothills, 9-50% slopes	20 to 40 in. to paralithic contact	Well drained	Hard, fractured shale and sandstone	Depth to rock, slow permeability, and slope
Millsholm	Uplands, 5-75% slopes	10 to 25 in.	Well drained	Hard shale and sandstone	Depth to rock, and slope
Mocho	Alluvial fans, 0-9% slopes	40+ in.	Well drained	Recent alluvium from sandstone or shale	Slow or fast permeability, flooding
Oceano	Coastal dunes, 0-50% slopes	40+ in.	Excessively drained soils	Sandy eolian deposits	Fast permeability
Perkins	Terraces, of 0-30% slopes	40+ in.	Well drained	Gravelly or cobbly alluvium	Slow permeability, slope, and depth to rock
Rincon	Old alluvial fans, stream terraces and marineterraces, 0-30% slopes	60+ in.	Well drained	Alluvium from sedimentary rock	Slow permeability, and slope
Saugus	Slopes of disected terraces and foothills, 9-50% slopes	20-56 in. to paralithic contact	Well drained	Fractured shale, sandstone, and weakly consolidated granitic sediments	Slow permeability, depth to rock, and slope
Sorrento	Alluvial fans and valleys, 0-15% slopes	60+ in.	Well drained	Medium textured alluvium from sedimentary rocks	Slow permeability

Appendix D: Characteristics and Qualities of Soils that Occur in Malibu*
(Continued)

SOIL SERIES	GEOGRAPHICAL SETTING	EFFECTIVE DEPTH FOR ROOTS	DRAINAGE	SUBSURFACE GEOLOGIC SOURCE	POSSIBLE CONSTRAINTS TO SEPTIC TANK ABSORPTION FIELDS
Vina	Alluvial fans and floodplains, 0-9% slopes	60+ in.	Well drained	Recent alluvium from mixed sources	Slow permeability, flooding, slope
Yolo	Alluvial fan and valleys, 0-9% slopes	40+ in.	Well drained	Alluvium from sedimentary rock	Slow permeability, and flooding
Ysidora	Alluvial fans and terraces, 2-30% slopes	12-40 in.	Somewhat poorly to moderately well drained	Gravelly alluvium	Slow permeability, depth to cemented pan, and slope

*Characteristics are estimated based on information from "Soils of the Malibu Area", (SCS, 1967) and the USDA Soil Conservation Service's "Official Series Descriptions" (1967 to 1988). The range of characteristics that are presented for each series may exceed those of the current SCS series. This is because the concept of a soil series by SCS may have changed since it was defined and mapped (SCS, 1967), (e.g., the Saugus series).

APPENDIX E: BIBLIOGRAPHY

Note: A more extensive bibliography can be found in the Technical Memos indicated in the "( )" after each topic. The bibliography is arranged by topics with documents alphabetized within topics. An extensive bibliography of documents before 1986 can be found in: Los Angeles, County of, 1986, Montgomery Report.

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APPENDIX F: GLOSSARY

absorb: The process by which one substance is taken into and incorporated into another (e.g., water into soil).

adsorb: The adhesion of molecules or viruses as an ultrathin layer on the surface of solids or liquids. The particles adsorbed require an electrical charge.

aerobic: Growing in or occurring only in the presence of molecular oxygen (e.g., aerobic bacteria).

anaerobic: Growing or occurring in the absence of molecular oxygen.

biological oxygen demand (BOD): Measure of the concentration of organic impurities in water. Or, the amount of oxygen required by bacteria to stabilize organic material under aerobic conditions -- in this sense a measure of the biologically available food to the microbes and the amount of oxygen required by them to consume all the food.

biological mat: A crust formed from dead and living microbes, deposited minerals, and clogged pores at the interface of the gravel filled trench or other excavation of a drainfield and the surrounding soil.

blackwater: Liquid and solid human body "wastes" and the water they are transported within. Toilet wastewater.

coliform: A group of bacteria predominantly inhabiting the intestines of humans and other animals but, occasionally, found elsewhere. A very general indicator of the presence of animal feces in freshwater. Of ambiguous validity in saltwater.

combined wastewater: Combined greywater and blackwater.

correlation coefficient: In statistics, a measure of the linear relationship between two quantifiable variables (e.g., water consumption and septic tank size). Correlation coefficients vary from -1 (perfect negative correlation) to 0 (no linear relationship) to +1 (perfect positive relationship). See Appendix D.

decay rate (also known as bacterial die-off): The rate of disappearance of bacteria and viruses depending on the pH, salinity, temperature, and light-intensity and other biological qualities of the water. Sometimes expressed at T_{90} -- the time required for 90% of the bacteria to die.

dispersion: A measurement of the "scattering" of a component of water (e.g., pathogens or nitrates) in various directions.

dissolved oxygen (DO): Oxygen dissolved in wastewater expressed in milligrams per liter (mg/l).

dosing: Periodic application of septic tank effluent using a pump or a dosing siphon to increase the aerobic aspects of treatment and prolong the longevity of the drainfield.

drainfield (also disposal field, leachfield): A means to finally treat and dispose of septic tank effluent by means of subsurface soil-absorption and adsorption.

effluent: Water, sewage or any other liquid (partially treated or in its natural state) that is flowing out of a reservoir, septic tank, or treatment plant.

enterococci: A group of comma- or rod-shaped, unicellular bacteria that receive their name because many have been found in the intestines of animals. Includes many groups associated with specific diseases but are common in many non-harmful forms.

evaporative demand: The number of inches of water that a particular plant can absorb and transpire measured in inches of water within the root zone.

evapotranspiration: The actual loss of water by evaporation from soil and water bodies as well as transpiration from plants.

greywater: "Wastewater" generated by household appliances and fixtures with the exception of the toilet, possibly the garbage grinder, and non-bathing water bodies (jacuzzis, swimming pool, spas).

hydraulic conductivity: As applied to soils, the ability of the soil to transmit water in liquid form through pores. Also applies to any porous medium (fractured bedrock, beach sands). Usually measured by Darcy's Law.

hydraulic gradient: A ratio between the difference in hydraulic head and the distance between measurement points in the direction of flow.

hydraulic head: The potential energy per unit weight of water. Measured by a piezometer. Also, the sum of atmospheric pressure plus water weight above the point of measurement.

influent: Water, wastewater, or other liquid flowing into a reservoir, basin, or treatment plant.

infiltration: The movement of water into (vs. through) a soil.

leachfield: (See drainfield.)

littoral: Of or pertaining to a shoreline or near-shore waters.

manifold: A pipe fitting with many branches to convey fluids between a large pipe and several smaller pipes or permit a choice of dividing flow from one of several sources or to one of several discharges.

non-normal distribution: An assumption in statistical mathematics about how a variable (e.g., septic tank size) is distributed. Normal curves state distribution or frequency of septic tank sizes forms a bell-shaped curve which is symmetrical on either side of the top of the bell. A non-normal distribution does not have this shape. For instance, there could be two peaks in the distribution because most septic tanks are either very small or very big. Many of Malibu's on-site variables do not have normal distributions. The applicable mathematical formulas must take this into account.

osmotic pressure: The "pressure" exerted on a membrane (e.g., cell wall) by differing concentrations of salts or other substances on either side of the membrane. In extreme, it can burst or dessicate a cell.

pathogen: An organism or virus producing or capable of producing a disease (e.g., polio virus).

percolation: The downward movement of water through porous soils or filtering medium. The liquid may or may not fill all the pores of the medium.

permeability: The ease with which gases, liquids or plant roots penetrate or pass through a soil. Permeability depends on the density of the liquid or gas, gravity, and viscosity.

porosity: The ratio or relation of the open pore space in a soil to its total volume, usually expressed as a percentage (e.g., a sand with 30% porosity).

potential evaporation: In the presence of an unlimited water supply, the rate of anticipated or actual evapotranspiration.

probability (p): In general, the weight of the evidence for determining the null hypothesis. For instance, a null hypothesis might be: the number of bedrooms has no relation to home water use. "p" or the p-value is called "level of significance" and states a level of confidence in rejecting the null hypothesis. The smaller the probability, the more confidence we can feel that the opposite is true.

safety factor: The ratio of the total force tending to resist movement to the total force tending to cause movement, or, alternatively, the ratio of the maximum shear strength that can be mobilized along the critical surface, i.e., the surface most likely to fail, to the maximum shear stress that can be mobilized along that surface for a given set of conditions.

saturated flow: Flow of water or effluent in which the pores or interstices of the soil are essentially filled with water. Saturated flow has a strong lateral or horizontal component.

seepage bed (disposal bed): When the bottom of the drainfield is wider than about four feet and has a rough rectangular shape, the drainfield may be referred to as a seepage bed.

seepage pit: When the shape of the drainfield receiving septic tank effluent is a cylindrical excavation, the drainfield is called a seepage pit.

setteable solids: The matter in wastewater which will not stay in suspension during a period of time such as an hour or day. It either settles to the bottom or floats to the top.

slake: To crumble or disintegrate (i.e., mudstones in water).

t-test: Test for the rejection of the null hypothesis (see "probability) which makes fewer assumptions about the normal curve and sample size.

total organic carbon (TOC): The amount of organic carbon in wastewater as determined by a specific furnace test. Usually underestimates carbon by a small amount.

total suspended solids (TSS): Solid matter that will settle to the bottom of a cone-shaped cylinder in 60 minutes (vs. dissolved solids). More refined definitions are used in certain tests.

unsaturated flow: Water movement when mixed with soil gases ("air"). Moves in a predominantly vertical direction.

APPENDIX G: ABBREVIATIONS

BOD: Biological oxygen demand

CC (or CCC): Coastal Commission or California Coastal Commission

COM: City of Malibu

CZMA: Coastal Zone Management Act

CWA: Clean Water Act

DO: Dissolved oxygen

DOH: Los Angeles County Department of Health

(LAC) DPW: Los Angeles County Department of Public Works

EPA: United States Environmental Protection Agency

ET: Evapotranspiration (see Glossary)

GPD: Gallons per day. Occasionally, gallons per dwelling.

GPP: Gallons per person

ISF: Intermittent sand filter

K: Hydraulic conductivity

LCP: Local Coastal Plan

LUP: Land Use Plan

MWD: Metropolitan Water District

N: Number of items in a statistical sample

NGVD: National Geodetic Vertical Datum

NOAA: National Oceanic and Atmospheric Administration XX

NPDES: Nonpoint XX Elimination System

PCH: Pacific Coast Highway

PEWARA: Peter Warshall and Associates

PWA: Philip Williams and Associates

RBC: Rotating Biological Contactor

RWQCB: Regional Water Quality Control Board

SCS: Soil Conservation Service

SDG: Small diameter gravity sewer

SFR: Singe family residence

STEP: Septic tank effluent pump system

TLVRCD: Tapia-Las Virgenes Resource Conservation District

TOC: Total organic carbon

TSS: Total suspended solids

TWRP: Tapia Water Reclamation Plant

UCLA: University of California, Los Angeles

UPC: Uniform Plumbing Code

USGS: United States Geological Survey

WWTP: Wastewater treatment plant