Stinson Beach County Water District
Stinson Beach, California

STINSON BEACH
HYDROLOGIC SURVEY

February 1998

Todd Engineers
2200 Powell Street, Ste. 225
Emeryville, CA 94608
510/595-2120
Fax: 510/595-2112
http://www.toddengineers.com

Questa Engineering
1220 Brickyard Cove Road, Ste 206
Pt. Richmond, CA 94807
510/236-6114
Fax: 510/236-2423
http://www.QuestaEC.com

Table of Contents

Page

Executive Summary ES-1

Introduction 1
- Background 1
- Purpose 2
- Scope 2
- Study Area 2
- Acknowledgment 3

Field Program 4
- Installation of Monitoring Wells 4
- Identification of Existing Wells 6
- Water Level Monitoring 7
- Water Quality Sampling 7

Hydrogeologic Setting 9
- Geography and Land Use 9
- Climate and Surface Water 9
- Geology and Soils 10

Groundwater Conditions 13
- Occurrence of Groundwater 13
- Groundwater Levels and Flow 13
- Groundwater Level Changes 18
- Groundwater Use and Wells 19

Water Quality Conditions 21
- Beneficial Uses of Groundwater 21
- Groundwater Quality 22
- Impacts of Wastewater on Water Quality 25
- Nitrate Loading Analysis 30
- Groundwater Impact from Fertilizer Use 36
- Summation 38

Alternatives for Improved Water Quality Management 40
- Overview of Wastewater Management 40
- Alternative Treatment-Disposal Methods 41
- Onsite System Monitoring 44
- STEP System Alternative 45
- Water Resource Monitoring 48

Table of Contents, continued

Conclusions 51

Recommendations 53

Bibliography 54

Appendices

A. Monitoring Well Construction and Geologic Data
B. Water Level Data
C. Water Quality Data
D. Nitrate Loading Calculations

List of Tables

Page

1. Monitor Well Construction Details.....5
2. Groundwater and Surface Water Level Data 16
3. Stinson Beach Production Wells.....20
4. Summary of Predicted Groundwater Nitrate Loading Concentrations 35

List of Figures

Following
Page

1. Study Area....2
2. Wells and Monitoring Sites, Seadrift and Patios....4
3. Wells and Monitoring Sites, Old Town, Highlands, Calles, and Patios....4
4. Typical Geologic and Well Construction Log....5
5. Location of Cross Sections....11
6. Geologic Cross Section A-A'through Seadrift and Dipsea Areas....11
7. Geologic Cross Section B-B'along Calle del Resaca....11
8. Water Table Contour Map, Seadrift and Patios....14
9. Water Table Contour Map, Old Town, Highlands, Calles, and Patios....14
10. Groundwater Levels and Flow Patterns, Seadrift....15
11. Groundwater Levels and Flow Patterns, Calle del Resaca....17
12. Monthly Precipitation and Groundwater Levels in Well G4, 1991-1997....18
13. Total Dissolved Solids and Groundwater Flow Patterns, Seadrift....23
14. Total Dissolved Solids and Groundwater Flow Patterns, Calle del Resaca....24
15. Location of Septic Systems near Monitoring Wells, Seadrift....25
16. Location of Septic Systems near Monitoring Wells, Calle del Resaca....25
17. Ammonia and Groundwater Flow Patterns, Seadrift....25
18. Ammonia and Groundwater Flow Patterns, Calle del Resaca....26
19. Total and Fecal Coliform and Groundwater Flow Patterns, Seadrift....26
20. Total and Fecal Coliform and Groundwater Flow Patterns, Calle del Resaca....27
21. Cross Section C-C' through Area B 1987 Seadrift Study....29
22. Cross Section D-D' through Areas C and E 1987 Seadrift Study....29
23. Cross Section E-E' through Area D 1987 Seadrift Study....29
24. Study Areas for Nitrate Balance....30
25. Potential STEP Community System....47

EXECUTIVE SUMMARY

Stinson Beach is a community of approximately 650 residences on the California coast that relies on onsite wastewater treatment and disposal systems. The Stinson Beach County Water District (District) provides water supply to the community and manages the onsite wastewater systems through its innovative Onsite Wastewater Management Program (OWMP). Concern over continuing construction of new residences and onsite wastewater systems led the District Board of Directors to impose a temporary building moratorium while a Hydrologic Survey was conducted to provide an improved understanding of local water resource systems, to evaluate impacts of wastewater systems on water quality and beneficial uses, and to provide recommendations to improve District water and wastewater management.

The Hydrologic Survey is summarized in this report. The study focused on areas with rapid soil percolation rates in the Seadrift, Calles, and Patios portion of Stinson Beach. Field work conducted in the late summer of 1997 included installation of nine permanent monitoring wells and three surface water staff gages, five water level measuring events, and three water quality sampling rounds. The new monitoring wells will provide the foundation for future groundwater quality monitoring.

Analysis of groundwater levels and flow revealed that the ocean and Bolinas Lagoon are the receiving surface water bodies for groundwater in Stinson Beach. Specifically, groundwater flow from the oceanside portions of Stinson Beach, Old Town, and Highlands areas generally is toward the ocean, while flow from the remaining portions of Seadrift, Calles, and Patios is toward Bolinas Lagoon. Easkoot Creek intercepts groundwater and conveys it to Bolinas Lagoon.

Groundwater use in Stinson Beach includes the municipal water supply pumping by the District, which relies on its Aldergrove 2 well, located along Stinson Gulch, for about 30 percent of its supply. The remaining water supply consists of springs and surface water sources. In addition, private wells have been drilled for irrigation purposes. Two wells located in the Highlands also have been identified as possible domestic drinking water sources.

General groundwater quality data showed that groundwater in the Seadrift, Calles, and Patios area consists of fresh water, derived from rainfall, landscape irrigation, and septic systems, that floats on underlying, higher-density seawater. Tidal fluctuations result in a mixing of freshwater and seawater, as does pumping. Groundwater underneath Seadrift and the Calles and Patios is not a likely drinking water supply because of the influence of seawater. In addition, no impacts on drinking water wells of wastewater disposal in the Seadrift, Calles, and Patios areas is expected because these areas are downgradient from the water supply wells.

Nonetheless, wastewater disposal is influencing groundwater quality in the Seadrift, Calles, and Patios areas, as indicated by the detection of ammonia and MBAS in most of the monitoring wells sampled during this study. However, the concentration of such wastewater indicators generally decreases with increasing distance along the groundwater flow path. Detections of fecal coliform were confined to two wells, suggesting that fecal contamination of groundwater is limited and localized. Concentrations of total coliform declined with successive sampling, suggesting that the detections could be the result of insufficient well purging and may not be representative of aquifer conditions.

Beneficial uses of surface water include contact water recreation in the lagoons and shellfish harvesting in Bolinas Lagoon; both of these beneficial uses raise concern over bacterial contamination. Surface water sampling revealed detections of coliform at or below the level of detection in Seadrift Lagoon. Total coliform was detected in Bolinas Lagoon at levels of 79 Most Probable Number (MPN)/100 milliliters (ml); fecal coliform also were detected once. Easkoot Creek showed consistent high levels of total and fecal coliform, amounting to counts of 1600+ and 920 MPN/100 ml, respectively. This suggests that the most significant impacts of wastewater on surface water occur through Easkoot Creek.

Nitrate loading calculations for the Seadrift, Calles, and Patios areas predict that current wastewater disposal practices would result in nitrate concentrations in groundwater that are generally within the drinking water standard of 10 milligrams per liter (mg/L). This estimate is consistent with the concentrations of nitrogen measured in groundwater during this study. In addition, the nitrate loading calculations show that under buildout conditions, nitrate loading would increase, but could remain within drinking water standards if the current practice of using sand filter systems is continued. The nitrate loading calculations also demonstrate that the preponderance of nitrate in groundwater is the result of wastewater disposal, and that landscape irrigation is a minor factor. Accordingly, a policy regulating fertilizer use for landscaping is not warranted.

Although the water quality data from this study are limited, wastewater disposal in the Seadrift, Calles, and Patios areas appears to have only a small influence on beneficial uses in Bolinas Lagoon. The impact on Bolinas Lagoon of Easkoot Creek, reflecting drainage from the Highlands and Old Town, appears to be more significant. Accordingly, the focus of future water quality monitoring and protection should be the Highlands, Old Town, and Beach Park areas and Easkoot Creek. Additional permanent monitoring wells will be needed in the area, as well as analysis of the hydrogeology and impacts on water resources of wastewater disposal. Based on the findings of the Hydrologic Survey, the District's routine water monitoring program should be revised to include a network of reliable groundwater monitoring wells that cover not only the Seadrift, Calles, and Patios areas, but also the Highlands and Old Town. Monitoring should be extended to include wet season water level measurements and sampling. A community STEP (Septic Tank Effluent Pump) system may be warranted to serve the Old Town area, as well as portions of the Highlands, Calles, and Patios. The most promising site exists in the vicinity of the Highlands Tank on federal park land. Implementation of a STEP system in Stinson Beach will require cooperative efforts with the federal government, and potentially could be done in a way that would improve the existing waste disposal practices within the park itself.

With regard to the study area including the Seadrift, Calles, and Patios areas, the District has intensively monitored selected sand filter systems, documenting their good to excellent performance. A review of existing design criteria conducted in this study reveals no compelling reason to change the current criteria. Nonetheless, the District should consider broadening the criteria to allow variations in wastewater practices and innovative technologies, including changes in leachfield application rates, recirculating sand filters, aerobic treatment systems, ultraviolet disinfection systems, and subsurface drip irrigation systems.

INTRODUCTION

Background

Stinson Beach is a community of approximately 650 residences located on the California coast 20 miles north of San Francisco. The community is unsewered, having consistently rejected centralized wastewater treatment and disposal plans. Accordingly, local homes and businesses rely on onsite wastewater treatment and disposal systems.

The Stinson Beach County Water District (District) was established in November 1962 to provide water and wastewater management, including conservation of water supply, prevention of water contamination, and improvement of water quality. Protection of the water quality and environmental benefits of Bolinas Lagoon has been a key concern of the local community. The District boundaries encompass the watershed areas tributary and to the east of Bolinas Lagoon, extending beyond Copper Mine Gulch to the north. The developed service area focuses on the community of Stinson Beach itself.

The District provides municipal water supply to Stinson Beach and manages the numerous onsite wastewater systems through its innovative Onsite Wastewater Management Program (OWMP). The OWMP includes regular review of proposed systems with regard to District standards, inspection and monitoring of existing systems, enforcement of District criteria for wastewater system performance, surface and groundwater quality monitoring, and other services such as public education on the proper use of onsite wastewater systems. The District summarizes its onsite wastewater management program in quarterly and annual reports, which are submitted to the San Francisco Bay California Regional Water Quality Control Board (RWQCB). In addition, the District has conducted a number of special investigations of water resources and the effects on water quality of wastewater disposal and treatment.

In recent years, construction of new homes and onsite wastewater disposal systems was allowed in areas with soil permeabilities that exceed percolation rate requirements through the granting of regulatory variances. This practice and the overall, continuing construction of new systems raised concerns with the District and RWQCB that increased use of onsite wastewater disposal systems would result in a threat to public health through contamination of local groundwater and surface water. As a result, the District Board of Directors adopted ordinance 1996-02 on November 16, 1996, which imposed a temporary moratorium on the granting of variances to the percolation rate requirement to allow construction of wastewater systems for new construction. In addition, the District authorized the performance of this Hydrologic Survey.

Purpose

The purpose of the Hydrologic Survey is to provide an understanding of the local groundwater system that is the physical context for onsite wastewater disposal. In addition, the Survey provides an overall evaluation of wastewater systems on groundwater quality, an assessment of the OWMP, and recommendations for improving District activities to ensure future water quality protection that is consistent with the beneficial uses of water defined by the RWQCB. This Hydrologic Survey provides the foundation for future water management by the District. In addition, the Hydrologic Survey establishes the basis for determining if the moratorium should continue or be rescinded.

Scope

The Hydrologic Survey was initiated on May 24, 1997 and completed on December 20, 1997. The survey included field work during the summer and early autumn, including installation of nine permanent groundwater monitoring wells and three surface water staff gages, five water level measuring events, and three water quality sampling rounds. Considerable water quality and level information was compiled, reviewed, and organized to assist in the documentation of local hydrogeologic conditions, wastewater practices, and evaluation of water quality. Existing reports and data compilations are listed in the Bibliography. A major focus was analysis of available groundwater and surface water quality data to evaluate background groundwater quality and to assess impacts of wastewater discharge on groundwater and associated surface water. Analysis also included preparation of a nitrate balance to evaluate nitrate loading from onsite wastewater systems and from landscaping fertilizer applications. In order to provide recommendations for improved water and wastewater monitoring and management, current onsite wastewater disposal practices and the OWMP were evaluated, and the potential for a STEP (Septic Tank Effluent Pump) community system was considered.

Study Area

The study area encompasses the community of Stinson Beach, shown in Figure 1. The community often is described in terms of distinct areas, including the Highlands, Old Town, Stinson

Beach Park, Calles, Patios, and Seadrift. Seadrift, in turn is subdivided into the Seadrift Road and Dipsea Road areas. The Hydrologic Survey is focused on the areas with rapid soil percolation rates in the Seadrift, Calles, and Patios areas.

Acknowledgment

This report was prepared by Iris Priestaf and David Abbott of Todd Engineers and Norman Hantzsche of Questa Engineering, with assistance by staff members of both firms, notably Thomas Suggs and Alain Boutefeu of Todd Engineers and Randall Smith and Noahdiah Eckman of Questa. We appreciate the considerable assistance of District staff, most notably Richard Dinges and Bonnie Jones, and District consultant Troy Pearce. Acknowledgement also is due to staff of the Regional Water Quality Control Board, Rich Condit and Blair Allen, who provided invaluable guidance.

FIELD PROGRAM

Installation of Monitoring Wells

Weeks Drilling and Pump Company, Sebastopol, California, drilled nine 4-inch diameter monitoring wells (MW-1 through MW-9) in Stinson Beach between August 19 and August 25, 1997. The purpose of these wells was to obtain geologic information, monitor water quality, and document groundwater levels and flow directions in two representative locations. Five monitoring wells (MW-1 through MW-5) were constructed in a north-south transect from Dipsea Road to Seadrift Road and four wells (MW-6 through MW-9) were drilled in a northeast-southwest transect along Calle del Resaca. Locations of the monitoring wells are shown on Figures 2 and 3; note that these two maps portray the single, elongated study area and that a match line linking the two maps is provided. Construction details for the monitoring wells are summarized in Table 1. A tenth well near Seadrift Road was not completed due to lack of owner permission to access the site.

Drilling was expected to encounter a low-permeability clay layer underlying the beach and sand dune deposits and overlying a sand and gravel aquifer. To preserve the integrity of the clay layer and to protect the underlying aquifer, drilling was terminated after penetrating approximately three feet of gray organic clay. However, two 50-foot borings (MW-5 and MW-9) were planned to determine the local stratigraphy. MW-5 was drilled to 51 feet. MW-9 was drilled only to 36 feet after the driller encountered difficult drilling conditions. The clay layer was not encountered in either MW-5 or MW-9.

The monitoring wells were drilled with a Mobile Drill hollow stem auger rig using a 13-inch diameter bit and 10-inch inner diameter (ID) augers. Figure 4 shows a typical geologic and well construction log. Appendix A includes the geologic and well construction logs for MW-1 to MW-9 and water well completion reports. Soil samples were collected with a split spoon sampler at five foot intervals and inspected in the field for lithologic characteristics. The well casings were constructed of 4-inch ID, schedule 40 PVC pipe with flush threaded couplings. The screens consist of 5 or 10 feet of 0.020-inch (aperture width) slot PVC placed near the top of the saturated zone. MW-6 was drilled to weathered bedrock and the screen was set in the bottom of the hole. With the exception of MW-6, all other wells were fitted with a 3 to 5-foot tail pipe to act as a silt trap. To ensure that sufficient water will be available to collect water samples throughout the year, each well was drilled to a depth greater than ten feet below mean sea level.

insert table 1

Each well has a sanitary surface seal between the 4-inch PVC casing and the 13-inch borehole consisting of at least 4 feet of Portland cement and 0.5 to 1 foot of bentonite pellets. Each well has a filter pack of No. 2 Monterey sand extending from approximately 1 to 2 feet above the top of the screen to the bottom of the hole. The wells were logged and field activities were recorded by Todd Engineers. MW-1 through MW-3 were fitted with stovepipe-type locking well covers since these wells are not in areas of vehicular traffic. The balance of the wells were constructed with locking caps and flush-mounted, traffic-rated well covers.

Well development was performed on September 2, 1997 by Blaine Tech, Inc. The wells were developed by pumping at a constant discharge of 6 gallons per minute (gpm) with a 3-inch submersible electric pump to remove fine-grained materials adjacent to the well screen, filter pack, and surrounding formation materials. Blaine Tech pumped approximately 20 casing volumes (200 to 300 gallons) from each well. However, MW-2 and MW-7 had very low yields, producing less than 50 gallons of water during development. Turbidity, pH, and electrical conductivity were measured at regular intervals during development. Pumped water was essentially clear and silt free by the end of development for each well. Formal pumping tests were not conducted following development.

Identification of Existing Wells

Numerous PVC wells, or stand pipes, are known to exist at Stinson Beach as a result of building permit requirements to document depth to groundwater. However, there is a general lack of construction information for most existing PVC wells, making it difficult to know, in many cases, whether the water in the well is groundwater or merely standing rain water. Existing stand pipe wells were field checked by Todd Engineers together with District staff to determine whether they would make suitable points for monitoring water levels or water quality. The water level and total depth of the well was measured. Together these measurements were used to compute the depth of water encountered in the well and to assess the well's potential usefulness for monitoring. Nine PVC stand pipe wells were determined to be sufficiently deep to provide water level information. Water quality samples were not collected from any existing wells, because of the lack of construction details documenting the zone being sampled.

In addition, Todd Engineers acquired all available water well drillers reports from the California Department of Water Resources for production wells in the vicinity of Stinson Beach. Known production wells in Stinson Beach are discussed in the section Groundwater Use and Wells.

Water Level Monitoring

Reference point elevations were surveyed by Questa for the nine selected existing stand pipe wells, the nine new monitoring wells, and three staff gages. A staff gage consists of a graduated scale mounted on a vertical board or plate that is placed in a surface water body and used to measure surface water levels. In Stinson Beach, groundwater and adjacent surface water bodies were expected to be hydraulically continuous; for example, with tides affecting groundwater levels. Accordingly, staff gages were located in the major water bodies including Bolinas Lagoon adjacent to MW-1, Seadrift Lagoon near MW-3, and Easkoot Creek at the Calle del Arroyo bridge (see Figures 2 and 3).

Water level monitoring was conducted on September 3, September 9, September 17, October 14, and October 28, 1997. All monitoring events included the nine new monitoring wells (MW-1 through MW-9). Staff gage readings were begun on September 9, 1997. Four to nine existing stand pipe wells were included in the last three monitoring events.

Because it was recognized that ocean tides can affect groundwater levels, especially in wells located close to the lagoons and beaches, water levels were measured rapidly in each of the monitoring rounds. The two lagoon staff gages were also measured at the beginning and at the end of each of the latter monitoring rounds to record the total amount of tidal fluctuation during the monitoring event. Wells MW-1 and G-45, both located immediately adjacent to Bolinas Lagoon, were found to show significant tidal water level changes exceeding two feet. Due to the lack of an ocean tide gage, the Bolinas Lagoon gage was assumed to approximate ocean tide levels.

Water Quality Sampling

Three water quality sampling events were planned to occur during the late summer and autumn of 1997. Sampling was planned for the new monitoring wells plus additional selected surface water and groundwater monitoring sites. The new monitoring wells were sampled immediately following installation and development on September 3. Two additional sampling events occurred on September 30/October 1 and October 21/22. These later sampling events included the new monitoring wells plus three surface water sampling sites including Easkoot Creek near Calle del Resaca, Stinson Lagoon near MW-3 and Bolinas Lagoon near MW-1. No additional groundwater monitoring sites were selected, largely because of the lack of well construction information for existing wells.

The monitoring wells (MW-1 through MW-9) were first sampled September 3, 1997 by Questa Engineering personnel. Each well was first measured for depth to groundwater by use of an

electric coaxial water level sounder. Additionally, any monitoring wells within a few hundred feet were also measured for depth to groundwater before any removal of groundwater began. The amount of water present in the well casing was calculated for each well to determine how much groundwater to remove before sampling. Through the use of pre-cleaned disposable plastic bailers, each well was purged of approximately five well casing volumes of groundwater before samples were collected. Questa staff used sterile disposable latex gloves for the handling of bailers and sampling equipment to minimize potential cross-contamination of samples.

For subsequent monitoring events on September 30/October 1 and October 21/22, a centrifugal pump was used in place of bailers to purge groundwater from the wells. Pumping of the wells allowed sufficient drawdown of groundwater to obtain a sample representing a larger volume of the aquifer, In addition, pumping reduces handling of sampling equipment and thereby lessens the potential for cross-contamination. Clean plastic tubing was placed down the well casing to pump 10 volumes of groundwater per well. The pump was decontaminated between each well by pumping chlorinated water (1:50 ratio of bleach and water) through the pump and tubing.

Groundwater samples were collected from the bailer or pump discharge line into 8 ounce sterile plastic containers for total and fecal coliform analysis; 1-liter plastic bottles for nitrates, total Kjeldahl nitrogen, and ammonia nitrogen analyses; and into 2-liter plastic bottles for total dissolved solids, MBAS as LAS, alkalinity, major cations and anions, turbidity, electrical conductivity and pH. Samples were labeled and stored on blue ice at 4 degrees Celsius until delivered later the same day to a laboratory courier for transport to Brelje and Race Laboratory, Santa Rosa, a State Certified Laboratory.

HYDROGEOLOGIC SETTING

Geography and Land Use

Stinson Beach is situated where the westernmost flanks of Mount Tamalpais reach the Pacific Ocean. As a result the community is confined by topography to the lower slopes of Bolinas Ridge, which forms the community's backdrop, to small alluvial fan areas at the base of the ridge, and to an elongated line of sand dunes that parallel the coast. These dunes form a long, east-west trending sandspit that separates Bolinas Lagoon from the ocean except for a narrow channel at the foot of Bolinas Mesa to the northwest. Topography along the sandspit and sand dunes generally is within 20 feet of mean sea level (MSL). The topography steepens abruptly at the foot of Bolinas Ridge, rising to 400 feet MSL within the study area and to more than 1,900 feet at the crest of the ridge.

The community is relatively isolated from the greater San Francisco Bay metropolitan area, but attracts numerous visitors and temporary or seasonal residents as a result of its recreational attractions. These attractions include Stinson Beach Park and other portions of the Golden Gate National Recreation Area (GGNRA), which completely surrounds the community. Stinson Beach includes a resident population and small commercial area, but is best known for its numerous weekend and summer residences. The population is approximately 1,500 persons year-round, but can swell to ten times that number on summer weekends, with an added influx of numerous day visitors. Such seasonal peak populations place considerable demands on both water supply and wastewater disposal capacity.

The community has existed as a recreational destination since the 1870's. Resort hotels and vacation homes were built around Old Town before the 1920's, followed by development of the Calles and Patios in the 1940's. The period after 1945 was marked by development of the Highlands subdivision and by development of Seadrift beginning in the 1960's. In 1972, establishment of the GGNRA effectively encircled the community, limiting any future growth to infilling. Nonetheless, the Stinson Beach water supply and onsite wastewater disposal systems could experience increased demand and loading, respectively, as a result not only of increased residential density, but also increased year-round residence.

Climate and Surface Water

Stinson Beach enjoys a Mediterranean climate characterized by cool, rainy winters and dry, foggy summers. Precipitation generally ranges from about 25 inches near the coast to over 50 inches at higher elevations. District rainfall records indicate an average annual rainfall of 28 inches between 1978 and 1997; however, recent years have been characterized by higher rainfall, averaging 43 inches between 1994 and 1997.

Surface water drainage in Stinson Beach is generally towards Bolinas Lagoon. Bolinas Lagoon is an estuary encompassing about 1,100 acres with a watershed of 16.7 square miles Wetlands Research Assoc., August 1995). The Lagoon is publicly owned and managed as open space and is a valuable natural habitat for marine invertebrates, fish, birds, and mammals. The major management issue is continuing sediment accumulation and loss of estuarine habitats within Bolinas Lagoon.

Seadrift Lagoon was created during development of the Seadrift Subdivision, when the sandspit was widened on the Dipsea side and dredged in the center to create an artificial lagoon. Water supply to the lagoon is provided by means of an intake near the northwestern end (see Figure 1), which typically is opened during high tide to allow inflow from Bolinas Lagoon. In addition, an outfall to Bolinas Lagoon exists on the southeastern end. The intake and outfall facilities are operated to maintain a stable elevation in the lagoon and to allow regular flushing of water through Seadrift Lagoon.

The major stream in the study area is Easkoot Creek, which originates above Stinson Beach on the flank of Bolinas Ridge and flows through Old Town. The historic stream likely flowed from its Old Town channel directly toward the ocean in the vicinity of the Beach Park, but now turns northwestward into Bolinas Lagoon. The next major stream to the northwest is Stinson Gulch, which also originates on Bolinas Ridge and flows to Bolinas Lagoon. Stinson Gulch and its associated groundwater are the major source of water supply to Stinson Beach.

Geology and Soils

The major geologic feature in the Stinson Beach area is the San Andreas fault zone, which trends in a northwesterly direction through Bolinas Lagoon. The fault separates Franciscan bedrock complex on the eastern side of the fault and Bolinas Lagoon from younger sedimentary rocks, such as Merced Formation and Monterey Shale, on the western side of Bolinas Lagoon in the vicinity of Bolinas. The youngest geologic units in the area are alluvium and dune sand.

Given its position largely on the eastern side of the fault, the Highlands and Old Town are underlain by Franciscan Complex, an assemblage of sandstones, shales, cherts, limestones,

conglomerates, and basalts that have been deformed intensively (Galloway, 1977; Boudreau, July 1979). Locally, the Franciscan includes highly fractured and deeply weathered sandstones and shale along the lower slopes of Bolinas Ridge that is marked by landsliding. The higher and steeper portions of Bolinas Ridge are underlain by a harder and less weathered sandstone (Boudreau, July 1979; Harding-Lawson, December 1980).

Alluvium occurs in alluvial fans at the mouth of Stinson Gulch and along Easkoot Creek in the Old Town area. The alluvium consists of a wedge of unconsolidated sand, gravel, and clay deposits that thicken toward the stream and in a downstream direction. In the vicinity of Alder Grove on Stinson Gulch, the alluvium reaches a thickness of 67 feet (Boudreau, July 1979) and is characterized by a low-permeability clay layer overlying sands and gravels.

Dune sands parallel the coast, underlying the Stinson Beach Park area, Calles, Patios, and Seadrift. The dune sands consist generally of loose and well-sorted sand. Seadrift is largely a natural sandspit, but has been altered, particularly on the Dipsea side, by addition of finer-grained artificial fill from dredging of Seadrift Lagoon. The bedrock underlying Seadrift is unknown but is assumed to be Franciscan.

Figure 5 shows the locations of cross sections in the study area, while Figures 6 and 7 are cross sections illustrating the geology underlying the Seadrift and Calles areas, respectively. Figure 6 crosses Seadrift through the new monitoring wells; in this area, Seadrift Lagoon is about 500 feet wide. As shown, Seadrift is underlain by about 20 to 30 feet of sand that thickens toward the ocean. Underlying this sand on the Dipsea side is a clay zone overlying gravel. These clay and gravel zones likely correspond to the clay layer and gravel and sand layer encountered in alluvium at the lower end of Stinson Gulch. As shown, the clay layer extends to an unknown extent beneath Seadrift Lagoon and is absent on the Seadrift side of the sandspit. The underlying gravel layer is known to extend under the Dipsea side and Seadrift side in the vicinity of MW-2 and MW-5, respectively.

Figure 7, extending along Calle del Resaca (see Figure 5), shows that the surficial geology consists of a wedge of dune sand that thickens toward the ocean. Bedrock was encountered in both MW-6 and MW-7. The material in MW-6 consisted of weathered limestone and sandstone in a clay matrix. The geologic materials found below about ten feet depth in MW-7 also were clay, and may have included alluvial clay (like that encountered at Dipsea) overlying bedrock. Bedrock was not encountered in MW-8 and MW-9 at depths of 25 and 35 feet, respectively.

Soils in the Stinson Beach area have been mapped as part of the overall Marin County soil survey (USDA Soil Conservation Service, 1985). Two major soil types are present, including the beach and sand dune soils along the coast and Seadrift sandspit, and the Cronkhite-Barnabe soils complex on the lower slopes of Bolinas Ridge. Additional soil types occur higher on the ridge. The

beach and sand dune soils, which underlie the Seadrift, Patios, Calles and Beach Park areas, are deposits of loose sand with rapid permeability. The Cronkhite-Barnabe complex include the deep, slow-permeability Cronkhite loams; the shallow, moderate-permeability very gravelly Barnabe loams; and other related soils and rock outcrops.

GROUNDWATER CONDITIONS

Occurrence of Groundwater

Groundwater in Stinson Beach exists in the bedrock, alluvium, and sand dune geologic units. Local groundwater ultimately is derived from rainfall across the study area and the tributary watersheds along Bolinas Ridge. Locally, the groundwater also is recharged by streamflow and by onsite wastewater disposal systems.

Groundwater generally occurs under unconfined or water table conditions and is hydraulically continuous with, and discharges to, surface water in the ocean, Bolinas Lagoon, and Seadrift Lagoon. Groundwater also is hydraulically continuous with Easkoot Creek along portions of its channel. In general, Easkoot Creek is a drain for groundwater in its upper reaches (above Highway 1), where groundwater seeps and springs yield a year-round flow of groundwater to the creek. Along the middle reach of Easkoot Creek, roughly between Highway 1 and the Calles, flow dwindles seasonally and may cease near the end of the dry season and during droughts. This suggests that the water table falls to a level below the creek channel bottom, and that the creek provides recharge to the groundwater. In the lower reach below Calle del Arroyo, Easkoot Creek is tidal, and again hydraulically continuous with the wetlands groundwater and Bolinas Lagoon.

Confined conditions (in which groundwater occurs under pressure greater than atmospheric pressure) can occur in the alluvium in lower Stinson Gulch following the rainy season, as indicated by artesian flow from Aldergrove 2 in spring 1990. The artesian conditions indicate that the clay layer beneath Stinson Gulch is sufficiently extensive and impermeable to confine groundwater in underlying sand and gravel zones, and that vertical groundwater gradients are upward. Such conditions also likely extend beneath Bolinas Lagoon and the Dipsea side of Seadrift; a noticeable inflow of water into MW-2 during drilling into the sand and gravel zone suggests a relatively high hydraulic head in the lower zone.

Groundwater Levels and Flow

In Stinson Beach, the water table typically mimics the ground surface in a subdued way. Accordingly, highest groundwater levels (relative to mean sea level) occur in the Highlands, with levels declining toward mean sea level at the shore. The water table generally is less than 20 feet below ground surface in the Highlands area and less than 10 feet deep in the Old Town, Calles, Patios, and Seadrift areas.

Figure 8 is a water table contour map for Seadrift and part of the Patios, while Figure 9 shows water table contours for part of the Patios, Calles, Highlands, and Old Town. The maps reflect generalized conditions and are based on water level measurements not only from this study, but also previous investigations in 1975-1976 and 1987. Use of information spanning 20 years was deemed appropriate because local groundwater production is small and no evidence exists for progressive groundwater declines. In addition, groundwater level fluctuations in the lowland areas are restricted by topography and the proximity of the ocean and lagoons. Data used in the maps are presented in Appendix B.

As shown in Figure 8, groundwater levels along the Seadrift sandspit range from mean sea level (MSL) to nearly four feet MSL. Overall, groundwater occurs as a long, linear mound furrowed along the center axis by Seadrift Lagoon. The water level in Seadrift Lagoon is relatively steady at about 2.5 feet MSL. Two secondary mounds occur respectively under the Seadrift Road and Dipsea Road sides of the sandspit, reaching elevations exceeding three feet MSL. The mound under the Seadrift side extends from the sandspit into the patios area.

The water table contour map indicates that groundwater flow along the entire Seadrift sandspit is generally divergent outward to the ocean and Bolinas Lagoon. Under the Seadrift Road side, groundwater flow is towards the ocean and Seadrift Lagoon. Groundwater flow on the Dipsea side probably includes some flow toward Seadrift Lagoon, but appears to be largely toward Bolinas Lagoon.

Figure 9 illustrates groundwater levels in eastern Stinson Beach, including the Highlands, Old Town, Calles, and Patios. Note that the water table contour interval in the Calles and Patios is one foot, while the contour interval for the Highlands area is forty feet. The very steep groundwater gradients suggested for the Highlands area indicates that the permeability of the bedrock is low. Under the Highlands and Old Town, groundwater flow generally is toward the ocean. Groundwater also flows locally toward springs and Easkoot Creek.

The Patios area is characterized by an elongated groundwater mound mirroring the line of dune sands. This mound is generally continuous with the groundwater mound underlying the Seadrift Road portion of the sandspit. Groundwater flow is toward the ocean and toward the Easkoot Creek wetlands.

The water table contour maps shown in Figures 8 and 9 represent average and regional groundwater levels and flow conditions. However, groundwater levels and flow at a specific time and place in Stinson Beach are the result of the dynamic interaction of rainfall, stream, and wastewater system recharge with discharge to tidal surface water bodies. These factors vary daily, seasonally, and over a period of years.

Figure 10 presents three schematic cross sections that illustrate the variability of groundwater levels and flow patterns across Seadrift, as documented in the new monitoring wells during this Hydrologic Survey. The general position of residences and septic tanks are illustrated. Groundwater level patterns are shown for the monitoring wells and staff gages on each cross section for September 9, September 17, and October 28. The actual measurements for these dates (and the other measurement events in September and October) are also recorded in Table 2 and Appendix B. It should be noted that groundwater levels are not shown to scale, and that levels are vertically exaggerated; review of measurement values reveals that they vary by tenths of a foot.

Review of the Seadrift side of the sandspit for all three dates shows a relatively constant pattern of a groundwater mound with groundwater flow diverging toward the ocean and Seadrift Lagoon. Groundwater levels probably fluctuate along the ocean beach as a result of tides, but no data are available. Documented groundwater levels and flow patterns are relatively stable on the Seadrift Lagoon side, reflecting the stability of the lagoon and the presence of numerous residences providing recharge through landscaping and septic return flows.

The Dipsea side of Figure 10 shows greater variability in groundwater levels and flow patterns. As shown for September 9, Seadrift Lagoon remained steady, but Bolinas Lagoon experienced a low tide prior to the groundwater level measurements. Groundwater levels decline from Seadrift Lagoon to Bolinas Lagoon, suggesting groundwater through-flow under Dipsea. On September 17, the Seadrift Lagoon level was relatively high and Bolinas Lagoon was rising toward a high tide. Under these conditions, groundwater levels are relatively high near the lagoons and relatively low in the interior, suggesting a brief period of groundwater flow converging toward the center of Dipsea. However, this pattern of converging flow is only a temporary phenomena due to high tides. A pattern of throughflow or diverging flow must be more typical, allowing groundwater discharge or outflow to occur, because recharge from rainfall, irrigation, or wastewater disposal is known to occur.

A third pattern is apparent on October 28. During this well monitoring event, Seadrift Lagoon showed a typical water level, while Bolinas Lagoon experienced a very low tide. Groundwater levels under Dipsea are higher than those in the lagoons, and groundwater flow diverges outward toward both lagoons, albeit with a steeper gradient and greater flow to Bolinas Lagoon. This pattern of divergent groundwater flow also was recorded on October 14, despite a rising tide in Bolinas Lagoon.

insert Table 2

The greater variability shown on the Dipsea side relative to the Seadrift side of the sandspit probably reflects the relatively narrow area between Seadrift and Bolinas Lagoons and the lower number of residences. Because only a single row of homes exists (as compared to the double row along Seadrift Road), recharge from landscape and septic return flow is less likely to be sufficient to maintain a stable groundwater mound as under the Seadrift side.

It should be cautioned that Figure 10 represents only a single section across Seadrift with measurements taken during a relatively brief, late summer period. Nonetheless, a range of flow patterns is indicated. Different portions of the sandspit may be best characterized by a single flow pattern. For example, the eastern portion of Dipsea is characterized by a relatively high groundwater mound (see Figure 8); this mound may be relatively stable, leading to predominance of the October 28 divergent flow pattern. Similarly, the westernmost end of Seadrift, or areas with low housing density may be better characterized by the pattern recorded on September 9. The groundwater flow patterns recorded in September and October also change with the seasons and through drought and high rainfall periods. For example, it stands to reason that the rainy winter season and high rainfall years would be marked by increased rainfall recharge, greater development of groundwater mounds, and increased divergent groundwater flow and discharge to the ocean and lagoons.

Figure 11 presents two schematic cross sections that illustrate the variability of groundwater levels and flow patterns along Calle del Resaca. Groundwater level measurements are shown for the monitoring wells and staff gages for September 9 and October 28. It should be reiterated that the groundwater levels are not shown to scale, and actually vary only by feet and inches.

As shown by the measurements on September 9, a continuous groundwater gradient exists from the edge of the Highlands to the ocean, indicating a southward groundwater flow. Seven weeks later on October 28, groundwater levels under the sand dunes were higher and water levels in the vicinity of Easkoot Creek were relatively low, resulting in groundwater flow converging in this area.

Consideration of these two distinct patterns and review of the water table contour map (Figure 9) suggests that the Calles are transitional between Old Town, where groundwater flow is toward the ocean, and the Patios, where groundwater flow diverges toward the ocean and Easkoot Creek wetlands. This transition probably occurs seasonally. Under wet conditions, Easkoot Creek would be flowing and providing recharge to the underlying groundwater. This would help maintain a continuous groundwater gradient to the ocean. Under dry, low streamflow conditions (e.g., late dry season or drought) Easkoot Creek flows diminish or cease and local groundwater levels would decline. However, recharge from landscaping and septic return flows would be maintained along the dune line, resulting in a divergent groundwater flow pattern like that in the Patios area.

Overall, the ocean and Bolinas Lagoon are the discharge points or receiving surface water bodies for groundwater in Stinson Beach. Groundwater flow from the oceanside portions of Stinson Beach, Old Town, and Highlands areas generally is toward the ocean, while groundwater flow from the remaining portions of Seadrift, Calles, and Patios is toward Bolinas Lagoon. Easkoot Creek intercepts groundwater and conveys it to Bolinas Lagoon.

Groundwater Level Changes

Only limited information is available on groundwater levels through the seasons and over the long term. As noted previously, sustained groundwater trends are unlikely, given the limited use of groundwater resources locally. Seasonal fluctuations were not documented during this study; however, some data are available from previous investigations.

Groundwater levels in test wells and piezometers were measured between October 1970 and January 1971 for a soils investigation (Lee and Praszker, February 1971). Prior to and during the investigation, rainfall amounted to 22 inches and groundwater levels rose, with increases ranging between 1 and 3.5 feet in the Seadrift, Patios, and Calles areas. Highest increases occurred in piezometers adjacent to Bolinas Lagoon, while groundwater level increases near Seadrift Lagoon and near Easkoot Creek at Calle del Ribera were about one foot.

Groundwater level change data also are available from the routine groundwater monitoring program of the District, which has included regular measurement of groundwater levels as part of sampling procedures. These water level data were reviewed for seven wells to assess the range of seasonal water level changes; of these, the water level data for Well G4, located near the beach at Joaquin Patio (see Figure 2) are most complete and representative. Figure 12 shows the water level fluctuations from October 1991 to April 1997 in Well G4 along with monthly rainfall for comparison. The water level data reveal a regular seasonal pattern of winter rainy season peaks ranging between 2.3 and 4.5 feet MSL and summer dry season lows of 0.8 to 1.0 feet MSL. The typical seasonal fluctuation is 2.5 to 3.5 feet.

Groundwater Use and Wells

Table 3 summarizes information on production wells that is available from water well drillers reports filed with the California Department of Water Resources. As indicated, information is

available on fourteen production wells. The locations of these wells are shown on Figures 2 and 3, with the exception of the Ranch Tank Wells 1 and 2, Highlands Tank Well, and 6500 Panoramic Highway well, located off the maps and generally uphill of the study area.

The known production wells are grouped in two areas, Stinson Gulch and in the eastern portion of Stinson Beach including the Highlands, Panoramic, and Beach Park areas. The wells drilled in Stinson Gulch include the Stinson Beach school irrigation well, and the District's Aldergrove, Ranch, and Ranch Tank wells. The school well is shallow with a ten-foot sanitary seal, but is used only for irrigation purposes. Of the District municipal wells, only Aldergrove 2 is currently in production, yielding approximately 30 percent of District municipal supply, with the remaining supply provided by springs and surface water. Aldergrove 2 is 80 feet deep with an 18-foot sanitary seal. It penetrates nearly 70 feet of alluvium, including shallow clayey materials overlying sand and gravel. The well screens are opposite the sand and gravel in the lower portion and also include a section in underlying bedrock.

The wells include three private wells in the Highlands (15 Avenida Las Baulinas, 200 Belvedere, Leonard), one well on Panoramic Highway, and one well at the Beach Park. Three of these wells are intended for irrigation purposes only, but two of the Highlands wells also were intended for domestic purposes.

insert Table 3

WATER QUALITY CONDITIONS

Beneficial Uses of Groundwater

The Stinson Beach County Water District was established not only to provide water and wastewater management, but also to prevent water contamination and improve water quality. The District cooperates and is guided by the California Regional Water Quality Control Board, San Francisco Bay Region, whose primary planning and policy document is the Water Quality Control Plan for the region (RWQCB, June 1995). This plan includes definition of beneficial uses of water resources, including surface waters, groundwater, and wetlands.

Beneficial uses are defined for the Bolinas Bay basin, of which Stinson Beach is a part, and specifically for Bolinas Lagoon, which include the following:

Ocean, commercial, and sport fishing
Marine habitat
Fish migration
Preservation of rare and endangered species
Water contact recreation
Noncontact water recreation
Shellfish harvesting
Fish spawning, and
Wildlife habitat.

The beneficial uses of the Bolinas Lagoon wetland areas also are identified, including marine habitat, contact and noncontact water recreation, wildlife habitat. Although the Stinson Beach area is not identified as a groundwater basin, the use of local groundwater for municipal and domestic supply is a beneficial use.

Based on the water quality study sponsored by the District in 1976, water quality criteria were established for the surface water and groundwater quality stations. As noted in the District's Fifteenth Annual Report for the OWMP, the criteria have been revised subsequently.

In brief, the criteria for the surface water stations along Easkoot Creek and in Seadrift Lagoon refer to contact recreation. For the nontidal stations of the creek (S1, S2, S3, and S4 shown in Figure 3) fecal coliform concentrations shall not exceed 400 Most Probable Number (MPN)/100 milliliters (ml). For the tidal stations S5, S6, and S7, the total coliform shall not exceed 10,000 MPN/100 ml

and the fecal coliform concentrations shall not exceed 400 MPN/100 ml (Stinson Beach County Water District, Fifteenth Annual Report). It should be noted that the RWQCB water quality objectives for fecal coliform bacteria with regard to shellfish harvesting call for median concentrations less than or equal to 14 MPN/100 ml and 90th percentile counts of 43 MPN/100 ml or less. The objectives for total coliform similarly are 70 and 230 MPN/100 ml. Federal drinking water standards include maximum permissible limits that disallow more than ten percent of standard 10-ml samples in one month showing coliform (Todd, 1980).

For Stinson Beach surface water and groundwater stations, the criteria also state that concentrations of selected constituents shall not cause nuisances or adversely affect beneficial uses. The selected constituents and criteria are:

Nitrate + Nitrite (mg/L as Nitrogen)	10 mg/L
Ammonia (mg/L as Nitrogen)	Not to exceed levels observed during the 1976 study (averaging 0.30 mg/L)
MBAS	0.05 mg/L threshold concentration 0.5 mg/L limiting concentration.

The ammonia limits were established with reference to specific monitoring wells (e.g., G1, G2), some of which no longer exist, so the applicability of these limits to current conditions is debatable. The 0.30 milligrams per liter (mg/L) criteria is very close to the detection limit of 0.20 mg/L used in this study.

Groundwater Quality

Major factors affecting groundwater quality include the relative quantity and quality of recharge sources, the chemical characteristics of the aquifer materials, and the amount of time and distance that groundwater flows through the aquifer. In Stinson Beach, the last two factors are relatively constant, while the first factor, the character of groundwater recharge is variable through time and from place to place. Major sources of recharge are rainfall infiltration, stream recharge, landscape irrigation percolation, septic return flow, and seawater intrusion.

Water quality sampling and analysis for the Hydrologic Survey included analysis of general mineral quality in order to understand background or existing groundwater quality in Stinson Beach. The laboratory analyses, presented in Appendix C, included major cations (calcium, magnesium, potassium, sodium), major anions (bicarbonate, sulfate, chloride), hardness, alkalinity, pH, total dissolved solids (TDS), electric conductivity (EC), and turbidity. Appendix C also shows selected analyses for comparison, including standard mean ocean water and analyses from the District's Aldergrove 2 and the Beach Park wells.

Review of these analyses shows that ambient groundwater quality in Stinson Beach includes a calcium/magnesium/sodium bicarbonate type that is characteristic of Aldergrove 2 Well, Beach Park, and MW-6, which is screened in bedrock. These analyses show TDS concentrations of 180 to 250 mg/L, which meet California drinking water standards for TDS.

Local groundwater also includes a type that is dominated by seawater. This type is best exemplified by MW-2, MW-3, and MW-4 near Seadrift Lagoon. These wells are characterized by sodium chloride groundwater with TDS concentrations ranging from 1,000 to over 30,000 mg/L. This water is not suitable for drinking water purposes.

General groundwater quality in the remaining monitoring wells ranges between these two types, reflecting varying degrees of mixing between seawater and recharge from rain, streamflow, irrigation, and septic systems.

Figure 13 shows the measured TDS concentrations in the monitoring wells across Seadrift for the three sampling events on September 3, September 30-October 1, and October 21, 1997. The lagoons were not sampled on September 3 because the surface water stations had not yet been established. Because groundwater flow directions are an important factor in determining groundwater quality at Seadrift, the TDS data are displayed with reference to the three groundwater flow patterns described in the previous section on Groundwater Levels and Flow. However, it should be noted that the groundwater flow patterns were not documented at time of sampling. For example, for the uppermost cross section on Figure 13, groundwater quality was sampled on September 3, while groundwater levels were measured on September 9. Accordingly, the specific relationships between groundwater flow and groundwater quality cannot be considered definitive at this time. Nonetheless, general relationships can be discerned and warrant discussion.

The uppermost cross section showing September 3 results indicates a broad range of TDS from 290 to 30,000. Highest TDS levels occur next to Seadrift Lagoon, reflecting seawater mixing, particularly in MW-3. Lower TDS groundwater reflects recharge from rainfall, irrigation, and septic returns.

The TDS concentrations in the center cross section (September 30-October 1 sampling) are

higher than in the previous sampling. This reflects in part a change in the sampling procedure; the first round of samples was collected through bailing the wells, while the second and third rounds were accomplished through pumping the wells. Pumping wells removes a greater volume of water from the aquifer and allows sampling of groundwater that represents a larger area. The higher TDS levels in the both the second and third rounds shows greater influence of seawater, indicating that fresh water exists locally as only a thin lens floating above denser seawater. Seawater is 2.5 percent denser than fresh water and naturally tends to maintain a vertical stratification of water types with a small mixing zone. Infiltration from rainfall and septic systems recharge the upper fresh zone, while brackish water persists with depth.

The convergent groundwater flow pattern shown in the center cross section also would contribute a larger portion of seawater, as indicated by the high TDS contents in MW-1 and MW-2 on the Dipsea side. The TDS concentrations for the October 21 sampling could be representative of the divergent groundwater flow pattern shown in the lowermost cross section or of the through-flow pattern in the uppermost section.

Figure 14 shows TDS concentrations measured along Calle del Resaca for the three sampling events with reference to the two main groundwater flow patterns described in the previous section on Groundwater Levels and Flow. The uppermost cross section shows the Highlands-to-ocean pattern that prevailed before September 15. The TDS concentrations range from a low of 230 mg/L in MW-6 to a high of 710 mg/L in MW-7. The low TDS content in MW-6 reflects groundwater inflow from the bedrock Highlands, while the high TDS in MW-7 likely reflects inflow of brackish water from the tidally-influenced Easkoot Creek. The TDS decreases downgradient toward the ocean, reflecting recharge of relatively fresh water from rainfall, irrigation, and septic returns.

The TDS concentrations in the lower portion of Figure 14 are considerably higher, with the exception of groundwater in MW-6, the bedrock well. As before, the higher TDS in the second and third rounds reflect the pumping procedure for sampling, which pulled in a greater portion of underlying seawater than did the bailing procedure used on September 3. This effect is particularly pronounced in MW-9, located closest to the ocean.

In summation, available data on general mineral groundwater quality are relatively scanty, but nonetheless are revealing about major factors influencing groundwater quality. Groundwater quality in Stinson Beach is influenced by the source and character of groundwater recharge, including recharge from rainfall, streamflow, landscape irrigation, and septic return flow, as well as seawater intrusion. The particular sources affecting groundwater quality
at any particular time and place is determined by groundwater flow patterns.

Impacts of Wastewater on Water Quality

Impacts of wastewater on groundwater and associated surface water quality were assessed through analysis of the current water quality sampling data generated during this study, review of existing water quality data from previous investigations and monitoring programs. The next section summarizes preparation of nitrate balances.

Current Water Quality Sampling. The water quality sampling conducted during the Hydrologic Survey focused on the nine new monitoring wells (MW-1 to MW-9) and associated surface water gages. The locations of the monitoring well transects were selected to provide a cross section through the Seadrift and Calles areas and thereby to illuminate groundwater flow conditions. Another factor in selecting the monitoring well sites was access to property; wells were sited on public property and rights-of-way when possible, or on vacant private property. The wells were not sited with regard to existing septic systems. Subsequently, it was determined that the Seadrift transect is in an area of standard gravity septic systems, as shown in Figure 15, and not sand filter systems. Similarly, the Calle del Resaca wells, situated along or within the calle itself, are bracketed by standard gravity leachfields on both sides of the calle (Figure 16). Thus, the monitoring results from these areas would tend to reflect the worst-case impact of septic systems in the dune sands.

The water quality sampling and analysis for this study included documentation of several indicators of wastewater influence including nitrogen concentrations (nitrate, ammonia, and total Kjeldahl nitrogen), total and fecal coliform counts, and MBAS, reflecting the presence of foaming agents or detergents.

Nitrogen. With regard to nitrogen, ammonia was selected for particular analysis because of its presence in many sampled wells. Nitrate was very rarely detected in the monitoring wells with the exception of the bedrock well, MW-6, which showed consistent nitrate concentrations of about 1.6 mg/L. Nitrate also was detected in Easkoot Creek at concentrations of 0.2 to 0.7 mg/L. Total Kjeldahl nitrogen was detected in many wells in concentrations paralleling ammonia concentrations, but at a higher level.

Figure 17 shows ammonia concentrations from the three sampling rounds with reference to the groundwater flow patterns described previously for Seadrift. As with the discussion on TDS, it needs to be reiterated that groundwater flow patterns were not documented at time of sampling, so the factors affecting groundwater quality can be discussed only in general terms.

As shown in all three sections on Figure 17, ammonia concentrations are very low or below

detection (not detected, nd) on the Seadrift side. On the Dipsea side of the sandspit, concentrations are generally higher, ranging from less than one to seven mg/L. The most notable feature of the ammonia distribution on the Dipsea side is the decrease in concentrations along the down-gradient groundwater flow direction. This pattern is most clearly shown on the uppermost cross section, but may also exist for the convergent and divergent flow patterns. This suggests that ammonia is reduced by subsurface processes to concentrations less than one mg/L prior to entering adjacent lagoons.

Figure 18 similarly shows ammonia concentrations from the three sampling rounds with reference to the two groundwater flow patterns identified for the Calles. The uppermost graph, showing the through-flow pattern of groundwater flow toward the ocean, indicates a general decrease in ammonia concentrations downgradient from MW-7. The contribution of ammonia to groundwater is apparently greatest in the vicinity of MW-7, possibly reflecting the local shallow depths to groundwater and/or the operating condition of nearby septic systems.

The lower cross section shows the same pattern of decreasing concentrations toward the ocean, despite the changed groundwater flow condition. The samples for the latter two rounds were pumped rather than bailed, and the higher ammonia concentrations shown on the lower cross section indicates that pumping resulted in interception of wastewater-influenced from one or more septic sources.

With regard to water quality criteria established for the groundwater stations in the 1976 Stinson Beach study, the concentrations of ammonia documented in this study generally exceed the 0.30 mg/L criteria. The surface water samples analyzed for this study showed no ammonia.

Coliform. Figure 19 shows total and fecal coliform concentrations with reference to the groundwater flow patterns in the Seadrift area. As shown in all three sections on Figure 19, total coliform counts are at or below the level of detection on the Seadrift Road side, and no fecal coliform were detected. On the Dipsea Road side, fecal coliform were detected only once. Total coliform were detected consistently in MW-2, and in all three Dipsea wells during the first sampling round. The results of the first sampling round may reflect insufficient well purging and may not be representative of aquifer conditions, given that coliform were not detected subsequently in MW-1 and MW-3 and greatly reduced in MW-2. This is supported by turbidity measurements, which typically were highest in the first sampling and have declined consistently since then. Alternatively, the decline over time in coliform detections could reflect changing groundwater flow patterns or the operation of nearby septic systems.

The lagoons were sampled only in the last two sampling events, showing coliform at or

below the level of detection in Seadrift Lagoon, and total coliform in Bolinas Lagoon at levels of 79 MPN/100 ml. Fecal coliform also were detected in Bolinas Lagoon during the second sampling.

Figure 20 shows total and fecal coliform counts in the monitoring wells along Calle del Resaca. The number of detections were greater in the first sampling than subsequent sampling, when no wells indicated coliform detections except MW-7, which shows rapidly declining counts of both total and fecal coliform over the sampling period. As noted in the Seadrift area, this could reflect progressive purging or cleansing of the well.

Easkoot Creek was sampled during the second and third sampling rounds; both times, total and fecal coliform counts of 1600+ and 920 MPN/100 ml were recorded.

MBAS. MBAS also was analyzed in all the monitoring wells for three sampling events and in the lagoons and Easkoot Creek for the last two sampling events. The sampling indicate that all wells except MW-1 on Bolinas Lagoon and MW-6, the bedrock well, show concentrations of MBAS in the range of 0.05 to 0.35 mg/L. The surface water samples also showed MBAS in the range of 0.05 to 0.12 mg/L. Similar to the other parameters, MBAS concentrations tend to decline along the groundwater flow pathways. Overall, the concentrations fall between the limiting and threshold criteria of 0.05 and 0.5 mg/L set in 1976 for Stinson Beach.

Review of Existing Water Quality Data. The District has initiated several water quality investigations, including the 1975-1976 Surface Water and Groundwater Study (Eutek, April 1977). This study first documented that wastewater disposal was influencing groundwater, and established seven surface water stations and twelve groundwater stations (G1-G3, G5-G13) to monitor local water quality.

Subsequently, the groundwater and surface water stations established in the 1976 study became the basis for the District's routine water sampling program, which has continued to the present. The most recent ten years (1986-1996) of data from this routine sampling program have been compiled by the District in its *Summary of Groundwater Studies* (1996) and updated with information from the 1997 program. The sampled wells included G1 through G10; however, the sampling period for each well varies as wells were added to or deleted from the program. The number of sampling events also varied as individual wells at times could not be sampled because they were dry or contained too little water for sampling. Analyses were performed for ammonia, nitrate and nitrite, MBAS, and total and fecal coliform; detection limits for the constituents varied over the period.

Review of the water quality data indicates considerable variability, some of which can be

explained by changing conditions in nearby septic systems. In addition, the variable water quality results probably reflect the changing groundwater flow conditions documented in this study. However, at the time, such conditions were not documented. In addition, it is also likely in some cases that the analytical results do not accurately represent groundwater quality in the aquifer. Most notably, G1 is located above all residential developments and should reflect background quality without influence of wastewater. The lack of any detections of ammonia, nitrate, or MBAS over the well's 10-year sampling period support this assumption. Nonetheless, fecal coliform was detected in 51 percent of samples, suggesting contamination of the well itself and/or sampling problems.

In brief, the routine water quality data were not relied upon for this study. This is due to the lack of well construction and geologic information for the wells, absence of information on hydrologic conditions, and uncertainty over well conditions and sampling procedures.

In 1987, the District conducted an investigation of wastewater impacts on groundwater quality at Seadrift (see Stinson Beach CWD, *Summary of Groundwater Studies,* 1996). This investigation consisted of two parts, monthly sampling of ten selected wells and Seadrift Lagoon over the period January through October 1987, and an intensive one day survey on March 16, 1987 that included two rounds of water level measurements in the wells and Bolinas Lagoon and water quality sampling of the wells.

The 1987 study included selection of a number of existing wells for sampling, including ten wells for the monthly sampling, and nineteen wells for the March 16 survey. The wells were selected for a variety of land use and wastewater disposal intensities and grouped in five distinct areas A through E, which are shown on Figure 2. As indicated, Area A consisted of a grid of five wells (G5, G31-G34), while the wells in the other areas consisted of alignments of three to four wells. It was recognized that these alignments were similar in concept to the monitoring well transects developed for this study, and would allow extension of this study's analysis to additional cross sections along Seadrift. Accordingly, the available topographic, well location, water level, and water quality data from the 1987 study were used to develop three additional cross sections through Seadrift. The location of these cross sections (C-C', D-D', and E-E') are shown on Figure 5.

Figure 21 shows cross section C-C' through Area B, showing groundwater levels and water quality on the morning of March 16, 1987. The well depths and construction are unknown, as indicated by the query at the bottom of each well. Area B is located 700 feet east of and is similar to the Seadrift Road portion of cross section A-A' (see Figures 13, 17, and 19). As shown in Figure 21, a low groundwater mound is indicated, with divergent flow to the ocean and apparently to Seadrift Lagoon, which apparently was not measured for water levels at the time. A typical water level of about 2.5 feet MSL was assumed, consistent with current levels and descriptions of outfall facilities

(Questa, 1994). TDS concentrations are lower than those measured in 1997, probably reflecting seasonal effects and sampling procedures in 1987. It is likely that the sampling skimmed relatively freshwater from the water table that had been recharged during the preceding wet months. The water quality from Well G39 shows the influence of nearby septic systems, but it is noteworthy that the groundwater quality improves in a downgradient direction.

Figure 22 combines the transects through Areas C and E to create cross section D-D', located about 1,200 feet west of cross section A-A'. The groundwater levels and flow apparently are similar to those measured along cross section A-A' on September 3, 1997, with a broad groundwater mound on the Seadrift Road side. On the Dipsea Road side, groundwater may have been slightly mounded with divergent flow to both lagoons or there may have been through-flow from Seadrift Lagoon to Bolinas Lagoon. Bolinas Lagoon experienced a rising tide on the morning of March 16, 1987, but little response in wells was recorded. As in cross section C-C', TDS levels are relatively low across the Seadrift Road side, but clearly show the influence of seawater on the Dipsea side, particularly adjacent to Bolinas Lagoon. Little influence of wastewater disposal is indicated, with the exception of nitrate.

Figure 23 shows cross section E-E' through Area D, located about 2,700 feet west of cross section A-A'. This section also shows apparent groundwater through-flow from Seadrift Lagoon to Bolinas Lagoon on the Dipsea side. TDS concentrations are elevated, particularly reflecting the seawater influence of Seadrift Lagoon. Again, little influence of wastewater disposal is indicated, with the exception of nitrate.

In summation, the reinterpreted results of the March 16, 1987 study are consistent with the findings of the 1997 Hydrologic Survey in terms of groundwater flow patterns and effects of seawater intrusion. In addition, both the 1987 and 1997 studies detected the localized influence of wastewater on groundwater quality, but suggest that groundwater quality often improves along the groundwater flow pathway.

Nitrate Loading Analysis

Although no clear geographical or temporal trends are apparent, high concentrations of nitrogen have been detected by the District from time-to-time at some of the groundwater monitoring locations in the Seadrift, Patios, and Calles areas. For example, review of the results of the routine groundwater sampling program between 1986 and 1997 indicated that ammonia concentrations exceeding 0.3 mg/L occurred periodically in G3 located near Calle Occidente and Easkoot Creek, and in G8 on Dipsea Road, while high nitrate concentrations occurred regularly in samples from G5

on Seadrift Road, particularly in summer and autumn. Additionally, the focused sampling of the sand filter treatment units over the past few years has confirmed what was generally expected, i.e., that high levels of nitrogen are contained in the septic tank effluent and, to a lesser degree, the sand filter effluent that is being discharged to leachfield systems in the sandspit areas. There has also been a concern that nitrate may be reaching the groundwater as a result of fertilizer applications to the very sandy, excessively-drained dune soils. The effect of these nitrogen sources on local water quality and beneficial uses may not be adequately addressed by current practices and this is of concern to the District.

To address these concerns a nitrate loading analysis was completed to supplement and expand the understanding of the water quality data obtained through the field sampling program. The specific purpose of the nitrate loading analysis was to estimate the contributions of nitrogen from different sources (e.g., wastewater, fertilizer, natural sources), under different scenarios of wastewater treatment (with and without sand filters), and for different levels of development (e.g, current and future conditions). From this the projected long-term effects on groundwater nitrate concentrations were estimated.

Approach. The methodology employed a water-chemical mass balance following the general approach outlined by Hantzsche and Finnemore (1992). The specific approach and assumptions for this study was as follows.

Define Hydrologic Sub-areas. The first step was to divide the study area into sub-areas, based on groundwater conditions. Using the information developed from this study and described in Section 4 of this report, five sub-areas were defined as follows and mapped on Figure 24.

Calles. The Calles sub-area encompasses 30 acres in which there are 99 developed residential lots. Groundwater flow in this area is generally toward the ocean for most of the year, and includes a lateral groundwater flow from the hillside bedrock. The sub-area extends from Easkoot Creek to the ocean. This sub-area was assumed to be fully developed.

Patios. The Patios sub-area is defined as the area on the inland side of the dune line encompassing 20 acres and 83 developed residential lots. The groundwater flow is predominantly toward Bolinas Lagoon from a groundwater ridge that coincides roughly with the dune line. This sub-area was assumed to be fully developed.

Seadrift Road. The Seadrift Road sub-area encompasses 60 acres in which most of the groundwater flow is northerly into Seadrift Lagoon. It is recognized that a portion of

groundwater flow in this area is toward the ocean (see Figure 11). However, most of the septic systems are located east of the groundwater divide in the area of flow toward Seadrift Lagoon. There are presently 146 developed residential lots, and an estimated 180 total lots that may be developed at build-out.

Dipsea Road. The Dipsea Road sub-area includes the area between Seadrift Lagoon and Bolinas Lagoon. It has an area of approximately 47 acres, with 84 developed residential lots and an estimated 100 total lots at buildout. The groundwater flow is generally from Seadrift Lagoon toward Bolinas Lagoon, including lateral flow contributed by Seadrift Lagoon.

Seadrift Westend. The west end of Seadrift beyond the Lagoon, encompasses 10 acres between the dune line and Bolinas Lagoon, where the groundwater flow is predominantly toward Bolinas Lagoon. There are presently 40 developed residential lots and an estimated 50 total lots at build-out.

The above-noted build-out estimates are approximations, based on a drive-through lot count along with information supplied by the District (i.e., service connections) and Seadrift Association.

Construct Water Balance for each Sub-area. The water balance for each sub-area was constructed using the following assumptions:

Wastewater Flow (W). Examination of District water use records for a winter and a summer billing period were used as a basis for the following estimate of daily and annual wastewater flow rates:

- Calles and Patios: 145 gallons per day (gpd) [0.16 acre-feet per year (ac-ft/yr)]
- Seadrift Sub-areas: 175 gpd [0.2 ac-ft/yr]

Based on these unit flow estimates and previously noted lot counts, the projected daily wastewater flow for each of the sub-areas at build-out would be:

· Calles - 99 units @ 145 gpd
· Patios - 83 units @ 145 gpd
· Seadrift Road - 180 units @ 175 gpd

· Dipsea Road - 100 units @ 175 gpd
· Seadrift West End - 50 units @ 175 gpd

Rainfall. Average annual rainfall for Stinson Beach is 28 inches, based on the last 20 years of record from data taken at Stinson Beach Park (compiled by Bonnie Jones). However, over the past three years rainfall has averaged about 43 inches per year, which is likely to be reflected in the current monitoring results and represents "wet" conditions.

Runoff Rate. Runoff of rainfall is small to negligible due to the high permeability of the dune sands. Accordingly, an annual runoff rate of 2 percent was assumed for this study.

Evapotranspiration. An actual evapotranspiration rate of 6 inches per year was assumed due to the excessively drained dune sands and generally sparse vegetation. This is about half the normal rate that would apply to well developed upland soils in the same climatic region.

Net Rainfall Recharge (R). From the preceding assumptions, the net annual rainfall-recharge to each of the sub-areas was determined to be 21.5 inches (per unit area) for average rainfall conditions and 36.5 inches for the recent "wet" year conditions.

Lateral Groundwater Inflow (G). For the Calles and Dipsea Road sub-areas, a lateral flow component was incorporated in the water balance. For the Calles, the annual lateral flow from the hillside bedrock groundwater was estimated to be approximately 100 ac-ft/year; for the Dipsea Road sub-area the annual lateral dilution flow from Seadrift Lagoon was estimated to be roughly 80 ac-ft/year.

Wastewater Nitrogen Content (N_w). Based on locally collected monitoring data from the District along with published literature values, the concentration of total nitrogen (i.e., nitrate, ammonia, and organic nitrogen) was estimated to be 60 mg/l in septic tank effluent and 30 mg/l in sand filter effluent. The District's monitoring data included sampling of nitrate and ammonia concentrations in septic tank effluent and sand filter effluent for several systems in the Seadrift area that were in regular use. Note that the actual occupancy and water use/wastewater generation was not determined. The assumption was then made that all nitrogen will be converted to nitrate (i.e., nitrification via oxidation processes) as the effluent moves through the leachfield, sandy soils and groundwater. Based on District records, it was further estimated that approximately 36 percent of the

septic systems in the Seadrift area presently have sand filter systems; while there are virtually none in the Calles or Patios.

Estimate Soil Denitrification Rate (D). Denitrification is the conversion of nitrate to nitrogen gas which is carried out by certain anaerobic bacteria in an environment having a supply of organic carbon (i.e., organic matter). Marshlands are ideal for denitrification; but the sand spit areas of Stinson Beach are not likely to have sufficient organic matter to promote high levels of denitrification. Accordingly, a nominal denitrification rate of 10 percent of the wastewater nitrogen content was assumed. Higher rates undoubtedly occur at the margins of the sandspit where the groundwater enters the Bolinas Lagoon or the interior Seadrift Lagoon.

Estimate Background Nitrate Concentration (N_B). The background nitrogen associated with percolating rainfall or lateral groundwater flow was estimated, based on monitoring data, to be at the detection limit, or 0.1 mg/l. This concentration was also applied to the lateral dilution flow of water from Seadrift Lagoon through the Dipsea Sub-area. However, for the Calles, the lateral groundwater flow was assigned a background nitrate concentration of 1.7 mg/l based on the monitoring results from MW-6.

Fertilizer Nitrogen Contribution. For the initial set of calculations, the fertilizer nitrate contribution was assumed to be negligible and deferred to a separate detailed analysis, which follows later.

Calculations. Using the above factors and assumptions, the estimated average groundwater nitrate concentration (N_c) was calculated for each of the five sub-areas according to the following mass balance equation:

$$N_c = \frac{(W)(N_W)(1-D) + (R+G)(N_B)}{W+R+G}$$

Multiple calculations were made for each sub-area, covering various wastewater treatment assumptions and development scenarios. Calculation tables for each sub-area are provided in Appendix D. A summary of the results for all five sub-areas is provided in Table 4.

The following are indicated by the nitrate loading calculations:

> Wastewater disposal in the Calles and the Dipsea Road sub-areas is likely to have the smallest impact on groundwater nitrate concentrations, due largely to the lateral inflow of groundwater that helps to dilute nitrate concentrations in these areas. The predicted concentrations for existing conditions and build-out is less than 5.0 mg/l in both areas. For comparison, the data collected in the field program of this project showed an average total nitrogen concentration of 3.8 mg/l for the Dipsea Road area (MW-1,2 &3), and 2.5 mg/l for the transect of wells through the Calles (MW-7,8 & 9). These data are consistent and less than the model predictions, indicating the nitrate loading analysis to be on the conservative (safe) side. The residences near these monitoring wells appeared to be regularly occupied during the sampling period of this study.
>
> The calculations show a considerably higher potential for elevated nitrate concentrations in the Patios, along Seadrift Road and at the west end of Seadrift. The groundwater nitrate concentrations in these areas are predicted to approach, and possibly exceed, the drinking water standard of 10 mg/l. Monitoring data from the current field program was limited in these areas; the few sampling points (MW-4 and 5), did not reveal total nitrogen concentrations of more than a 2 to 3 mg/l.

insert table 4

The concentrations can be expected to rise slightly in the future in Seadrift with full build-out, even if sand filters are continued to be employed for all new systems. But the predicted impact would decline below drinking water limits if existing standard septic systems are converted over time to incorporate sand filters or an equivalent degree of nitrogen removal.

The Patios are essentially fully developed and no further increase in nitrate loading effects would be anticipated. In cases where existing small houses are replaced with much larger structures in the Patios and the Calles it is reasonable to assume that the District would require the incorporation of sand filters. Consequently, there would be no net increase in nitrogen loading even if there is an increase in wastewater flow. A significant reduction could be achieved, again reducing the predicted nitrate concentration below the drinking water limit, if sand filters or equivalent nitrogen removal are incorporated into the existing systems.

The ultimate pathway of groundwater nitrate in the Patios and Seadrift West End is to the marshland fringe of Bolinas Lagoon which, through natural denitrification processes, provides an ideal sink for the nitrate contained in the groundwater from the sandspit. Similarly, the groundwater from the Seadrift Road area discharges to Seadrift Lagoon, which also can be expected to provide for significant dilution and assimilation of the nitrate through denitrification along the lagoon bottom and via plant uptake. Consequently, elevated nitrate concentrations are and will continue to be confined to the shallow groundwater within the developed sandspit area.

Groundwater Impact from Fertilizer Use

To examine the potential impact of fertilizer use on groundwater nitrate in the study area, a qualitative and quantitative assessments were made.

Qualitative Assessment. The qualitative assessment involved a general canvassing of the study area and phone interviews with the Seadrift General Manager (Dick Kaminiecki) and several knowledgeable nursery people who work in the Stinson Beach area. The local nurseries contacted included Las Baulinas Nursery and Horseshoe Hill. The general findings of this survey included the following:

The vast majority of the properties in Seadrift have landscaping that consists of drought resistant ground cover (e.g., ice plant, beach grasses) and low maintenance ornamentals. Lawns, which have generally the greatest fertilizer use, are rare; but there are a few.

Some property owners have imported topsoil to improve the conditions and options for landscaping.

Many of the properties utilize services of local nurseries, such as Las Baulinas and Horseshoe Hill, who rely predominantly on organic, slow-release fertilizers. This type of fertilizer (as opposed to commercial fertilizers) release the nutrients (nitrogen, phosphorus, potassium) as a slow rate, making nitrate more available to the plant and less likely to be leached past the root zone into the groundwater. The nurseries also report that their use of fertilizers is very selective and generally in small quantities. The general opinion of the local nursery people, based on their practice and knowledge of the area, is that nitrate leaching from fertilizers is likely to be very limited.

Many of the property owners do their own gardening, and may employ traditional commercial fertilizers and at heavier rates. Also, some properties have little or no landscaping at all.

Quantitative Assessment. The nursery people interviewed were unable to quantify the typical fertilizer usage at properties in Stinson Beach. Therefore, to obtain some sense of the relative impact that fertilizer use might have, a worst case scenario was constructed. This scenario assumes that all properties in Seadrift have, or could have, a large lawn area of 5,000 square feet (sq ft), and that the lawn is maintained in a fashion similar to a golf course green or tee, for which there is reasonably good information on fertilizer use rates and leaching potential. This information was used to predict the nitrate loading through a similar mass balance calculation as presented previously for the wastewater nitrate loading analysis. The assumptions and calculations were as follows:

All 326 of the potentially buildable lots in Seadrift were assumed to have 5,000 sq ft of maintained turf grass;

Annual nitrogen fertilizer application rate was assumed to be 5 lbs N/1,000 sq ft, or 25 lbs

nitrogen per lot per year;

The leaching fraction was assumed to be 10 percent of the applied nitrogen, based on test plot studies of golf course greens (Brauen, 1995);

Additional water use for turf maintenance was assumed, and 25 percent of the irrigation water (approximately 0.1 ac-ft per year) was assumed to percolate and add to the recharge of the local groundwater;

The fertilizer nitrogen and irrigation return flow was calculated to amount to an annual flow of 0.1 ac-ft/lot, with a nitrate-nitrogen concentration of about 9.1 mg/l. This was then combined (in a mass balance calculation) with the previously estimated rainfall recharge volume and the assumed background concentration of 0.1 mg/l, to give an adjusted worst case background nitrate-nitrogen concentration of 0.95 mg/l. This calculation demonstrates the relatively insignificant impact on groundwater nitrate concentrations from fertilizer use, even in a very conservative, worst case scenario that greatly overstates the existing or potential fertilizer use in the study area. Based on this analysis, further investigation or focus on fertilizer practices in Stinson Beach does not appear warranted, at least from the standpoint of groundwater quality protection.

Summation

In brief, the results of this Hydrologic Survey and earlier investigations and monitoring confirm that there are wastewater impacts on local water resources, most notably indicated by the presence of nitrogen and MBAS in groundwater and surface water.

With regard to beneficial uses, the impacts on groundwater of onsite wastewater disposal systems in the Seadrift, Calles, and Patios areas do not represent a threat to human health through drinking water. The nitrate loading analysis predicts, using conservative assumptions, that concentrations in the study area under existing conditions approach but do not exceed drinking water standards. Predicted concentrations under buildout conditions could exceed the drinking water standard, but could be mitigated by use of sand filter systems. Onsite wastewater disposal systems apparently are contributing coliform bacteria locally to groundwater and surface water. However, analyses of groundwater from the monitoring wells for this survey indicated few and declining detections of fecal coliform, suggesting insufficient well purging. Furthermore, the groundwater in the Seadrift, Calles, and Patios areas is not a likely source of drinking water because of seawater

intrusion. In addition, there is little risk of contamination of the municipal supply. The municipal Aldergrove 2 well is located upgradient and is afforded an additional degree of protection by the clay layer underlying the well site. This study indicates no threat to human health through drinking water pathways under current conditions or in the reasonably foreseeable future, and provides no technical basis to support the building moratorium.

Nonetheless, numerous beneficial uses exist in Bolinas Lagoon. These include water contact recreation and shellfish harvesting, for which concentrations of coliform bacteria are a concern. Sampling of Bolinas Lagoon for this Hydrologic Survey included one detection of fecal coliform; however, this survey shows that fecal coliform is far less likely to be contributed to the lagoon by groundwater than by Easkoot Creek, which was documented to be most significantly affected by bacteria.

Accordingly, additional study should be focused on Easkoot Creek and areas tributary to the creek in the Old Town and Highlands areas. It should be noted that the only known potential domestic wells are in Highlands, and the impact of wastewater on these wells is not known. In addition, inclusion of the Stinson Beach Park also is recommended, given its proximity to Easkoot Creek and considerable wastewater discharge during the summer season.

ALTERNATIVES FOR IMPROVED WATER QUALITY MANAGEMENT

Overview of Wastewater Management

In January 1978, the RWQCB adopted Resolution 78-1, allowing for the continued use of onsite wastewater treatment and disposal systems in Stinson Beach under the management authority of the District. Initially, the District was granted authority for inspections, monitoring and abatement activities; this was later expanded in 1987 to include the authority to establish regulations and issue permits for all existing and new onsite wastewater systems. The current District Wastewater Ordinance was adopted in 1996.

The present study was commissioned to evaluate the water quality impacts of onsite wastewater disposal systems in the rapidly permeable sandspit areas of Stinson Beach, which encompasses the Seadrift, Patios, and Calles areas. Prior to the District assuming management authority for onsite wastewater systems, most of the study area had been developed using conventional gravity septic tank-leachfield systems. This practice continued with new development in the Seadrift area until 1987, when the concern was raised that the groundwater depth in the sandspit area was insufficient to meet the minimum guidelines of the RWQCB. In response, the District adopted the practice of requiring the use of an intermittent sand filter treatment unit ahead of the leachfield to provide a higher and more reliable level of effluent renovation prior to discharge to the sandy soils. The District issued a set of interim design criteria for sand filters and agreed to conduct ongoing monitoring of these systems and their effects on the groundwater quality within the Seadrift area.

Periodic problems were experienced with some of the sand filters, mostly related to equipment failures and sand clogging. This led to modification of the design criteria in 1995, incorporating the use of coarser sand media and shorter, more frequent dosing of the filter bed. These criteria were adopted in the District code in 1996. At this time, it was also brought to the District's attention that the RWQCB (and the new District code) prohibits the use of any onsite wastewater system in areas having a percolation rate faster than one minute per inch. This rapid percolation condition was found to exist throughout the sandspit area, requiring that the District process formal variance requests for any new wastewater systems in these areas. At about the same time, the District intensified their sand filter monitoring efforts to answer questions from the RWQCB about the viability and impacts of these systems in the Seadrift area that previously had not been answered satisfactorily.

Alternative Treatment-Disposal Methods

The existing District Wastewater Ordinance requires the use of an intermittent sand filter ahead of the leachfield for the study area, and includes specific criteria for design and construction of these systems. The District staff has intensively monitored several of the sand filter systems over the past few years documenting the treatment performance, which has generally met all expectations. The results of this monitoring are summarized in several reports, the last of which (Final Report) was completed on June 30, 1997.

Sand Filter Design Criteria. Sand filters are in common usage throughout many areas of California and the U.S., but the design criteria are by no means standardized. The criteria contained in the Stinson Beach code are more specific than in most areas. Greater latitude is generally afforded to the system designer in other jurisdictions (e.g., County of Marin). As a matter of comparison, the differences between the Stinson Beach Code and Marin County Regulations are as follows:

Media Size. Stinson Beach requires a special coarse sand media that is not available locally. Marin County specifies a medium-coarse sand equivalent to the sand specification that was initially followed for sand filters at Stinson Beach.

Dosing. Stinson Beach requires timed dosing; Marin County allows timed or flow-actuated dosing.

Distribution System Design. Stinson Beach Code contains very specific design requirements for the pressure distribution system. Marin County provides general parameters for the pressure distribution system design, but leaves many of the specifics to the system designer.

Leachfield Loading Rate. Stinson Beach allows sand filter effluent to be discharged to leachfield systems in the study area at a rate of 2.4 gpd/sq ft, roughly double the rate previously permitted for septic tank effluent. Marin County Regulations also allow a doubling of the wastewater application rate under certain conditions. However, in rapidly permeable soils with high groundwater conditions, Marin County actually requires a *reduction* in the loading rate to spread the wastewater flow and slow migration of wastewater to the groundwater.

The District's sand filter monitoring study has shown good to excellent performance for systems installed under the current sand filter design criteria. With only a few exceptions, the sand filters installed under the former design criteria (finer textured sand and flow-actuated dosing) appear also to be performing satisfactorily. The main purpose of the sand filters is to provide greater pathogen reduction before disposal to the sandy soils. The sand filters are clearly achieving this goal. Additionally, the sand filters are providing measurable reduction in nitrate-nitrogen concentrations in the wastewater effluent as well as high levels of solids and organic (BOD) removal. Our review of the monitoring and performance data revealed no compelling reason to change the current design criteria or to require redesign of the older sand filters to meet the current standards; there is nothing inherently wrong with either set of criteria.

Possible Wastewater System Improvements. Maintaining consistent, standardized design criteria has advantages for initial design review, construction quality control and on-going system maintenance. However, given that on-site wastewater technology is an ever-changing field, the District should remain flexible and open-minded with respect to innovations and adjustments in local design practices. Some of the current possibilities that are not covered in the District's existing code are reviewed below.

Leachfield Wastewater Application Rate. As noted previously, the District code currently allows sand filter effluent to be dosed at 2.4 gpd/sq ft into leachfields in the sand spit, and requires a dual 200 percent leachfield system (per RWQCB requirements). Two leachfield systems are provided to assure that one is always available in reserve in the event that the other field fails. Given the high degree of treatment provided by the sand filters, the possibility for a leachfield to fail is extremely remote. A greater spread of effluent and enhanced treatment in the dune soils could be achieved by utilizing the entire field as a single system, with an effective application rate of 1.2 gpd/sq ft. This would not change the overall amount of leaching area required, but it would increase the amount of treatment received by the effluent during vertical migration through the sands. Given the small amount of leachfield required, the system could be designed (through valving and pump selection) to operate with either half or all of the leachfield "open". This design concept would have the most value in the higher groundwater areas.

Recirculating Sand Filters. The District code requires intermittent sand filters as the

standard system in the study area. However, the District has permitted the use of recirculating sand filters in other repair situations. Recirculating sand filters are becoming more and more common for individual residential applications than they have in the past. They have several advantages: (1) they require less land area due to the use of a very coarse sand media and high loading rate (4 to 5 gpd/sq ft); (2) they provide a greater degree of nitrogen removal than intermittent sand filters (generally producing less than 20 mg/l total N); and (3) they are more resilient to fluctuations in wastewater flow rates. The District should consider incorporating criteria and offering recirculating sand filters as a design option throughout the sandspit area.

Aerobic Treatment Systems. There are a variety of proprietary aerobic treatment systems available. Some units produce standard secondary effluent quality, while others produce advanced secondary effluent similar to that from sand filters. Some of these systems are reported to provide higher nitrogen removal than recirculating sand filters. However, aerobic treatment systems are not generally as effective as sand filters in regard to pathogen removal. The main advantage of aerobic treatment units at Stinson Beach would be the ability to produce high quality aerated effluent in very tightly constrained lots. Along with sand filters, such systems have been documented to be very effective in renovating existing failed leachfield systems. The District should entertain the possibility of utilizing aerobic treatment units, beginning first with repair situations. Those systems producing advanced secondary effluent quality should be given primary consideration.

Disinfection. Simple UV (ultraviolet) disinfection units are now commercially available for incorporation in residential wastewater systems (Cruver, 1997). Such units could be incorporated following sand filter (or other secondary+) treatment. There is no demonstrated need to incorporate disinfection units as a routine requirement. Nonetheless, their use may be justified in connection with repairs or waiver situations to overcome high groundwater constraints. Disinfection would also be required in connection with the use of subsurface drip irrigation as a disposal option (see below).

Subsurface Drip Irrigation. Subsurface drip irrigation has recently been approved for a residential application in Stinson Beach and should be given further consideration in other cases. The best opportunity for its use may be in the study area where the soils are very uniform. The wide-spread, low-rate distribution of the treated effluent through drip tubing

would eliminate the concentrated, near-saturated flow of effluent through leaching beds. Other advantages of drip irrigation are as follows.

It is resistant to root intrusion, which is a common problem in the sandy dune soils.

The wastewater flow can supply some of the landscaping irrigation needs.

As compared with normal leachfields, additional nitrogen removal is obtained through plant uptake.

One possible action for the District to take at this time would be to permit sub-surface drip irrigation to be installed as a substitute for the second half of the normal dual leachfield system in the sand spit area; the second leachfield is largely redundant and this would offer an opportunity for cost savings as well as valuable experience with the application of this technology in a situation where it seems ideally suited.

Onsite System Monitoring

Time and money limits the amount of monitoring of on-site systems that can be performed by the District staff. Therefore, it is important that the monitoring that is performed be performed in an efficient manner and that the District make use of all available resources and technology. There are two major options to expand the amount of data that are available to the District.

Data Recording Control Panels. The standard pump control panel has an event counter and an elapsed time meter, which gives useful but limited data. Microprocessor-based control panels are available (at a competitive price) that provide full data-logging capabilities, as well as remote access via modem. Such systems are being developed specifically for application in the onsite wastewater industry and could greatly expand the ability to monitor and diagnose system problems. Conversion to this type of control panel (with or without modem access) should be considered for new installations and commercial system repairs.

Maintenance/Pump-out Reporting. Septic tank maintenance work and pump-outs are performed periodically on systems located within the District but the performance of and observations during the work is not necessarily reported to the District. Oftentimes the maintenance

people will observe conditions that should be recorded and may be important for future preventative action. Some counties have expanded the reporting requirements for septic tank pumpers, requiring that they complete a separate form covering key observations during their work. The District may want to consider establishing a similar practice by providing the specific inspection forms to be completed and instructions to the contractors who work in the area.

In terms of the actual monitoring activity done by the District, the recent emphasis on sand filter performance monitoring can be scaled back or eliminated; the data collected has verified the adequacy of these systems. Future water quality monitoring should be reserved for spot checks on problem systems and greater attention to groundwater monitoring. New sand filter installations should continue to provide for the installation of onsite monitoring wells, but it may be more beneficial for the District to retain the option of directing the system owner to install the monitoring well in a strategic off-lot location to expand the network of groundwater monitoring wells throughout the study area.

STEP System Alternative

It is clear from the monitoring data collected in this study and from past water quality sampling that wastewater disposal in the Old Town and Highlands portion of Stinson Beach continue to have an adverse impact on Easkoot Creek and Bolinas Lagoon. Management of onsite sewage disposal systems in these areas is made difficult by clayey soils, high groundwater, steep slopes, limited land area and other constraints. Many of these properties, especially in the Old Town area, could benefit greatly from a community collection/treatment/disposal system that provides for offsite disposal in a location having more suitable conditions. Some properties in the Patios and Calles, including the District office itself, are operated on holding tanks or other marginal systems and could also benefit from access to a community wastewater system.

Part of this study was devoted to a preliminary examination of the potential feasibility of a community system for these portions of Stinson Beach. The concept explored was based upon the use of a STEP (Septic Tank Effluent Pump) collection system. In this type of system the septic tanks at each property would be maintained for primary wastewater treatment, and only the effluent would be collected (by gravity or by a small pump unit) in a network of small diameter pipes (typically 2 to 4-inch diameter) and lift stations, as needed, leading to a central point for treatment and then disposal in one or more locations. This type of system contrasts with a conventional sewer system in which larger sewer pipes (6 to 8-inch diameter) are used to collect all liquid and solids, eliminating the need for on-lot septic tanks. The STEP system concept makes sense for Stinson Beach due to the existence

of septic tanks at all (or nearly all) properties that might be served by such a system. It has other important advantages including the following.

The use of small diameter pipes minimizes construction costs and disruption during installation.

It can be conformed more easily to hilly terrain since it is designed and installed for conveyance of liquids only, much the same as water distribution piping.

Lift station and treatment facilities are less costly and less complex due to the elimination of solids handling.

Infiltration and inflow is negligible due to the watertight joints and the elimination of manholes in favor of clean-outs along the pipeline route.

Although the collection system is generally one of the most significant costs of a community wastewater system, its feasibility is rarely in question. The key issue is the method of treatment and final disposal. This is a particularly difficult problem for Stinson Beach because of the existing level of development, the geography and terrain, and the limited availability of suitable land for disposal of large volumes of wastewater. A review of maps along with field reconnaissance was completed to identify potential disposal sites. The following were initially identified:

1. GGNRA open space lands in the vicinity of the Highlands Water Tank.
2. GGNRA open space lands south and east of Panoramic Highway
3. Open space land within Seadrift
4. Beach dunes

Of these potential alternatives, only the first is considered reasonably viable and worthy of further investigation. The other options represent possible sites having sufficient land area for a community wastewater disposal system; however, there are likely to be overwhelming environmental constraints that would preclude their use for this purpose. The Highlands area, on the other hand, appears to have the most desirable physical capabilities and the least environmental constraints.

The Highlands site is indicated on Figure 25. The area of interest encompasses approximately eight acres of a gently sloping (10 to 15 percent) colluvial fan immediately west of the Highlands

Water Tank. The published USDA Soil Survey identifies the soils to be gravelly loams of the Cronkhite-Barnabe complex. These soils are reported to be moderately well drained, which is substantiated by field observations. No soil profile investigation was included within this preliminary evaluation, but the area was walked and surface soils were examined and appeared consistent with the Soil Survey description. A recent geotechnical investigation of the Highlands Tank site by Kleinfelder (March 1997) revealed deep colluvium (old landslide debris), in excess of 30 feet deep, with groundwater encountered at a depth of 23.5 feet. The groundwater level is probably closer to the surface in the identified potential disposal area, which is about 50 feet lower in elevation than the tank site. The site is vegetated with annual grasses and scattered brush. There are no defined water courses in the area, which suggests very well drained soil conditions. Drainage from the area eventually emerges in a wetland-willow thicket before concentrating in a small drainage channel that drops down to Highway 1 and Bolinas Lagoon, just north of the District office.

From available information, the Highlands site appears to be very suitable for wastewater disposal. However, further confirmation would be needed in the form of soil profile inspection, groundwater observations and percolation testing. The field studies would also be needed to establish the disposal capacity that could be provided at the site and the degree of wastewater treatment needed preceding disposal (i.e., primary or secondary treatment). As a rough preliminary guide, deep well drained soils as are expected at this site can generally support wastewater loading rates of 5,000 to 10,000 gpd per acre of septic tank effluent. This potentially could be increased with the incorporation of sand filter or equivalent secondary treatment. Thus, if soil and groundwater conditions are consistent with preliminary expectations, the 8-acre area identified may have potential disposal capacity for 40,000 to 80,000 gpd, or more. Based on a conservative unit wastewater flow of 200 gpd/dwelling, this would equate to a capacity for 200 to 400 dwelling units (or the equivalent). This should be more than sufficient to accommodate the critical Old Town area of Stinson Beach as well as other selected problem lots from the Highlands, Calles and Patios.

The Highlands site is considerably higher in elevation than the Old Town area, which will require significant pumping. The disposal site elevation is approximately 350 feet above sea level; therefore, a minimum of two lift stations would be required. Although a variety of routes are possible, the most likely routing of a force main from the Old Town to the site would appear to be via Calle del Mar, Buena Vista, Lincoln, and Avenida Farralone. One lift station would be located in the Old Town area and could collect flow by gravity or pumping (e.g., a STEP collection line from the Calles area). Additionally, an intermediate booster lift station would be located along the force main route and could also be used to collect flow from selected properties in the Highlands. An alternative approach might be to locate a central lift station in the vicinity of the District office, with

the force main following an overland route on the west side of the Highlands. Finding a suitable overland route is likely to be difficult, but there may be cost savings or other advantages that warrant consideration of this piping alternative.

Technically, the above-described conceptual plan for a community wastewater system for portions of Stinson Beach appears very feasible. The major obstacle is gaining the concurrence of the Park Service to permit the identified Highlands site to be used as a wastewater disposal area. The potential environmental impacts of wastewater disposal in the identified area are likely to be minimal in comparison with existing impacts within the community and Bolinas Lagoon from the marginal septic systems functioning in portions of the town. Additionally, it is conceivable that the development of this community wastewater site could also provide capacity to serve the Stinson Beach Park rest rooms, which currently discharge septic tank effluent to absorption beds in the sand dunes. If the District is committed to pursuing a long-term permanent wastewater solution for the Old Town and other problem areas, the next step should be to initiate discussions with the Park Service about the concept outlined here. Enlisting the support of the Regional Water Quality Control Board, other regulatory agencies, environmental groups and local legislative representatives should also be considered due to the general resistance and controversy that typically accompanies any proposal to utilize Park land for public improvements such as this.

Water Resource Monitoring

This Hydrologic Survey was focused on Seadrift and the Calles and Patios. In addition, the survey was planned to extend through the summer and into late autumn 1997. Findings of the survey indicate that wastewater impacts to Easkoot Creek are significant, and that additional hydrogeologic work, examination of wastewater systems, and water quality monitoring should be conducted in the Old Town, Highlands, and Panoramic areas that contribute to the creek. In addition, the water levels and quality monitoring should be extended through the wet season.

Accordingly, a second phase of the Hydrologic Survey is warranted to establish the hydrogeologic context for wastewater disposal in the Old Town and Highlands area, to evaluate impacts on water quality, and to develop an overall program for water monitoring and protection and wastewater management that will include all of Stinson Beach. Planned groundwater exploration for supplemental District water supply wells could be conducted concurrently, thereby providing a more comprehensive water resources management plan.

The second phase should include installation of additional monitoring wells aligned in one or more transects through eastern Stinson Beach, with the possibility of siting some wells to tie into the

existing Calle del Resaca and Seadrift transects. No more than ten wells are envisioned at this time. The installation and logging of the new monitoring wells, consistent with the procedures established in this study, would allow development of additional geologic cross sections and accompanying geologic analysis. One or more relatively deep wells are recommended to document the depth to bedrock. The wells would be sited, designed, and installed to provide reliable, year-round, long-term data collection. Each well would be identified on maps and fully documented in terms of well construction, geology, and wellhead elevation, allowing meaningful analysis of water level and water quality data. A pumping test also would be useful in determining aquifer characteristics.

Phase 2, possibly extending from January or February 1998 through the summer, would include not only hydrogeologic studies, but also continued monitoring and analysis. The water level and water quality monitoring of the nine existing monitoring wells should be continued in order to document winter and spring conditions. In addition, the monitoring should be extended to the new wells. During the second phase, water levels should be taken monthly in the nine existing wells, ten new wells, and existing staff gages. Subsequently, water level measurements probably would be reduced to four times a year. Water level measurements also would be taken from existing piezometers (e.g., G4) to continue documentation of seasonal trends in water levels. One or more synoptic surveys of Easkoot Creek, involving a series of streamflow measurements at gage sites along the creek, should be conducted to assess the relationship between streamflow and groundwater. These data will be useful in assessing the existing stream stations (S1 through S5).

Water quality sampling also should be continued in the existing monitoring wells and surface water stations, and extended possibly to additional surface water stations along Easkoot Creek. Water levels should be taken concurrently with water quality samples to determine groundwater level and flow conditions at time of sampling. Water quality procedures used in this study, and involving pumping of the wells to extract samples, should be applied. Three sampling events probably would be sufficient. The water quality analyses for the new wells should include the same suite of general mineral constituents, physical parameters, nitrogen species, and bacteriological examination as in the first phase. The analyses for existing monitoring wells probably would be reduced to key parameters (e.g., specific conductance, nitrogen, MBAS, coliform). In the future, complete analysis probably would be warranted only periodically, while sampling and analysis of key parameters would occur on a quarterly basis.

The water levels and quality monitoring programs should include prompt compilation of data into spreadsheets and analysis through means such as plotting of hydrographs or plotting of quality data on cross sections or maps. This would ensure that any errors or problems in data are detected and remedied quickly.

The second phase of the hydrologic survey would be summarized in a final report, presenting all data, analyses, findings and recommendations. Thereafter, the water quality monitoring program could be summarized in an annual report that would present the data and analysis to all interested parties. A brief mid-annual report would keep the District and RWQCB informed promptly of any changed conditions.

CONCLUSIONS

The ocean and Bolinas Lagoon are the receiving surface water bodies for groundwater in Stinson Beach.

Groundwater flow from the oceanside portions of Stinson Beach, Old Town, and Highlands areas generally is toward the ocean.

Groundwater flow from the remaining portions of Seadrift, Calles, and Patios is toward Bolinas Lagoon. Easkoot Creek intercepts groundwater and conveys it to Bolinas Lagoon.

Groundwater in the Seadrift, Calles, and Patios areas is not a viable drinking water supply because of the influence of seawater.

Wastewater disposal is influencing groundwater quality in the Seadrift, Calles, and Patios areas.

The concentration of wastewater indicators, such as MBAS and nitrogen, generally decreases with increasing distance along the groundwater flow path.

Detections of fecal coliform were confined to two wells, suggesting that fecal contamination of groundwater is limited and localized.

Sampling and analysis of Seadrift Lagoon, Bolinas Lagoon, and Easkoot Creek water during this study indicated that the most significant impacts of wastewater on surface water occur in Easkoot Creek, which showed consistent high levels of fecal contamination.

Nitrate loading calculations for the Seadrift, Calles, and Patios areas predicts that current wastewater disposal practices would result in nitrate concentrations in groundwater that are generally within the drinking water standard of 10 mg/L.

According to nitrate loading calculations under buildout conditions, nitrate loading would increase, but could remain within drinking water standards if the current practice of utilizing of sand filter systems is continued.

Nitrate loading calculations demonstrate that the preponderance of nitrate in groundwater is the result of wastewater disposal, and that landscape irrigation is a minor factor.

A policy regulating fertilizer use for landscaping is not warranted.

Wastewater disposal effects on groundwater in the Seadrift, Calles, and Patios areas do not pose a threat to human health, and appear to have only a small influence on beneficial uses in Bolinas Lagoon. Accordingly, no technical basis exists to support the building moratorium.

The impact on Bolinas Lagoon of Easkoot Creek, reflecting drainage from the Highlands and Old Town, appears to be more significant.

The focus of future water quality monitoring and protection should be the Highlands, Old Town, and Stinson Beach Park areas and Easkoot Creek.

The District's sand filter monitoring study has shown good to excellent performance for systems installed under the current sand filter design criteria.

Review of the sand filter monitoring data reveals no compelling reason to change the current design criteria; nonetheless, innovative technologies and practices exist that can improve onsite wastewater system performance.

Onsite wastewater system monitoring can be improved through use of data recording control panels and expansion of reporting requirements for septic tank maintenance work.

A community STEP system may be warranted to serve the Old Town area, as well as portions of the Highlands, Calles, and Patios. The most promising site exists in the vicinity of the Highlands Tank on federal park land.

RECOMMENDATIONS

A second phase of the Hydrologic Survey is recommended, with a particular focus on the Highlands, Old Town, and Beach Park areas. Additional monitoring wells will be needed in the area, as well as analysis of the hydrogeology, streamflow conditions, and impacts on water resources of wastewater disposal.

The District's routine water monitoring program should be revised to include a set of reliable groundwater monitoring wells that cover not only the Seadrift, Calles, and Patios areas, but also the Highlands and Old Town. Monitoring should be extended to include wet season water level measurements and sampling.

A community STEP system may be warranted to serve the Old Town area, as well as portions of the Highlands, Calles, and Patios areas. A potential site exists in the vicinity of the Highlands Tank on federal park land. Implementation of a STEP system in Stinson Beach will require cooperative efforts with the federal government, and potentially could be done in a way that would improve the existing waste disposal practices within the park itself.

The District should consider broadening the onsite wastewater disposal system criteria to allow variations in wastewater practices and innovative technologies, including changes in leachfield application rates, recirculating sand filters, aerobic treatment systems, ultraviolet disinfection systems, and subsurface drip irrigation systems.

The District should consider implementation of monitoring system improvements including data recording control panels and expansion of reporting requirements for septic tank maintenance.

BIBLIOGRAPHY

Reports

Allen, Blair, Lloyd Kahn and Julie Jones, *Septic System Owner's Manual*, unpublished manuscript, 199-.

Boudreau, E.H., *Geology and Ground Water Potential of the Stinson Beach Area*, Report to Stinson Beach County Water District, July 23, 1979.

Brauen, S.E. and G. Stahnke, "Leaching of Nitrate from Sand Putting Greens," U.S. Golf Association *Green Section Record*, January/February 1995.

California Regional Water Quality Control Board, San Francisco Bay Region, *Water Quality Control Plan*, June 21, 1995.

Cruver, James, "Improved Disinfection of Small Wastewater Treatment Effluents," in *Proceedings* of the 9th Northwest Onsite Wastewater Treatment Short Course, September 1997.

Eutek Process Development & Engineering, *Stinson Beach Wastewater Facilities Planning Study, Summary of Comparison of Treatment Alternatives*, November 1975.

Eutek Process Development & Engineering, *Stinson Beach Wastewater Facilities Planning Study, Project Report*, April 1977.

Galloway, Alan J., *Geology of the Point Reyes Peninsula, Marin County, California*, California Division of Mines and Geology Bulletin 202, 1977.

Hantzsche, Norman and E.J. Finnemore, "Predicting Ground-Water Nitrate-Nitrogen Impacts," *Ground Water*, vol. 30 no. 4, July-August 1992.

Harding-Lawson Associates, Water Well Feasibility, Stinson Beach County Water District, Letter to Ray Foreaker from Stephen Korbay, December 16, 1980.

Hem, John, Study and Interpretation of the Chemical Characteristics of Natural Water, U.S. Geological Survey Water Supply Paper 2254, 1985.

Lee and Praszker Consulting Civil Engineers, *Soils Investigation for the Proposed Stinson Beach Sewage Collection System*, February 8, 1971.

Marin County Department of Health Services Division of Environmental Control, *Stinson Beach Sewage Survey*, May 1972.

James M. Montgomery Consulting Engineers, Inc., *Report on Stinson Beach Groundwater Study*, February 1978.

Questa Engineering Corporation, *Relocation of Seadrift Lagoon Outfall Pipe through 23 Dipsea Road*, Letter report to Seadrift Association, September 22, 1994.

Rich, A.A. and Associates, *Feasibility Study to Rehabilitate the Fishery Resources of Easkoot Creek, Marin County*, prepared for The Environmental Action Committee, Point Reyes Station, draft report, 1992.

Romberg Tiburon Center, San Francisco State University, *State Route 1 - Lone Tree Slide Mitigation: Bolinas Lagoon Mitigation Project, Mitigation Monitoring Annual Report: 1996*, February 1997.

Sonoma County Water Agency, Status of Steelhead Trout in the Western United States, letter from Jon Niehaus to Mark Richardson, August 5, 1992.

Stinson Beach County Water District. *Report on the Stinson Beach Onsite Wastewater Management District for 1/17/78 through 12/31/81*, prepared for SWRCB Sacramento.

_____. Sixth Annual Report *Onsite Wastewater Management Program, 1/1/92 -- 12/31/83.*

_____. Fifteenth Annual Report *Onsite Wastewater Management Program 1/1/92 -- 12/31/92* (Including Data Summary of 1/1/86 -- 12/31/91.

_____. Sixteenth Annual Report *Onsite Wastewater Management Program, 1/1/93 -- 6/30/94.*

_____. Seventeenth Annual Report *Onsite Wastewater Management Program, 7/1/95 -- 6/30/95.*

_____. Eighteenth Annual Report *Onsite Wastewater Management Program, 7/1/95 -- 6/30/96.*

_____. Nineteenth Annual Report *Onsite Wastewater Management Program, 7/1/96 -- 6/30/97.*

_____. *Summary of Groundwater Studies*, 1978-1992, Stinson Beach County Water District & Compilation of Data from Routine Groundwater Sampling Regime, 1986-1996, December 5, 1996.

_____. *Homeowner's Guide: Onsite Wastewater Disposal System*, June 30 1997.

_____. Sand Filter Monitoring Report, Onsite Wastewater Management Program, June 30 1997.

Todd, David Keith, *Groundwater Hydrology*, John Wiley & Sons, 2nd ed, 1980.

Todd Engineers, Pumping Test Performed on Alder Grove Well 2, Memorandum by David W. Abbott to Mark Richardson, February 3, 1992.

Todd Engineers, Effects of Pumpage at Alder Grove Well 2 on Salt Water Intrusion, Memorandum by David W. Abbott to Mark Richardson, March 5, 1992.

U.S. Department of Agriculture Soil Conservation Service, *Soil Survey of Marin County*, California, 1985.

Wetlands Research Associates, Philip Williams Associates, and Avocet Research Associates, Bolinas Lagoon Management Plan Update, Draft report, August 1995

Maps

Eutek Process Development & Engineering, Topographic Maps of Stinson Beach,
Base Map Master (1"-300') and Drawing Nos. 1-0 through 5-0 (1"-100'), 1977.

Marin County, Assessor’s Parcel Maps, Stinson Beach.

SPH Associates, Overall Utility Plan, July 1947(?)

R.M. Towill Corporation, Topographic Maps of Bolinas Lagoon for SBCWD,
Job No. 4-82791-0 Sheet No. 6,7,8,9,10 & 11, May 16, 1968.

Yarnell & Assoc, Map of Water Quality Monitoring Wells Established by Stinson Beach County Water District Showing Location & Elevation, (1" = 108'), March 19, 1987.