APPENDIX E

ATTACHMENTS TO COMMENT LETTER 209 FROM WITTWER & PARKIN, LLP.,
JONATHAN WITTER, DATED DECEMBER 23, 2009

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
SAN FRANCISCO BAY REGION

RESOLUTION NO. 78-14

POLICY ON DISCRETE SEWERAGE FACILITIES

I. Whereas, on June 16, 1966, the Board adopted a policy statement, Resolution No. 768, with respect to sewerage in urbanizing areas of the region, and;

II. Whereas, the policy has been followed by the Board and its staff in judging the acceptability of the use of septic tanks or small community systems since 1966, and;

III. Whereas, this Regional Board finds:

A. The application of Resolution No. 768 has been difficult due to its indirect nature (it requests City and County government to act rather than stating the Regional Board will act).

B. There is a need for restatement of the Regional Board's policy to clearly set forth the actions which the Regional Board will take with respect to proposals for new discrete sewerage systems, as well as what it will request of local governments.

IV. Whereas, this Regional Board has prepared a negative delcaration in accordance with the California Environmental Quality Act (Public Resources Code, Section 21000 et seq.) and the State guidelines, and the Board determines that there will be no substantial adverse change in the environment as a result of the project.

V. Whereas, on September 20, 1977, October 18, 1977, December 20, 1977, April 18, 1978, and July 18, 1978, this Board held public hearings and heard and considered all comments pertaining to this matter, and;

VI. Whereas, this Regional Board has determined that there are no state mandated local costs under Section 2231 of the Revenue and Taxation Code as a result of the foregoing regulation because such regulation is not an executive regulation by virtue of Section 2209 of the Revenue and Taxation Code, and;

VII. Therefore, Be It Resolved that this Regional Board adopts the policies set forth in the attached document entitled "Policy on Discrete Sewerage Facilities" and rescinds this Board's Resolution No. 768 to become effective upon approval by the State Water Resources Control Board.

I, Fred H. Dierker, Executive Officer, do hereby certify the foregoing is a full, true, and correct copy of a Resolution adopted by the California Regional Water Quality Control Board, San Francisco Bay Region, on July 18, 1978.

FRED H. DIERKER
Executive Officer

POLICY ON DISCRETE SEWERAGE FACILITIES

BACKGROUND

As the population of the Bay Area increases, demand for residential development increases. In many cases, residential development is occurring in close proximity to existing urban areas and within the service areas of existing municipal sewerage agencies. In an increasing number of instances, however, development is being proposed in outlying areas which cannot easily be served by existing sewerage agencies. In these instances discrete sewerage systems are being proposed (i.e. separate from existing sewerage systems). In many cases the legal and financial arrangements for the planning, design, operation and maintenance of these discrete sewerage systems are uncertain at the time the residential development is proposed.

On June 16, 1966 this Regional Board adopted a policy statement (Resolution 768) with respect to sewerage in urbanizing areas of the region. Resolution 768 contains the following request of City and County governments.

"BE IT FURTHER RESOLVED, that it is the policy of this Regional Board:

A. That City and County government is requested to:

1. Prohibit the use of septic tanks and leaching systems for sewage disposal:

   a. For any subdivision of land which comes under the provisions of the Subdivision Map Act of California unless the subdivider clearly demonstrates to the satisfaction of the governing body having jurisdiction that the use of septic tanks will be in the best public interest and that the beneficial uses of water of the State will not be adversely affected; and

   b. For any other area where minimum lot sizes and dwelling densities, meeting the approval of the appropriate health officer, have not been established by ordinance.

2. Prevent the development of any subdivision, trailer park, or similar development that will use its own community system for the disposal of sewage unless:

   a. The subdivision, trailer park, or similar development is within a pre-existing governmental sewerage entity (city or district) that has authority to and has stated its intent to assume responsibility for the planning, construction, operation, and maintenance of the sewerage system; and

   b. The governmental sewerage entity (city or district) has developed a master plan for sewerage which includes the subdivision, trailer park, or similar development;"

Resolution 768 does not set forth a course of action for the Regional Board to follow when proposals are made for discrete systems. Since the adoption of Resolution 768 both State and Federal law have been amended to strengthen the regulatory authority of the Board.

The Regional Board has determined that there is a need for restatement of its policy to clearly set forth the actions which the Regional Board will take with respect to proposals for new discrete sewerage systems. Definitions of certain terms used in this document are included at the end of the document.

PRINCIPLES

This Regional Board is a State regulatory agency which has been given legislative authority and direction to protect the quality of the waters of the State. The Board's basic authority and responsibilities are set forth in the Porter-Cologne Water Quality Control Act. The Regional Board has no authority to regulate land use as a Responsible Agency under the California Environmental Quality Act (CEQA). This Regional Board has operated under the principle that regulation of land use is the responsibility of city and county governments. The policies which follow are based upon this principle.

This Regional Board will apply the following principles to all wastewater discharges:

1. The system must be designed, constructed, and installed so as to be capable of preventing pollution or contamination of the waters of the State or creating nuisance for the life of the development.

2. The system must be operated, maintained and monitored so as to continually prevent pollution or contamination of the waters of the State and the creation of a nuisance.

3. The responsibility for both of the above must be clearly and legally assumed by a public entity with the financial and legal capability to assure that the system provides protection to the quality of the waters of the State for the life of the development.

POLICY

The policy of this Regional Board with respect to the use of new discrete sewerage systems is set forth below. The policy recognizes that there are certain actions which are best undertaken by local governments to minimize the potential for water quality problems resulting from the use of new discrete sewerage systems.

POLICY 1

It is the Policy of this Regional Board that city and county governments are requested:

1. Prohibit the use of new discrete sewerage systems where existing community sewerage systems are reasonably available. The determination of whether or not existing systems are reasonably available will be the responsibility of the local agency or agencies having jurisdiction over the project.

2. Prohibit the use of individual septic tank disposal systems for any subdivision of land unless the governing body having jurisdiction determines that the use of septic tanks will be in the best public interest and that the existing quality of the waters of the State will be maintained consistent with the State Water Resources Control Board's Resolution No. 68-16, "Statement of Policy with Respect to Maintaining High Quality Waters in California."

3. Assure that individual disposal systems are maintained to the satisfaction of the responsible Health Officer. This could be accomplished through establishment of special maintenance districts, by the amendment of existing ordinances assuring adequate maintenance documented through periodic inspections, or other alternatives as deemed appropriate by the local Health Officer.

4. Consider the cumulative impacts of individual disposal system discharges as a part of the approval process for development.

POLICY 2

This Board will require a Report of Waste Discharge to be filed for all proposed waste discharges which involve the use of new community wastewater treatment an disposal systems. Before this Board will consider the Report of Waste Discharge to be complete, the following requirements must be met:

A. A public entity must assume legal authority and responsibility for the planning, design, financing, construction, operation, and maintenance of the proposed wastewater treatment and disposal system. The Report of Waste Discharge must be submitted by the public entity.

B. The Report of Waste Discharge must include the following:

   1. A final Environmental Impact Report or Negative Declaration covering the totel project, unless categorically exempt, prepared and approved by the local lead agency pursuant to the California Environmental Quality Act of 1970 (as amended) and Chapter 3, Division 6, Title 14, of the California Administrative Code (as amended).

   2. Include operation, maintenance, revenue and contingency plans for the wastewater treatment end disposal facility or a commitment by the public entity to prepare such plans and submit them to the Regional Board at least sixty (60) days prior to the initiation of discharge. In the absence of a satisfactory report, the discharge will be prohibited.

RATIONALE: The filing of a Report of Waste Discharge is required by Section 13260 of the California Water Code. The requirement for a public entity to assume authority for the proposed treatment and disposal system is based upon State-wide experience with small community wastewater systems. In general, it has been the experience of this Regional Board and other Regional Boards throughout the State, that public entities are more capable of providing adequate resources to assure the proper planning, design, construction, operation, and maintenance of wastewater systems. With the establishment of a public entity, legal procedures and remedies are greatly simplified in the event of violation of Board Requirements. The California Environmental Quality Act of 1970 requires that a final Environmental Impact Report or Negative Declaration (unless categorically exempt) be considered by this Regional Board prior to the adoption of waste discharge requirements. The preparation of this document should be the responsibility of the local agency responsible for approval of the project.

Operation and maintenance and revenue plans have been required for all new facilities constructed through the grant program. The development of these plans helps to assure proper operation and maintenance of a facility once it is constructed and future replacement of that facility. The development of these plans for all new facilities will help assure proper operation and maintenance and will aid the public entity in determining the appropriate level of funding and staffing for the operation and maintenance of the facilities. Contingency plans have been required from all dischargers pursuant to the Board's Resolution No. 74-10.

POLICY 3

This Regional Board will pursue the following course of action with respect to the use of individual wastewater treatment and disposal systems.

A. It will require assessments of the cumulative impact of discharges from individual wastewater treatment and disposal systems on water quality and public health where the density of systems is such that adverse impacts may occur. The Board will identify each area where such assessments are necessary and will adopt individual time schedules for the appropriate public entity to develop the required report. The Executive Officer is directed to work with local planning and health departments to:

   1. Identify areas within each County where the ultimate density of individual wastewater treatment and disposal systems is such that adverse impacts on water quality or public health might occur.

   2. Define the scope and time schedule for each cumulative impact assessment.

   3. Estimate assessment costs and identify potential sources of funding.

B. It will periodically review its waivers of the reporting of waste discharge pursuant to Section 13269 of the California Water Code to determine if they should be continued. The criteria by which the Board will determine whether or not to continue the waivers will be the adequacy of local ordinances for the control of individual wastewater treatment and disposal systems and the actions of local agencies in implementing those ordinances.

This Board believes that adequate surveillance and maintenance of individual wastewater treatment and disposal systems is imperative. In the review of its waivers, the Board will look for provisions for adequate maintenance such as periodic inspections or establishment of maintenance districts and will also evaluate the response of local agencies to Policy 1 and Policy 3A.

This Board will adopt guidelines by which it will judge the adequacy of local ordinances for the control of the individual wastewater treatment and disposal systems.

C. It will require a Report of Waste Discharge to be filed for all individual wastewater treatment and disposal systems which discharge to the surface of the land or to surface waters of the State.

RATIONALE: Individual treatment and disposal systems are an acceptable means of wastewater disposal in rural area. Septic tanks and leachfields have been the predominant types of individual systems. It has been the experience of this Board that water quality and public health problems can result when such systems are used inappropriately. Failure of septic tank systems may occur due to their design or the physical characteristics of the disposal site or failure may occur due to inadequate or improper construction, maintenance or operation of the system. Adequate local ordinances for the control of individual systems should help prevent the first cause of failure. In the absence of a governmental public entity that has assumed this responsibility, only proper maintenance and operation by the homeowner can prevent the second cause noted above. Homeowner maintenance and operation is generally inadequate. Periodic inspections by local agencies or the establishment of maintenance districts should assure proper operation and maintenance.

The use of proper design codes and good operation and maintenance practices will minimize the failure of individual systems. However even a properly functioning system will contribute nitrate nitrogen and TDS to groundwaters. High nitrate or TDS concentrations will impair the beneficial uses of groundwater.

The impacts of the discharge from individual system on groundwaters must be analyzed on a case-by-case basis for each groundwater basin. It is obviously not necessary to study all groundwater basins. Those basins should be studied where the density of individual systems may result in elevated nitrate or TDS concentrations. The studies will assure the use of individual systems will not impair beneficial uses of the groundwaters and will be consistent with the State Water Resources Control Board's Nondegradation Policy (Resolution No. 68-16).

POLICY 4

This Regional Board will prohibit the discharge of wastes which threaten to cause water pollution, water quality degradation, or the creation of health hazards or nuisance conditions or which do not comply with the provisions set forth in Policy 2 above.

RATIONALE: Section 13243 of the California Water Code states that a Regional Board, in a water quality control plan or waste discharge requirements, may specify certain conditions or areas where the discharge of waste, or certain types of waste, will not be permitted.

POLICY 5

It is the position of this Board that the Alameda Creek Water shed above Niles must receive special consideration with respect to the use of new discrete sewerage systems. It is the intent of this Board to discourage new discrete discharges within the Alameda Creek Watershed which will not be part of the LAVWMA export project until a water quality management plan for the Alameda Creek Watershed above Niles has been completed and approved by this Regional Board.

RATIONALE: The Alameda Creek Water shed above Niles has been an area of critical Regional Board Concern for over two decades. To date, the Board's efforts have focused on the three major dischargers in the Livermore-Amador Valley, however, the Board has on several occasions expressed concern over the lack of water quality management planning for the entire watershed.

The Niles Cone groundwater system and Livermore-Amador Valley groundwater basin are two of the most important groundwater systems in the Region. Both are used as sources of domestic water supply and they serve a combined population of approximately 250,000.

There is a long history of actions taken by the Regional Board to protect the Niles Cone and Livermore-Amador Valley groundwaters. In the past three years the Board has taken several actions in the attempt to get local agencies to develop an overall water quality management plan for the entire Alameda Creek Watershed above Niles.

Existing wastewater disposal practices are creating water quality problems in both the Niles Cone and Livermore-Amador Valley groundwaters. The Regional Board has prohibited wastewater discharge to the surface waters of the watershed. Implementation of this prohibition through the LAVWMA export project and application of the prohibition to any new discharges proposed for the watershed will protect the Niles Cone groundwaters from discharges in the Livermore-Amador Valley. Recent studies indicate that degradation of the Livermore-Amador Valley groundwaters will continue even with the export of all wastewaters. New discharges could accelerate that degradation.

The Alameda County Flood Control and Water Conservation District - Zone 7 has recoznized this problem through adoption of an Interim Policy (Resolution 823) which prohibits any new reuse of treated wastewater within the Livermore-Amador Valley and express its intent to evaluate the long-term effects of existing reuse on the groundwater resources.

A water quality management plan is necessary to determine if new discharges should be allowed in the watershed and to provide appropriate management practices to protect the quality of the groundwaters.

DEFINITIONS

Terms used in this policy are defined as follows:

COMMUNITY SYSTEMS - collection sewers plus treatment facilities serving multiple discharges under separate ownership, such as package plants or common septic tanks plus disposal facilities such as evaporation ponds or leachfields.

INDIVIDUAL SYSTEMS - systems for an individual home such as septic tank and leachfield systems.

MAINTENANCE DISTRICT - an entity established to own, monitor, inspect, and maintain individual treatment and disposal systems. Pursuant to SB430 on-site wastewater disposal zones may be formed which have broader powers than those described above.

PUBLIC ENTITY - A local agency, as defined in the State of California Government Code Section 53090 et seq., which is empowered to plan, design, finance, construct, operate, maintain, and to abandon, if necessary, any sewerage system or the expansion of any sewerage system and sewage treatment facilities serving a land development. In addition, the entity shall be empowered to provide permits and to have supervision over the location, design, construction, operation, maintenance, and abandonment of individual sewage disposal systems within a land development, and shall be empowered to design, finance, construct, operate, and maintain any facilities necessary for the disposal of wastes pumped from individual sewage disposal systems and to conduct any monitoring or surveillance programs required for water quality control purposes.

WATERS OF THE STATE - as defined in Section 13050 of the California Water Code, means any water, surface or underground, including saline waters, within the boundaries of the State.

WATER QUALITY MANAGEMENT PLAN - a plan which integrates the following elements into a management tool in a manner compatiable with maintaining the quality of the waters of the State consistent with the water Quality Control Plan for the San Francisco Bay Basin.

(1) Water supply (surface & groundwater);
(2) Surface water quality;
(3) Groundwater quality;
(4) Water-related recreation & wildlife preservation;
(5) Water reclamation, reuse, and conservation; and
(6) Wastewater collection, treatment and disposal.

LOCAL LEAD AGENCY - as defined in Section 21062 and 21067 of CEQA means any public agency other than a State agency, Board, or Commission which has the principal responsibility for carrying out or approving a project which may have a significant effect upon the environment.

U.S. ENVIRONMENTAL PROTECTION AGENCY

REGION 9

NPDES COMPLIANCE EVALUATION REPORT

SEWER AUTHORITY MID-COASTSIDE
HALF MOON BAY
GRANADA SANITARY DISTRICT
MONTARA WATER AND SANITARY DISTRICT

NPDES Permit No.:	CA0038598 (Regional Board Order No. 00-016)
Dates of Inspection:	Site visits: November 3 - 5, 2004; January 13, 2005 Information Updated Through: February 2006
Inspection Participants:	Jack Foley, Sewer Authority Mid-Coastside Tony Pullin, Sewer Authority Mid-Coastside George Irving, Montara Water and Sanitary District Mike Donovan, Nute Engineering (consultant to MWSD) Paul Nagengast, City of Half Moon Bay Ed Marlow, Somas Engineering (consultant to Half Moon Bay) Chuck Duffy, Granada Sanitary District Brenda Donald, Sewer Authority Mid-Coastside Pat McGowen, Sewer Authority Mid-Coastside Norm Simons, Special Investigator for NOAA Greg Walker, California Regional Water Quality Control Board Ken Greenberg, USEPA Region 9 Dianne Stewart, SAIC Bill Hahn, SAIC
Report Date:	August 18, 2006

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NPDES COMPLIANCE EVALUATION REPORT
Sewer Authority Mid-Coastside

1 INTRODUCTION

Under contract with the U.S. Environmental Protection Agency (EPA), Science Applications International Corporation (SAIC) conducts NPDES compliance evaluations. On November 3 - 5, 2004, EPA Region 9 and SAIC conducted a compliance evaluation inspection of the collection system operated by the Sewer Authority Mid-Coastside (SAM) and SAM member agencies. SAM is a regional sewer authority that provides wastewater treatment for the City of Half Moon Bay, the Granada Sanitary District, and the Montara Water and Sanitary District; all located in San Mateo County, California. SAM owns and operates regional sewer interceptor pipes that collect wastewater from the member agencies and convey the wastewater to the SAM wastewater treatment plant in Half Moon Bay. Each member agency owns and operates its own local collection system which convey sewage either directly to the SAM treatment plant or to the SAM interceptor.

Inspection participants included: Jack Foley, Tony Pullin and Pat McGowen (SAM); George Irving, Montara San District and Mike Donovan of Nute Engineering (consultant to Montara); Paul Nagengast, City of Half Moon Bay and Ed Marlow of Somas Engineering (consultant to Half Moon Bay); Chuck Duffy of Dudek Engineering, General Manager for the El Granada Sanitary District; Norm Simons, Special Investigator for NOAA; Greg Walker, California Regional Water Quality Control Board (RWQCB), San Francisco Bay Region; Ken Greenberg, USEPA Region 9; and Dianne Stewart and Bill Hahn (SAIC).

A meeting was held with all of the representatives except Chuck Duffy on the morning of November 3rd to discuss the overall system. In the afternoon the inspectors visited several of the SAM facilities. On the morning of November 4, the inspectors met with representatives of the Montara Water and Sanitary District and toured the Montara collection system. In the afternoon of November 4, the inspectors met with representatives of the City of Half Moon Bay and toured its collection system. On Friday, November 5th, the inspection team met with the El Granada Sanitary District, and conducted a closeout meeting at the SAM offices. On January 13, 2005, Ken Greenberg and Dianne Stewart met with SAM representatives, Brenda Donald, Jack Foley, Tony Pullin, and Pat McGowen, to discuss the source control program implemented by SAM. Between January 2005 and February 2006, SAM provided additional information related to the inspection by letter and e-mail in response to inquiries by EPA.

Attachment 1 to this report consists of photographs taken during the inspection. Attachment 2 is a list of sanitary sewer overflows reported during the period from 2000 through 2004. Attachment 3 is a list of pump stations and their characteristics.

2 APPLICABLE REGULATIONS

Under section 301(a) of the CWA, 33 U.S.C. § 1311(a), it is unlawful for any person to discharge any pollutant from a point source into "navigable waters" except in compliance with a permit issued under the CWA. Pollutants include sanitary sewage. 33 U.S.C. § 1362(6). A point source is any confined and discrete conveyance, including a pipe or other conduit. 33 U.S.C. § 1362(14). Navigable waters are defined as 'waters of the United States," which include all waters used in interstate commerce, including tidal waters and all their tributaries. 33 U.S.C. § 1362(7); 40 C.F.R. §122.3, 230.3(s).

Under section 402 of the CWA, the State of California, Regional Water Quality Control Board issued National Pollutant Discharge Elimination System permit number CA0038598 to SAM and its member agencies authorizing the discharge of treated wastewater from the SAM wastewater treatment plant to the Pacific Ocean. The SAM permit was last reissued on March 15, 2000. The permit states that the discharger (SAM) and its member agencies (City of Half Moon Bay, Montara Sanitary District and El Granada Sanitary District) shall comply with the requirements of the NPDES permit.

Several provisions of the NPDES permit apply to the collection systems owned by SAM and the member agencies. Some of the applicable provisions are listed below:

- Provision A.1. prohibits the discharge of wastewater from any location other than the authorized ocean outfall.
- Provision A.3. prohibits the discharge of water, materials or wastes to storm drains or waters of the State except as authorized by the permit.
- Provision E.6. Inflow/Infiltration Plan: requires development of an Inflow/Infiltration Reduction Plan by November 30, 2000 with annual reports due each year by November 30th.
- Provision E.9. Treatment Facilities Evaluation Program: requires a regular review and evaluation of the permittees' wastewater conveyance, treatment and disposal facilities with annual reports due to the Regional Board by April 15th each year.
- Self-Monitoring Program, Part A section F.2. requires immediate reports to the Regional Board of any violation of the waste discharge prohibitions.
- Self-Monitoring Program, Part B.1.E. requires monthly reports to the Regional Board of any "bypass or overflows from manholes, pump stations or collection system".
- Standard Provisions, Paragraph A.4. requires that "the discharger shall take all reasonable steps to minimize or prevent any discharge in violation of this order and permit which has a reasonable likelihood of adversely affecting public health or the environment..."
- Standard Provisions, Paragraph A.8. requires that "collection, treatment, storage and disposal systems shall be operated in a manner that precludes public contact with wastewater, except where excluding the public is inappropriate, warning signs shall be posted."

- Standard Provision section D.1 requires proper operation and maintenance of all facilities.

The Pacific Ocean offshore of SAM's service area has been designated as a marine sanctuary (Monterey Bay National Marine Sanctuary), and thus some provisions of the National Marine Sanctuaries Act apply to discharges from SAM and its member facilities. Seetion 15 CFR 922.132(a)(2)(i) prohibits:

> Discharge or depositing from within the boundary of the Sanctuary, any material or other matter except: (A) Fish, fish parts, chumming materials or bait used in or resulting from traditional fishing operations in the Sanctuary; (B) Biodegradable effluent incidental to vessel use and generated by marine sanitation devices approved in accordance with section 312 of the Federal Water Pollution Control Act, as amended, (FWPCA), 33 U.S.C. 1322 et seq.; (C) Water generated by routine vessel operations (e.g., cooling water, deck wash down and graywater as defined by section 312 of the FWPCA) excluding oily wastes from bilge pumping; (D) Engine exhaust; or (E) Dredged material deposited at disposal sites authorized by the U.S. Environmental Protection Agency (EPA) (in consultation with the U.S. Army Corps of Engineers (COE)) prior to the effective date of Sanctuary designation (January 1, 1993), provided that the activity is pursuant to, and complies with the terms and conditions of, a valid Federal permit or approval existing on January 1, 1993.

Provision E.13 of the NPDES permit requires SAM to concurrently notify the Monterey Bay National Marine Sanctuary offices in Monterey and San Francisco, in writing, about any violations of effluent limitations, receiving water limitations, or sludge management practices.

2.1 Enforcement Actions

On May 23, 2003, the US Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), the agency charged with enforcing the National Marine Sanctuaries Act, issued a warning letter to SAM. The letter was in response to overflows of raw sewage into the marine sanctuary from the Montara Pump Station. These overflows occurred on or about May 5 - 7, 2000. The warning letter cited 15 CFR 922.132(a)(2)(i) as the regulation that was violated.

On March 21, 2001, the Regional Board issued Order No. 01-033 that contained a penalty amount of $21,000 for effluent violations during the period from January to June 2000. The violations consisted of exceedances of the permit's total chlorine residual and total coliform limitations.

3 BACKGROUND

Sewer Authority Mid-Coastside (SAM) was formed in 1976 by its three member agencies; the City of Half Moon Bay, the Granada Sanitary District, and the Montara Sanitary District (now the Montara Water and Sanitary District). SAM operates a secondary wastewater treatment facility and ocean outfall to treat and dispose the wastewater from about 22,000 people from its member agencies. It also owns about 8 miles of large diameter interceptor pipeline which includes 1.9 miles of gravity sewer and 5.8 miles of force mains. These pipes and the associated pump stations are collectively referred to as the Intertie Pipeline System (IPS). The IPS parallels Highway 1 from Montara to the SAM treatment plant and collects sewage from the member agencies. SAM owns 3 pump stations which transport wastewater from the member agencies to the treatment facility. The treatment facility is located in the City of Half Moon Bay, and discharges into the Pacific Ocean through a submerged diffuser that extends about 1900 feet offshore. The wastewater is discharged directly into the Monterey Bay National Marine Sanctuary.

The Monterey Bay National Marine Sanctuary is a Federally protected marine area offshore of California's central coast. Stretching from Marin to Cambria, the MBNMS encompasses a shoreline length of 276 miles and 5,322 square miles of ocean. It is one of the world's most diverse marine ecosystems, home to numerous mammals, seabirds, fishes, invertebrates and plants.

The SAM service area is approximately 12 square miles, and is located on the western edge of San Mateo County. Approximately half of the service area is within the boundaries of the City of Half Moon Bay, with the remainder equally divided between Granada Sanitary District and Montara Water and Sanitary District. The service area is approximately 30 miles south of San Francisco, and 40 miles north of San Jose. The three member agencies retain ownership and responsibility for their individual collection systems. They have separate capital improvement programs, and each has a different consulting engineering firm for advice on capital improvement projects. Each of the member agencies contracts with SAM for collection system operation and maintenance with the level of service provided by SAM being determined by each member agency. Costs of operating and maintaining the SAM facilities are shared among the member agencies using a cost sharing formula established in the Joint Powers Agreement. In the FY2005-05 budget, 45% of SAM costs are provided by the City of Half Moon Bay, 31% by the Granada Sanitary District and 23% by the Montara Water and Sewer District.

The City of Half Moon Bay (HMB) collection system serves a population of around 10,000 with approximately 3,750 service connections. The HMB service area includes the City of Half Moon Bay except for the northern most portion of the City which is served by the Granada Sanitary District. The HMB collection system includes approximately 35 miles of gravity sewer pipes and an estimated 3 to 4 miles of force mains. Gravity sewer pipes are almost exclusively vitrified clay and force mains have historically be constructed with asbestos cement pipe. The City owns the portion of laterals between the property line and the main. The City owns 3 sewage pump stations in its collection system.

The Montara Sewer District was formed in the late 1950s to provide sewer service to the unincorporated communities of Montara and Moss Beach. On August 1, 2003 it acquired the community water system from a private operator, and changed its name to the Montara Water and Sanitary District (MWSD). MWSD sewage collection system serves a population of about 5,500 with approximately 1,500 to 1,600 connections. The MWSD collection system includes approximately 23.6 miles of gravity sewers and approximately 3 miles of force mains. Most gravity pipe consists of vitrified clay (VCP). In 1998, MWSD established PVC pipe as the standard for installation of new sewer mains, but repairs of existing VCP mains can be performed using VCP. Asbestos cement pipe has been used for some force mains. In the MWSD service area, the homeowner owns all of the lateral up to the connection with the sewer main. The MWSD owns 13 sewage pump stations on its mainlines and 23 point-of use (POU) pump stations serving individual homes in the geologically active Seal Cove area. Both the mainline and POU pump stations are maintained by SAM under contract with MWSD.

The Granada Sanitary District (GSD) serves the central portion of the SAM service area, including El Granada, Princeton-by-the Sea and the northern portion of the City of Half Moon Bay. GSD services about 3,200 connections (2,957 equivalent dwelling units (EDUs)). The population served was not stated. The GSD collection system includes about 33 miles of gravity sewers, and under 200 feet of force mains. In the GSD, the homeowner owns the entire lateral from the house to the main, but GSD maintains the portion from the property line to the main. GSD owns one pump station, the San Pablo Lift Station.

Table 1 shows a summary of the pipe size distribution for each of the collection systems. Throughout the SAM service area, most of the gravity pipe is vitrified clay and most of the force mains are made of asbestos cement pipe. System-wide, approximately 65% of the gravity sewer lines are 6-inch diameter pipes which are generally more prone to blockage because of the small size. In the GSD system, 83% of the gravity pipeline is 6-inch diameter while 92% of the MWSD gravity pipes are 6-inch diameter.

Table 1: Pipeline Length (feet)

Pipe Diameter	GSD	HMB	MWSD	SAM	Total
6"	117,049	81,725	115,160		313,940
8"	36,002	84,377	3,790		124,177
10"	7,711	3,014	-		10,725
12"	9,177	4,795	5,600		19,584
15"	2,844	-	-		2,844
18"	1,150	11,305	-		12,455
21"	-	60	-		60
Gravity Total	173,933	185,276	124,550	10,032 (21 & 24-inch)	461,389

Table 1: Pipeline Length (feet)					
Pipe Diameter	GSD	HMB	MWSD	SAM	Total
Force Mains	166	Est. 17,400 - 23,200	17, 930	31,152 (8, 12 & 14-inch)	49,082
TOTAL	173,933 (~33 miles)	185,276 (~35 miles)	142,480 (~27 miles)	41,184 (~8 miles)	542,873 (~103 miles)

Numeric information on pipe age was provided by GSD and MWSD. In the GSD service area, approximately 72% of pipes were installed before 1965, according to a pipe database provided by the District. MWSD provided data indicating that about 85% of its 24 miles of sewer mains were constructed in the 1960s. Pipes were installed in the downtown area of HMB beginning in the 1930s, but no further specific information was provided by HMB on pipe age.

4 SANITARY SEWER OVERFLOW RESPONSE AND REPORTING

SAM performs sanitary sewer overflow (SSO) response, record keeping and reporting for all of the SAM member agencies.

4.1 SSO Reporting Requirements

Spill reporting requirements for SAM and its member agencies can be found in several places. First, the NPDES permit establishes spill reporting requirements. (Self-Monitoring Program, Part A, section F.2 requires immediate (24-hour) reports of violations of the WDR prohibitions (could include spills) to the Regional Board. Self-Monitoring Program, Part B.1.E. requires monthly reports of all spills to the Regional Board.) State regulations require reporting of certain spills to the Office of Emergency Services. In a May 1999 memo, the Regional Board clarified the various spill reporting requirements and explained spill response expectations. Finally, in November 2004, the Regional Board issued a Water Code 13267 letter requiring all collection systems, including SAM, to report spills through a web-based electronic reporting system. Since the NPDES permit has not been modified, both the permit and 13267 reporting requirements remain in affect.

In a memo dated May 3, 1999, the Regional Board provided recommended procedures for notification, reporting and cleanup response actions for sewage spills. The memo requires immediate verbal notification to the Regional Board and a written follow up report within 5 working days for all sewage spills exceeding 1,000 gallons. The Office of Emergency Service and the state Department of Fish and Game must be notified in the event of a fish kill. Spill response procedures from the May 1999 memo are described in section 4.2 below.

On November 15, 2004, the Regional Board issued a Water Code 13267 letter requiring all collection systems, including SAM, to report spills through a web-based electronic reporting system beginning December 1, 2004. The Board required 24-hour reporting of spills of 1,000 gallons or more and spills that cause a fish kill or imminently and substantially endanger human health. All other spills of 100 gallons or more are to be reported within 10 days and a tabulation of all spills of any volume must be submitted in annual reports.

In contrast to the 1999 and 2004 letters, SAM's NPDES permit requires reporting of all spills (regardless of volume) to the Regional Board on a monthly basis (Self-Monitoring Program, Part B.1.E.).

4.2 SAM's Spill Response and Reporting Procedures

SAM's spill response procedures are shaped in part by the guidelines delineated in the Regional Board's May 1999 memo. The Board's memo states that warning signs should be posted in the affected area; the signs should remain until County Health or the Regional Board staff authorize their removal or until receiving water sample results indicate that background levels (levels as determined by upstream samples) have been attained. The memo states that all sewage flows should be contained and diverted to the nearest sanitary sewer or removed by vactor. Sewage solids should be raked up and/or vactored and the area should be flushed with clean water. According to the memo, all flush water should be contained and removed and disinfectants should not be used. If the spill exceeds 10,000 gallons, the memo stipulates that sampling for fecal coliform, dissolved oxygen and ammonia should be conducted both upstream and downstream of the point where sewage entered the receiving water. During wet weather flushing and sampling may be omitted if impractical.

SAM staff are currently using a May 2000 spill response plan entitled *Sanitary Sewer Overflow Response Procedures*. The plan includes spill reporting procedures consistent with the permit and state regulation requirements for reporting 1,000 gallon spills and 100 gallon spills to waters to the Regional Board, OES and the San Mateo County Department of Health Services (County Health). In the event of a fish kill, the state Department of Fish and Game must be notified immediately. The plan includes emergency phone numbers, a spill reporting form, a copy of a warning sign, and includes three methods for estimating spill volume. The plan does not include monthly spill reporting required by the permit or the new spill reporting requirements established in the Board's November 2004 13267 letter.

The May 2000 plan describes procedures for relieving the spill, spill containment and recovery, cleanup and disinfection, sign posting and barricading. The plan states that SAM will post the contaminated water warning sign, block the contaminated areas with yellow caution taped barricades and check the signs daily to ensure that they are still in place. The plan calls for County Health to notify SAM when they have released any areas which were posted based on their sampling and lab testing. The May 200 plan, however does not include procedures for cleaning spills from storm drains.

During the inspection, SAM provided a copy of a *Draft Sewer Overflow Response, Reporting, and Mitigation Plan*, dated September 2004. The September 2004 draft plan is much more comprehensive than the May 2000 version. The new draft plan includes a spill detection and notification flow chart, a chronological listing of field crew response activities and associated flow chart, a response procedures checklist, cleanup and mitigation methods, spill investigation, tracking and documentation procedures, spill volume estimation and spill reporting procedures. The September 2004 draft includes 24-hour reporting procedures consistent with the permit, state regulations and the November 2004 13267 letter. The plan also incorporates the new Regional Board electronic reporting protocol. The inspection revealed two deficiencies in the 2004 draft plan. The draft plan stipulates that spills less than 5 gallons that do not reach a waterbody need not be reported to any agency, but the 13267 letter requires annual reporting of all spills, regardless of volume. Secondly, the draft plan does not include procedures for monthly reporting of all spills as required by the NPDES permit.

The September 2004 draft plan calls for water quality sampling by SAM staff to determine the area impacted by a spill that entered a waterbody. The draft procedures call for sampling (ammonia monitoring) any time 100 gallons of sewage or more enters a creek, stream, lagoon, wetland or impoundment. The draft plan, however, does not call for sampling of spills to the ocean. In addition, the draft plan includes procedures for requesting support from County Health for all major spills that enter a waterbody, or spills of any size that enter the ocean or occur on or near a bathing beach or other area used for water contact activity.

In terms of public notification of spills, the September 2004 draft plan states that warning signs should be posted in the vicinity of an overflow when streams, creeks, rivers, impoundments, wetlands, and/or ocean beaches have been contaminated with sewage. The draft plan goes beyond the May 2000 plan in that it notes that major spills may warrant broader public notice, including notification of local media. In some cases, SAM might involve 'special interest organizations' (such as Surfrider) to assist in notifying segments of the public.

As of the date of the EPA inspection, the September 2004 draft plan had not been adopted as SAM's official procedures. SAM should modify the draft plan to ensure complete consistency with the reporting requirements in the NPDES permit and the Board's 13267 letter and then adopt the updated plan.

4.3 Spill Response and Record Keeping Practices

The inspection included a review of SAM's spill response practices to determine if they were consistent with SAM's response plans and regulatory requirements.

According to SAM staff, they usually learn about spills by calls from the public. An emergency telephone number is posted on the SAM website. During working hours, the phone is answered by SAM staff and during off-hours, calls go to a voice-mail box that will automatically dial the SAM staff person designated as the after-hours on-call responder. SAM staff receiving a call of sewer problems completes the first page of a two-page form titled "Collection Crew Callout/Nuisance Complaint." This form provides a record of the problem complaint and the dispatch of a crew to address the sewer problem.

The SAM spill responders' first effort is to stop the overflow by relieving the problem in the pipe. The crew also attempts to block the wastewater from entering storm drains or creeks. Once this has been done, the crew concentrates on cleanup. A vendor may be called in to provide a large vactor if needed to clean up any wastewater that has pooled. Cleanup consists of removal of debris, followed by flushing with clean water. Disinfectant is not used. The flush water is allowed to enter the storm drain, a practice that is not consistent with the 1999 Regional Board guidance. SAM does not use CCTV to aid in evaluating the cause or corrective action for spills, although the individual member agencies may do so.

The volume of the spill is estimated beginning with the time that the call is received, unless they have other information indicating an earlier start time, such as pooled wastewater, or the time that a pump station was offline. The volume of flush water is not included in this estimate, however. Crews receive training in spill volume estimation.

SAM staff stated that they collaborate with County Health in determining when to post a spill. Responsibility for actual placement and removal of the signs rests with SAM. They do not post for spills that occur at the Montara pump station because they believe there is no use of this area by the public. They also do not post if the area is already posted, for instance, where creeks are already posted due to stormwater runoff or animal contamination. In addition, if SAM cleans up a spill that doesn't enter a waterbody, they generally do not post the area. Tests of water quality by County Health determine when signs can be removed. SAM does not perform any tests. Posted beaches are identified on a website maintained by County Health.

SAM maintains records of all spills on the second page of the callout form in the section titled "Sanitary Sewer Overflow (SSO) Report Form." The response crew completes the SSO report form after returning to the SAM office. These SSO report forms include information on spill location; date, time and duration of the spill; response date and time; spill volume; receiving waters; spill cause; and spill response and cleanup method. The form also has a section to indicate if and when notifications are made to County Health, the Regional Board or OES. If the staff determines that a spill is 'reportable' (see below), they will also complete a standard spill report form on SAM's e-mail system. Spill data from the SSO report forms is periodically entered into SAM's SSO database.

SAM spill response crews do not record spill information while in the field responding to a spill. Many collection systems require spill response crews to complete a spill record form while at the scene of the spill. This allows for the recording of information at the scene where field observations can be made and while the incident is fresh in the minds of the response crew.

Since December 2004, SAM has been reporting spills to the Regional Board's SSO database in accordance with the Board's November 2004 13267 letter (24-hour reporting of 1,000 gallon spills and 10-day reporting of spills between 100 and 1,000 gallons). Prior to December 2004, SAM was reporting spills to the Regional Board in accordance with SAM's May 2000 SSO Response Procedures and the Board's 1999 guidance. At no time, during the period reviewed in the inspection, has SAM reported all spills (any volume) in its monthly reports to the Board as required by SAM's NPDES permit. SAM is required to conform with the spill reporting requirements established in both the 13267 letter and the NPDES permit.

5 SANITARY SEWER OVERFLOWS

During the inspection, Mr. Foley provided EPA with a list of sewer overflows from the SAM and member agency collection systems. The list includes 174 overflows that occurred from January 2000 through December 2004. In February 2006, SAM provided a list of 23 spills recorded during 2005. All of these spills are listed in Attachment 2.

For the 2000 - 2004 spill list provided to EPA, Mr. Foley explained that he made his best effort to include only the spills for which SAM or its member agencies are responsible. In other words, he excluded spills where there was clear indication that the spill was on private property and caused by a problem in the private property owner's lateral or plumbing. According to Mr. Foley, despite these efforts, because SAM spill responders did not always record the spill source mainline vs private), the spill lists provided to EPA may still include some private property spills. In addition, three spills, clearly recorded as private lateral spills, were intentionally left in the list provided to the EPA inspectors because they had been previously included in SAM's spill reports to the Regional Board or NOAA.[1] SAM's current spill response procedures call for recording who is responsible for the spill (public system or private property owner) and SAM staff are now keeping accurate records of responsible party.

Sections 5.1 through 5.5 below address spills between January 2000 and December 2004. Section 5.6 includes an analysis of spills between January 2005 and December 2005.

5.1 Spill Statistics, 2000 to 2004

The number of spills each year is summarized in Table 2. There was a general increase in the numbers of spills from 2000 through 2003. The total number of spills for each agency decreased

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[1] The private lateral spills occurred on 1/31/2000, 2/28/2002, and 3/18/2002, all in GSD.

in 2004. Table 3 lists the source or device from which the spills occurred. The majority of the reported spills are overflows from manholes on the gravity sewer mains.

Table 2: Spills by Year

Year	GSD	HMB	MWSD	SAM	Grand Total
2000	9	8	13	2	32
2001	14	13	4	2	33
2002	12	17	11	0	40
2003	14	9	18	3	44
2004	8	7	8	2	25
TOTAL	57	54	54	9	174

Table 3: Spills by Device, January 1, 2000 to December 31, 2004

Device	GSD	HMB	MWSD	SAM	Grand Total
Force Main	1	1		1	3
Lateral	3				3
Gravity Main	35	41	37		113
Outfall		1			1
Pump Station	1	3	7	8	19
Unknown	10				10
Blank	7	8	10		25
Grand Total	57	54	54	9	174

Of the 174 spills, 52 (30%) were identified by SAM as having entered storm drains or waterbodies. Of these, 19 spills (36%) were equal to or greater than 1,000 gallons in volume. An additional 92 spills (53%) were indicated as going onto the ground, and for 30 spills (17%) no information on the destination of the spill was provided. Table 4 shows the number of spills less than or equal to 1,000 gallons, the number greater than 1,000 gallons, and the number of spills that entered storm drains or waterbodies for SAM and each member agency. SAM did not report the volume for 16 spills.

Table 4: Spill Statistics for Each Agency

	GSD	HMB	SAM	MWSD	Total
No. spills < or = 1,000 gal	49	38	0	44	131
No. spills > 1,000 gal	4	12	5	6	27
No. spills to storm drain or waterbody	10	23	9	10	52

SAM reported six spills that were at least 10,000 gallons in volume, and another two spills exceeded 9,000 gallons. Five of the spills of 10,000 gallons or more were associated with pump stations, and two of the five occurred as a result of lack of capacity at the Portola and Montara pump stations during the 12/27/2004 rain event. The other three spills associated with pump stations occurred due to equipment failures on 2/26/2002 and 2/15/2003 (Charthouse pump station) and 5/7/2000 (Montara pump station). The remaining spill of 10,000 gallons or more was due to a force main air release valve failure on 12/24/2003. The spills that exceeded 9,000 gallons were due to grease blockages at 445 Oak Avenue in Half Moon Bay on 4/14/2002 and 6/1/2003. All of these spills entered the ocean and/or creeks.

5.2 Spill Causes (2000 to 2004)

The causes of sewage spills reported by SAM are summarized in Table 5. The most common cause of sewage spills is mainline blockages, by roots, grease or debris, which are responsible for 74% of the spills where a cause is recorded. In the Granada and Montara systems, root blockages are the most common cause of overflows. Both Granada and Montara service areas are heavily wooded. Montara has one to two miles of sewer mains in easements. Adding to the risk of blockage spills, the Granada and Montara systems both have a high percentage of small (6 inch) diameter sewer pipes. In contrast, Half Moon Bay had only one spill reported as being caused solely by root blockage. In Half Moon Bay, grease blockages are the most common cause of spills. HMB staff explained that most grease blockage spills have been in residential areas near high density housing such as apartment buildings. The HMB service area is generally flat, which may contribute to the risk of grease accumulation. The nine spills from the SAM IPS were caused by equipment failure (pump station or force main) or insufficient capacity. These spills are more fully described below in the pump station and capacity sections of the report.

Table 5: Causes of Overflows, January 1, 2000 to December 31, 2004

Cause	GSD	HMB	MWSD	SAM	Grand Total
Unknown	16	19	14		49
Root Blockage	20	1	15		36
Grease Blockage	4	17	8		29
Debris Blockage	7	3	5		15
Equipment Failure	1	4	7	3	15
Multiple Causes*	2	6	4		12
Pipe Break	3	3			6
Capacity		1	1	6	8
Private Lateral Problem	3				3
Construction	1				1
Grand Total	57	54	54	9	174

* "Multiple causes" typically consists of a blockage caused by grease and roots.

5.3 Spills to Waters (2000 to 2004)

From 2000 to 2004, at least 14 spills entered the Monterey Bay National Marine Sanctuary. These are the spills that SAM identified as flowing directly to the Pacific Ocean. However, wastewater that enters storm drains and creeks in SAM's service area will reach the ocean. Therefore it is possible that any of the 52 spills to storm drains and waterbodies could have entered the Marine Sanctuary. Together, these spills to waters and storm drains amounted to a minimum of 417,800 gallons of wastewater (several spills had no volume estimate). Warning signs were posted for only 14 of the 52 spills to waters and storm drains. Warning signs were not posted for some of the spills that flowed directly to the ocean and for some large spills to creeks or storm drains that could have impacted beaches or ocean waters. The failure to post warning signs for spills to the ocean and significant spills to creeks and storm drains leading to beaches appears to conflict with the County Health Department policy to post warning signs anytime that waters are contaminated by known sewer spills.[2]

5.4 Repeat Spills (2000 to 2004)

SAM and the member agencies have experienced a number of repeat spills, i.e., spills that occur in the same location on different dates. For example, during the period from January 2000 through December 31, 2004, three spills occurred at 1 Terrace Avenue in Moss Beach (9/16/2000, 8/13/2002, 8/20/2002). One of these was identified as being caused by grease, while the causes of the other two were not identified. Each of these overflows was between 30 to 50 gallons. In Montara, there were two grease blockage spills at 1191 Cedar Street (4/8/2000 - 50 gallons; 8/13/2003 - 500 gallons). Roots caused repeat spills (3/25/2002 - 250 gallons; 3/1/2004 - 50 gallons) at 11th and Main Street within MWSD. Roots caused repeat spills (1/13/2001 - 800 gallons; 9/22/2003 - 15 gallons) at 466 El Granada Blvd within GSD. Spills occurred at the Charthouse pump station on 2/26/2002 and 2/15/2003, reportedly due to equipment failures. Six spills occurred due to lack of capacity or equipment failure at the Montara pump station (2/13/2000, 5/7/2000, 12/1/2001, 12/2/2001, 12/29/2003, 12/27/2004). This is only a partial list of repeat spills within the SAM service area.

Repeat spills at the same location can be an indicator of maintenance deficiencies including incomplete cleaning of the initial pipe blockage, failure to repair a defective pipe or pump equipment. The system also clearly has capacity shortfalls in certain well-known locations. SAM and its member agencies should take aggressive steps to eliminate repeat spills.

5.5 Comparisons of Spill Rates (2000 to 2004)

Table 6 provides a comparison of spill rates in the SAM service area. The spill rate is a normalized measure of spill frequency that allows for comparison of collection systems of

[2] http://www.co.sanmateo.ca.us/smc/department/home/0,,1954_191102_187763,00.html

different sizes. The spill rate also provides a good overall indicator of system performance as affected by system capacity, management, operations and maintenance practices. A well managed and maintained system with adequate capacity tends to have a lower spill rate than a poorly managed system or a system with inadequate capacity. Taken as a single system, the SAM service area has an average spill rate of 32 spills per 100 miles of collection system per year. Spill rates for the member agencies range from 30 to 40 spills per 100 miles of collection system per year. These spill rates were calculated excluding the three private lateral spills identified by SAM, and the 'outfall' spill (due to a relief valve failure on the outfall force main).

A benchmark study of more than 80 municipal sewage collection systems in southern California conducted by Ken Greenberg of EPA Region 9 show a median spill rate of 3 spills per 100 miles of collection system per year (SSOs/100 mi./yr.) and an average spill rate of 5 SSOs/100 mi./yr. Thus, the rates experienced by SAM and the member agencies are well above the southern California benchmark level.

TABLE 6: Comparison of Spill Rates (2000 to 2004)

System	Pipe Length (miles)	Number of SSOs	Spill Rate (SSO/100 miles/year)
GSD	33	54 (excludes 3 lateral spills)	32.7
HMB	38	53 (excludes 1 outfall spill)	27.9
MWSD	27	54	40
SAM	8	9	22.5
TOTAL System	106	170	32.1

Note: Pipe length includes gravity mains and force mains but excludes laterals. Number of spills includes all types of SSOs for which the system is responsible regardless of volume or destination.

5.6 Year 2005 Spills

In February 2006, SAM provided a list of spills in the SAM service area between January 1, 2005 and December 31, 2005. During this time period, there were a total of 23 spills, with 8 of these spills being in the GSD system, 5 in HMB and 10 in the MWSD. There were no spills in 2005 from the SAM IPS or pump stations. This data reveals a continuing downward trend in the annual number of spills. The previous three years had 40, 44 and 25 spills in 2002, 2003 and 2004 respectively. In 2005, there was a marked decrease in spill volume compared to previous years. SAM reported a total spill volume of 3,562 gallons in 2005 compared to about 108,000 gallons spilled in both 2003 and 2004. In 2005, only 4 spills were equal to or greater than 100 gallons and each of these was reported to the Regional Board's SSO database as required by the Board's 13267 letter.[3] The spill volumes were less in 2005 than previous years because there were no capacity or pump station related spills. The system successfully conveyed all wastewater without a capacity related spill during rainy weather in early 2005 and through some heavy storms in December 2005. Only two spills in 2005 reached surface waters and both of these were to the golf course lake in Ocean Colony in the HMB system.[4]

In other respects, spills in 2005 showed a similar pattern to previous years. Root blockages (10 spills) and grease blockages (5 spills) were the leading causes of spills. With 10 spills in 2005, MWSD had both the largest number of spills and, as in previous years, the highest spill rate (37 spills/100 miles of pipe/year) among the SAM member agencies.

6 PUMP STATIONS AND FORCE MAINS

SAM and HMB each own three pump stations, GSD owns one, and MWSD owns 13 mainline pump stations. In addition, MWSD owns 23 point-of-use pumps located at private residences. The largest pump stations are located along the Intertie Pipeline System (IPS) used to convey sewage from the Montara WSD and Granada SD to the sewage treatment plant. (See Attachment 4, map of IPS) MWSD's Chart House pump station and SAM's Montara pump stations collect most of the wastewater from Montara and direct it into the northern end of the IPS. MWSD's Vallemar Pump Station collects much of the Moss Beach wastewater and sends it into the IPS. Wastewater from the Princeton Harbor area is directed through SAM's Princeton Pump Station to the IPS. In El Granada, all of the IPS flow passes through the Portola Pump Station, the largest in the SAM service area, where it is pumped through the final force main section on the IPS and into the gravity flow section of the IPS leading to the treatment plant. Half Moon Bay wastewater is introduced into the final gravity section of the IPS just upstream of the sewage treatment plant.

SAM maintenance mechanics perform routine maintenance for all 20 pump stations in the service area. SAM also hires contractors to test generators annually under load and perform pump tests. All of the maintenance work performed on member agency pump stations is done by SAM on a contractual arrangement with the member agencies. Each agency is responsible for capital improvements on its own stations. A list of the stations and relevant information is provided as Attachment 3.

[3] 900 gallon spill in MWSD on February 9, 2005; 1,000 gallon spill in MWSD on March 13, 2005; 100 gallon spill in GSD on May 18, 2005; and 750 gallon spill in HMB on September 29, 2005.

[4] A 750 gallon spill in HMB on September 29, 2005 to the golf course lake and an 80 gallon spill on December 24, 2005 in HMB to a storm drain leading to the golf course lake.

Many of the pump stations have experience sewage spills related to electrical and control system problems or insufficient pump or force main capacity. In some instances, pump station alarms failed to alert SAM to the spills. A summary of pump station spills is provided in Table 7.

Table 7: Spills at Pump Stations

Station	Owner	SSO Dates	Volume	Cause	Alarm Failure?
Airport Lift Station	MWSD	10/9/2004	400	suspect low voltage	Yes
Chart House Lift Station	MWSD	2/20/2002	100,000	motor starters tripped	Yes
		2/15/2003	10,000 to 15,000	control failure	Yes
Date Harte Lift Station	MWSD	12/27/2004	2,410	lack of capacity	NA
Montara Pump Station	SAM	2/13/2000	Unknown	lack of capacity	NA
		5/5/2000	116,000	pump run relay failure/alarm failure	Yes
		12/1/2001	Unknown	lack of capacity	NA
		12/2/2001	Unknown	lack of capacity	NA
		12/29/2003	63,000	lack of capacity	NA
		12/27/2004	83,970	lack of capacity	NA
Ocean Colony Lift Station	HMB	3/4/2001	3,700	pumps tripped	Yes
		12/14/2002	1,000 to 10,000	power failure/ generator failure	Unknown
		11/3/2004	9,773	UPS failed	Yes
Portola Pump Station	SAM	12/19/2002	5,000	controller failure	Unknown
		12/27/2004	19,020	lack of capacity	NA
Princeton Pump Station	SAM	2/27/2003	5,000	failed start/stop switch	Unknown
Seal Cove 3 Lift Station	MWSD	2/26/2000	3,000	level control failure	Unknown
		3/1/2000	300	level control failure	Unknown
Seal Cove 4 Lift Station	MWSD	12/16/2002	100	power failure/ controller failure	Unknown

Findings from the EPA inspection team visits to 10 pump stations are summarized below.

Montara PS, SAM (Photos 1 - 6) - The Montara Pump Station, owned by SAM, is located on the bluffs above the ocean in Montara. This station experienced six overflows during the period from January 2000 through December 2004. Spills on February 13, 2000; December 1 and 2, 2001; December 29, 2003 and December 27, 2004 were due to insufficient capacity during heavy rains. The May 5, 2000 spill of 116,000 gallons was caused by a pump run relay failure accompanied by a failure of the alarm dialer. All of these Montara PS spills flowed into the ocean. SAM has addressed the alarm failure problem by installing a redundant alarm and testing it weekly. A high level alarm is transmitted both by autodialer and by radio directly to the SCADA system.

In late 2002, SAM converted an old sewage treatment tank adjacent to the Montara PS to a 430,000 gallon off-line storage tank (Photo 1) for excess wet weather flow. This tank was in operation for most of the 2002/03 wet weather season and all of the 2003/04 season. The purpose of the tank is to provide off-line storage for peak wet weather flows that exceed the capacity of the Portola Pump Station pumps or the intertie pipeline force main downstream of the Portola PS. During wet weather, the pumps at Montara PS are set on automatic controls such that as the wet well fills at the Portola PS rises the pumps at Montara will slow down, and as the Portola PS wet well level falls the Montara pumps will speed up. In this wet weather operating mode, as the pumping speed at Montara PS is reduced, incoming wastewater can exceed the capacity of the Montara PS wet well. At this point, rather than pumping the excess wastewater down the IPS to the over-capacity Portola PS, wastewater coming into the Montara PS is diverted to the off-line storage tank. When the Montara storage tank becomes full, an overflow will occur from a maintenance hole on the diversion pipe.

The spill on December 29, 2003 illustrates how overflows occur at the Montara PS in the wet weather operating mode. (Because the storage tank control system was new, on December 29, 2003 SAM operated the Montara/Portola pump speed interplay in a manual mode. The resulting operation, however, was similar to the automatic mode.) During a heavy rain storm on December 29, 2003, wastewater exceeded the capacity of the Portola PS. At this point, SAM operators reduced output of the Montara PS pumps. The Montara PS overflow storage tank filled and overflowed from the diversion pipe. The overflow ran across the ground, down a gully and into the ocean.

SAM representatives explained that the wet weather operating mode is established to preferentially overflow at the Montara PS rather than at or near the Portola PS in El Granada. This is how the system worked on December 29, 2003 when Montara PS overflowed but there was no spill from the Portola PS. But even with the Montara/Portola wet weather operating scheme in use, SAM was not able to prevent the Portola PS from being overwhelmed by the storm flows on December 27, 2004. In this event overflows occurred both from the Montara PS storage tank and from gravity pipes flowing into the Portola PS. A more complete description of the Portola PS overflows is provided below.

There were several wet weather capacity related spills at the Montara PS prior to completion of the offline storage tank including the spills on February 13, 2000 and December 1 and 2, 2001.

The inspection team observed that the Montara PS wet well appears to have a thick grease layer. MWSD and SAM representatives explained that wet wells are vactor cleaned as needed by a SAM contractor.

Princeton PS, SAM (Photos 7 - 11) - Between January 2000 and December 2004, there was one overflow from the Princeton PS, on February 27, 2003. Corrosion and short circuiting of a pump start/stop switch caused a 5,000 gallon spill that entered the harbor at West Point Avenue. The alarm system also failed and SAM estimates that the spill had gone on for 10 hours before it was discovered. The station has both an autodialer and radio alarms. SAM representatives were not able to explain why the alarm system failed. It is not clear if these alarms were installed, or fully operational, at the time of the spill.

A July 7, 2005 letter from SAM states that responding personnel restarted the pumps and that the failed start/stop switch was replaced. SAM's long-term plan is to continue annual electrical inspections, including start/stop switches.

The inspection team observed that the wet well appears to have a thick grease layer.

Portola PS, SAM (Photos 12 - 15) - Between January 2000 and December 2004 the Portola PS experienced two overflows. A spill of 5,000 gallons on December 19, 2002 was caused by problems in the computer program for the pump controller system. The station was operating on emergency generator power at the time of the controller failure. The staff manually placed the diversion tank at the Montara pump station online to address the problem while the controller was reprogrammed. On December 27, 2004 a rain event caused a spill estimated at 19,024 gallons. Despite use of the Montara PS off-line storage tank, incoming wastewater overwhelmed the capacity of the Portola PS. Incoming wastewater backed up from the Portola PS wet well into the gravity pipes feeding into the Portola PS causing overflows from the two lowest upstream manholes. One overflow was from the manhole at the RV park adjacent to the Surfers' Beach and the second overflow was from a manhole near the Miramar Beach Inn at Marada Road and Magellan. Both of these overflows flowed to the beach and into the ocean.

The Intertie Pipeline System Capacity Evaluation, Phase II, Final Report (dated September 18, 1998, Carollo Engineers) found that the Portola pump station is a bottleneck because the IPS downstream of this station has a rated capacity of only 4 MGD. The alternatives to correct this situation are to either install a storage tank at or near the station, or to enlarge the IPS downstream of the Portola station. The report also recommends reductions in rainfall dependent inflow and infiltration (RD I/I) in the member agency collection systems. SAM is considering improvements to eliminate the wet weather flow bottleneck at the Portola PS. The proposed improvements are addressed in the Capacity section below.

Chart House PS, MWSD (Photos 16 - 17) - Between January 2000 and December 2004, the Chart House PS had overflows on February 20, 2002 and February 15, 2003. Both of the Chart House PS spills flowed to a gully or creek tributary to the Pacific Ocean at Montara State Beach. The 2002 spill, with a reported volume of 100,000 gallons, was caused when "both motor starters tripped." According to SAM's pump station operation manual, alarms are transmitted to a service (Half Moon Bay Alarm) via auto-dialer. A mis-communication during the 2002 spill resulted in staff who responded to the alarm going to the wrong pump station; they found no spill and assumed it was a false alarm. The Chart House PS spill was not discovered until the next day during a routine maintenance visit to the station. The duration of this overflow was 15.75 hours. The 2003 spill, estimated at 10,000 to 15,000 gallons, occurred as a result of a controller failure and an alarm failure caused by a housing nick in a new PG&E supply cable. The spill flowed into a gully next to the station. SAM's written reports on the Chart House PS spills do not indicate how far these spills flowed or whether they actually entered the ocean. During the inspection, however, SAM staff said they didn't think either spill reached the ocean. Since the

2003 spill, the PG&E power supply cables have been replaced, and separate backup power to the alarm and controller has been installed.

The City plans to remove the dry pit pumps and install submersible pumps to reduce the possibility of flooding and eliminate the need for confined space entry to work on the electrical controls at this location.

Vallemar PS, MWSD (Photo 18) - This station receives flow from 7 smaller stations in the MWSD and pumps the wastewater into the inter-tie pipeline. Alarms for the Vallemar PS go to Half Moon Bay Alarm service by auto-dialer, and to the SCADA system. The SCADA system automatically calls the operator on call. According to SAM's pump station operation manual, as a safeguard in the event of pump station failure, overflows from Vallemar PS flow by gravity to the Niagara PS. SAM plans to install a third, smaller, pump at the Vallemar PS to handle dry weather flows and eliminate flow spikes to the wastewater treatment plant caused by the large pumps at Vallemar.

Seal Cove 4, MWSD (Photo 20) - Between January 2000 and December 2004, the Seal Cove 4 PS experienced one overflow, on December 16, 2002. The volume of this overflow was estimated to be about 100 gallons, and the cause was a failure of the pump controller following a power outage. The wastewater overflowed into a house.

Seal Cove 3, MWSD (Photo 22) - Between January 2000 and December 2004, the Seal Cove 3 PS experienced two overflows. On February 26, 2000, the air compressor for the wet well level control system failed resulting in a reported 3,000 gallon spill. The bubbler was replaced, but the new one failed and caused a 300 gallon spill on March 1, 2000. The bubbler compressor was replaced again and no further spills have occurred since. Both spills were reported to have flowed to the Pacific Ocean in the Fitzgerald Marine Reserve off Moss Beach.

A 7/7/05 letter from SAM states that "MWSD made $80,000 in control system upgrades at Seal Cove 4, including radio communications, variable frequency drives and control enclosures. Seal Cove #3 now communicates with Seal Cove #4. If Seal Cove #4 is not in a ready state, Seal Cove #3 will not pump to it."

Airport PS, MWSD (Photos 23 - 26) - The Airport PS experienced one overflow between January 2000 and December 2004. On October 9, 2004 the pump station failed resulting in a reported 400 gallon spill. SAM suspects that the failure was caused by low voltage from PG&E causing the pumps to trip off. Alarms from the Airport pump station go to the Half Moon Bay Alarm service by auto-dialer. The station did not send an alarm, however, because the autodialer's backup battery failed and the station does not have an uninterruptible power supply (UPS). Although the station has a standby generator onsite, it did not function because the breaker was tripped. After SAM learned of the problem, it took three hours to stop the overflow. When the Airport PS failed, the wet well filled, wastewater backed into the tributary sewer main and overflowed at an upstream manhole located in the nearby mobile home park. The EPA inspection team visited the overflow site, and found that spills from the manholes in Photo 25 would flow to the concrete-lined ditch shown in Photo 26. A topographic map shows that this ditch leads towards a marsh and Pillar Point Harbor. The ditch was posted with a warning sign as a result of the 10/9/04 spill.

It is possible that the overflow could have been controlled more quickly rather than continuing for three hours after SAM learned of it. Use of a vacuum truck to capture the sewage prior to the overflow point in the mobile home park could have reduced the size of the spill.

According to SAM's pump station operation manual, this station has three hours of storage time during normal dry weather before an overflow would occur. However, it is necessary for operators to receive alarms from the station in order to respond quickly enough to prevent overflows. Therefore, it is recommended that a UPS be installed for the autodialer.

Ocean Colony PS, HMB (Photos 29 - 30) - The Ocean Colony pump station experienced three overflows between January 2000 and December 2004. On March 4, 2001, the pumps tripped off due to an electrical overload resulting in a 3,700 gallon spill to the ocean. The alarm company did not notify SAM.

A power outage on December 14, 2002 resulted in a spill from the Ocean Colony PS, with an estimated volume of 1,000 to 10,000 gallons, that flowed to the nearby golf course pond and on to the ocean. The onsite emergency generator failed to operate during the power outage.

The third spill occurred on November 3, 2004. SAM and HMB representatives suspect that the station failed when the Uninterruptible Power Supply failed. The pump station alarm system failed and the spill was discovered by chance by a system employee who happened to be visiting the nearby Ocean Colony facilities. The spill, with an estimated volume of 9,733 gallons, entered the golf course pond, which has an outlet to the ocean. Alarms from this station are supposed to go to Half Moon Bay Alarm by auto-dialer, and to SCADA by radio. The station was upgraded in late 2003 with installation of new variable frequency drives, an auto switch for the generator, level controls, and a UPS. The spill report for this event states that the UPS failed. There are plans to replace the station's force main.

San Pablo PS, GSD (Photos 33 - 37) - This station, located in the Miramar section of Half Moon Bay, is also equipped with alarms that go by auto-dialer to the Half Moon Bay Alarm service. The wet well was examined and found to be fairly clean. The station's two pumps are equipped with stirring devices so that less wet well cleaning is needed. GSD has plans to reroute the force main for this PS so it connects to the Intertie Pipeline downstream of the Portola PS thus allowing for abandonment of the precarious force main crossing of Media Creek near the beach.

General Comments on Pump Stations - SAM depends on automatic dialers to notify of alarms at most of the pump stations. Autodialers at all pump stations should have a true Uninterruptible Power Supply (UPS) rather than just a battery. Battery back-up units switch to the battery in the event that the power level drops below a usable level for the computer in both brownout and blackout situations. A true UPS is always delivering filtered power from a 'reservoir' of clean power, so there is no switching that occurs during low power or blackout conditions.

Intertie Pipeline Force Main, SAM - The IPS includes about 5.8 miles of force main (including force mains from the associated pump stations). The IPS came on-line in 1983. The IPS force main is made of tar coated steel pipe. It has not been inspected other than at the pipe ends that go into junction structures. When the junction structures were replaced about 2 - 3 years ago, the ends of the force main looked good. SAM has a capital project to conduct an intertie structural integrity analysis and propose an appropriate maintenance and improvement schedule. This project is ongoing.

On December 24, 2003, bolts holding an air relief valve in place on the IPS force main failed, and the valve fell down into the force main. This resulted in a spill of 10,000 gallons. SAM's system includes about 30 such valves.

The IPS is the only means of conveying wastewater to the SAM wastewater treatment plant. However, SAM's Draft *Sewer Overflow Response, Reporting and Mitigation Plan* (September 2004) includes no contingency provisions in the event of a failure along the IPS. This plan mentions monthly inspections of the force mains and intertie pipeline but does not provide details of how such inspeetions would be conducted.

Continuous operation of the IPS is crucial to the save conveyance of wastewater to the SAM WWTP. Unlike pump stations, there is no redundancy or failure alarms for the IPS. Because of the large size of the IPS pipeline and the fact that it carries all flow in the service area, failure of the IPS could result in a major spill that could be difficult to repair. SAM should complete condition inspeetions of the gravity and force main sections of the IPS and make necessary repairs or replacements. SAM should implement a regular program to maintain and replace air release valves on the force main sections of the IPS. SAM should develop an emergency contingency plan for responding to a failure of the IPS. As part of the contingency plan, SAM should consider whether to install parallel force mains that could serve as a backup in the event of a catastrophic failure of one of the force main sections. (Carollo Engineers considered options for construction of a parallel force main downstream of the Portola Pump Station to relieve the capacity bottleneck in this section of the IPS.)

7 COLLECTION SYSTEM MAINTENANCE

Each of the member agencies in the SAM system is responsible for cleaning and maintaining its own system. The agencies either contract with SAM for sewer cleaning or hire outside contractors. None of the member agencies has staff or equipment for conducting their own sewer cleaning. Each of the member agencies establish a sewer cleaning schedule for SAM which consists of routine (production) cleaning and/or hot spot cleaning based on the history of SSOs and previous cleaning needs. SAM also provides spill response and other problem call-outs on a contractual basis for the member agencies. Because there is only one SAM sewer cleaning crew, production cleaning can be interrupted by call-outs. SAM receives about 10 to 20 call-outs per month. SAM should evaluate whether its staffing level is sufficient to meet the production and call-out cleaning demands of the member agencies.

At the time of the inspection, SAM indicated that it does not provide emergency or spot repair services for the member agencies. Instead, this work is arranged by the member agencies with outside contractors. In correspondence dated February 10, 2006, however, Sam explained that "the member agencies have given SAM greater authority to implement repairs to greatly reduce response times."

Equipment owned by SAM includes a 700-gallon hydroflusher truck that includes a 100-gallon vactor; power snake for laterals; 500-gallon vactor trailer; 2-inch and 4-inch trash pumps; and 700 feet of discharge hose. At the time of the inspection, SAM did not have CCTV equipment for sewer pipe inspections, so all CCTV work was arranged by the individual member agencies with outside contractors. But, SAM obtained a new hydro flusher truck equipped with CCTV and DVD recording equipment. This new equipment should enable SAM to more quickly identify sewer pipe defects that may be leading to sewage spills. The CCTV equipment can also be used to conduct quality assurance (QA) checks on sewer cleaning operations. Other systems evaluated by EPA have found CCTV QA checks to be an effective means of improving the quality of pipeline cleaning.

Neither SAM or the member agencies use a computerized maintenance management system or GIS tools to manage the sewer cleaning, maintenance and repair functions. SAM representatives explained that the member agencies use SAM to varying degrees with the City of Half Moon Bay being the biggest user of SAM's cleaning services. Because cleaning schedules are dictated by member agencies, there is not a consistent approach across the service area and no system-wide prioritization of sewer cleaning needs. Each agency's sewer cleaning and maintenance practices are described below.

7.1 Montara Water and Sanitary District

Prior to 2002, MWSD contracted with SAM for annual cleaning of its entire system. The MWSD representative stated "SAM cleaning was always falling behind" on that schedule. At the time of the inspection, Montara was near completion of a three-year, system-wide cleaning and CCTV program implemented by an outside contractor. Since the inspection, SAM reported that MWSD had renewed it's contract with SAM for "a one-year program to clean all sewer lines" (February 10, 2006 letter from SAM). It is not clear if this means that MWSD will have SAM clean the entire MWSD system on a annual basis.

Aside from the production cleaning described above, MWSD has identified 22 hot spots for cleaning by SAM with 20 of the hot spots on a semiannual schedule and 2 being cleaned every 4 months. From June 2004 through May 2005, SAM cleaned 1.9 miles of sewer pipe in the MWSD system (7% of its system, including repeat cleaning).[5] Despite having the highest spill rates in the SAM service area, MWSD representatives explained that they do not believe additional cleaning would be cost effective. MWSD has retained the services of a contractor to do chemical root treatment.

MWSD has not completed any spot or emergency sewer repairs in the lest few years. Instead, repair needs are placed in the Capital Improvement Program (CIP) which has a longer planning horizon than is typical for spot repairs.

In contrast to MWSD, other systems evaluated by EPA have successfully reduced spills with a combination of increased hot-spot cleaning and timely spot repairs of defective pipes.

7.2 Granada Sanitary District

The GSD contracts with SAM to clean its entire system on a three-year cycle, so one-third of the system is cleaned annually. The District also contracts with SAM for semiannual cleaning of 11 hot spots. From June 2004 through May 2005, SAM cleaned 10.7 miles of sewer pipe in the GSD system (32% of its system, including repeat cleaning).[6]

7.3 City of Half Moon Bay

The City of Half Moon Bay contracts with SAM for annual production cleaning of its entire system. In addition, the City contracts with SAM for cleaning 44 hot spots with 19 on a semiannual schedule and 25 being cleaned every 2 months. Several of the hot spots on the two-month cleaning schedule are known problem areas for grease accumulation. From June 2004 through May 2005, SAM cleaned 49 miles of sewer pipe in the HMB system (129% of its system, including repeat cleaning).[7]

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[5] July 7, 2005 letter from John Foley, SAM to Ken Greenberg, EPA.

[6] July 7, 2005 letter from John Foley, SAM to Ken Greenberg, EPA.

[7] July 7, 2005 letter from John Foley, SAM to Ken Greenberg, EPA.

8 GREASE CONTROL

Food related grease is a common cause of blockages in sewage collection systems. Grease is introduced to sewers from residents, restaurants and other food processing facilities. Grease can accumulate more rapidly on roots growing into sewer pipes or at other sewer pipe defects, such as pipe sags or offset joints. In the SAM service area, for spills where they were able to determine the cause of the spill, grease was identified by SAM as the primary cause of 24% of spills and a contributing cause in 34% of all spills.[8] Grease may also be a factor in some of the 49 spills whose cause was identified as unknown. Grease blockage spills are most common in the City of Half Moon Bay system where between 47% and 64% of the spills were caused by grease accumulation in the sewer mains.[9]

In 1994, SAM developed a sewer use ordinance (SUO) aimed at controlling grease discharges to the sewer system. Since then, each member agency has adopted the same ordinance. These SUOs require each restaurant (exceptions noted below) to have a grease control device, and prohibits the use of garbage grinders. The SUOs include provisions for inspections and enforcement actions.

SAM is responsible for implementing the source control program for all of the member agencies. The program is funded by user permit fees. SAM has issued permits to 52 restaurants and six food processors (including grocery stores). Each of these food service establishments (FSEs) is required to have grease control equipment such as a trap or interceptor. Three car washes also have grease control devices. Facilities that do little food preparation are not permitted. Examples include coffee or sandwich shops such as Starbucks or Subway. Restaurants in the Harbor area are also subject to SAM's program. Unrelated to food origin grease discharges, there are several other types of facilities permitted under the SAM source control program including automotive facilities (17), photo developers (4), dry cleaners (3), septic dump stations (2), agricultural (2), groundwater remediation (1), and a rental hall. A total of just over 100 sewer use permits have been issued.

Each of the 52 permitted restaurants have some type of grease control device. Ten facilities have large in-ground interceptors. The remainder have smaller control units, such as grease traps, that are typically located in the kitchen. SAM's policy has been to base grease trap or interceptor sizing on the Uniform Plumbing Code. Approval of the grease trap or interceptor design in new or remodeled restaurants is the responsibility of City or County building inspectors. SAM representatives informally coordinate with the building inspectors to keep track of new restaurant

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[8] 29 grease blockage spills out of 122 total spills with designated cause. Additional 12 spills with "multiple" causes, usually including grease.

[9] Half Moon Bay system had 17 spills designated as grease blockage and an additional 6 with "multiple causes" out of a total of 36 spills with designated causes.

plans. SAM representatives explained that the SUO oil and grease (O&G) limitation of 200 mg/L may also be used to aid in determining whether a grease trap is sized properly, although routine sampling is not done.

For restaurants and other food processors, the permit specifies how often the unit must be cleaned. The required cleaning frequency is determined by SAM based on factors such as the flow rate, seasonal business trends, experience, reports from the collection maintenance staff, and consultation with the grease hauler. SAM requires some small grease traps to be cleaned three times per week, whereas a large interceptor may only need to be cleaned twice per year. FSEs are required to keep a log identifying when its grease control unit was cleaned. Typically, restaurant staff clean out the small grease trap units located in kitchens, placing the waste in bins or barrels for later pickup by the grease hauler. The SUO contains no specific interceptor maintenance requirements, such as the 25% accumulation rule, but only specifies that the interceptor must be maintained in efficient operating condition by periodic removal of the accumulated grease (Article IV, Section 4.3(f)). The SUO does not require kitchen best management practices (BMPs).

SAM schedules inspections of permitted facilities based on the amount of daily water usage. Every facility is scheduled for inspection at least once per year. For every 1,000 gallons above the initial 1,000 gallons, another annual inspection is added to the schedule. The largest water user is scheduled for eight inspections per year.

A review of SAM's inspection records revealed that SAM is not conducting annual inspections of every permitted food service establishment (FSE). The percentage of FSEs receiving at least one annual inspection was 64% in 2002, 36% in 2003 and 64% in 2004.[10] SAM representatives explained that, in addition to on-site inspections, FSEs may also be evaluated by telephone interview or review of grease hauling manifests that are mailed to SAM. SAM does not have an inspection checklist form for use in the FSE inspections and does not produce written reports of their FSE inspections.

Collection system maintenance staff have referred facilities to the source control program on occasion. Mezza Luna Restaurant was given as an example. After it was determined that grease discharges from this restaurant were causing grease accumulation in the pipes, in April 2004 SAM issued an NOV to get this restaurant to install a larger grease trap. The trap was installed by July 2004. The Harbor District in general and the residential area around Oak and Pilarcitos Streets in Half Moon Bay were also identified as grease hot spots. Grease in sewer mains in the latter area is thought to be from residential sources, as there is high density housing in the area. Here, the grease accumulation problem is further exacerbated by accumulation in a siphon crossing of Pilarcitos Creek. SAM developed a door hanger with information in both English

[10] March 18, 2005 letter from John Foley, SAM to Ken Greenberg, EPA.

and Spanish and distributed it in an effort to address the problem. At the request of the City of Half Moon Bay, SAM also increased the sewer cleaning frequency in the area.

The EPA team accompanied SAM staff to inspect two facilities: 3 Amigos and Mezza Luna. The grease trap at 3 Amigos is located in the kitchen. Staff opened the trap for examination by the inspectors. There was only a light amount of grease on the surface. It is not known when the trap was last cleaned, but the light grease accumulation indicates that either the trap was not working effectively or that it had been cleaned very recently. During the inspection, the SAM inspector did not check whether a baffle was present in the grease trap. Baffles are essential to achieve grease removal and should always be checked during FSE grease control inspections.

Mezza Luna installed two new grease traps inside their kitchen in 2004 after enforcement action was taken by SAM. The new units are a unique design incorporating a valve to draw off the grease. Thus the units do not have to be opened as frequently for cleaning, although it is still necessary to open the unit periodically to remove solids from the bottom. Mezza Luna staff demonstrated the grease draw-off procedure. SAM staff explained that this treatment unit has been effective at reducing grease discharges to the sewer.

The EPA inspectors discussed a variety of fats, oils and grease (FOG) control measures employed by other Cities in California that SAM should consider for it's program. Some of the measures include:

- kitchen BMP requirements[11];
- 25% accumulation rule limiting the build-up of grease and solids in grease removal devices;
- standard inspection checklist forms; and
- FOG characterization studies.

A number of Cities in Orange County are conducting FOG characterization studies as part of their new FOG control programs. SAM has had a FOG program in place for several years and seems to have a good handle on the location of FOG hot spots. Nevertheless, some elements of the FOG characterization approach may be useful. The hallmark of the FOG characterization approach is to use CCTV inspection of sewer pipes to determine if the FOG problem is caused by FSE discharge, sewer pipe defects, incomplete sewer pipe cleaning or a combination of these factors. FOG problems should be addressed by a combination of source control, sewer cleaning and sewer pipe repair. After an initial FOG characterization, systems can continue to use CCTV to do spot quality checks on sewer cleaning and to check on grease accumulation in sewer mains impacted by suspect restaurants.

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[11] Typical BMP requirements include dry wiping kitchenware, disposal of grease and fryer oil in barrels, use of sink strainers, exhaust hood cleaning practices and worker training and awareness

9 SEWER ASSESSMENT, REHABILITATION AND REPLACEMENT PROGRAM

Each of the SAM member agencies is independently responsible for inspecting their sewer systems and conducting necessary pipe repairs or replacement. SAM has no role in pipe inspection or repairs within the member agency systems. Sewer inspection and rehabilitation/replacement practices of each member agency is described below.

9.1 Montara Water and Sanitary District

MWSD is in the fourth phase of a multi-year project to correct system deficiencies. In Phase 1 (1986-1988), Montara televised its entire system and assigned a numerical condition rating to each pipe. In Phase II (1987-1993), MWSD conducted major renovations and/or construction of pump stations and the collection system. In Phase III (1994-1996), second tier problems involving repairs to the pump stations and collection system were addressed. At the time of the inspection, MWSD was continuing Phase IV, a three-year program, started in 2002, to CCTV its entire collection system for the purpose of identifying and correcting I/I problems and overflows. Since the site visit, MWSD reported that the CCTV inspection work was completed in 2005.

During the inspection, MWSD provided a map of the district with color coded indicators of which sewer pipes have been rehabilitated or replaced over the last three decades (1980's, 1990's and 2000's). Measurement of the marked pipe segments indicates that MWSD has rehabilitated or replaced about 4.5 miles of pipe, or 17% of its system, since 1980.

MWSD does not believe pipe rehabilitation (such as slip lining or cured-in-place pipe) is an effective means of correcting pipe deficiencies. The service area is hilly, and the original clay pipes tend to break. Therefore, their rehabilitation and repair program is based largely on pipe replacement. The District will make spot repairs if it is an emergency, but normally they just add the problem area to the capital improvement project (CIP) contract. MWSD has two major contractors, and an emergency contingency fund of about $30,000 to $50,000 per year. By contrast, the City of Half Moon Bay repair and replacement program does about 70 percent repair or rehabilitation and 30 percent pipe replacement. While replacement will completely correct any pipe deficiencies, it represents the most expensive approach to doing so. A blend of repair and replacement projects may represent a more cost effective approach to sewer rehabilitation, thus allowing more deficiencies to be addressed in a shorter period of time for the same cost.

MWSD uses a combination of user fees and new connection charges to fund its capital improvement projects. The replacement budget set at 2.5% of asset value is supplemented with new connection charges resulting in a total CIP budget of from $444,000 to $489,000 per year (according to the July 2004 Five Year Capital Improvement Program). In the July 2004 Five Year Capital Improvement Program, MWSD is proposing to spend from $230,000 to $310,000 per year to replace sewer lines identified in Phase IV efforts. In addition, various pump station upgrades are planned, with about $150,000 per year allocated for this. A total of $107,000 is proposed for I/I testing during the five year period.

As noted in Table 6, MWSD has the highest spill rate among the SAM agencies based on data from 2000 to 2004. Many of the spills are caused by root blockages, an indication of pipe defects such as cracked pipes or offset joints. MWSD is also known to have significant infiltration and inflow, another indication of sewer pipe defects. Despite the extensive pipe rehabilitation and replacement completed to date (4.5 miles since 1980) it may be necessary for MWSD to complete additional sewer pipe rehabilitation and replacement as an element of a strategy to deal with the spill and I&I problems. MWSD should use CCTV to examine sewer pipes at overflow sites to determine if pipe repair or rehabilitation is needed.

9.2 Granada Sanitary District

GSD performed smoke testing on their entire system in 1999. Inflow due to missing cleanout caps was the major finding and the caps were replaced. In 1998 and 1999, GSD conducted CCTV evaluations of approximately 25,000 feet of sewer pipe in its system. A larger CCTV effort was conducted in 2002, with an additional 82,000 feet televised. During the 2004-2005 rainy season GSD is performing flow monitoring. Based on the results of the flow metering additional targeted CCTV work may be done.

Since 1988, GSD has rehabilitated or replaced approximately 9.7 miles of sewer pipe, or 29% of the GSD system. Prior to 1988, there had been little pipe rehabilitation or replacement completed in the GSD system.

According to a 5-Year Capital Improvement Program for FY2001/2002 through FY2005/2006 (prepared by Kennedy/Jenks, March 2001), GSD planned to spend about $500,000 to $560,000 per year for sewer repair and replacement. This includes associated sewer televising and lateral replacement. GSD's FY2004-2005 budget shows $400,000 allocated for the Medio Creek Bridge Sewer Line Relocation Design and Construction. $65,000 is allocated for an I/I study, and $9,000 for lateral repairs. No other projects for replacement or rehabilitation of gravity sewer mains are included in this budget.

9.3 City of Half Moon Bay

In 1998, the City hired a consultant to develop a three-phase capital improvement program for the City's collection system. At the time of the inspection, the City had completed the first two phases and was implementing the third phase. In each of the first two phases, the City rehabilitated or replaced about 20,000 feet of sewer pipe to repair structural defects and reduce infiltration. Work in the first phase was based primarily on CCTV inspections conducted in the early 1990's. In 2002, the City again TV'd the entire system and the results of these inspections were used to target work for the second and third phases. Phase III work, with funding of

$700,000 per year, will include sewer pipe point repairs (expected to total less than 5,000 feet of pipe), upgrades to pump stations and force mains and any other sewer pipe rehabilitation needs that may be revealed by the new CCTV inspections.

So far, most of the pipe work done by the City has been replacement by pipe bursting, for about 30% of the work to date, with the remaining work being fold-in-form type pipe rehabilitation. According to the City's figures, by the end of the three phase project, the City should have rehabilitated or replaced as much as 45,000 linear feet of sewer pipe or about 22% of its system.

10 CAPACITY ASSURANCE

The SAM sewer system does not have sufficient capacity to convey peak flows during the winter rains. The capacity shortages are manifested most noticeably in the large volume overflows at the Montara Pump Station or from manholes upstream of the Portola Pump Station. Table 8 provides a summary of capacity related overflows in the SAM service area between January 2000 and December 2005. For the first time in five years, there were no capacity related spills in 2005.

TABLE 8: Capacity Related Overflows, January 2000 to December 2005

Date	Overflow Volume (gallons)	Location	Agency
12/13/00	unknown	Montara PS	SAM
12/1/01	unknown	Montara PS	SAM
12/2/01	unknown	Montara PS	SAM
12/19/02	5000	Portola PS	SAM
12/19/02	500	First/Grove St.	HMB
12/29/03	63,000	Montara PS	SAM
12/27/04	83,970	Montara PS	SAM
12/27/04	19,020	upstream of Portola PS	SAM
12/27/04	2,410	Date/Harte PS	MWSD

As noted above, SAM and the member agencies have identified only 8 spills since 2000 as being caused by inadequate capacity. Most of the other spills during this time period are attributed to blockages by roots, grease or debris. A review of the spill data, however, reveals that there are typically more blockage spills during the wet winter months than during the dry months. It may be that I/I is influencing this pattern. If the sewer mains are flowing near full in the wet season they will more readily overflow (spill) if there is a blockage. If this is the case, it may be possible to reduce blockage related spills with a more aggressive cleaning effort in advance of the wet season.

Capacity assessment studies conducted by SAM indicate that the capacity problems stem primarily from excess infiltration and inflow (I/I) in the member agencies' sewer systems. This excess wet weather flow can cause spills within the member agencies systems (see HMB and MWSD spills in Table 8 above). The largest spills, however, have occurred when the excess wet weather flow hits bottlenecks in the SAM IPS at the Montara and Portola Pump Stations.

Infiltration is the introduction of groundwater to the sanitary sewer system through pipe defects such as cracks or offset joints. Infiltration typically increases in the rainy season as the ground becomes saturated. Inflow involves a more direct and rapid introduction of rain water to the sanitary sewers through illicit storm drain and roof drain connections or standing water flowing into pick holes in manhole covers. Capacity limitations caused by I/I can be managed either by reducing the I/I, conveying the excess flow through larger sewers and storage basins, or a combination of these two basic approaches. Eliminating inflow sources is normally the cheapest and quickest control measure. Infiltration control can be costly and is generally accomplished by repairing or replacing sewer mains and/or laterals. Expansion of sewage conveyance and storage capacity can also be expensive and is normally accomplished by eliminating bottlenecks with relief sewers (typically in the interceptors) or larger pump stations, or by constructing off-line storage for excess flow.

SAM hired Carollo Engineers to conduct a series of studies to evaluate wet weather flows in the IPS and offer recommendations for relieving the capacity restrictions in the IPS. In 1998, Carollo conducted a wet weather flow metering study that examined flow inputs to the IPS and capacity of the IPS pipe and pump stations. (*Wet Weather Flow Monitoring and Model Calibration*, by Carollo Engineers, 1998.) The 1998 report made general recommendations to install off-line flow storage on the IPS, expand the capacity of the IPS downstream of the Portola PS and conduct a comprehensive I/I evaluation and corrective measures in each of the member agency collection systems. In 2002, SAM installed a 430,000 gallon off-line storage tank at the Montara PS at the head of the IPS. MWSD made some modifications to the Vallemar and Niagra pump stations and reconfigured force mains to provide some additional capacity relief at these stations and in the IPS. In 2003 and 2004, Carollo examined the effectiveness of these measures and made recommendations for additional capacity relief at the Portola PS on the IPS. (*Wet Weather Flow Management Program Facility Plan Update*, Carollo Engineers, August 2004 and *Additional Analysis of Alternative 1A of the Wet Weather flow Management Program Facility Plan*, Carollo Engineers, October 2004.) The 2004 studies, did not identify I/I sources or make recommendations for corrective measures in the member agency systems.

SAM has elected to pursue Alternative 1A from Carollo's August 2004. In October 2004, Carollo suggested, and SAM selected, variation 1A-2 which uses a pipe rather than a basin for storage at the Portola PS. Alternative 1A (with variation 1A-2), has a total project cost of $3.2 million and includes construction of a 200,000 gallon off-line storage pipes upstream of the Portola Pump Station, replacement of pumps at the Portola PS and improvements to controls and equipment at the Portola PS. The off-line storage pipes are designed to temporarily hold wet weather flows that exceed the capacity of the bottleneck in the Portola PS and downstream IPS. After flows subside, the stored wastewater can be conveyed through the Portola PS and on to the WWTP. Carollo recommended implementing the project in two phases, starting with installation of the off-line storage at a cost of $1.3 million. SAM is now pursuing funding to implement Alternative 1A-2 but has not yet committed to a schedule for completing the project. The improvements are designed to accommodate excess wet weather flow from a 5-year, 6-hour storm (2 inches of rain in 6 hours).

Carollo also considered alternatives for conveying the larger 5-year, 24-hour storm event (4 inches of rain in 24 hours). For this size storm, Carollo devised alternative 2A (2.3 million gallons of storage at Portola) at a cost of $11 million and alternative 2B (400,000 gallon storage at the Portola PS, 470,000 gallon storage at the WWTP and a new 8,850 foot 14" parallel force main downstream of the Portola PS) at a cost of $10 million. Carollo also estimated that, in storms larger than the 5-year, 24-hour storms, excess wastewater would overflow in the member agency systems before reaching the IPS.

Pending completion of additional permanent overflow storage, in 2005, SAM installed 4 temporary storage tanks at the Montara PS and 2 temporary tanks at the Portola PS. Each of tank has a capacity of 21,000 gallons for a total capacity of 126,000 gallons. The tanks are set to capture excess wet weather flow in the IPS.

Carollo's flow monitoring studies looked at member agency inputs to the SAM IPS and concluded that each of the member systems was experiencing significant levels of I/I. Carollo's flow monitoring during two storms in February 1998 showed peaking factors ranging up to 6.0 in the MWSD system, 3.0 in the GSD system and 4.7 in the HMB system. (The peaking factor indicates the ratio of flow during a storm compared to normal dry-weather flow.) Using an alternative measure of I/I, gallons of flow per mile of sewer pipe, Carollo reached the same conclusion that each system had I/I, with MWSD and HMB having higher rates than GSD. Based on monitoring of storms in the 2003/04 rainy season, Carollo concluded that recent improvements in the member agency systems have yielded as much as 1 million gallons of I/I reduction during a 5-year, 6 hour storm, but that I/I remains high. Over the years, each of the member agencies has done some level of flow metering and I/I study within their systems. In fact, each of the member agencies was planning to conduct flow monitoring either in the 2004/05 or 2005/06 rainy seasons. These local studies could be used to pinpoint I/I sources and identify pipe repairs and other measures that could reduce I/I, the root cause of SAM's capacity problems. Brief descriptions of the I/I studies conducted by the member agencies is provided below.

MWSD staff explained that, in 1997, the District conducted smoke testing to look for inflow sources. MWSD did not find this study to be effective, but did not explain why. At the time of the site visit, MWSD had not done wet weather flow metering or modeling of its system. (Since then, MWSD reports that they have entered into an agreement to conduct wet weather flow monitoring, although we don't know the scope of this planned study.) During the inspection, MWSD staff explained that they have concluded that infiltration in the MWSD service area is not concentrated in any particular area but is widespread throughout the system. The District believes that storage and capacity increases on the SAM IPS are the key to preventing wet weather overflows. It is not clear that the District has conducted sufficient studies to support these conclusions or to determine if there are options for cost effective I/I control in its system. MWSD should conduct an I/I evaluation of it's system to determine if there are options for cost effective control of I/I.

GSD completed a smoke testing program in 1999 and eliminated some inflow sources, including replacement of cleanout caps. During the 2005/06 rainy season, GSD is conducting wet weather flow metering at 10 locations. The goal is to identify which sub-basins have the greatest I/I problems and determine if there are opportunities for cost effective I/I control. GSD is also implementing a project to reroute the Naples Beach Pump Station (also known as San Pablo PS) away from Medio Creek and directly into the SAM IPS downstream of the Portola PS. This will reduce the flow at the Portola PS bottleneck.

HMB did an I/I assessment program in the mid-1990's but did not take action to correct I/I following those studies. HMB was planning to conduct flow monitoring during the 2004-2005 rainy season and will also model the system. This work may also provide information on I/I reductions realized from the recent sewer pipe rehabilitation and replacement as well as information on the I/I contribution from private laterals.

The regional agreement between SAM and the member agencies creates some challenges for effectively managing I/I and wet weather capacity problems. Each member agency is responsible for managing and maintaining the sewer pipes within their jurisdictions. As noted above, the historic record shows that most of the wet weather capacity spills occur on the SAM IPS and not in the local member agency systems. SAM has not placed limitations on wet weather flow that the member agencies convey to the IPS. In addition, SAM is responsible (using revenues from the member agencies) for capacity capital improvements to the IPS. The MWSD has high levels of I/I and the misfortune to connect to the SAM IPS upstream of the bottlenecks at the Montara and Portola Pump Stations. On the other hand, HMB, which also has high levels of I/I, connects to the SAM IPS at a point where there is no capacity bottleneck. But neither system is required by SAM to reduce I/I and neither system has a financial incentive to reduce I/I. In fact, under the regional agreement, MWSD contributes only 20% of the revenue for capacity fixes to the SAM IPS. I am not saying that any of the member agencies are taking advantage of this arrangement and avoiding improvements to their systems. In fact, each member agency has spent considerable amounts of money on capital improvements to their systems and has rehabilitated or replaced significant portions of their pipe networks. In addition, SAM meets regularly with the member agencies so they can plan and coordinate their shared and individual capacity management efforts. Yet, I/I remains and SAM is faced with making capacity fixes on the IPS.

I recommend that SAM and the member agencies continue to work together and look for ways to enhance the effectiveness of the regional capacity management efforts. From an engineering stand-point, the best technical approach is to conduct a regional I/I assessment and determine the most cost-effective mix of I/I controls, capacity expansion and excess flow storage. This is not being done in the SAM service area since each agency is on its own to study and plan I/I controls. But SAM has an opportunity to approximate a regional I/I approach by ensuring that each member agency conducts comprehensive I/I studies using similar methodology. With the data from comprehensive and uniform I/I studies, SAM and the member agencies could then see what is the most cost effective mix of controls in the regional service area. SAM could consider cost sharing options to create incentives for the member agencies to pursue cost effective I/I controls within their systems. (For example, base member fees on peak flows rather than average dry-weather flows.) SAM could consider establishing commitments for I/I reductions from the member agencies. This type of regional approach will take time and SAM should not delay planned improvements to the IPS pending completion of the member agency I/I studies.

11 BUDGETS

SAM's most recent annual budget document (*Comprehensive Budget Fiscal Year 2004-05* dated June 28, 2004) includes a two-year estimate of the Operating Budget (FY 04-05 and FY 05-06) and a five-year Capital Asset Management Plan (Capital Budget).

Each of the member agencies contributes funds to SAM. Each member agency relies on a variety of revenue sources to support its wastewater collection and treatment expenses including household user fees, commercial user fees, new connection fees, and property taxes. The state plans to claim a portion of the property tax that the districts would normally receive, due to the budget crisis. To offset the projected 40% loss in their property tax share, GSD increased annual household sewer service charges a few months ago from $273.50 to the current $314.

Table 9 summarizes the projected revenues and expenditures for the member agencies during FY 04-05. This table is constructed from numbers provided in the budgets provided by each member agency and from SAM's budget figures.

Table 9: Summary of Member Agency Budgets

Item	HMB	GSD	MWSD
Revenue Sources	sewer service charge based on water usage; connection fees	flat rate sewer service charge ($314); property tax; connection fees	flat rate sewer service charge ($320 - $500); property tax; connection fees
Revenue	$2,484,000	$1,320,498	$1,640,160
Transfers to SAM for administration	$334,625	$195,474	$132,525
Transfers to SAM for WWTP operation	$705,454	$483,583	$324,879
Transfers to SAM for collection operation	$110,353	$121,077	$148,084
Transfers to SAM for Capital (mostly WWTP)	$382,444	$264,329	$181,959
Total Transfers to SAM	$1,532,875	$1,064,463	$787,447
Member agency collection system capital budget	$1,560,000	$830,329	$483,350

11.1 SAM's Operating Budget

SAM's Treatment Operating Budget is funded by contributions from the member agencies based on percentage of average flow (HMB - 46.6%; GSD - 31.9%; and MWSD - 21.5%) during the twelve-month period from June 2003 through May 2004. The total wastewater treatment operating budget for FY 04-05 is $1,512,731.

The Collection Operating Budget is paid by the member agencies based on average employee hours recorded for SAM work for each member agency during the previous year. The distribution in the FY 04-05 budget is HMB - 28.5%; GSD - 32.0%; and MWSD - 39.5%. MWSD has the highest percentage because of the number of pump stations maintained by SAM and the number of call-outs to address sewer problems and overflows. But, at the time of the inspection, MWSD had the lowest use of SAM staff for routine sewer pipe cleaning. Fixed costs for insurance and contract services are also added to each member's total contributions to SAM. The total Collection Operating budget for FY 04-05 is $380,563.

11.2 Capital Improvements

SAM's capital improvement budget for FY 04-05 totals $940,391. Over $600,000 is for Wet Weather Capital Improvements. These could include the recommended capacity improvements to the IPS and Portola Pump Station. Future capital budgets will include not only the remainder of the Wet Weather Capital Improvements but also wet weather flow monitoring, which will measure the impact of the previous year's capital improvement. SAM also has a capital contingency fund of $40,000 to address unanticipated equipment failures. SAM has also budgeted $55,000 to analyze the structural integrity of the inter-tie pipeline system.

MWSD plans to completely rehabilitate the Chart House PS and put in a third pump. There are also plans to improve the Niagara station and add a third, smaller, pump at Vallemar. Pipeline projects have been awarded and were scheduled to begin in November 2004. MWSD has assigned an asset value for its system of $10 million. The district puts aside two percent of this amount annually for capital replacements.

HMB capital projects include upgrades to the Pelican Point and Bell Moon stations. They plan to install a grinder in the Bell Moon PS. They are waiting for a coastal development permit to replace piping, improve pumps, and raise the Pelican Point station. Capital projects also include Phase III of the sanitary sewer study and sewer replacements.

GSD capital projects in FY 04-05 include $400,000 for design and construction of the project to reroute the Naples Beach PS force main away from the Medio Creek crossing. GSD also plans to spend $65,000 on an I/I study and $25,000 for the District's 5-year capital plan.

12 RECOMMENDATIONS

1. SAM should adopt the September 2004 *Draft Sewer Overflow Response, Reporting, and Mitigation Plan* after making some recommended modifications including:
   - Include cleanup and mitigation procedures for spills that occur inside buildings that are due to problems in the sewer mainline.
   - Add procedures for cleanup and mitigation of spills that enter storm drains.
   - Include procedures for preventing the flow of spill cleanup flush water to storm drains.

2. SAM should submit monthly reports of all spills to the Regional Board as required by its NPDES permit. Perhaps the Regional Board could make the NPDES spill reporting requirements consistent with the 13267 letter when it renews SAM's NPDES permit.

3. SAM should conform to the policy of the San Mateo County Health Department to post warning signs whenever a wastewater spill contaminates recreational waters, so that the public can avoid activities that could expose them to sewage pathogens. SAM should

also post warning signs if Montara pump station overflows enter the ocean. (Neither the May 2000 or the draft September 2004 overflow plans provide an exception for posting at this or any other spill location.)

4. Spill response crews should record spill information in the SSO report form before they leave the scene of a spill. This allows for better recording of field observations while the incident is fresh in the minds of the response crew

5. It is recommended that SAM make efforts to reduce the size of overflows by using a vacuum truck, temporary pump around, or other means to prevent sewage from overflowing the collection system into the environment.

6. The Intertie Pipeline, especially the force main sections, are a critical element of the SAM system. Failure of the pipeline could be difficult to repair and result in a large spill. SAM should take the following measures to safeguard against failure of the intertie pipeline:
   - Complete condition inspections of the gravity and force main sections of the IPS and make necessary repairs or replacements.
   - Implement a regular program to maintain and replace air release valves on the force main sections of the IPS.
   - Develop an emergency contingency plan for responding to a failure of the IPS. As part of the contingency plan, SAM should consider whether to install parallel force mains that could serve as a backup in the event of a catastrophic failure of one of the force main sections.

7. Autodialers at all pump stations should be equipped with true Uninterruptible Power Supplies (UPS) rather than just a battery.

8. At the time of the inspection, SAM was not able to fully explain the failure of alarm systems and backups that contributed to spills at the Princeton and Ocean Colony Pump Stations. SAM should determine the causes of these failures and take measures to prevent recurrence.

9. SAM should conduct annual inspections of each permitted FSE and complete reports on each inspection.

10. The EPA inspectors discussed a variety of FOG control measures employed by other Cities in California that SAM should consider for it's program. Some of the measures include:
    - kitchen BMP requirements;
    - 25% accumulation rule limiting the build-up of grease and solids in grease removal devices;

- standard inspection checklist forms; and
- FOG characterization studies.

11. The SAM system, including its member agencies, experiences a higher rate of spills than surveyed systems in southern California. Other systems have managed to reduce spills with well managed and expanded sewer cleaning programs. SAM recently obtained a new sewer cleaning truck equipped with CCTV. This should help its sewer cleaning efforts. SAM and the member agencies should consider the following:
    - Adopting regional criteria or standards for sewer cleaning by the member agencies. Taking a regional approach to identifying hot spots and recommending minimum cleaning frequencies by the member agencies.
    - Increase hot spot cleaning locations and frequency as needed to reduce spills.
    - Identify repeat spill locations and take aggressive steps (cleaning and/or pipe repair) to eliminate repeat spills.
    - SAM should evaluate whether its staffing level is sufficient to meet the production, hot spot and call-out cleaning demands of the member agencies.
    - Chemical root control where appropriate. Control of roots from private laterals as needed.
    - Conduct more aggressive hot spot cleaning in advance of the rainy season to reduce the number of rainy season blockage spills.
    - Use the CCTV equipment to make follow-up inspection of sewer pipes at spill sites and document any observed pipe defects.
    - Use the CCTV equipment to conduct a sewer cleaning QA/QC program. Such a program could involve random CCTV of pipe segments after cleaning to determine the effectiveness of the cleaning. Effective cleaning should remove all sediment and debris, and restore the pipe to its nominal diameter.
    - SAM should develop a computerized sewer cleaning Maintenance Management System to provide ready access to the maintenance history for any pipe segment and facilitate maintenance scheduling.

12. SAM should proceed expeditiously with planned capacity improvements to the IPS.

13. The SAM member agencies should complete comprehensive and uniform I/I studies and then work together with SAM to identify and implement cost effective I/I controls.

14. SAM and the member agencies should look for ways to improve the regional management of capacity control measures and create incentives for completion of the most cost effective capacity control improvements.

Attachment I
Inspection Photographs

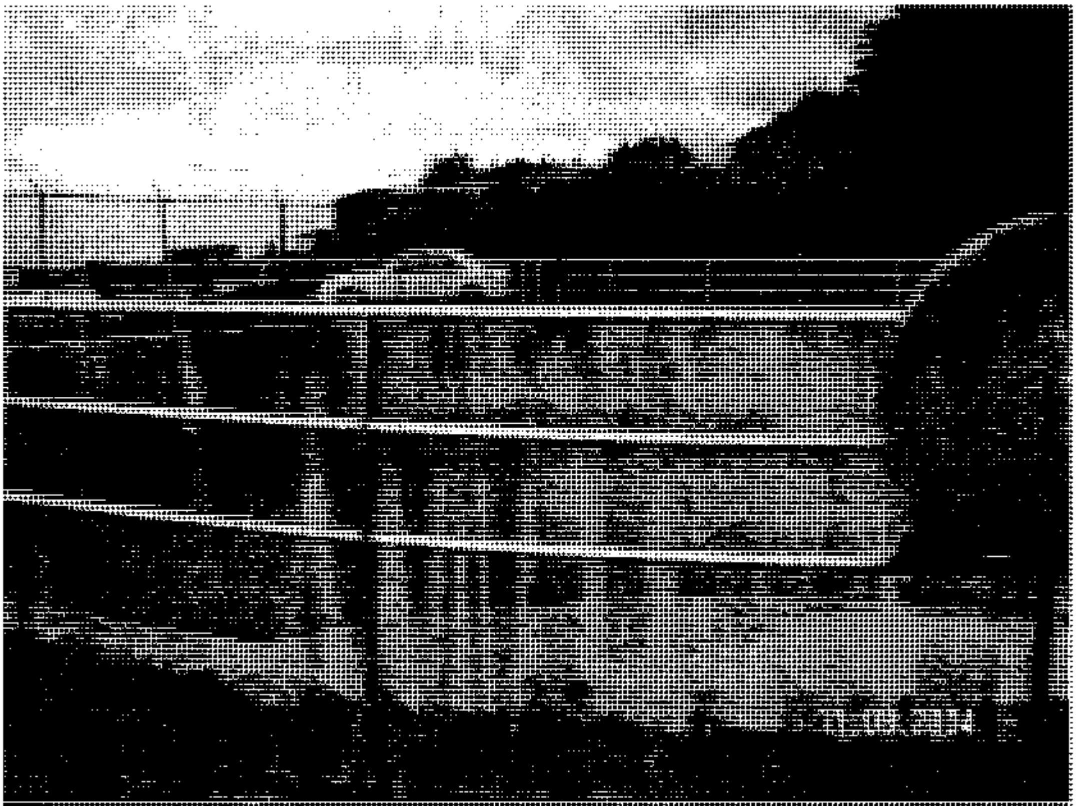

Photo 1: SAM - Montara PS wet weather storage tank

Photo 2: SAM - Montara PS pumps

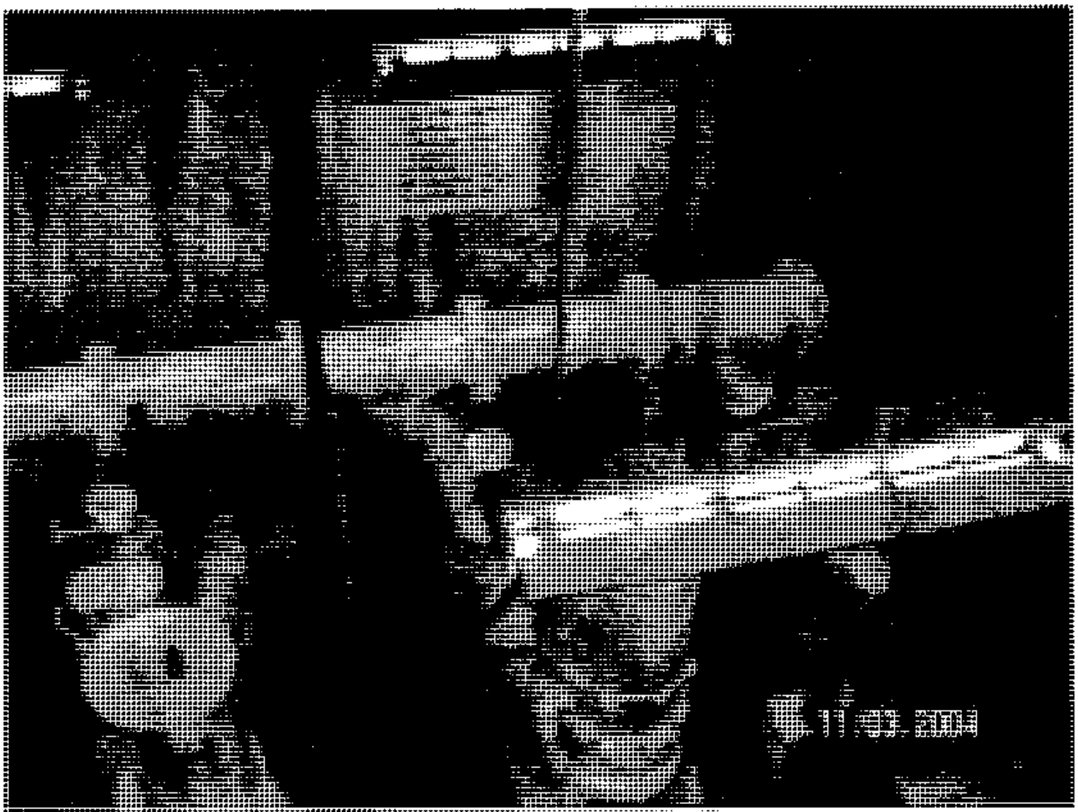

Photo 3: SAM - Montara PS pumps


Photo 4: SAM - Montara PS manhole that overflows

Photo 5: SAM - Montara PS path of wastewater overflow to ocean

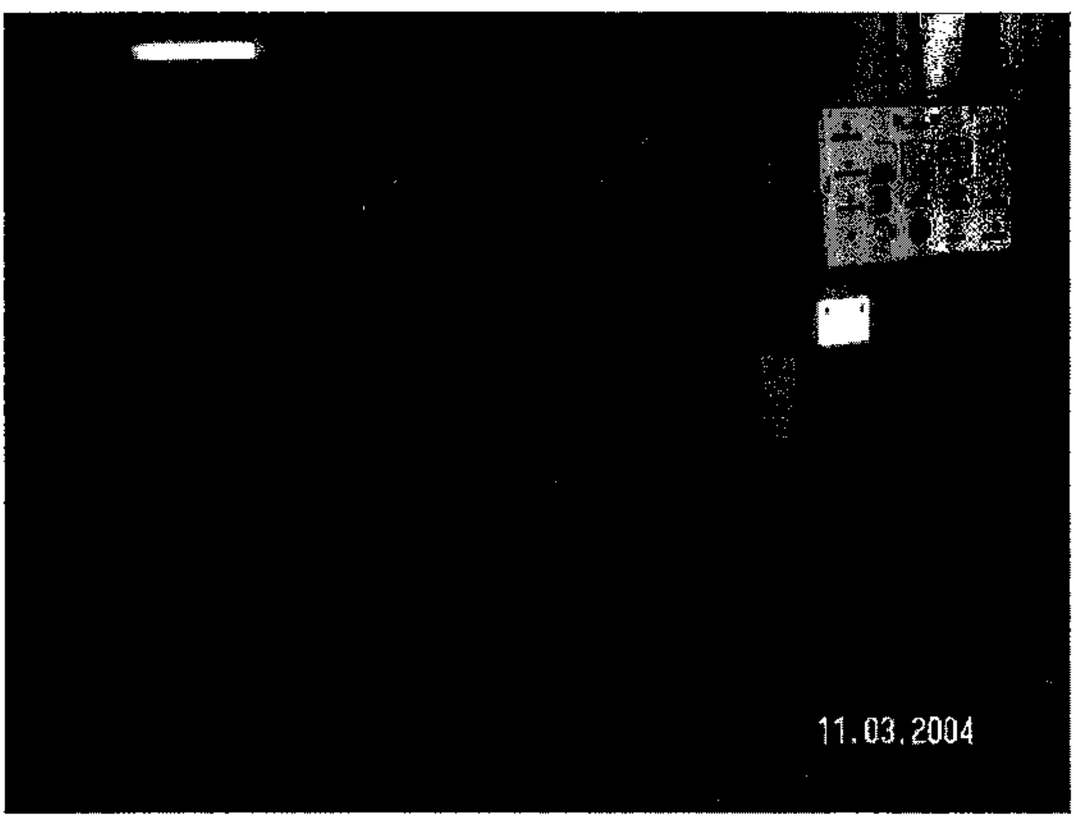

Photo 5: SAM - Montara PS generator

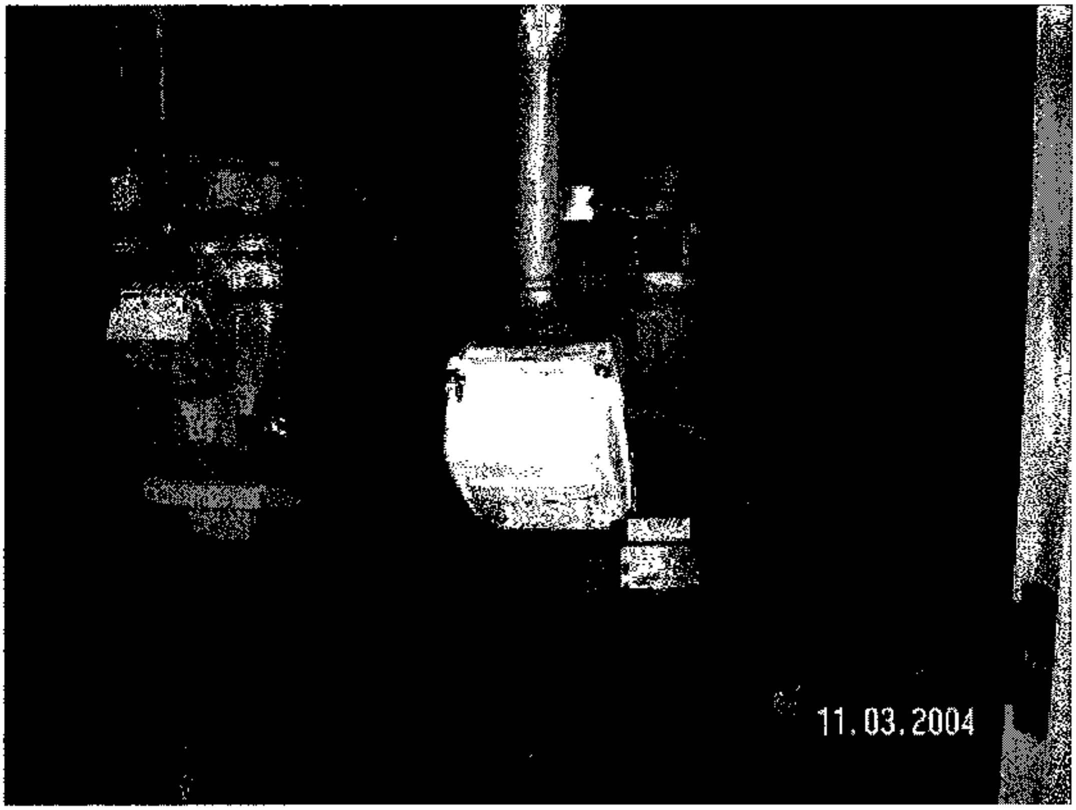

Photo 7: SAM - Princeton PS pumps

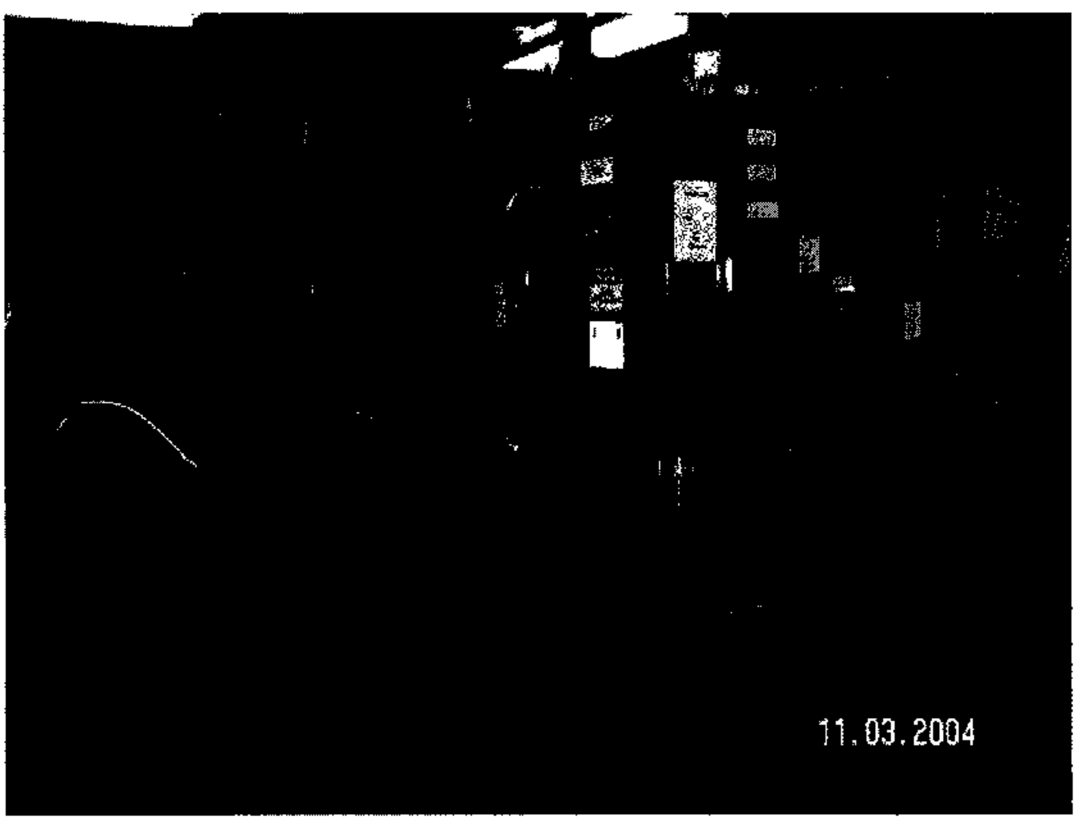

Photo 8: SAM - Princeton PS generator

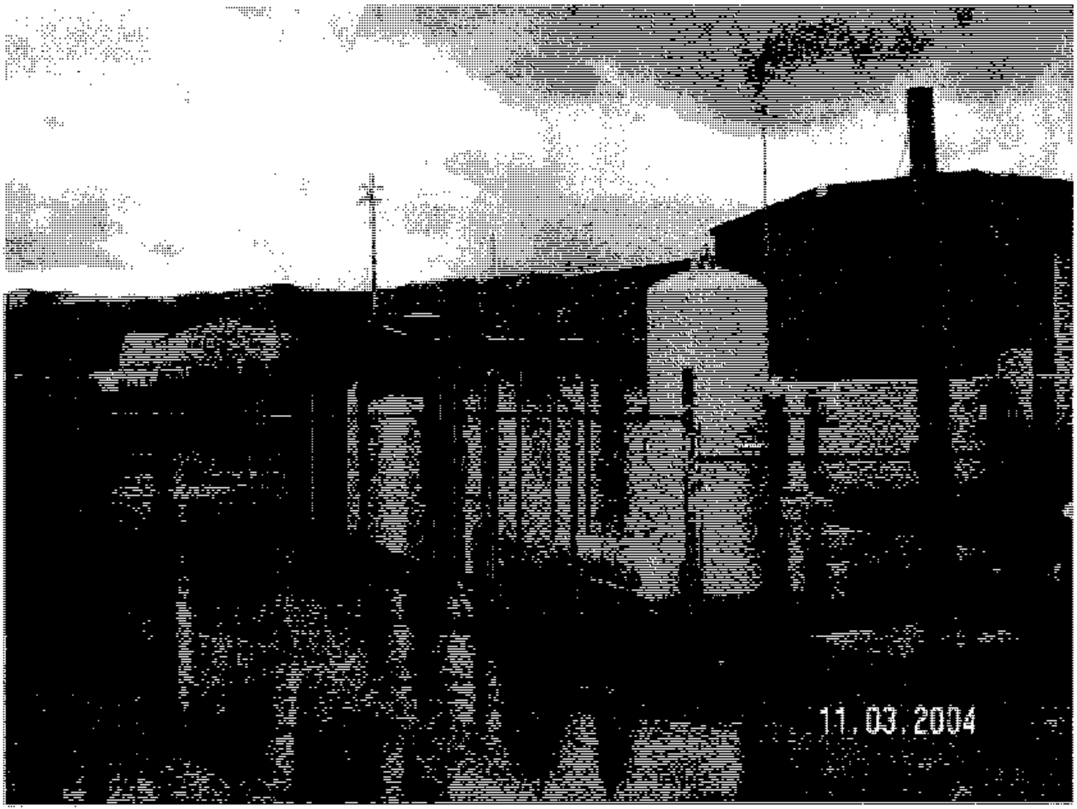

Photo 9: SAM - Princeton PS


Photo 10: SAM - Princeton PS manhole that overflows to ocean

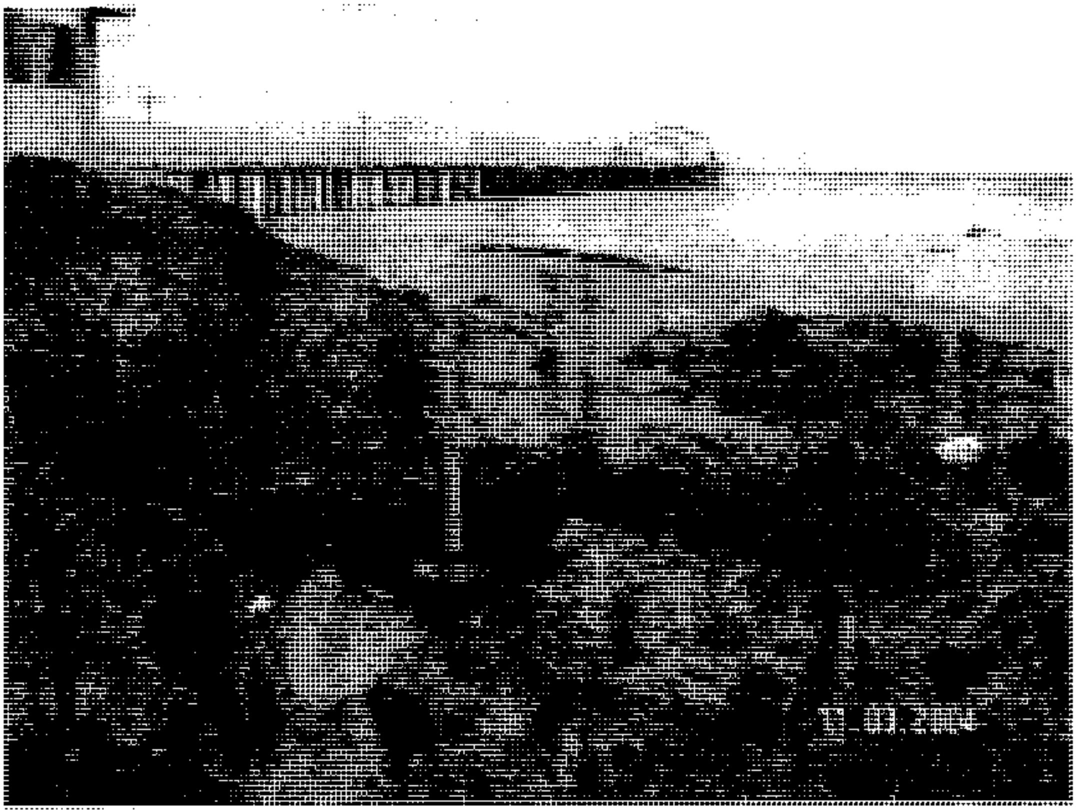

Photo 11: SAM - Princeton PS overflow point to ocean

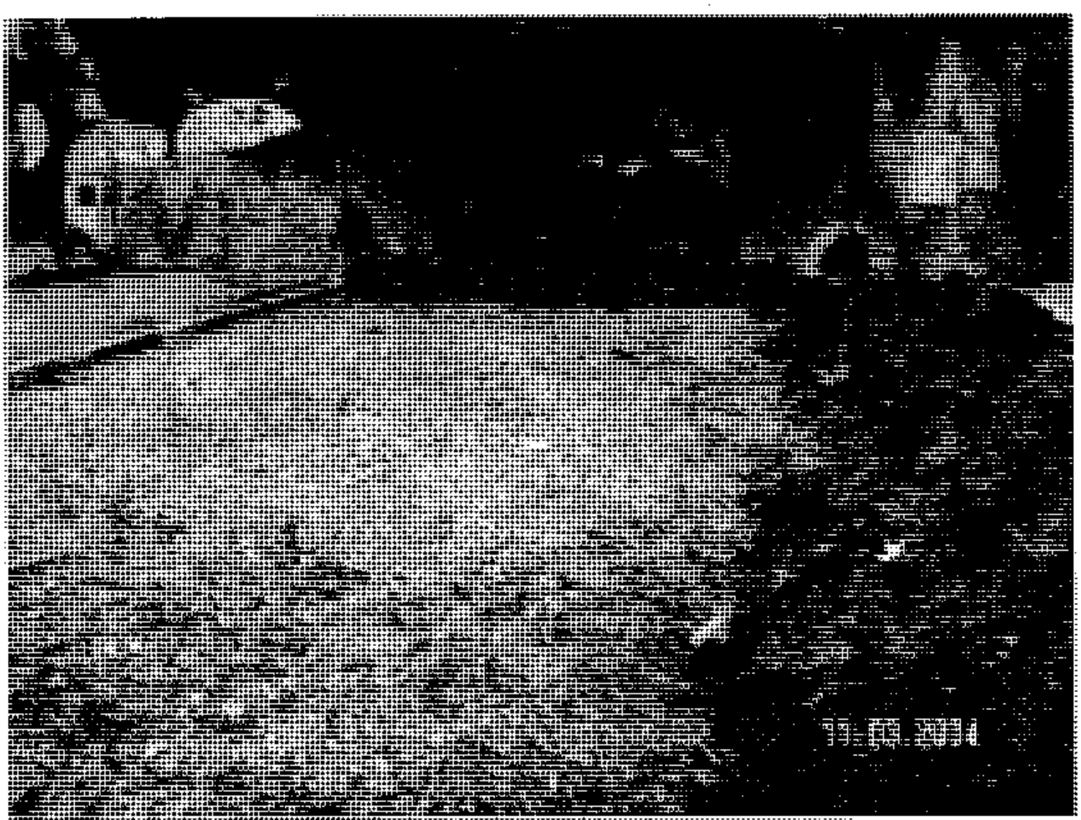

Photo 12: SAM - Portola PS biofilter

Photo 13: SAM - Portola PS pumps

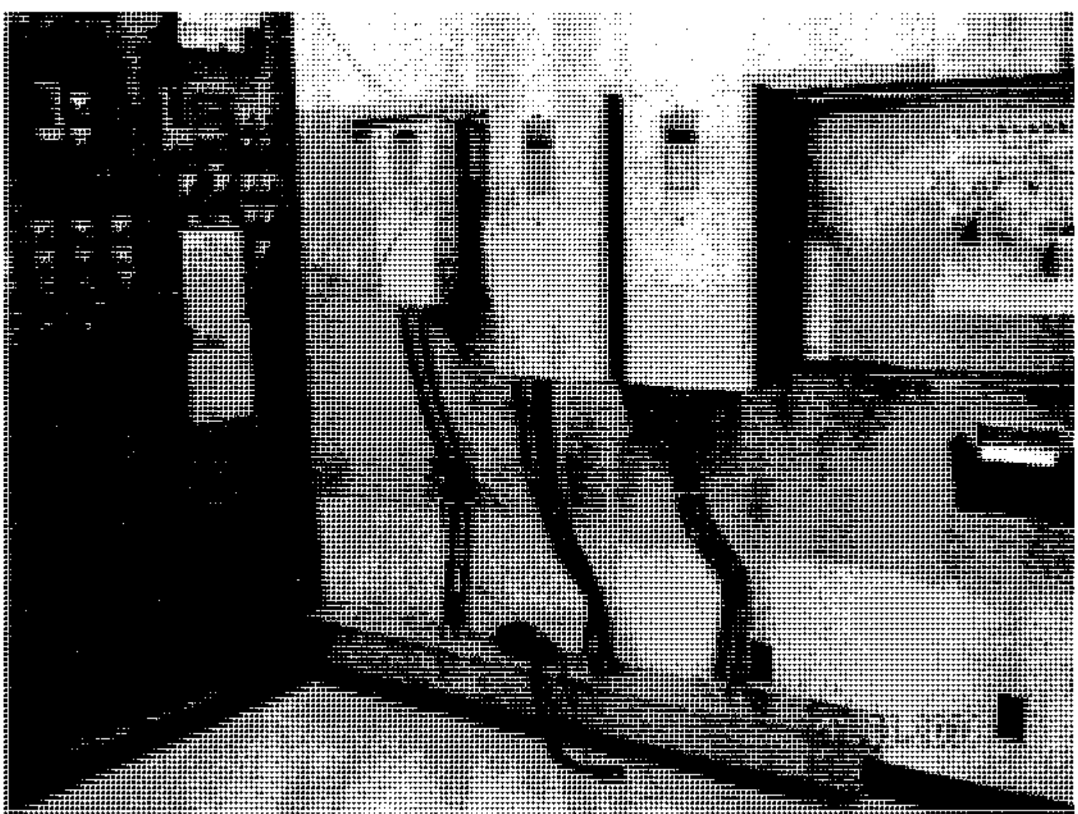

Photo 14: SAM - Portola PS alarm system

Photo 15: SAM - Portola PS overflows go to this channel

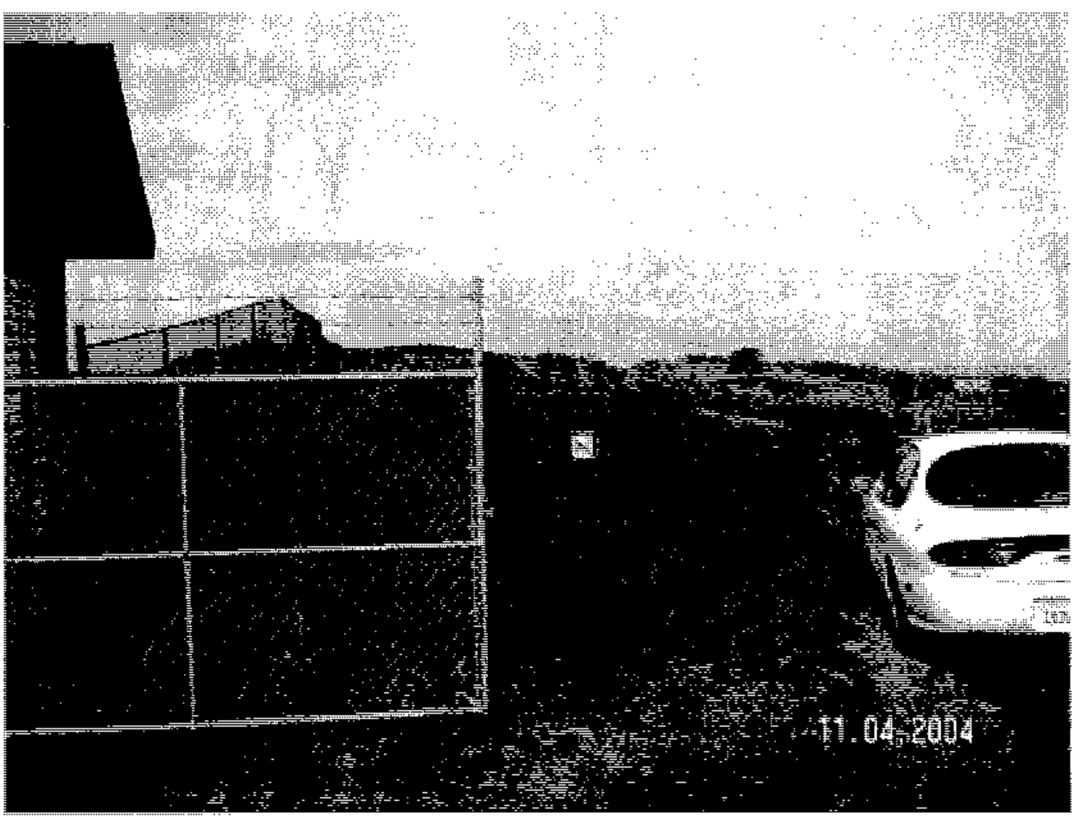

Photo 16: MSD - Charthouse PS overflow point to ocean

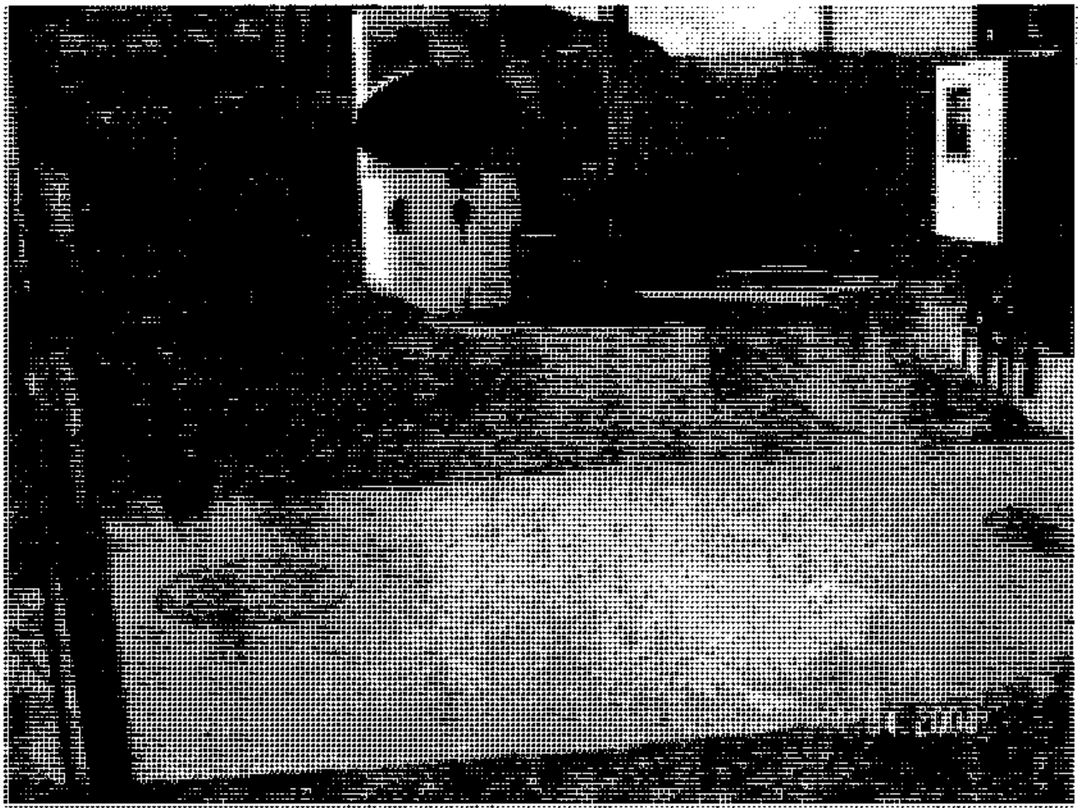

Photo 17: MSD - Charthouse PS storage tank

Photo 18: MSD - Vallemar PS

Photo 19: MSD - Vallemar FM air relief valve location

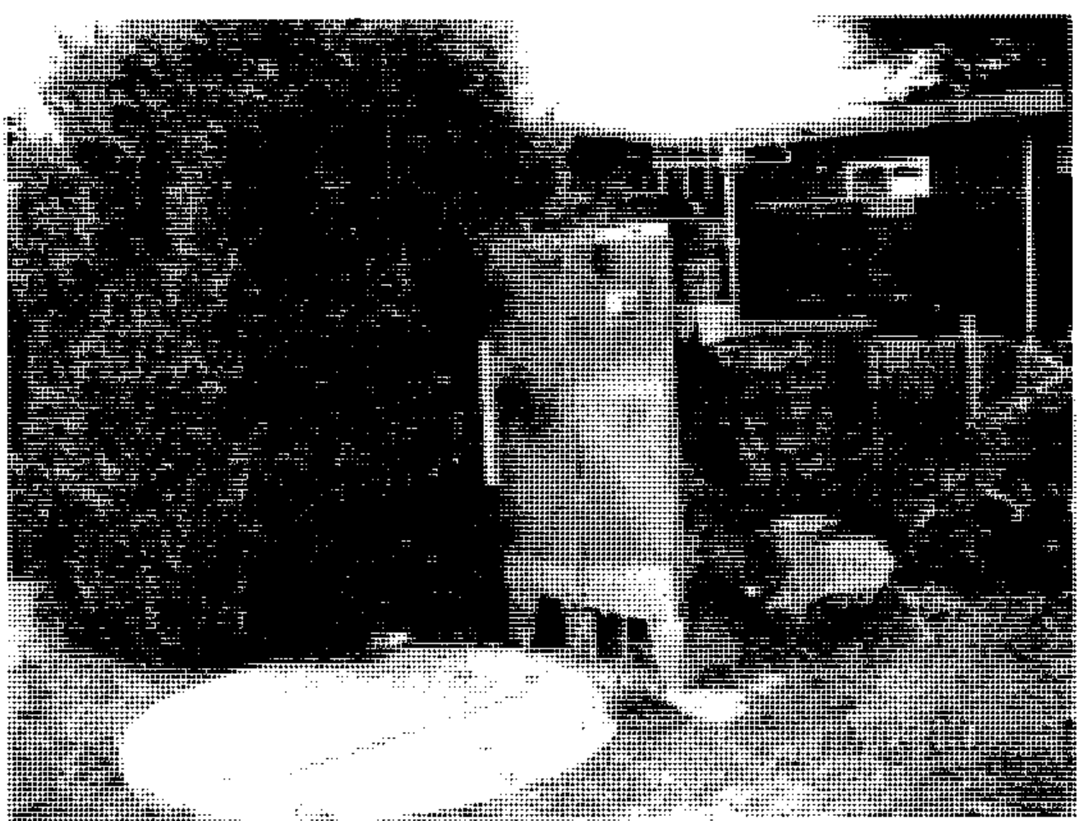

Photo 20: MSD - Seal Cove 4 PS

Photo 21: MSD - typical grinder PS

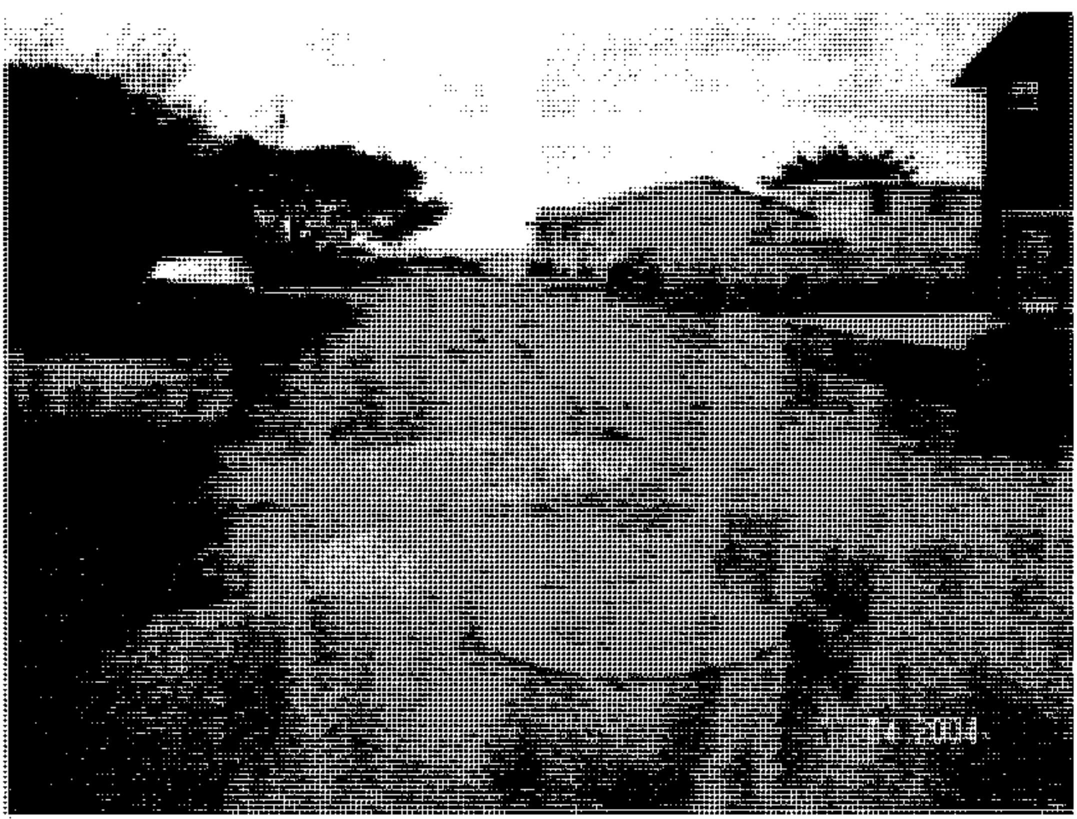

Photo 22: MSD - Seal Cove 3 PS

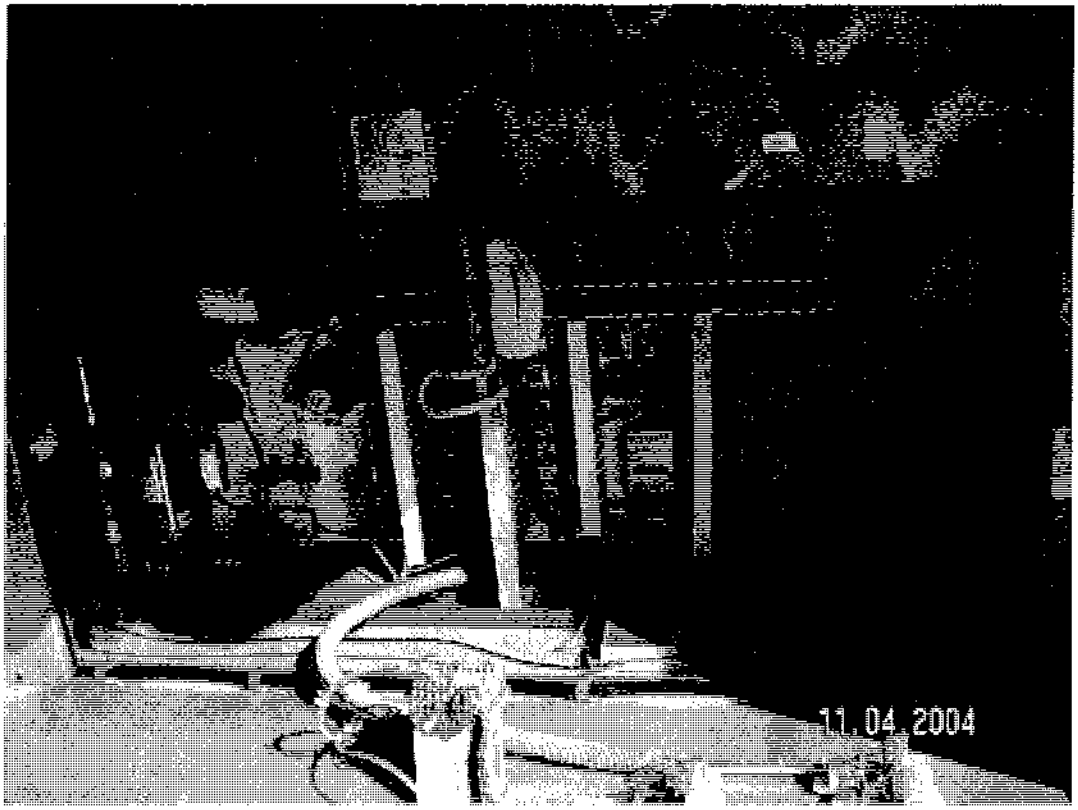

Photo 23: MSD - Airport PS panel

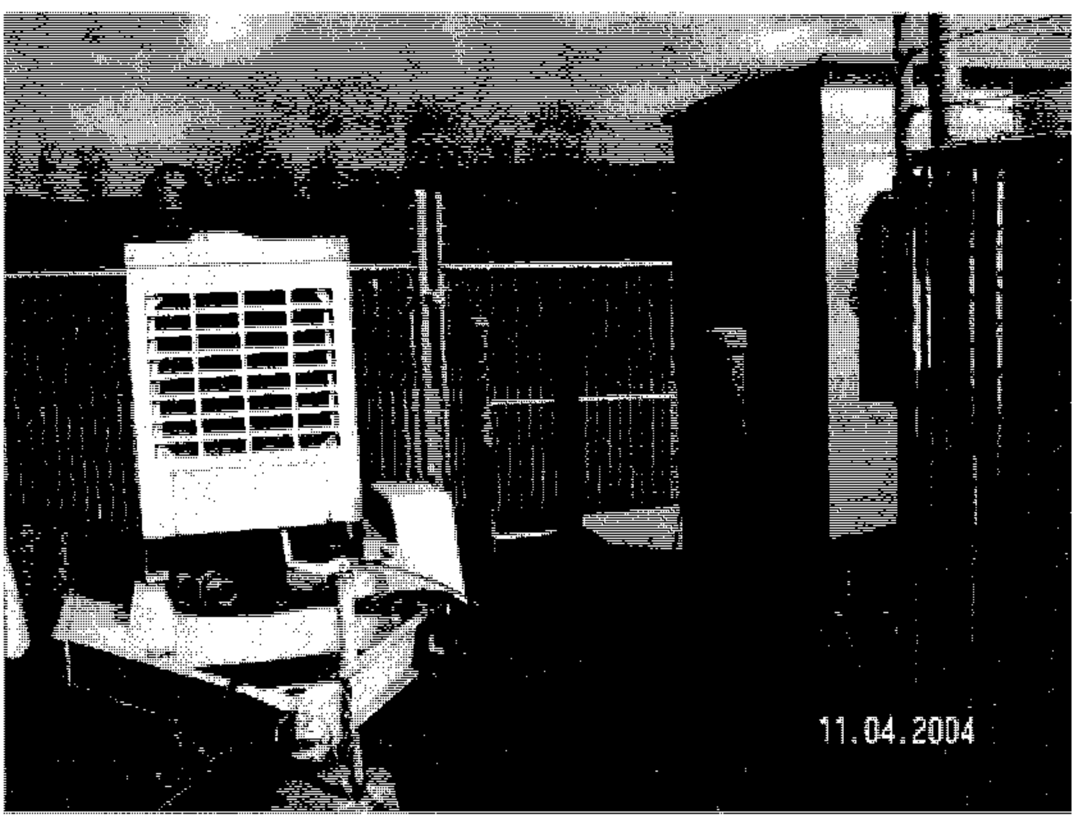

Photo 24: MSD - Airport PS generator


Photo 25: MSD - Airport PS overflow from this manhole

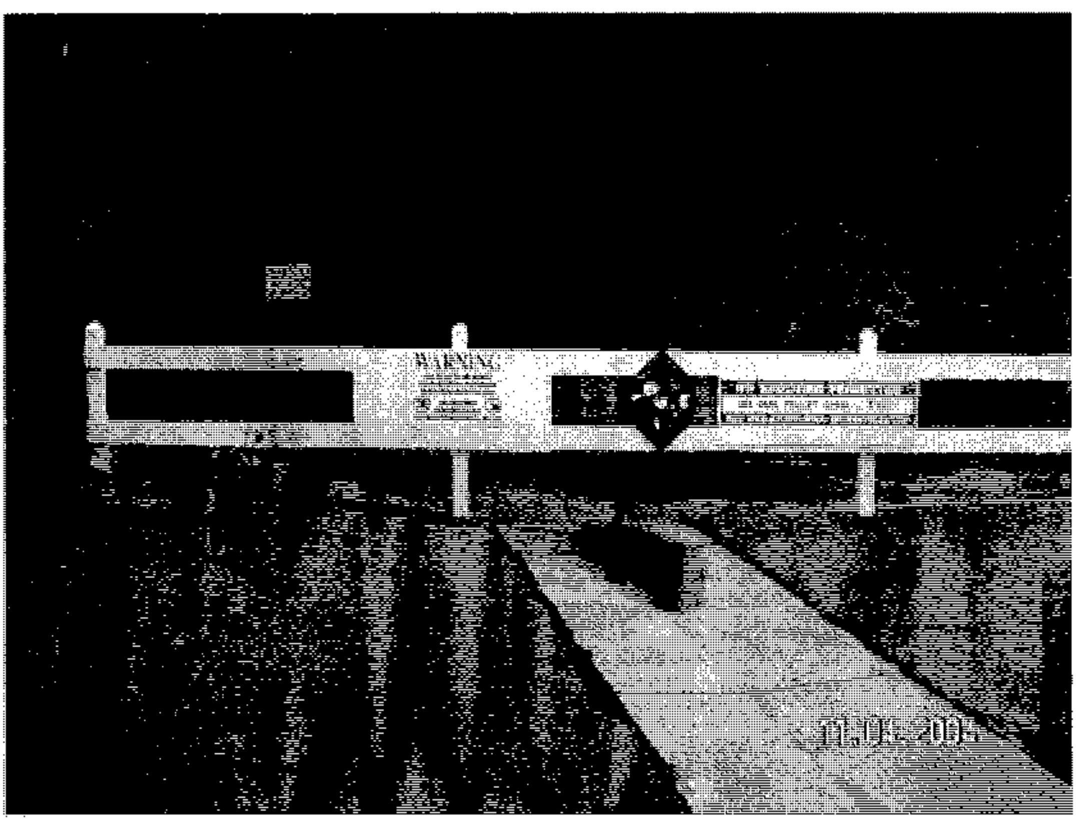
Photo 26: MSD - Airport PS overflow to ditch

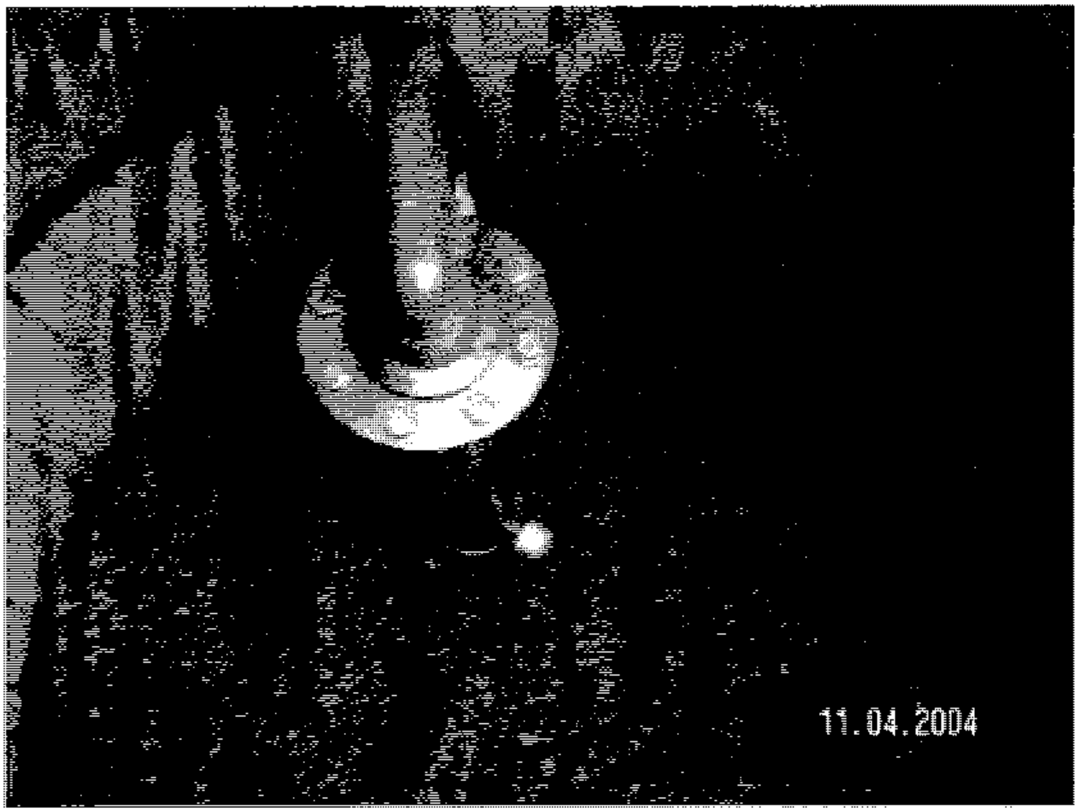

Photo 27: Example of new type of ARV in use by SAM

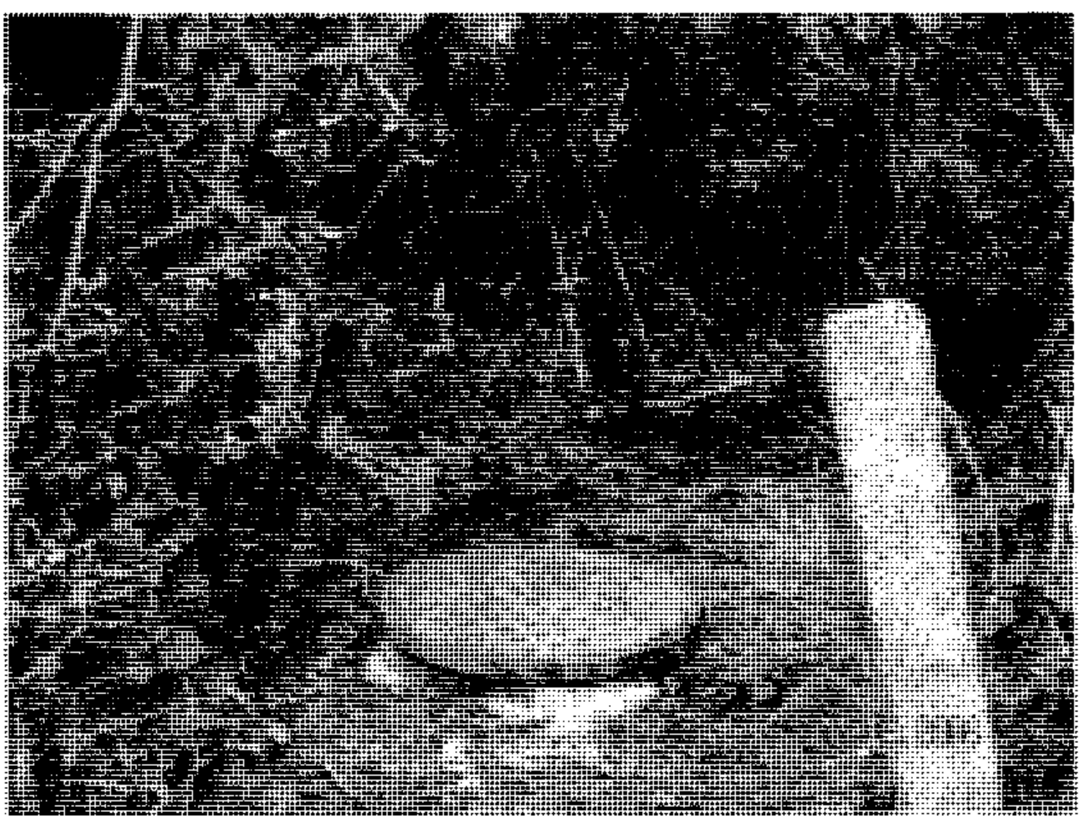

Photo 28: HMB - Oak Street spill site adjacent to creek

Photo 29: HMB - Ocean Colony PS spill location

Photo 30: HMB - Ocean Colony PS

Photo 31: GSD - Isabella and Columbus spill area

Photo 32: GSD - Isabella and Columbus spill area

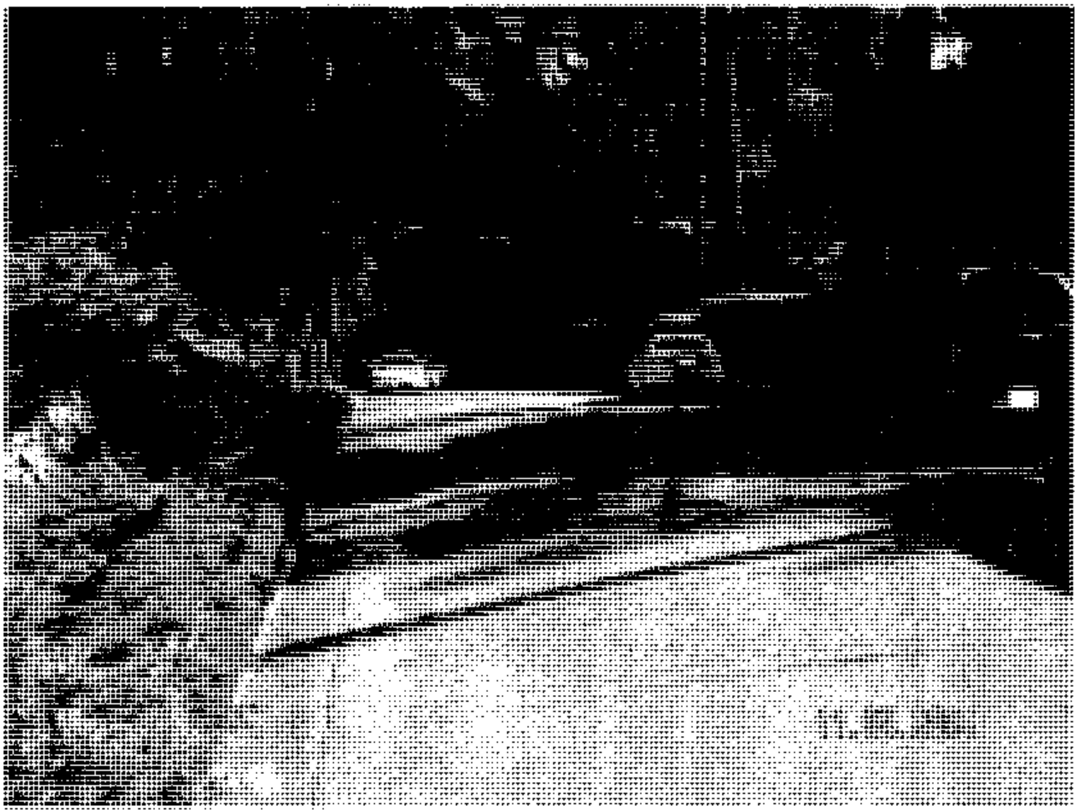

Photo 33: GSD - 546 Isabella area

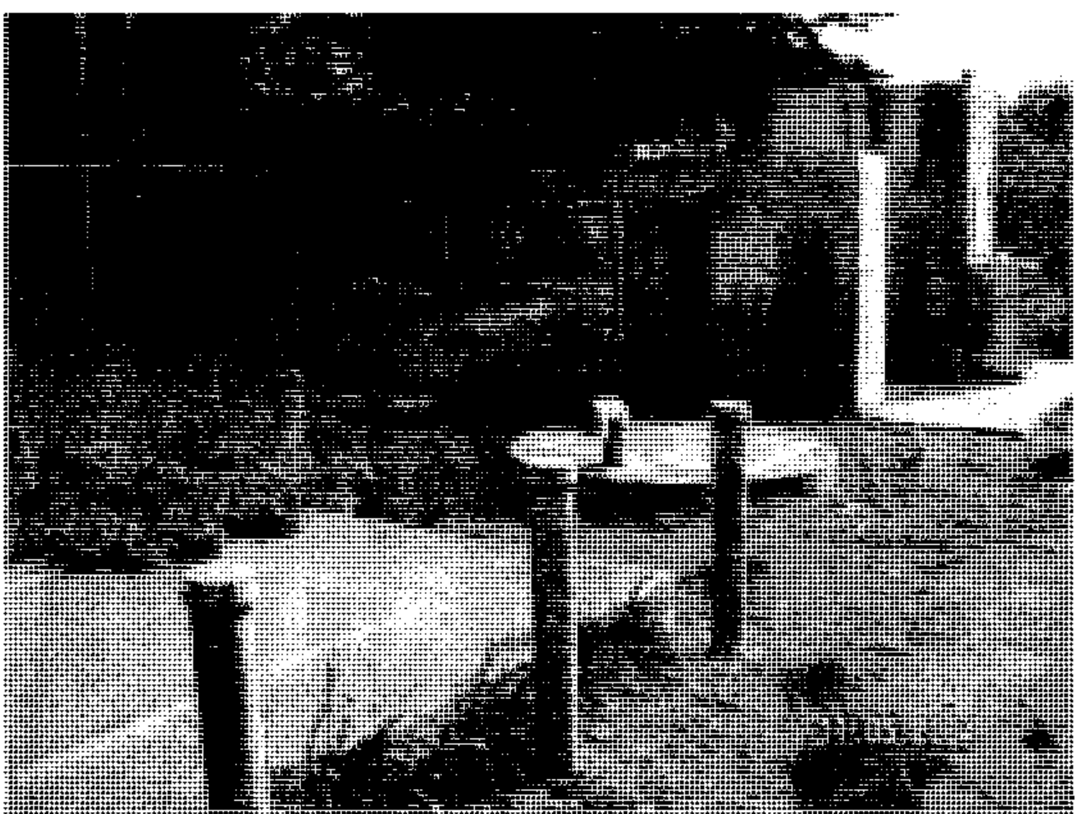

Photo 33: GSD - San Pablo PS

Photo 34: GSD - San Pablo PS wet well


Photo 35: GSD - San Pablo FM break area


Photo 36: GSD - San Pablo FM overflow would move toward beach

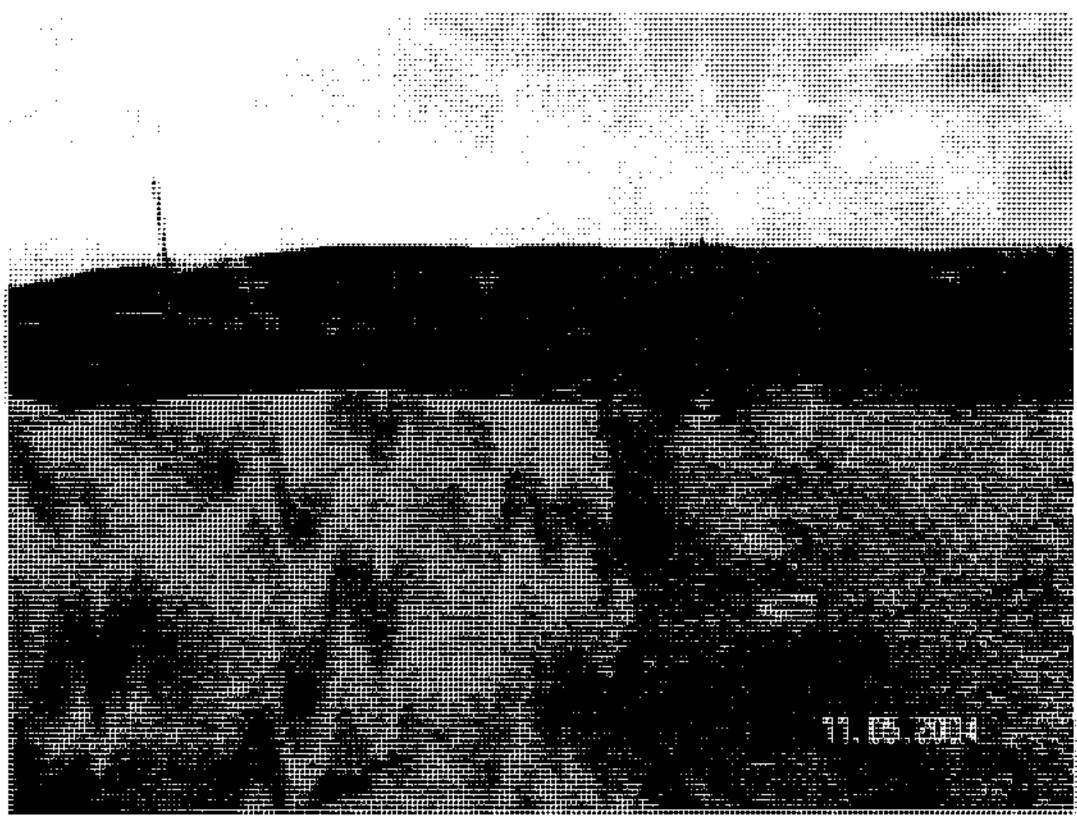
Photo 37: GSD - San Pablo FM break area

Photo 38: SAM - cleaning truck

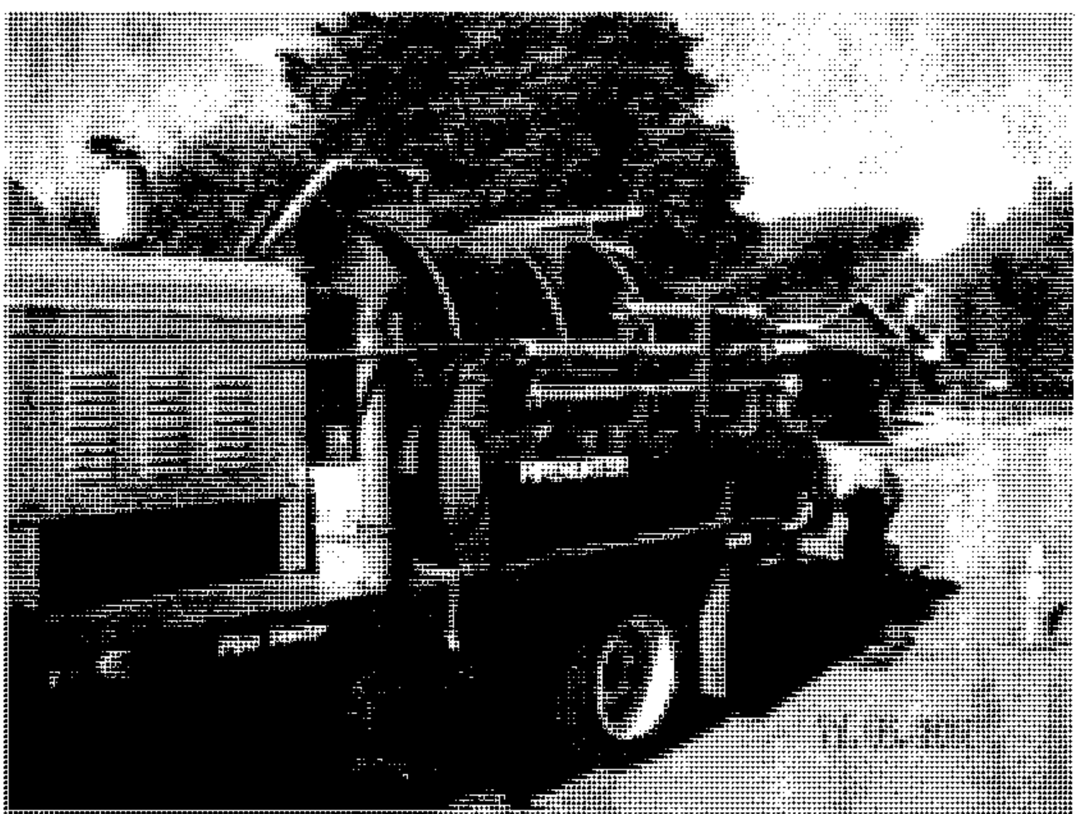

Photo 39: SAM - cleaning truck

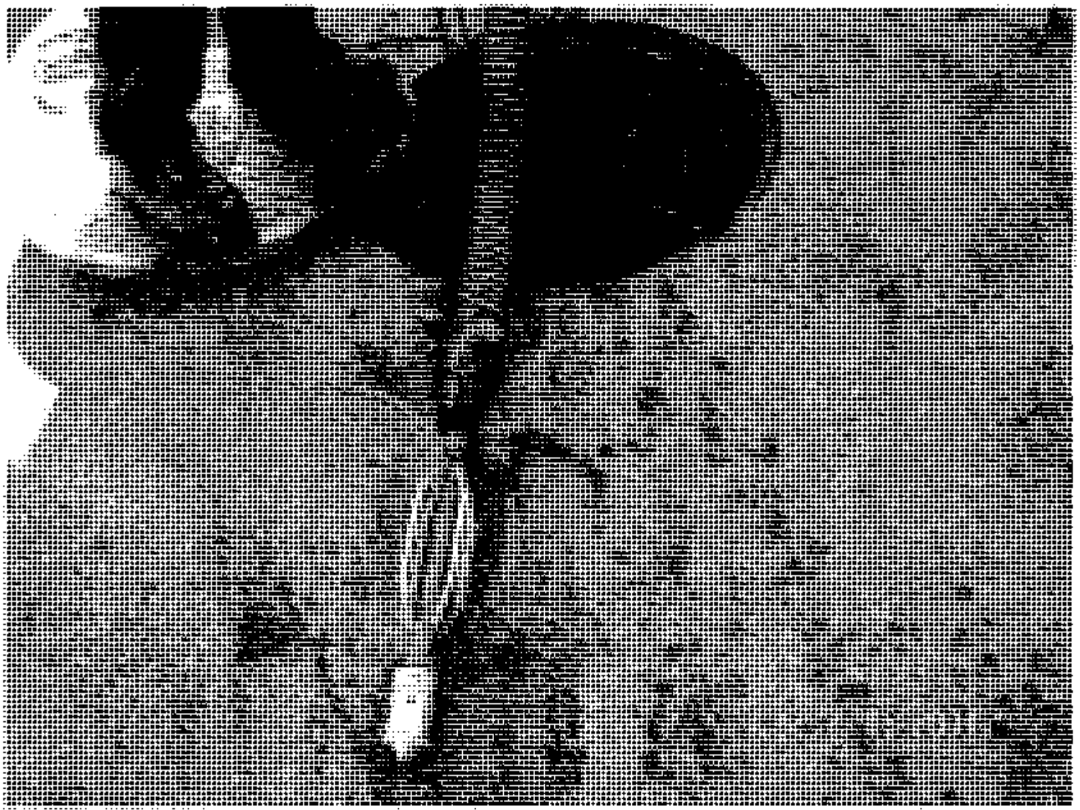

Photo 40: SAM - cleaning truck jet nozzle

Photo 41: SAM - cleaning truck root cutting nozzle

Attachment 2
Sanitary Sewer Overflows During the Period 2000 through 2005

Attachment 2
SSOs Reported by SAM
1/2000 - 12/2005

Date	Location Of Overflow	District/ Owner	Receiving Waters	Into Waterway ?	VolumeOf Overflow	Description Of Event	Description Of Response	AdditionalComments	Cause
12/27/2005	161 Kelly	HMB	On to ground	No	5	Lateral			lateral
12/24/2005	Pembroke Court	HMB	Into storm drain	Yes	80	Roots			roots
12/23/2005	618 Alsace Lorraine	HMB	On to ground	No	2	Possible offset in lateral			lateral
11/22/2005	423 Francisco	GSD	On to ground	No	15	Roots			roots
11/19/2005	570 Vermont	MWSD	On to ground	No	75	Grease			grease
11/1/2005	506 Portola Ave	GSD	On to ground	No	50	Grease			grease
10/22/2005	1045 Tamarind	MWSD	Into Home	No	30	Roots			roots
10/16/2005	478 El Granada Blvd	GSD	On to ground	No	75	Roots			roots
9/29/2005	Ocean Colony	HMB	Golf Course Lake	Yes	750	Grease			grease
9/10/2005	906 Sevilla	GSD	On to ground	No	50	Rocks in Mainline			rocks
8/30/2005	La Piazza, Main Street	HMB	On to ground	No	90	Broken lateral			lateral
8/17/2005	4 Terrace	MWSD	On to ground	No	80	Grease			grease
7/24/2005	180 Los Banos	MWSD	On to ground	No	90	Roots			roots
7/23/2005	423 Francisco	GSD	On to ground	No	20	Roots			roots
7/13/2005	115 Los Banos	MWSD	On to ground	No	25	Broken forcemain			forcemain break
6/26/2005	Main Street	MWSD	On to ground	No	75	Grease			grease
6/21/2005	Corner of Beach and Park	MWSD	On to ground	No	5	Forcemain separation			forcemain break
5/18/2005	Corner of Miramar and Purisima	GSD	On to ground	No	100	Unknown			unk
5/12/2005	10th Fairway, Ocean Colony Golf Club	HMB	On to ground	No	50	Air release valve stuck open			equipment failure
5/2/2005	366 11th Street	MWSD	On to ground	No	10	Broken mainline			main break
4/12/2005	838 Ferdinand	GSD	On to ground	No	50	Broken mainline			main break

Attachment 2
SSOs Reported by SAM
1/2000 - 12/2005

Date	Location Of Overflow	District/ Owner	Receiving Waters	Into Waterway ?	VolumeOf Overflow	Description Of Event	Description Of Response	AdditionalComments	Cause
4/12/2005	160 Delores	GSD	On to ground	No	2	Roots			roots
3/13/2005	2nd Street	MWSD	On to ground	No	1,000	Roots			roots
2/23/2005	525 Metzgar	HMB	On to ground	No	20	Roots			roots
2/9/2005	Corner of Fir and Harte	MWSD	On to ground	No	900	Roots			roots
2/5/2005	211 San Mateo Rd	HMB	On to ground	No	20	Broken lateral			lateral
1/18/2005	146 Patrick Way	HMB	On to ground	No	10	Broken lateral			lateral
1/16/2005	146 Patrick Way	HMB	On to ground	No	10	Paper stoppage			debris
1/5/2005	861 Railroad	HMB	On to ground	No	1	Mud in lateral			lateral
12/27/2004	Date Harte Lift Station	MWSD	Montara Creek	Yes	2,410	Rain event			capacity
12/27/2004	Montara Pump Station	SAM	Pacific Ocean	Yes	83,970	Rain event			capacity
12/27/2004	Portola PS Magellan/Mirada and 560 Obispo Ave	SAM	Pacific Ocean	Yes	19,020	Rain event			capacity
11/3/2004	Ocean Colony Lift Station	HMB	Golf course pond	Yes	9,773	UPS failed, leaving controller and alarm system without power.			equipment failure
10/9/2004	Airport PS El Granada Mobile Home Park	MWSD	On to ground	No	400	Lift Station Failure. Suspected low voltage tripped both pumps. We have been unable to re-create the problem. The generator breaker was also tripped. While we could not re-create the problem with the generator breaker	Area mainline was thought to be plugged. When investigated, it was decided to check lift station. When lift station was found not operational, maintenance staff was called in. Electrical vender and San Mateo County Health Services official were called		equipment failure
9/18/2004	1107 Columbus	GSD			100	Roots And Offsets In Line	Rootsawed And Flushed Mainline	Mainline Has Numerous Offsets Advise CCTV To Determine Extant Of Defects	roots
9/16/2004	416 Granelli	HMB			15	Grease And Rags	Flushed Main And Broke Plug	Mainline Should Be Televised	comb

Attachment 2
SSOs Reported by SAM
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Date	Location Of Overflow	District/ Owner	Receiving Waters	Into Waterway ?	VolumeOf Overflow	Description Of Event	Description Of Response	AdditionalComments	Cause
9/4/2004	762 Buena Vista	MWSD	On to ground	No	500	Plug In Main Line 200 ft Mostly Paper	Flushed Mainline 200 ft Finding Plug Consisting Of Paper (Possible Belly In Line) Told Homeowner To Contact One Of Sewer Cleanup Places / Then Call MSD TO Report Problem	Owner Contact Fire Dept First/Then They Went Thru County Com Approx 45mins Till Sam Got Called Sewage Visible Throughout Downstairs Of House Paper/Debris Sewerage Under house Also	debris
8/17/2004	Nurseryman's Exchange	GSD			100	Paper	Flushed Main		debris
8/6/2004	471 Francisco	GSD			30	Roots Possible Offset	Flushed Main 230ft Finding Roots, Snaked Service Line 16ft Finding Mud Possible Offset		roots
7/29/2004	Ocean Colony PS	HMB	On to ground	No	450	Force Main Cracked	Shut Off Pump At Ocean Colony Pump Station, Contracted With A-1Septic to Haul Waste Water From Pump Station, Andrini Bros. Excavated And Repaired the Force Main	Adv Paul Nag, Charlie Voos, With City HMB	pipe
6/5/2004	North End of Purissima St	HMB	On to ground	No	80	Grease	Flushed Mainline		grease
5/26/2004	50 Portola on Isabella	GSD			5	Paper	Flushed main		debris
3/19/2004	200 Sevella	GSD	On to ground	No	10	Possible Offsets	Flushed to clear. Lateral that overflowed on to lawn		pipe
3/12/2004	643 Isabella	GSD			30	Roots	Rootsawed main		roots
3/8/2004	130 11th Street	MWSD			30	Bucket in mainline	Flushed mainline Removed bucket		debris
3/7/2004	725 Johnston	HMB			50	Paper - Grease	Flushed main will return for clean up of main 3-8		comb
3/1/2004	11th Street	MWSD	On to ground	No	50	Roots	Flushed Mainline		roots
2/26/2004	1006 Birch	MWSD			5	Roots	Flushed mainline	Returned 2/27/04 - cleared roots from mainline	roots
2/18/2004	540 Lancaster Blvd.	MWSD	Into storm drain	Yes	1,000	Mainline plug that backed up into house	Flushed mainline and took pictures		unk
2/16/2004	4 greenbrier Court	HMB	On to ground	No	30	Roots in manhole and mainline.	Root saw main line and clean roots from manholes		roots
2/14/2004	1006 Birch Street	MWSD	On to ground	No	Unknown	Rags	Flush Main, break plug and clean up area.		debris
2/12/2004	214 De Monte	GSD			30	Roots in mainline	Flushed mainline removed root mass	SSO had stopped by the time we arrived will return 2-13 am to check	roots
1/24/2004	1020 Bancroft	HMB	On to ground	No	10	Grease	Flushed		grease

Attachment 2
SSOs Reported by SAM
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Date	Location Of Overflow	District/ Owner	Receiving Waters	Into Waterway ?	VolumeOf Overflow	Description Of Event	Description Of Response	AdditionalComments	Cause
1/20/2004	Nurseryman's Exchange	GSD			50	Paper Solids	Flushed line 26-25		debris
12/30/2003	2651 N. Cabrillo Hwy.	GSD	On to ground	No	60	Solid build up due to excess flow in force main	Flushed line 26-25		debris
12/29/2003	Montara Pump/Storm Water Retention Station	SAM	Pacific Ocean	Yes	See additional Comments	Montara Pump station overflowed after filling Storm Water Retention Tank. The mid-Coastside area experienced heavy rain fall measuring 2.61" for the day as measured at the Sewer Authority Mid-Coastside Treatment Facility.	Monitored system to minimize overflow. Pumped to Portola pump station as much as possible without causing an overflow at the Portola site.	Originally estimated in the field at 120,000 gallons, revised to 80,000 gallons based on Carollo report dated January 22, 2004, further revised to 63,000 per Carollo report to Board of August 19, 2004; written report to be prepared by Carollo and distributed to reporting agencies.	capacity
12/27/2003	1006 Birch	MWSD	On to ground	No	10	Roots	Roots sawed mainline	Lamp hole needs to be raised in backyard at 1006 Birch. Mainline needs televised suspect offset-break in main.	roots
12/26/2003	338 Alameda Street	GSD	On to ground	No	10	Roots	Flushed Lateral and Main		roots
12/25/2003	Columbus and Isabella	GSD			5	Roots	Flushed Main - Washed down gutter		roots
12/24/2003	546 Isabella Road	GSD	pond	Yes	50	Mainline plug	Flushed mainline to stop the flow		unk
12/24/2003	Cypress	MWSD	On to ground	No	25	Main Line plug	Flushed main line to stop the flow		unk
12/24/2003	North side of Vallemar Street Cul-de-sac, Montara	SAM	storm drain to Pacific Ocean	Yes	10,000	Force main appurtenance malfunctioned, letting water escape from the system	Vactored manhole to uncover air release velve. Repaired force main appurtenance - replaced damaged parts		equipment failure
12/17/2003	570 Vermont, Montara	MWSD	On to ground	No	50	Grease Blockage	Flushed Main Line		grease
12/12/2003	Sunshine Valley Station	MWSD	On to ground	No	70	Roots grease in main line	Root sawed main line		comb
11/15/2003	Cedar	MWSD	On to ground	No	750	Roots in Mainline	Flushed mainline		roots
11/11/2003	Ave Cabrillo	GSD	On to ground	No	100	Roots in main line 200"	Flushed main line/debris		roots
11/10/2003	Main Street at Stone pine	HMB	storm drain to Pillarcitos Creek	Yes	300	Mainline Stoppage	Flush mainline to remove stoppage		unk
11/9/2003	720 Edison	MWSD	On to ground	No	10	Roots in Mainline 280'	Flushed mainline 280"		roots

Attachment 2
SSOs Reported by SAM
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Date	Location Of Overflow	District/ Owner	Receiving Waters	Into Waterway ?	VolumeOf Overflow	Description Of Event	Description Of Response	AdditionalComments	Cause
11/8/2003	839 Columbus	GSD	On to ground	No	100	Roots/Mainline	Hose down area		roots
9/28/2003	Filbert Myrtle	HMB	On to ground	No	10	Roots, Grease, and rags	Flushed mainline 750'		comb
9/22/2003	466 El Granada Boulevard	GSD	On to ground	No	15	Roots in service at mainline	Flushed to clear	Copy to GSD	roots
9/2/2003	471 El Granada Boulevard	GSD	On to ground	No	500	Mainline Plug	Flushed the mainline		unk
9/1/2003	Main Street, Montara	MWSD	On to ground	No	1,000-2,000	Manhole overflow due to roots in main line. Wastewater escaped system and ran into open ditch storm drain. Storm drain went to Montara State Beach where wastewater soaked into sand at the end of drain area (about 50 yards from water's edge)...	Used different heads on flusher truck trying to clear blockage from both ends of main line. Finally got through with root saw to clear stoppage.		roots
8/13/2003	1191 Cedar	MWSD	On to ground	No	500	Heavy grease accumulation	roots/flush heavy greases overflow from c/o in front yard		grease
8/10/2003	612 Magnolia	HMB	On to ground	No	100	Grease rags causing under house flooding	root sawed line to remove grease rags		comb
8/2/2003	475 Virginia Avenue	MWSD	On to ground	No	50	Flush Main Line	Washed down back into manhole		unk
6/14/2003	Cypress	MWSD	On to ground	No	75	Roots	Flushed Main Line 40' Roots		roots
6/6/2003	150 Winkie Way, Moss Beach	MWSD	On to ground	No	10	Main line block probably roots and drop line in manhole	Flushed main and broke plug		roots
6/5/2003	1035 Tamarand	MWSD	On to ground	No	20	Roots	Flushed main line		roots
6/5/2003	223 Palma Street	GSD	On to ground	No	5	Paper	Snaked / Cleaned out		debris
6/1/2003	445 Oak Ave, Half Moon Bay	HMB	on to ground and Pilarcitos Creek	Yes	9,000+	Grease and debris blockage around B-132A caused an overflow from manhole B2-123 onto surrounding field and Pilarcitos Creek. Note: This line was flushed (maintained) approximately two weeks ago.	Relieved stoppage with hydro flusher.		grease
5/31/2003	178 Wienke Way, Moss Beach	MWSD	On to ground	No	3	Main Line plugged (grease)	Flushed main line and broke plug		grease
5/30/2003	604 Grove Street	HMB	On to ground	No	5	Main line plug (lot of grease)	Flushed main line and broke plug		grease

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SSOs Reported by SAM
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Date	Location Of Overflow	District/ Owner	Receiving Waters	Into Waterway ?	VolumeOf Overflow	Description Of Event	Description Of Response	AdditionalComments	Cause
5/20/2003	807 Mill Street	HMB	On to ground	No	40	Mainline Plug	Flush Mainline and broke the plug		unk
4/23/2003	345 Ave Cabrillo	GSD	On to ground	No	10	Lateral and or Main Fail	Flushed the mainline and the lateral		pipe
4/20/2003	324 Main Street	HMB	Into Home	No	3,232	Line Collapse causing blockage at Mill & Church	Arrive on scene Fire and Police were already there. Found blockage ASAP and flushed with jetter to clear blockage	Sewage backed up into lower room at 324 Main. Tenant contacted Ideal clean up Co. to clean effected area. Also took pictures of effected area. Line was last cleaned in Feb 2002. No problem was apparent at that time.	pipe
4/19/2003	650 Isabella	GSD	On to ground	No	10	Paper-roots	Flushed mainline 100'		comb
3/21/2003	Buena Vista	MWSD	On to ground	No	80	Roots in main line	Flushed		roots
3/11/2003	2205 Carlos Street	MWSD	On to ground	No	20	County knocked off manhole, dropping in debris	Flushed main multiple times then realized the way this manhole ties into main line in not at all right	This manhole should be moved over so it ties into the main line correctly	debris
3/9/2003	455 El Granada Boulevard	GSD	On to ground	No	10	unknown	flush line to make sure clear, plug has broken itself		unk
2/27/2003	Princeton PS Princeton and WestPoint	SAM	Pacific Ocean	Yes	5,000	Pump station failure. Investigation revealed a bad local start/stop switch.	Restart pumps and replace failed start/stop switch		equipment failure
2/18/2003	Cabrillo	GSD	On to ground	No	20	Mainline plug	Flushed the mainline to clear the plug		unk
2/17/2003	960 Wave Avenue	MWSD	On to ground	No	10	Roots at main line	Flushed main line and pulled lot of roots		roots
2/15/2003	Chart House Lift Station	MWSD	Pacific Ocean	Yes	10,000-15,000	Control circuit tripped. No alarm received.	Reset circuit, pumped down station to halt overflow.		equipment failure
2/4/2003	Manhole @ Fairway Drive	HMB	Water Hazard/Pond	Yes	500	Mainline stoppage, grease	Hydro-flushed mainline		grease
1/26/2003	170 & 174 Wienke Way, Moss Beach	MWSD	Pacific Ocean via storm drain	Yes	500	Main line blockage due to roots and grease	Flushed main to clear blockage		comb
1/18/2003	265 Francisco	GSD	On to ground	No	10	Flushed to clear roots	No solids, rinsed grass		roots
1/11/2003	618 Alsace Lorraine	HMB	On to ground	No	10	Possible flat line	Picked up solids, Rinsed Are		pipe
12/19/2002	2002 Avignon Place	GSD	Into storm drain	Yes	50	Manhole Overflowing	None - No Debris		unk
12/19/2002	First/Grove	HMB	Into storm drain	Yes	500	Heavy rain/local flooding, main lines full	Check manholes down stream for problems		capacity

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SSOs Reported by SAM
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Date	Location Of Overflow	District/ Owner	Receiving Waters	Into Waterway ?	VolumeOf Overflow	Description Of Event	Description Of Response	AdditionalComments	Cause
12/19/2002	Portola PS Magellan/Mirada	GSD	Pacific Ocean	Yes	5000-	Heavy rain. Portola Pump Station rapidly overwhelmed due to erratic pump controller while on generator power.	Pump down station in manual mode, open Montara diversion tank and rush in programmer to trouble shoot and repair controller code. Tested updated code multiple times (on generator), working well.		equipment failure
12/20/2002	Seal Cove 4 146 La Grade	MWSD	On to ground	No	100	Power failure, when PG&E restored power the controller in SC#4 did not reset and the station was overwhelmed by SC#3 pumping into it. The sewage was then directed into 146 Grand and the manhole across the street from the house	] Arrived and reset SC#4 to get it pumping again		equipment failure
12/14/2002	Ocean Colony PS Miramonte Point Road	HMB	Golf Course Pond and Pacific Ocean	Yes	1,000-10,000	Power loss, due to generator trip, at local lift station (Ocean Colony) resulted in no sewage pumping. Area believed to have experienced rapid back and forth PG&E failures. Generator has worked well since.	Did not witness any overflow in progress, but did see debris indicative of an overflow.		equipment failure
12/9/2002	416 Grove Street	HMB	On to ground	No	30	Flushed Mainline	Wash down Backyard Area		unk
11/24/2002	408 Casa Del Mar	HMB	On to ground	No	5	Offset/Paper	Snake Mainline 40"		debris
10/29/2002	515 Paloma Ave	GSD	On to ground	No	20	Mainline stoppage, dirt	Flushed mainline to relieve stoppage		debris
10/21/2002	Colony Club Golf Course	HMB	Pond near manhole	Yes	500	Manhole was overflowing into pond	Flushed mainline to clear blockage, grease was cause of blockage.		unk
9/3/2002	431 The Alameda	GSD	On to ground	No	20	Mainline Stoppage	Flushed mainline and lateral		unk
8/20/2002	1 Terrace Ave	MWSD	On to ground	No	50	Mainline stoppage	Flushed mainline		unk
8/15/2002	320 14th Street	MWSD	On to ground	No	20	Mainline stoppage	Hydro-flushed mainline		unk
8/13/2002	1 Terrace	MWSD			30				unk
7/2/2002	180 Los Banos	GSD	On to ground	No	10	Mainline stoppage, roots that looked like they were cut upstream and let down pipe	removed roots		roots

Attachment 2
SSOs Reported by SAM
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Date	Location Of Overflow	District/ Owner	Receiving Waters	Into Waterway ?	VolumeOf Overflow	Description Of Event	Description Of Response	AdditionalComments	Cause
7/2/2002	Pilarcitos	HMB	Into storm drain (not into waterway)	Yes	150	Heavy Grease Accumulation	Root sawed grease to clear stoppage	over 100 gals in storm drain did not make water way due to dry conditions.	grease
7/1/2002	570 Vermont	MWSD	On to ground	No	50	Mainline stoppage, grease	Relieve stoppage with flusher truck		grease
6/14/2002	719 Johston Street between 725 and 719.	HMB	On to ground	No	10	Mainline Plug	Flushed mainline		unk
6/13/2002	523 Ave Alhambra	GSD	Into storm drain	Yes	50	Mainline stoppage, grease and grit	Hydro-flushed mainline	Input on 10/8/02. Paper report indicated that 50 gallons went into storm drain while responders were present and 50 gallons went onto the ground. Discussed with John Caughlin to determine if this should have been a reportable. If so, will report to RWQCB.	grease
5/14/2002	330 Sonora Ave	GSD	On to ground	No	50	Construction to mainline	Called Mike - With Woods Construction		const
4/28/2002	918 Columbus	GSD	On to ground	No	20	Root Stoppage	Root sawed line		roots
4/20/2002	213 Miramontes Ave	HMB	Into storm drain	Yes	500	Manhole overflow just below B1-121. Steady stream from manhole down both sides of the street and into the storm drains at Miramontes/ Valdez	Flushed line and broke through plug. Cleaned line		unk
4/19/2002	424 St. Joseph	HMB	Into storm drain	Yes	30	Manhole overflow, grease	Flushed main		grease
4/18/2002	Bloom Lane	HMB			50	Manhole overflow	Flushed main		unk
4/15/2002	Main	HMB			Unknown	Manhole overflow	Flushed main line		unk
4/14/2002	445 Oak Ave	HMB	Pillarcitos Creek	Yes	9,000+	Grease & Debris blockage around B3 - 132A caused an overflow from manhole B2-123 onto surrounding field and Pilarcitos Creek	Root sawed through grease plug using manhole through plug and past manhole. The above line was then flushed at high pressure using flusher truck		comb
4/13/2002	435 El Granada Blvd	GSD			100	Irrigation hose (5') and stick blocking line	Arrived with flusher truck, broke plug and removed obstruction with fork		debris
4/1/2002	751 1st Street	HMB			30	Main line stoppage	Root sawed main		unk
3/29/2002	676 Sierra	MWSD			50	Mainline stoppage	Flushed main		unk

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SSOs Reported by SAM
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Date	Location Of Overflow	District/ Owner	Receiving Waters	Into Waterway ?	VolumeOf Overflow	Description Of Event	Description Of Response	AdditionalComments	Cause
3/25/2002	11th Street	MWSD			250	Main line stoppage, roots	Flushed main		roots
3/22/2002	Grand View Blvd.	HMB	On to ground	No	100	Manhole overflow, grease	Flushed manhole		grease
3/18/2002	1007 San Carlos	GSD			100	Lateral stoppage	Power snaked lateral, flushed main		lateral
3/5/2002	1123 Columbus	GSD			100	Main line stoppage, roots.	Flushed main		roots
2/28/2002	846 Columbus	GSD	On to ground	No	400	Lateral stoppage	Power snaked lateral		lateral
2/28/2002	Hwy 1 between 6th & 7th Streets	MWSD	On to ground	No	500	Main line stoppage	Flushed main		unk
2/27/2002	525 Kelly Avenue	HMB			25	Main line stoppage	Flushed main, grease		unk
2/23/2002	SW End of Cedar Street @ 1390	MWSD	Echo Creek	Yes	250	Grease accumulation cause by pump station operating at high level backing flow in to mainline causing grease and solids to block flow in mainline. Maintenance crew found large quantities of grit in wetwell.	Flushed to clear. Notified mechanic to address problem of wetwell operating at high level.		grease
2/26/2002	Chart House Lift Station	MWSD	On to ground, into creek	Yes	100,000	Staff discovered the Charthouse lift station over flowing. The station was found to have both motor starters tripped and had been overflowing since about 17:00 the evening before (2/19/2002) ***** SEE WRITTEN OVER FLOW REPORT - CHART HOUSE LIFT STATION	Immediately restart pumps (see description of event)		equipment failure
2/16/2002	411 Bayhill Road	HMB	Into storm drain	Yes	80	Manhole overflow, grease, defective trough	Flushed manhole		grease
2/8/2002	534 Grove	HMB			10	Main line stoppage	Flushed main		unk
1/18/2002	880 Lincoln	MWSD			25	Main line stoppage, plug	Flushed main		unk
12/18/2001	746 The Alameda	GSD	On to ground	No	20	Main line stoppage, roots and grease.	Power snaked lateral and flushed main.		comb
12/2/2001	Montara Pump Station, etc.	SAM	Pacific Ocean	Yes	Unknown	Rain related pump station overflow. Station pumped at full capacity and did well throughout the event	Monitored system for maximum through put		capacity

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SSOs Reported by SAM
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Date	Location Of Overflow	District/ Owner	Receiving Waters	Into Waterway ?	VolumeOf Overflow	Description Of Event	Description Of Response	AdditionalComments	Cause
12/1/2001	Montara Pump Station, etc.	SAM	Pacific Ocean	Yes	Unknown	Rain related pump station overflow. Station pumped at full capacity and did well throughout the event	Monitored system for maximum throughput		capacity
11/28/2001	410 Valencia	GSD	On to ground	No	10	Mainline stoppage	Snaked lateral and flushed mainline		unk
11/1/2001	747 The Alameda	GSD	Into storm drain	Yes	50	Mainline Stoppage	Flushed mainline to dislodge stoppage		unk
10/22/2001	416 Grove St	HMB	On to ground	No	4,000 (1,000net)	Main line blockage causing service line to overflow into backyards	Flushed main line to clear blockage	Bonnie also responded to location. 2000 gallons picked up with slurry trailer, 1000 pack to system from channeling, 1000 soaked into ground.	unk
10/3/2001	200 block of Miramontes	HMB	Into storm drain	Yes	200	Mainline overflow, grease	Root sawed mainline to dislodge stoppage		grease
9/11/2001	301 Grove St	HMB	On to ground	No	20	Mainline stoppage	Flushed mainline		unk
9/11/2001	552 7th st	MWSD	On to ground	No	50	Mainline stoppage, Roots & Grease	Flushed mainline to dislodge stoppage		comb
9/10/2001	411 Bayhill Rd	HMB	On to ground	No	400	Mainline stoppage, grease	flushed to clear		grease
8/28/2001	Pilarcitos, North of Kehoe	HMB	Into storm drain	Yes	3,000	Mainline stoppage due to grease and flow metering equipment which fell into pipe/manhole	Dislodge stoppage and remove fallen equipment		debris
8/20/2001	557 Isabella	GSD	On to ground	No	25	Mainline stoppage, Roots	Flushed Mainline to dislodge stoppage		roots
8/18/2001	Pilarcitos, South of Kehoe	HMB	Storm drain/Ground	Yes	1,000	Sewer stoppage in difficult access area	Flush lines from opposite directions to dislodge stoppage	Thought to be less than 1000 gallons but later decided that it may be marginal and to report.	unk
8/12/2001	154 Madrona	GSD	On to ground	No	50	Mainline or lateral stoppage (unsure)	Flushed mainline and snaked lateral		unk
7/30/2001	462 Portola	GSD	On to ground	No	800	Mainline stoppage, Roots	Flushed mainline to dislodge stoppage		roots
7/18/2001	San Pablo PS	GSD	On to ground	No	3,000	Force main cracked at joint	Used vactor trailer to capture all leakage until vactor truck arrived to enable lift station shut down. Captured roughly 1500 gallons of total spill		pipe
6/22/2001	2936 Alameda	GSD	On to ground	No	250	Mainline stoppage, grease	Flushed mainline		grease
6/16/2001	Nevada	MWSD	On to ground	No	50	Mainline stoppage, grease	Flushed mainline to dislodge stoppage		grease
6/11/2001		MWSD				lateral plug/mainline partial plug	flushed mainline 300' - grease, septic sewage	mainline appears to have a belly and grease problem.	unk

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SSOs Reported by SAM
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Date	Location Of Overflow	District/ Owner	Receiving Waters	Into Waterway ?	VolumeOf Overflow	Description Of Event	Description Of Response	AdditionalComments	Cause
6/9/2001	Pillar Point RV Park	GSD		No		Grease caused SSO	Root saw mainline. Police, Fire, Harbor Dist and Fish & Game were on site. Environmental Health came out and said it looked ok.		grease
5/19/2001	Francis State Beach	HMB				Outfall relief valve foaming over	hose down area		equipment failure
4/29/2001	273 6th Street	MWSD					flushed main line	flushed main - no problem.	unk
4/18/2001	#1 Fairway area of Golf course	HMB	On to ground	No	25	Mainline stoppage	Upon arrival mainline was flowing fine. Plug cleared itself.		unk
3/27/2001	250 Grove St	HMB	drainage ditch	Yes	2,000	Lateral overflow backyard. Plugged mainline (roots/grease)	flushed mainline		comb
3/8/2001	18 Arnold Way	HMB	On to ground	No					unk
3/4/2001	Ocean Colony Lift Station, Fairway Drive, HMB	HMB	Pacific Ocean	Yes	3,700	Pumps at lift station tripped out on overload and alarm company failed to notify personnel on call when alarm occurred.	Reset station and pumped station down, checked for solids and paper in area of overflow.		equipment failure
3/1/2001	Valdez @ Railroad	HMB	Into storm drain	Yes	300	Mainline stoppage due to stick in manhole	Relieve stoppage		debris
2/19/2001	546 Isabella	GSD	Into storm drain	Yes	2,200	Mainline plugged with roots overflowed from c/o. Running downhill to storm drain.	Root sawed to clear stoppage		roots
1/29/2001	120 San Pedro	GSD	On to ground	No	50	Water bubbling out of cleanout in backyard	Flushed mainline		unk
1/20/2001	736 Pilarcitos	HMB	On to ground	No	1,000	main line blockage, grease	flushed main line eto clear blockage		grease
1/13/2001	466 El Granada Blvd	GSD	On to ground	No	800	Mainline stoppage, Roots	Rootsaw and flush mainline		roots
1/6/2001	521 A The Alemeda	GSD	On to ground	No	Unknown	Mainline stoppage - Roots	Dislodge stoppage with flusher truck		roots
1/6/2001	Plaza Alhambra/Avenue Alhambra	GSD	Into storm drain	Yes	100	Rush of water from higher manhole that was plugged dislodged some grease and roots and temporarily plugged line.	Cleaned up area, picked up solids and washed area down. Broke up grease and pulled out roots.		grease
12/27/2000	Greenbriar	HMB	Pond	Yes	2,000	Mainline stoppage	Flushed to dislodge stoppage		unk
12/23/2000	270 Francisco	GSD	On to ground	No	10	Mainline stoppage - Roots	Snake Lateral sewer to dislodge stoppage		roots
12/1/2000	522 Columbus	GSD	On to ground	No	200	Cleanout overflow	Root sawed mainline		unk

Attachment 3
Pump Stations Characteristics

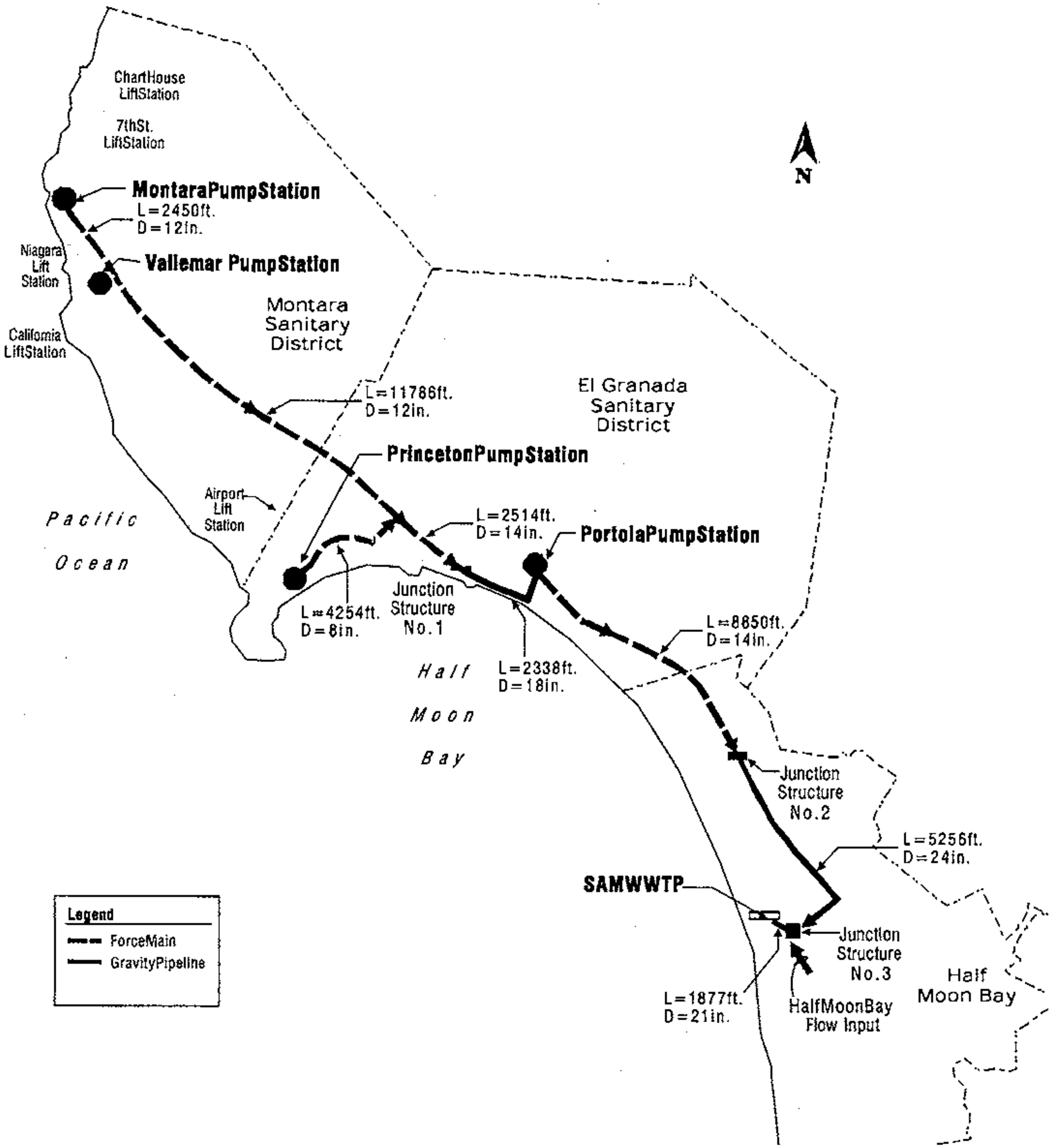
Attachment 3

Pump Station Details

Station	Owner	Storage Time	No. Pumps	Standby Power	Notes
Bell Moon Lift Station	HMB		2	No	Serves carwash, businesses, 1 house
Ocean Colony Lift Station	HMB		2	Yes	Has 2 wetwells
Pelican Point Lift Station	HMB		2	Yes	Serves mobile home and trailer parks
San Pablo Lift Station	GSD		2	Yes	
Airport Lift Station	MWSD	3 hours	2	Yes	
California Lift Station	MWSD	Very limited	2	Temporary	
Chart House Lift Station	MWSD	Has overflow tank	2	Yes	
Date Harte Lift Station	MWSD	Limited	2	Yes	
Distillery Lift Station	MWSD		2	No	Serves restaurant and 2 houses
Fifth Street Lift Station	MWSD	24 hours	2	No	Serves 3 houses
Niagara Lift Station	MWSD		2	Yes	Standby power from Montara PS
Seal Cove 1 Lift Station	MWSD		2	No	
Seal Cove 2 Lift Station	MWSD		2	No	
Seal Cove 3 Lift Station	MWSD		2	No	
Seal Cove 4 Lift Station	MWSD		2	No	
Seventh Street Lift Station	MWSD		2	No	Serves 6 houses
Vallemar Lift Station	MWSD	Very limited	2	Yes	
Montara Pump Station	SAM	Has overflow tank	2	Yes	
Portola Pump Station	SAM		4	Yes	Has surge tank
Princeton Pump Station	SAM		2	Yes	

Information from SAM's "Operations Manual for the Wastewater Pump Stations and Storage System"

Attachment 4
Map Showing Intertie Pipeline



SEWER AUTHORITYMID-COASTSIDE(SAM)

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Submarine discharge of nutrient-enriched fresh groundwater at Stinson Beach, California is enhanced during neap tides

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Abstract

The influence of fortnightly spring–neap tidal variability on submarine discharge of fresh and saline groundwater was examined at Stinson Beach, California. Stinson Beach is a residential community that utilizes on-site systems for wastewater disposal. Fresh, shallow groundwater at the site contains high concentrations of nutrients (dissolved inorganic nitrogen [DIN], soluble reactive phosphate [SRP], and silicate) and human fecal bacteria. A groundwater-derived freshening and nutrification of the surf zone during neap tides was observed, followed by a 4-d increase in chlorophyll *a* concentrations. Analytical models and a freshwater budget in the surf zone were used to estimate the saline and fresh discharge of submarine groundwater. We estimate fresh groundwater discharge between 1.2 and 4.7 L min^{-1} m^{-1} shoreline during neap tides compared with 0.1 and 0.5 L min^{-1} m^{-1} during spring tides. This compares with 15.9 and 22.0 L min^{-1} m^{-1} saline groundwater discharge (forced by waves and tides) during neap and spring tides, respectively. Despite the smaller total (fresh + saline) flux of groundwater during neap compared with spring tides, the larger fresh discharge component during neap tides raises surf zone silicate, DIN, and SRP by 14%, 35%, and 27%, respectively, relative to spring tides. This observed fortnightly pulsing of fresh groundwater-derived nutrients was consistent with seaward hydraulic gradients across the fresh part of the beach aquifer, which varied due to aquifer overheight near the beach face. Darcy–Dupuit estimates of seaward fresh groundwater flow in this area agreed well with the fresh discharge results of the mass balance.

Submarine groundwater discharge (SGD), defined as fresh and saline groundwaters discharging along the coastline at the land–sea interface (Burnett et al. 2006), can contribute nutrients, metals, pollutants, and freshwater to the coastal environment (Johannes 1980; Bone et al. 2007). Driving forces of SGD include meteoric hydraulic head, tide and wave pumping, seasonal evapotranspiration cycles (Michael et al. 2005), and variations in groundwater density. Additional factors influencing the timing and magnitude of SGD include regional geology, climate, and human activities along the coast such as groundwater pumping and artificial recharge. The importance of combinations of factors controlling SGD vary from site to site, and site-specific studies are often required to fully understand SGD in a given region. Although a large body of literature has documented the existence and variability of SGD along the world's coastlines (Taniguchi et al. 2002), we are still working to understand the many factors that influence and modulate discharge rates.

Human activities along coasts can influence the quality of SGD (Kroeger et al. 2006). Nutrients emanating from fertilizers applied to residential lawns or agricultural fields may percolate through the vadose zone and increase concentrations in surficial aquifers (Valiela et al. 1992). In some coastal regions, households utilize cesspools or septic systems with leach fields for sewage disposal. These practices can recharge surficial aquifers with freshwater contaminated with pathogens, pharmaceuticals, nitrogen, and phosphorous (Robertson et al. 1991; Scandura and Sobsey 1997; Swartz et al. 2006). Several studies have investigated SGD in areas where on-site wastewater treatment is prevalent and have shown that SGD can contribute substantial nutrient loads to coastal waters (Giblin and Gaines 1990; Lapointe et al. 1990; Weiskel and Howes 1991). To protect human and ecosystem health, it remains important to continually improve our understanding of the magnitude and timing of SGD in areas where septic systems are used for wastewater disposal.

A limited number of studies have documented the importance of spring–neap tides on total SGD (Kim and Hwang 2002; Taniguchi 2002; Boehm et al. 2004) but not on the fresh component of SGD specifically. A single study (Campbell and Bate 1999) has examined fortnightly variations in fresh SGD. The present study explores the influence of the fortnightly spring–neap tidal cycle on submarine discharge of fresh groundwater from an unconfined, septic effluent-affected coastal aquifer in

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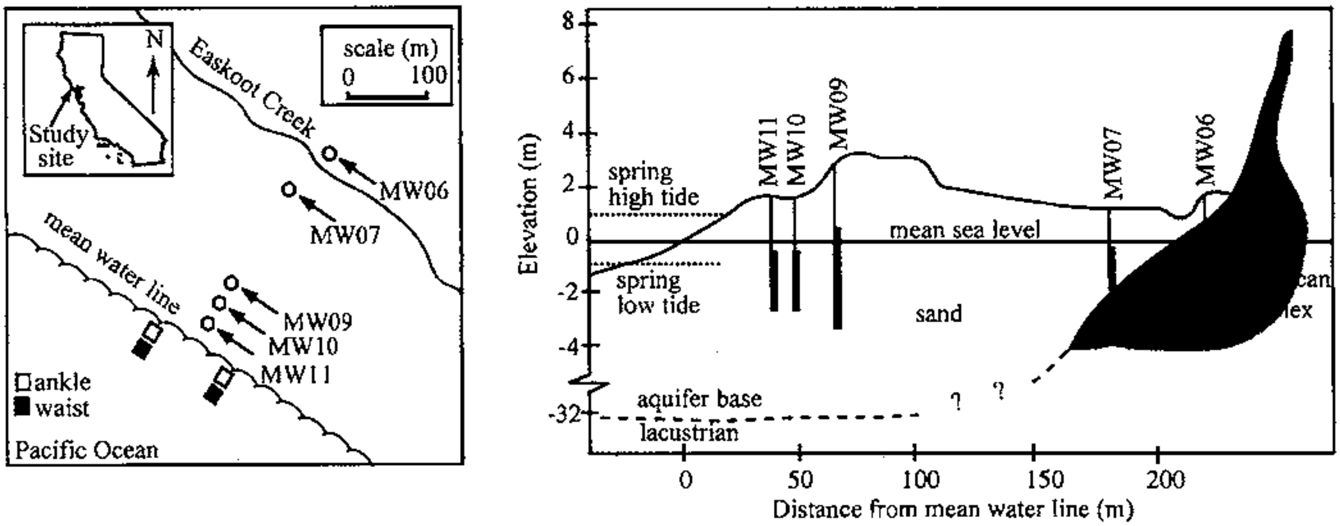

Fig. 1. Map of study area (left) and regional hydrogeology (right). Question marks in right panel indicate that contacts between geologic units in this region are uncertain.

Central California. Using a multifaceted approach that couples analytical models, hydraulic head measurements, and a nearshore freshwater budget, we document a neap tide pulsing of fresh, nutrient-enriched SGD. We link this enhanced neap tide discharge to fortnightly changes in seaward hydraulic gradient across the aquifer induced by aquifer overheight—the buildup or mounding of the water table near the land–sea interface as a result of tidal variation, wave setup, and wave run-up (Nielsen 1990; Turner et al. 1997; Horn 2006)—near the beach face. Using field data and a controlled mesocosm experiment, we explore the potential role of nutrient-enriched groundwater in causing increases of chlorophyll *a* (Chl *a*) in the coastal ocean at the site.

Methods and materials

Study site—Fieldwork was conducted from 14 through 28 July 2006 to characterize SGD from the unconfined aquifer over a spring–neap cycle at Stinson Beach, a small residential community 30 km north of San Francisco, California (37°53′58.387″N, 122°38′45.384″W, Fig. 1). The beach is an open-ocean, southwest-facing, reflective beach with mixed semidiurnal tides, a spring tide range of 2.4 m, typical breaker heights of 0.5–1.5 m, and a high energy surf zone. During the study, neap tide (17 July) preceded the spring tide (24 July).

The climate is Mediterranean with 60 to 120 cm of annual average rainfall occurring predominately between October and April (SBCWD 1998). During the dry season, Bolinas Lagoon (37°54′24.811″N, 122°40′54.732″W), a tidally influenced lagoon, and Webb Creek (37°53′7.332″N, 122°37′43.392″W), a nearby freshwater stream, are the only potential sources of fresh surface water to the nearshore marine environment within 7 km of Stinson Beach. There had been no precipitation in the watershed for approximately 2 months at the onset of the study, and no rainfall occurred during the study (data not shown). Easkoot Creek, a seasonal groundwater-fed creek, runs parallel to the shoreline through the field site approximately 200 m from the shoreline (Fig. 1). The creek discharges to Bolinas Lagoon and contains very little freshwater during the dry season.

Human development occupies 5% of the 29.3 km^2 Stinson Beach watershed and is primarily contained within 100 m of the coastline (geographic information system analysis not shown). Households use on-site septic systems and holding tanks exclusively for wastewater disposal. The areal density of standard gravity leach fields in the study area is approximately one leach field per 650 m^2 (SBCWD 1998).

The unconfined aquifer in the experimental area is composed primarily of beach and dune sands (Fig. 1, SBCWD 1998). At the beachhead, the sands are underlain by lacustrian clay at a depth of approximately 32 m below mean sea level (MSL) (Bergquist 1978). The unit overlies the Franciscan Complex, an assemblage of highly fractured sandstone, limestone, and shale (SBCWD 1998).

In systems with a high-energy surf zone, such as Stinson Beach, direct measurement of discharge with seepage meters is not possible (Libelo and MacIntyre 1994; Burnett et al. 2006). Breaking waves dislodge seepage meters and strong currents can induce flow through the seabed when passing over the objects (Huettel et al. 1996). This presents a unique challenge in the measurement of SGD in high-surf areas, and may explain the paucity of studies conducted on high-energy, open ocean coastlines in California and elsewhere. At Stinson Beach, we estimate SGD by combining three indirect methods: measurements of hydraulic head and Darcy–Dupuit calculations, a freshwater budget in the surf zone, and analytical models.

Hydraulic head measurements—Three permanent long-screen monitoring wells (MW06, MW07, and MW09) and two temporary piezometers (MW10 and MW11) were installed into the beach to create a cross-shore array (Fig. 1). Well construction details are shown in Table 1.

Table 1. Well construction details for the wells used in the study. Elevations are given in meters above mean sea level. Distances are given in meters from the mean water line.

Well ID	Diameter (cm)	Distance from mean water line (m)	Top of casing elevation (m)	Top of screen elevation (m)	Bottom of screen elevation (m)
MW06	10.16	223	1.46	−3.11	−4.63
MW07	10.16	178	1.36	−0.16	−1.69
MW09	10.16	70	3.10	0.05	−3.00
MW10	3.81	48	2.13	−0.92	−1.38
MW11	3.81	36	2.07	−1.13	−1.58

Beach topography and well elevations were surveyed relative to MSL. Measurements of hydraulic head were recorded in each well at 1-min intervals using pressure transducers (Solinst). The <1% of head measurements known to be misrepresentative of true aquifer conditions (hydraulic recovery after well installation and sampling) were removed and estimated by interpolation. All head measurements presented herein are presented as equivalent freshwater head. In the fresh part of the aquifer where hydraulic gradients are shallow (MW06 to MW09), the Dupuit assumptions are made. Namely, we assume that the hydraulic gradient is equal to the slope of the water table, and streamlines are horizontal and equipotential lines are vertical (Fetter 2001). Fortnightly average hydraulic heads at each well were calculated from head measurements collected during the entire experiment. Neap- and spring-tide head measurements were calculated by averaging measurements taken during the lunar day following the quarter (17 July) and new (24 July) moons, respectively.

Water sampling—At the low-low and high-high tide approximately every other day (n = 42 and 32, respectively), surf zone samples were collected at ankle and waist depths (0.2 and 0.7 m, respectively) along two cross-shore transects extending from the water line out into the surf zone adjacent to the well network (Fig. 1). Transects were approximately 100 m apart in the alongshore direction. At low-low tides only, the groundwater immediately adjacent to the water line was characterized by sampling from shallow pits dug into the beach approximately 10 m back from the water line (n = 19). In addition, subaerial seepage faces were sampled when they developed at the lowest tides (n = 17). Groundwater was sampled from the five wells approximately every 7 d ($2 \leq n \leq 5$ for each well). Surface offshore ocean water samples were obtained 180 m, 870 m, and 1,615 m from the shore in a cross-shore transect from our sampling site on the days of the third-quarter and new moons (n = 2 for each offshore location). The ebb flow from Bolinas Lagoon was sampled approximately every 4 d (n = 4). In all cases, clean, triple-rinsed 20-liter collapsible low-density polyethylene containers were used for water collection. A total of 100 liters for ocean and lagoon samples and 20–80 liters for groundwater samples were composited. A 1-liter subsample from large-volume samples was collected in clean triple-rinsed bottles and used for all chemical and biological analyses.

Tide elevation measurements were obtained from a National Oceanic and Atmospheric Administration tide gage at Point Reyes, approximately 30 km from Stinson Beach (http://tidesandcurrents.noaa.gov, Sta. ID 9415020, 37°59′48.12″N, 122°58′30″W). Data were recorded at 6-min intervals. Daily tidal range was calculated from daily maxima and minima.

Sand analysis for hydraulic conductivity (K_h) determination—A 2-m continuous core was collected near MW09, homogenized, and analyzed for grain size distribution using American Society for Testing and Materials standard C136. Hydraulic conductivity (K_h) was estimated from grain size distribution using the method of Hazen (1911).

Salinity, dissolved oxygen, and nutrient analysis—Salinity and dissolved oxygen were measured in situ using a handheld probe (Hydrolab). Salinity is reported according to the unitless Practical Salinity Scale and is accurate to ±0.01. A 30-mL aliquot of each sample was filtered with 0.45-μm pore size filter and stored at −20°C for nutrient analyses. The concentrations of soluble reactive phosphate (SRP), silicate, nitrate, nitrite, and ammonia were measured by standard methods with a nutrient autoanalyzer (Lachat QuikChem 8000). Samples were diluted as necessary to be within the machine's detection limits for each nutrient. Concentrations reported herein reflect both the required sample dilution and the precision of the analytical method. Dissolved inorganic nitrogen (DIN) was determined by adding molar concentrations of nitrogen species. Five percent of nutrient samples were analyzed in duplicate.

Chlorophyll a analysis—Waist-deep seawater samples were analyzed in duplicate for chlorophyll *a* using a modified version of Environmental Protection Agency (EPA) method 445.0 (Arar and Collins 1997). Samples were filtered immediately after collection through Whatman GF/F glass filters and stored at −80°C. Samples were analyzed approximately 7 months after collection, longer than the EPA-suggested holding time of 3 weeks. We assume that negative effects related to holding time are distributed equally across all samples, allowing intrastudy comparison. During analysis, filters were added to 10 mL of 90% acetone in water, shaken vigorously for 60 s, and steeped at 4°C for 18 to 24 h. Samples were then centrifuged and the supernatant was analyzed on a fluorometer (Turner Designs), acidified, and reanalyzed, as specified in the EPA method. The precision, on the basis of analysis of duplicates, is 5%.

Mesocosm experiments—Experiments were conducted to assess whether the addition of fresh groundwater to seawater promoted increases in Chl *a*. Stinson Beach seawater, collected from within the surf zone, was filtered through a 250-μm sieve to remove large zooplankton grazers (Pederson and Borum 1996). Groundwater from MW09 was 0.2 μm filtered to remove particulates. Filtered groundwater was added to sieved seawater to final concentrations (v/v) of 0%, 4%, and 8%. Mesocosms were run in duplicate in 3.5-liter clear plastic bottles. Bottles were spaced evenly under constant fluorescent light with illuminance 200 lm m^{-2} and incubated at 15°C for 2 d. Samples were collected and analyzed every 4 to 8 h via EPA method 445.0 for in vivo fluorescence. A subset of samples was also analyzed for in vitro Chl *a* by the same method. A best-fit curve was used to estimate the concentrations of Chl *a* from in vivo fluorescence for those samples for which only fluorescence had been measured. No more than 10% of bottle volumes was removed over the course of the experiment. Data collected on the final day of the experiment were averaged for determining final Chl *a* concentrations.

Fecal indicator bacteria analysis—Water samples were analyzed for fecal indicator bacteria to determine the degree of contamination by human waste. Fifty milliliters of each sample were collected in a sterile container, and immediately stored on ice. *Escherichia coli* (EC) and enterococci (ENT) were quantified from 10 mL of water diluted with 90 mL of Butterfield buffer (Weber Scientific) using Colilert-24 and Enterolert (IDEXX), respectively, within 6 h of collection. Tests were implemented in a 97-well format following manufacturer's direction and allowed for the detection of EC and ENT concentrations between 10 and 24,192 most probable number (MPN) (100 mL)$^{-1}$. Note that the units MPN (100 mL)$^{-1}$ are the standard units for reporting indicator bacteria concentrations in water. No duplicate samples were analyzed.

*Enterococcal surface protein (*esp*) gene analysis*—A subset of ENT-positive samples was analyzed for the *esp* gene, a putative human-specific marker in ENT (Scott et al. 2005). Media from positive IDEXX wells was removed using a 21 1/2 gauge needle and syringe, and pooled for each sample. One milliliter of pooled media was enriched in tryptic soy broth for 4 to 6 h at 41°C. DNAs were extracted from a 1-mL aliquot of enrichment media using QIAamp DNA Mini Kit (Qiagen). Polymerase chain reactions (PCRs) containing 3 μL of template were run using the conditions, primers, and buffers described by Scott et al. (2005), except we used Platinum Taq (Invitrogen). PCR products were run on a 1.5% agarose gel and stained with SYBR Gold (Invitrogen). Positive and negative PCR and extraction controls were run in conjunction with unknowns.

Data analysis—Pearson correlation coefficients (r_p) between measured parameters were determined using SPSS. Groups of data were compared using Student's *t*-test. Correlations were deemed significant if $p < 0.05$.

Flux calculations—Total SGD (D) can be expressed as $D = D_t + D_w + D_m + D_s + D_d$ (modified from Li et al. 1999) where D_t and D_w represent saline outflow from tidal- and wave-driven circulation of seawater through the beach aquifer, respectively, D_m represents SGD of meteoric and artificially recharged fresh groundwater, D_s represents saline SGD forced by the seasonal recharge–evapotranspiration cycle (Michael et al. 2005), and D_d represents the outflow of density-driven saline waters. We will not consider contributions from D_s or D_d in our estimates for D, and the reasons for and implications of these omissions will be discussed.

The outflow seepage rate driven by wave setup per unit alongshore distance, D_w, can be expressed as follows (Longuet-Higgins 1983):

$$D_w = K_h S_w L \tag{1}$$

where K_h is hydraulic conductivity of the beach aquifer media, S_w is the slope of the wave setup, and L is the surf zone width defined as the distance between the breaker line and the wave run-up line. Expressions for S_w and L can be calculated from the local oceanographic and geologic conditions including breaker height H_b, beach slope S_b, and wave period T_w (Li et al. 1999).

Li et. al. (1999) used Nielsen's solution predicting the height of the water table with time in response to tidal forcing to estimate the tidally driven groundwater outflow seepage rate per alongshore distance (D_t). The resulting discharge rate is tidally averaged, implies quasi-steady-state conditions, and should be viewed as a first-order approximation. Following Nielsen (1990, eq. 31) and Li et. al. (1999),

$$D_t = \frac{n_e A}{\kappa T_t}\exp(-\alpha)(\cos(\alpha) - \sin(\alpha)) + \frac{\sqrt{2} n_e A^2}{s_b T_t}\exp\left(-\sqrt{2}\alpha\right)\cos\left(\sqrt{2}\alpha\right) + \frac{n_e A^2}{s_b T_t} \tag{2a}$$

with

$$\kappa = \sqrt{\frac{n_e \omega}{2 K_h H}} \tag{2b}$$

and

$$\alpha = \frac{\kappa A}{s_b} \tag{2c}$$

In Eq. 2a–c, A corresponds to the tidal amplitude, T_t the tidal period, ω the tidal frequency, n_e the effective porosity of the beach sand, and H the aquifer thickness.

Input parameters required for calculating D_w and D_t at our study site are as follows. Beach slope was calculated from surveyed beach topography (s_b = 0.0378). Tidal amplitude (A) was set to 0.80 m and 1.12 m for neap and spring tides, respectively. The tidal period (T_t = 12.42 h) and frequency (ω = 1.41 × 10^{-4} rad s^{-1}) of the M_2 harmonic were used. During the study, the period of the dominant swell (T_w) was 9.6 s (http://cdip.ucsd.edu, Sta. ID 029). Breaking wave heights (H_b) were approximately constant during the study and estimated to be 0.8 m from observations in the field. Porosity was estimated to be 0.4 by displacement of a known volume of sediment in water in a volumetric flask; all porosity was assumed to be effective porosity (n_e). The hydraulic conductivity (K_h) of the sand was measured in the lab with aquifer material and determined to be 3.85 × 10^{-4} m s^{-1}, as described earlier.

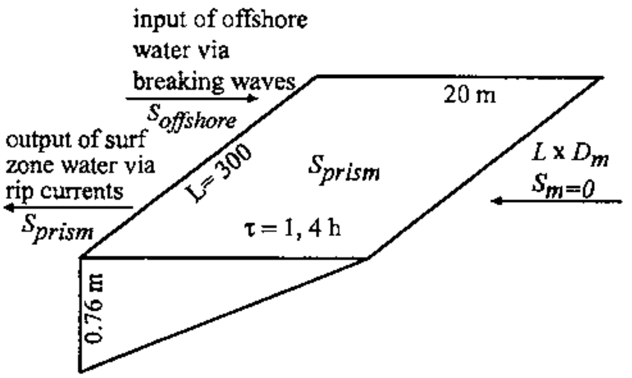

Fig. 2. Surf zone prism used as a control volume for the freshwater budget. Variables are defined in the text.

The unconfined aquifer thickness H was estimated to be 34 m from cores collected in the area, with an aquifer base approximately 32 m below sea level (Bergquist 1978; SBCWD 1998).

A mass balance was applied to the surf zone to calculate D_m at neap and spring tides using salinity as a tracer (Fig. 2). The surf zone adjacent to the well network was treated as a triangular prism with alongshore length (L) 300 m (typical distance between rip currents) and a right triangular cross-shore section of width 20 m (distance from shoreline to just beyond breakers) and offshore depth $20s_b$ (0.76 m). The salinity in the prism (S_{prism}) was determined for neap and spring tides by averaging all surf zone samples collected during the two lunar days before and after the quarter and new moons, respectively (two transects, both ankle and waist measurements, $n = 16$ and $n = 32$ for neap and spring tide, respectively). Although salinity measurements did not extend past 10 m in the offshore direction, surf zones are typically well mixed (Inman et al. 1971), so the calculated average salinity applied to the entire 20-m-wide prism. Water samples collected at 1,615 m offshore on the days of the third-quarter and new moons, which were the most saline and also the furthest from shore, were chosen as the offshore end member salinities ($S_{offshore}$). A salinity of 0 was assigned to the fresh groundwater end member. The following equation was used to estimate D_m per unit length of shoreline:

$$D_m = \frac{(S_{offshore} - S_{prism}) V_{prism}}{S_{offshore} L\tau} \quad (3)$$

where D_m is meteoric water flux in units of volume per time per unit length of beach, τ is the cross-shore residence time of water in the rip cell, L is the length of the shoreline of the prism (a single rip cell), V_{prism} is the volume of the prism, and S_{prism} and $S_{offshore}$ were defined previously. Following Boehm et al. (2004), we estimate the cross-shore residence time of water in a rip cell to be 1 to 4 h. Equation 3 assumes that D_m is small compared with the input of offshore waters into the surf zone via breaking waves (Fig. 2), and thus does not affect the water balance.

Estimation of fresh groundwater discharge across the land–sea interface is complicated by variations in fluid density, the existence of a seepage face, and the effects of tidal pumping. Our monitoring network is not as dense as would be needed for direct, accurate calculation of fresh and saline groundwater flux through the interface using Darcy's law. However, insight into the rate of fresh groundwater flow toward the land–sea interface, and thus the potential variation in freshwater discharge to the sea between neap and spring tides, can be provided by calculating groundwater flow through a landward section of unconfined aquifer using Darcy's law and the Dupuit assumptions (given previously), which are combined in the Dupuit equation (Fetter 2001):

$$Q' = -\frac{1}{2} K_h \left(\frac{h_1^2 - h_2^2}{Y} \right) \quad (4)$$

In Eq. 4, Q' is the flow per unit length of shoreline, K_h has been defined previously, and h_1 and h_2 are the saturated thicknesses at a distance Y apart. Flow was calculated between MW07 and MW09, the two furthest inland monitoring wells in the network installed in the unconfined aquifer, which are 178 and 70 m from the mean water line, respectively. The nature of the boundary between the unconfined aquifer and the highly fractured Franciscan Complex basement rock is uncertain, and for the purpose of this estimate we assume that the lacustrian clay at 32 m below MSL extends underneath the unconfined aquifer through this area, and that groundwater is fresh throughout the section. The flow through the landward part of the aquifer may not be exactly equal to D_m. Rather, since short-period (diurnal) tidal effects on head are small at MW07 and MW09 relative to effects of long-period (fortnightly) tides (data not shown), this flow rate can be thought of as the fresh groundwater entering the tidally pumped zone where density effects and vertical flow become important. It can also be considered a check on the mass balance-based estimates of D_m.

The "potential flux" (F_p) of nutrients to the surf zone via SGD was calculated as follows:

$$F_p = C_{fresh} D_m + C_{sal}(D_t + D_w) \quad (5)$$

where C_{fresh} and C_{sal} represent the end-member constituent concentrations in fresh and saline groundwaters, respectively. C_{fresh} and C_{sal} were estimated with mixing diagrams of salinity vs. nutrient for all groundwater samples (wells, pits, and subaerial seeps, $n = 55$), which were fit with a linear regression. The regression equation was extrapolated to fresh (0) and average offshore marine salinity (32.12) to determine C_{fresh} and C_{sal}, respectively. Multiplying groundwater end-member concentrations by SGD rates, as in Eq. 5, is a common method for estimating nutrient fluxes to the coastal ocean via SGD (Charette et al. 2001; Hwang et al. 2005*b*; Hays and Ullman 2007). However, the method assumes that the nutrient of interest behaves conservatively as it travels through the subsurface from aquifer to sea. In fact, sorption of SRP in groundwater systems is common (Slomp and Van Cappellen 2004) and the potential for nitrification and denitrification in the subterranean estuary has been demonstrated (Santoro et al. 2006, 2008). Therefore, Eq. 5 should be considered a first-order approximation of the true flux of nutrients.

Table 2. Arithmetic means for chemical concentrations and log-transformed bacterial concentrations in MPN $(100\ mL)^{-1}$ for sample groups. Ninety-five percent confidence intervals are given in parentheses. For bacterial calculations, samples below the detection limit of 10 MPN $(100\ mL)^{-1}$ were substituted with 5 MPN $(100\ mL)^{-1}$. The *esp* gene column indicates how many of analyzed samples were positive.

Sample group	n	Salinity (-)	DO (mg L^{-1})	SRP (μmol L^{-1})	Silicate (μmol L^{-1})	log EC	log ENT	*esp* gene
MW06	4	0.22 (0.00)	4.1 (0.6)	0.7 (0.0)	409 (31)	0.7 (0)	0.7 (0)	-
MW07	4	0.97 (0.30)	1.5 (0.3)	9.2 (4.0)	447 (50)	4.38 (0)	4.38 (0)	2 of 4
MW09	6	3.44 (3.87)	2.5 (0.9)	18 (3)	436 (29)	3.48 (0.74)	2.29 (0.91)	-
MW10 & MW11	5	11.86 (5.84)	3.0 (0.2)	16 (17)	230 (77)	1.45 (0.49)	1.19 (0.69)	-
Pits	19	31.75 (0.24)	3.4 (0.2)	2.8 (0.1)	141 (8)	0.82 (0.09)	1.14 (0.3)	3 of 3
Seeps	17	30.22 (1.39)	5.8 (0.1)	2.4 (0.2)	102 (9)	0.79 (0.08)	0.82 (0.14)	-
Surf zone	84	32.02 (0.05)	6.6 (0.1)	1.7 (0.1)	44.9 (1.2)	1.08 (0.1)	0.96 (0.1)	0 of 2
Offshore	6	32.09 (0.09)	7.0 (0.5)	1.6 (0.2)	40.8 (3.2)	N/A	N/A	-
Bolinas Lagoon	4	32.34 (0.51)	6.0 (0.9)	1.6 (0.1)	45.9 (3.5)	2.32 (0.45)	1.29 (0.88)	1 of 1

Sample group	n	NO_3^- (μmol L^{-1})	NO_2^- (μmol L^{-1})	NH_3 (μmol L^{-1})	DIN (μmol L^{-1})
MW06	4	76 (2)	0.0 (0.0)	1.1 (0.6)	78 (2)
MW07	4	1.4 (1.6)	1.9 (2.4)	530 (80)	530 (80)
MW09	6	8 (4)	0.3 (0.0)	36 (70)	44 (66)
MW10 & MW11	5	160 (110)	7.6 (6.4)	40 (34)	210 (80)
Pits	19	21 (6)	4.0 (1.0)	2.4 (1.2)	27 (5)
Seeps	17	14 (5)	2.6 (1.0)	5.3 (1.8)	22 (5)
Surf zone	84	15 (1)	0.4 (0.0)	4.1 (0.4)	19 (1)
Offshore	6	14 (3)	0.3 (0.0)	3.1 (0.6)	18 (3)
Bolinas Lagoon	4	11 (1)	0.3 (0.0)	4.5 (1.7)	16 (2)

We used the calculated nutrient discharge values (F_p) to examine if observed changes in surf zone nutrient concentrations could be attributable to SGD. The following expression, which includes mass fluxes from all SGD components, excluding D_s and D_d, was used to predict the equilibrium concentration of DIN, SRP, and silicate in the surf zone, C_{prism}, under spring and neap tidal conditions:

$$C_{prism} = [C_{fresh}D_m + C_{sal}(D_w + D_t) + C_{offshore}(V_{prism}/\tau - D_m - D_w - D_t)](\tau/V_{prism}) \quad (6)$$

D_m estimated from the freshwater budget was used. Surf zone residence times (τ) of 1 and 4 h were used. We then determined the predicted percentage change of each constituent in the surf zone during neap relative to spring tides and compared this with the constituent's actual change.

Results

Groundwater and coastal ocean water quality—The fresh groundwater in the unconfined aquifer at Stinson Beach contains high concentrations of fecal indicator bacteria, silicate, DIN, and SRP (Table 2). The presence of the *esp* gene in a subset of groundwater samples is consistent with their being affected by septic discharge (Table 2). A nutrient and fecal indicator bacteria-rich freshwater signature dissipates from inland wells (MW06, MW07, MW09) through the brackish mixing zone (MW10, MW11, pits and subaerial seeps) to the open ocean (surf zone and offshore samples). Fresh groundwater has, at most, 10, 130, 10, and 2,500 times higher silicate, DIN, SRP, and fecal indicato bacteria, respectively, compared with surf zone waters.

Tide range was positively correlated to salinity in the surf zone (Fig. 3, $r_p = 0.81$, $p < 0.01$), indicating a freshening of the surf zone during the neap tide. Tide range was negatively correlated to silicate, DIN, and SRP in the surf zone (Fig. 3, $-0.71 \leq r_p \leq -0.57$, $p < 0.01$, respectively), indicating nutrient enrichment in the surf zone during neap tides. Silicate, nitrate, DIN, and SRP concentrations were significantly negatively correlated to salinity (Fig. 3, $-0.73 \leq r_p \leq -0.49$, $p < 0.01$), supporting the idea that the freshening of the surf zone is caused by input of nutrient-enriched freshwaters and not by other large-scale saltwater nutrient sources such as upwelling, which can act on similar timescales.

The fresh component of discharges from Bolinas Lagoon and Webb Creek had little or no effect on the salinity in the surf zone at the experimental site. The salinity measurements taken during Bolinas Lagoon ebb flow were marine and were not significantly different ($p > 0.05$) from salinities in the surf zone at the study site. An 800-m alongshore transect of ankle-depth surf zone samples extending from the study site toward Webb Creek indicated that salinity was not decreasing with distance toward the creek (data not shown), indicating that the creek's freshwater plume does not substantially influence salinity of the surf zone at our site. Given these observations, we attribute the freshening of the surf zone during neap tides to discharge of fresh groundwater across the land–sea interface, and the corresponding nutrient increase . consequence of discharge of fresh groundwater to the coastal ocean from the surficial aquifer.

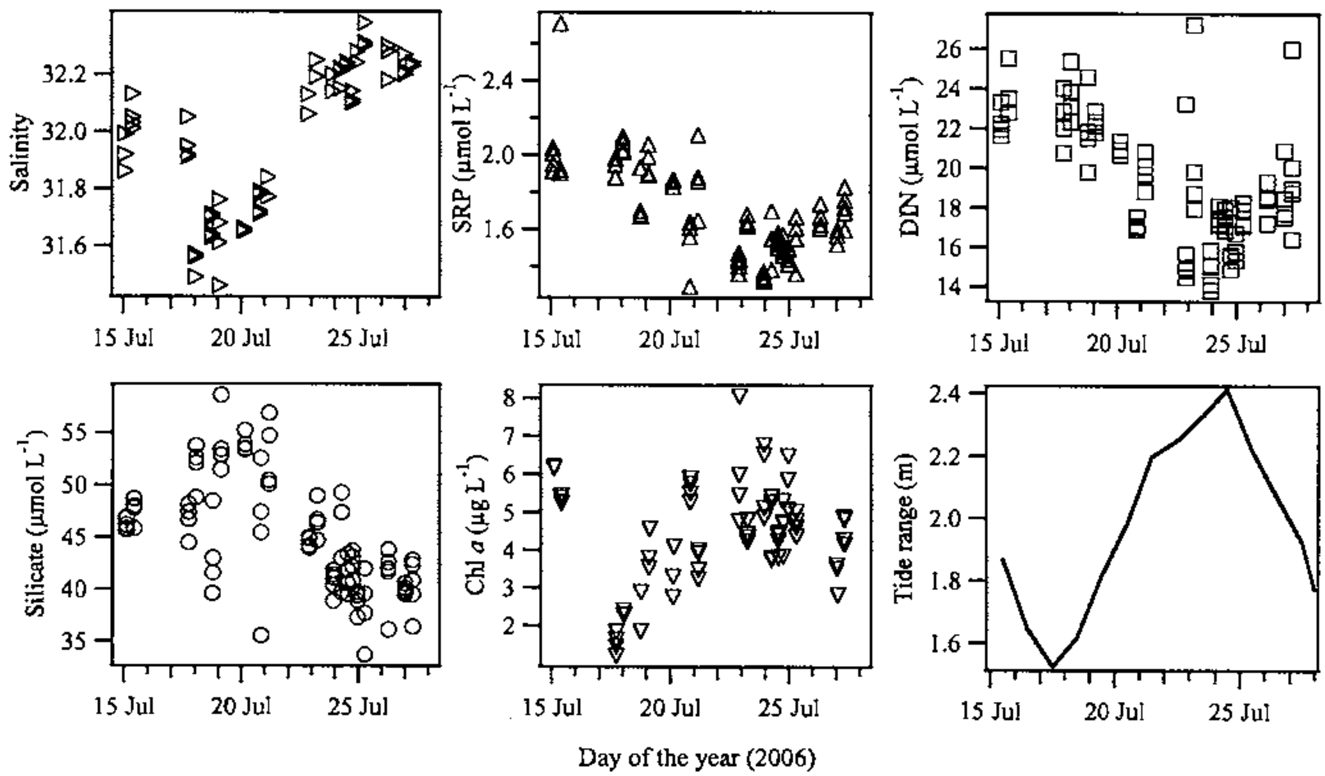

Fig. 3. Surf zone concentrations of salinity, SRP, DIN, SiO_4, Chl *a*, and tidal range plotted vs. time during the experiment.

Chl *a* concentrations in the surf zone increased substantially after the third-quarter moon. A least-squares regression of all Chl *a* measurements from 17 July (third-quarter moon) to 21 July with time ($r_p = 0.86$, $p < 0.05$) indicates an increase of over 1 $\mu g\ L^{-1}\ d^{-1}$.

Fecal indicator bacteria densities in the surf zone did not correlate significantly to salinity ($r_p = 0.16$, $p = 0.17$ for EC, and $r_p = 0.03$, $p = 0.79$ for ENT) or tide range ($r_p = 0.17$, $p = 0.13$ for EC, and $r_p = 0.01$, $p = 0.97$ for ENT). Despite the high concentrations of fecal indicator bacteria observed in fresh groundwater, they do not appear to be discharged with the fresh, nutrient-rich groundwater, indicating that they may be filtered as groundwater moves through the sand (Hijnen et al. 2005; Bolster et al. 2006).

Mesocosm experiment—Average Chl *a* with 95% confidence intervals at the start of the experiment (day 0, $n = 4$) and on the final day of the experiment (day 2, $n = 16$) are shown in Fig. 4. After incubation for 2 d, Chl *a* concentrations in bottles containing 4% and 8% groundwater exhibit significant ($p < 0.001$ in each case) increases relative to the seawater control. This experiment illustrates that a dissolved constituent present in the fresh groundwater at Stinson Beach, or a combination thereof, promotes the growth of phytoplankton in seawater when light and temperature are held constant.

Hydraulic head measurements—The head varied over a smaller range at the most inland wells compared with the wells closer to the sea (Table 3). The average hydraulic head over the fortnight at the well farthest from the sea, MW06, the only well installed into the bedrock at the landward boundary, the surficial beach aquifer, was higher than average heads at other wells installed into the beach

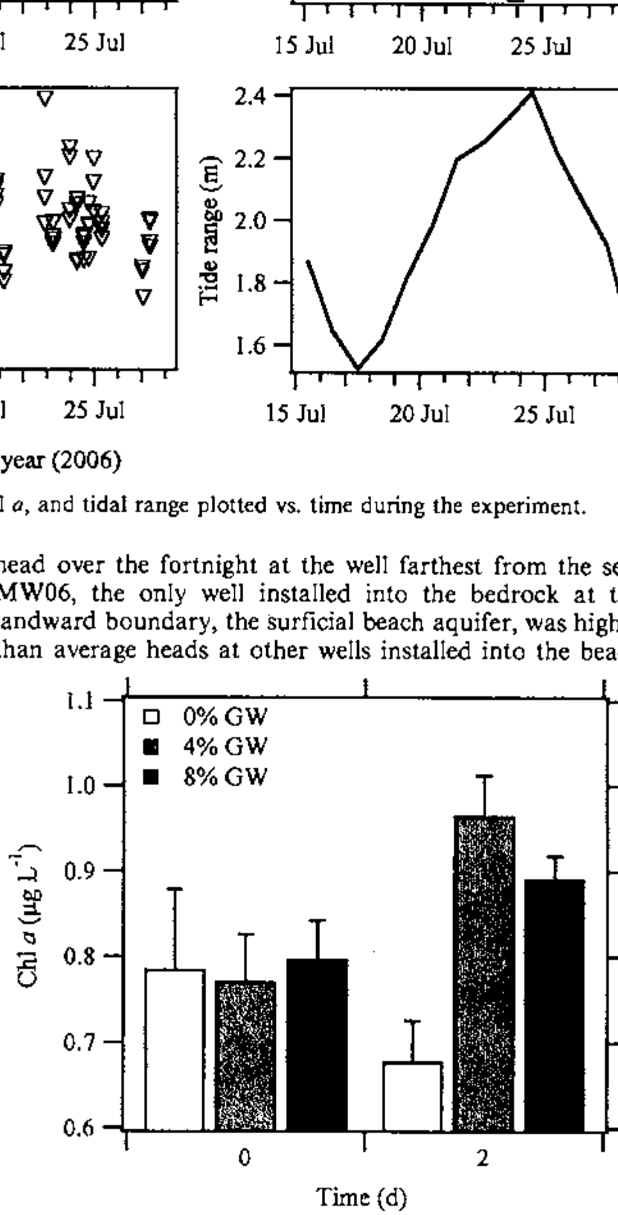

Fig. 4. Average and 95% confidence intervals of Chl *a* concentrations at time 0 and on day 2 of the mesocosm experiment for treatments (4% and 8% v/v groundwater and seawater) and control (0%). Concentrations in 4% and 8% treatments show significant increases above concentrations at time 0 and above control at day 2, suggesting that a dissolved constituent in groundwater is promoting growth of phytoplankton.

Table 3. The maximum and minimum equivalent freshwater hydraulic head (m) measured relative to mean sea level is shown for each well. Also shown are average heads during the fortnight, and during neap and spring tides. Sea level maximum, minimum, and average values are shown for comparison.

Well ID	Minimum (m)	Maximum (m)	Fortnight average (m)	Neap tide average (m)	Spring tide average (m)
MW06	1.26	1.39	1.32	1.33	1.28
MW07	0.41	0.55	0.48	0.49	0.44
MW09	0.24	0.56	0.42	0.37	0.44
MW10	0.08	1.03	0.45	0.26	0.55
MW11	0.08	1.01	0.43	0.39	0.49
Sea level	−1.28	1.18	0.09	0.11	0.18

aquifer (Table 3). This indicates that there was net flow from the bedrock to the surficial aquifer and out toward the sea, assuming a hydraulic connection. At the inland side of the unconfined aquifer, the hydraulic head in wells MW06 and MW07 was approximately 1 cm above the fortnight average during the neap tide and 4 cm below the fortnight average during the spring tide (Table 3). The reduction in head from neap to spring tide at these wells may be attributed to lagged response to low-frequency tidal constituents (Li et al. 2000; Raubenheimer and Guza 1999), or to the slow seasonal dropping of the water table during the summer months due to discharge and evapotranspiration. Changes to hydraulic head at the seaward side of the aquifer had an opposite and more substantial fortnightly trend. Neap tide average heads at wells MW09, MW10, and MW11 were 5, 19, and 4 cm below the fortnight averages, respectively, whereas spring tide heads at the same wells were 2, 10, and 6 cm, respectively, above the fortnight averages (Table 3). This illustrates an increase in aquifer overheight, or mounding of water at the land–sea interface during spring relative to neap tides.

SGD estimates—On the basis of the freshwater budget in the surf zone, D_m varies between 1.2 and 4.7 L min^{-1} m^{-1} of shoreline at neap tide to between 0.1 and 0.5 L min^{-1} m^{-1} at spring tide (range reported for 1- and 4-h residence times, Table 4). By comparison, estimates of discharge, on the basis of measurements in the fresh part of the aquifer, using the Dupuit equation are 1.2 L min^{-1} m^{-1} (neap tide) and 0.1 L min^{-1} m^{-1} (spring tide). Thus, agreement is excellent between the Dupuit freshwater discharge calculations and the mass balance estimates of D_m calculated with a 4-h residence time.

We calculate that D_w = 7.2 L min^{-1} m^{-1} of shoreline (constant throughout study) and D_t = 8.7 (neap) and 14.8 (spring) L min^{-1} m^{-1} of shoreline, respectively (Table 4). The sum of these estimates shows that total SGD (D) during spring tides (D_{spring}) is greater than SGD during neap tides (D_{neap}), which is consistent with results from other studies in unconfined aquifers, including those done with seepage meters (Kim and Hwang 2002; Taniguchi 2002; Boehm et al. 2004). Assuming a 1-h residence time 2.2% of D_{spring} is fresh groundwater, whereas 22.8% of D_{neap} is fresh groundwater, or 0.5% vs. 7.0%, respectively, assuming a 4-h residence time (Table 4).

Discussion

Fortnightly trends in surf zone nutrients and salinity at Stinson Beach can be linked to changes in the meteoric (fresh) component of total SGD, which in this environment appears to be controlled by tide- and wave-driven aquifer

Table 4. (A) Dupuit equation estimates of seaward groundwater discharge in the fresh part of the unconfined aquifer. (B) Model estimates of D_m, D_t, D_w, D, F_p SiO_4, F_p SRP, and F_p DIN. Estimates vary for 1- and 4-h residence times. (C) Predicted C_{prism} for nutrients predicted using Eq. 6. Actual nutrient concentrations in the surf zone are reported for neap and spring tides for comparison.

(A)	Neap tide			Spring tide		
Fresh discharge (L min^{-1} m^{-1})	1.2			0.1		
(B)	Neap tide			Spring tide		
	1 h	4 h		1 h	4 h	
D_m (L min^{-1} m^{-1})	4.7	1.2		0.5	0.1	
D_w (L min^{-1} m^{-1})	7.2	7.2		7.2	7.2	
D_t (L min^{-1} m^{-1})	8.7	8.7		14.8	14.8	
D (L min^{-1} m^{-1})	20.6	17.1		22.5	22.1	
F_p SiO_4 (μmol min^{-1} m^{-1})	3,780	2,303		2,697	2,528	
F_p SRP (μmol min^{-1} m^{-1})	101	55		62	56	
F_p DIN (μmol min^{-1} m^{-1})	1,677	949		1,072	989	
(C)	Neap tide			Spring tide		
	1 h	4 h	Actual	1 h	4 h	Actual
C_{prism} Silicate (μmol L^{-1})	66	97	49	56	98	43
C_{prism} SRP (μmol L^{-1})	2.6	2.3	1.9	1.9	2.4	1.5
C_{prism} DIN (μmol L^{-1})	30	41	23	25	39	17

overheight in the unconfined beach aquifer. Increased fresh groundwater discharge at neap tide corresponded with a drop in aquifer overheight at the land–sea boundary and a steepening of the seaward hydraulic gradient in the fresh part of the aquifer. Similarly, increased aquifer overheight near the beach face during spring tide corresponded with a shallowing of the hydraulic gradient in the fresh part of the aquifer, and reduced fresh groundwater discharge to the coastal ocean. Fresh groundwater at the field site is substantially enriched in nutrients; thus the freshening of the surf zone during neap tide is accompanied by nutrification of the surf zone.

The discovery of fecal indicator bacteria and *esp*-positive ENT in monitoring wells at the site suggests that high nutrient concentrations in fresh groundwater are due at least in part to contamination by septic effluent. This is not surprising given the high density of septic systems at the field site. Our field observations indicate that nutrients from fresh groundwater can be transported from the land to the sea through the subsurface, affecting coastal water quality. Interestingly, increased surf zone concentrations of groundwater-derived nutrients were not associated with an increase in fecal indictor bacteria concentrations, although fresh groundwater at the site is enriched with these organisms. This indicates that attenuation of bacteria in the unconfined beach aquifer at Stinson Beach is efficient. Future work will concentrate on quantifying attenuation rates of effluent-derived fecal indicator bacteria, pathogens, in particular viruses, and nutrients in individual septage plumes at the site.

During the 4 d after the nutrient pulse that occurred at neap tide at Stinson Beach, Chl *a* concentrations in the surf zone increased from approximately 2 μg L^{-1} to 6 μg L^{-1}. Numerous studies have implicated SGD in causing algal blooms in the coastal ocean (LaRoche et al. 1997; Hwang et al. 2005*a,b*), with some specifically linking SGD-derived nutrient inputs from septic systems to growth of algae in canals and coastal watersheds (Lapointe et al. 1990; Valiela et al. 1992; Charette et al. 2001). The mesocosm experiments illustrated that the addition of nutrient-rich fresh groundwater from well MW09 (average nutrient concentrations in Table 2) to seawater promoted significant increases in Chl *a* relative to a control with no addition. Although we are unable to definitively conclude that nutrification of the coastal ocean by fresh SGD during the neap tide caused the increase in Chl *a* in the coastal ocean soon thereafter, our field observations and mesocosm experimental results are consistent with this linkage. Other possible causes of the increased Chl *a* in the surf zone include changes in resuspension of benthic diatoms (Demers et al. 1987), turbidity (May et al. 2003), water column stability and light penetration (Comeau et al. 1995), and upwelling (Labiosa and Arrigo 2003).

For the purposes of testing whether the observed changes in nutrient concentrations in the surf zone could have been caused by the estimated changes to SGD across the fortnight, theoretical spring- and neap-tide nutrient concentrations (C_{prism}) were estimated using the calculated potential nutrient fluxes (Eq. 5). On the basis of groundwater mixing diagrams of salinity vs. nutrient concentration, groundwater end-member nutrient concentrations were 422 μmol L^{-1} silicate, 208 μmol L^{-1} DIN, and 13 μmol L^{-1} SRP for fresh groundwater, and 113 μmol L^{-1} silicate, 44 μmol L^{-1} DIN, and 2.5 μmol L^{-1} SRP for saline groundwater (mixing diagrams not shown). Using these end members with the corresponding discharge estimates, the potential flux F_{p} ranges from 2,303 to 3,780 μmol min^{-1} m^{-1} silicate, 949 to 1,677 μmol min^{-1} m^{-1} DIN, and 55 to 101 μmol min^{-1} m^{-1} SRP, depending on residence time and tidal condition (spring vs. neap) (Table 4). Variation in F_{p} between neap and spring tides is due to the different proportions of D_{m} and D_{t} in total SGD (D).

Using F_{p}, we calculated C_{prism}, the theoretical concentration of nutrients in the surf zone during neap and spring tides. For each nutrient constituent C_{prism} is greater than the actual measured concentration in the surf zone during both tidal conditions (Table 4). This is not surprising given that nutrients do not behave conservatively in the subsurface, although our calculation of F_{p} assumes they do. However, comparisons of the projected change in C_{prism} between spring and neap tides with the actual change in surf zone concentrations agreed reasonably well assuming a 1-h residence time: C_{prism} increases 18% (silicate), 20% (DIN), and 37% (SRP) during neap relative to spring tides, as compared with the measured increases of 14% silicate, 35% DIN, and 27% SRP. Thus, it appears that if we use the low-end residence time estimate, the fortnightly changes in the flux of fresh and saline groundwater from the beach aquifer to the coastal ocean can account for an increase in surf zone concentrations of nutrients during neap tides. If the residence time is instead 4 h, then our model predicts higher nutrient concentrations during spring compared with neap tides presumably due to increased saline discharge at spring tide. This is counter to our observations, and may indicate that the nutrient flux attributed to the saline groundwater discharge is overestimated by our model.

Neither the seasonal component D_{s} nor the density-driven component D_{d} was included in flux calculations. Seepage metering was instrumental in investigating D_{s} at a low wave-energy field site at Waquoit Bay, Massachusetts (Michael et al. 2005). In systems with a high-energy surf zone such as Stinson Beach, seepage metering is problematic if not impossible (Libelo and MacIntyre 1994; Burnett et al. 2006), and for this reason D_{s} was not included in our estimate of D. However, since it oscillates on a yearly timescale, we can assume that D_{s} would have been approximately constant across the 14-d study. We contend that had D_{s} been included in our formulation of D, the percentages of fresh SGD of total reported above would be reduced but the relative differences and our general conclusions would remain the same. The variability and role of D_{d} at Stinson Beach is uncertain, but we suggest that because the fresh groundwater at the site is so substantially enriched in nutrients relative to the saltwater end members, the nutrification effects attributed to D_{d} variability would be small compared with those attributed by the large changes in fresh groundwater flux across the fortnight.

To ground-truth our discharge results, it is useful to compare them with those made in similar environments. At Tomales Bay, a 21-km-long embayment along the San Andreas Fault approximately 27 km to the northwest of Stinson Beach, Oberdorfer et al. (1990) estimated D_m using both Darcy's law and a soil moisture budget approach. Saline discharge was not investigated. D_m estimates for the two methods were 6.6×10^3 m^3 d^{-1} and 25.3×10^3 m^3 d^{-1}, respectively, or 0.12 L min^{-1} m^{-1} and 0.44 L min^{-1} m^{-1} given the approximate length of shoreline along the bay (40 km). During a multiday experiment, Mulligan and Charette (2006) used Darcy's law and radon-based methods and estimated fresh discharge to Waquoit Bay, Massachusetts, at 2.8 L min^{-1} m^{-1} and 3.9 L min^{-1} m^{-1}, respectively. Kroeger et al. (2007) used Darcy's law and a water budget to estimate fresh SGD from the Pinellas Peninsula in Tampa Bay, Florida. D_m was estimated at 2.0 L min^{-1} m^{-1} and 0.8 L min^{-1} m^{-1} using the two methods, respectively. Hays and Ullman (2007) dammed subaerial seepage faces that developed during 16 spring tide monitoring events across an 18-month period at Cape Henlopen, Delaware, and measured D_m directly with a weir. They calculated annual average D_m during the study of 0.9 ± 0.4 L min^{-1} m^{-1}. The range of D_m presented in our study is consistent with the values reported above.

SGD field studies have specifically investigated neap–spring tidal forcing of SGD. Taniguchi (2002) used seepage meters in Osaka Bay, Japan, and found that total SGD increased from neap to spring tide. At a monitoring station in Korea's Yellow Sea, Kim and Hwang (2002) found that groundwater-derived ^{222}Rn and CH_4 concentrations near the seafloor increased sharply from neap to spring tide. Boehm et al. (2004) also found an increase in total SGD between neap and spring tides using radium isotopes as tracers. In all three cases, the results indicate a greater total discharge during spring tide relative to neap tide, and are consistent with the results presented herein. The only study that examined spring–neap variation in fresh SGD, specifically, was conducted in South Africa. Campbell and Bate (1999) used a Darcy's law approach to quantify the flux of fresh groundwater from a South African sand dune complex, and estimated D_m to be 0.11 L min^{-1} m^{-1} during spring tide and 0.23 L min^{-1} m^{-1} during neap tide. The increase in neap tide D_m vs. spring tide D_m is also consistent with the results presented here.

The precise physical explanation of the neap tide pulsing phenomenon is unknown, though two numerical experiments have been conducted to examine D_m and D_t at a hypothetical beach under varying tidal amplitude scenarios and no wave action (Ataie-Ashtiani et al. 2001; Robinson et al. 2007), both of which offer some insights.

Ataie-Ashtiani et al. (2001) simulated constant-density steady-state D_m and D_t from a thin isotropic aquifer with a constant-head landward boundary under zero, low-, and high-tidal amplitude scenarios. They showed that increasing tidal range (as would be expected during spring tides) increased both D_t and aquifer overheight at the boundary, and decreased D_m. Despite differences between the simulated and Stinson Beach environments, the results of the simulation are consistent with the results of our study.

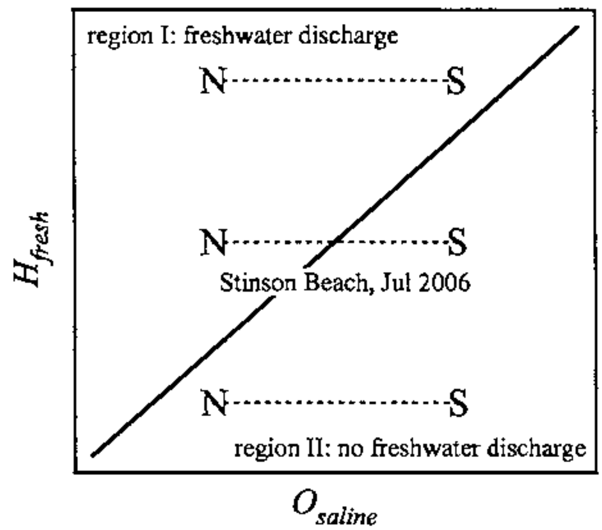

Fig. 5. A framework for understanding the timing of freshwater discharge at beaches similar to Stinson Beach. The dashed, horizontal lines connect the aquifer overheight (O_{saline}) during neap (N) and spring (S) tides at hypothetical beaches with varying hydraulic heads behind the overheight (H_{fresh}). The solid diagonal line separates regions I and II. In region I the aquifer overheight at the beach face is lower than the inland hydraulic head; fresh groundwater discharges to the coastal ocean. In region II, the aquifer overheight is higher than the inland hydraulic head; no freshwater discharge occurs. Fortnightly pulsed fresh groundwater discharge occurs when a beach straddles regions I and II.

Robinson et al. (2007) simulated variable-density steady-state D_m and D_t from a thick isotropic aquifer with a constant-flux fresh landward boundary and multiple tidal ranges. They showed that a saline tidally driven circulation cell develops approximately between the high and low tide lines. Under certain conditions, a freshwater "tube" discharges seaward of the tidal circulation cell near the low tide line. As tidal amplitude is increased, the depth and width of the saline circulation cell increase and the freshwater tube is forced to flow deeper in the aquifer and discharge further offshore. It is possible that during our study, fresh groundwater discharged to the surf zone at neap tide but discharged beyond the surf zone at spring tide, thereby producing a freshening of the surf zone at neap tide. Although we cannot rule out this possibility, no data collected at the site to date indicate a freshening of nearshore waters beyond the surf zone during spring tides (Table 2, additional data not shown).

Given the results described here, we present a qualitative framework for understanding the relationship between tide- and wave-driven overheight and the magnitude and timing of freshwater discharge from unconfined beach aquifers similar to that at our field site (Fig. 5). We introduce two variables, H_{fresh} and O_{saline}, where H_{fresh} is the hydraulic head in the fresh portion of the aquifer and O_{saline} is the hydraulic head due to overheight in the saline portion of the aquifer near the beach face. The magnitude of O_{saline} is controlled by several factors including wave setup, wave run-up, tidal height, and meteoric hydraulic pressure. H_{fresh} is measured just beyond the influence of tides and waves and, thus, controlled entirely by meteoric hydraulic head.

In Fig. 5, O_{saline} (horizontal axis) is plotted against H_{fresh} (vertical axis). The dashed, horizontal lines represent neap (N) and spring (S) tide conditions at hypothetical beaches where H_{fresh} is relatively constant but O_{saline} varies with tide range, as it does at Stinson Beach. If H_{fresh} is higher than O_{saline} during all tidal conditions, the system is in region I of Fig. 5 and shallow fresh groundwater continuously discharges throughout the fortnightly tidal cycle. This may be the case at Waquoit Bay, a site with small tidal range and minimal wave action where researchers have described freshwater discharging to the coastal ocean under a variety of conditions (Michael et al. 2003; Mulligan and Charette 2006). If H_{fresh} is low relative to O_{saline} at both neap and spring tides, then shallow fresh groundwater does not discharge over the fortnightly cycle, and the system is in region II. This likely was the case in Huntington Beach, California (Boehm et al. 2006), where very little to no fresh groundwater discharge occurred despite the presence of fresh groundwater just landward of the high tide berm. At Stinson Beach, H_{fresh} is higher than O_{saline} during neap tide but lower during spring tide; thus, the system straddles regions I and II, resulting in a pulsing of fresh groundwater during neap tides with little or no discharge during spring tides.

It is conceivable that at Stinson Beach and elsewhere, aquifers may occupy regions I or II (or both) during different parts of the year as seasonal waves of meteoric hydraulic pressure force fresh groundwater though the beach and interact with the wave- and tide-driven overheight at the boundary. It is also conceivable that variable wave conditions across neap–spring cycles may interfere constructively or destructively with the neap–spring overheight cycle described herein. For these reasons and numerous others, we expect that not all tide- and wave-driven systems will fit into the above classification scheme. Future work including field experiments and numerical modeling will explore this concept more fully.

This study illustrates the importance of fortnightly variation in aquifer overheight in tide- and wave-driven systems and presents a qualitative framework for categorizing fresh groundwater discharge from beach aquifer systems similar to Stinson Beach with respect to overheight at the land–sea interface. Understanding the interactions of mechanisms forcing SGD is particularly important in systems similar to Stinson Beach, where fresh submarine groundwater discharge from a polluted unconfined aquifer poses potential risk to nearshore ocean ecosystem health. Further work should be done to examine the importance of neap–spring tides on submarine groundwater discharge in other environments.

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