UNIVERSITY OF CALIFORNIA
Santa Barbara

A Water Quality Monitoring Plan for Santa Barbara's Urban Creeks

A Group Project Report submitted in partial satisfaction of the requirements for the degree of
Masters in Environmental Science and Management
for the
Donald Bren School of Environmental Science & Management

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WATER QUALITY MONITORING PLAN FOR SANTA BARBARA'S URBAN CREEKS

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The Group Project is required of all students in the Master's of Environmental Science and Management (MESM) program. It is a three-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. The final Group Project report is authored by MESM students and has been reviewed and approved by:

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ABSTRACT

Reducing non-point source pollution in the nation's water bodies has received increasing attention in recent years. A monitoring plan has been developed for the City of Santa Barbara that addresses water quality assessment in terms of impacts from the various land uses within the watersheds of the area. Drawing from the U.S. Geological Survey's National Ambient Water Quality Assessment (NAWQA) program, sites are divided into integrator sites and indicator sites. Integrator sites are selected to characterize overall watershed conditions. Indicator sites are chosen to examine inputs from drainage basins that consist of a homogeneous land use. Results from indicator sites are intended to provide insight into the impacts of specific land uses on the creeks in the area. Implementation of the monitoring program is anticipated to guide conclusions about land use impacts in Santa Barbara and effective policy measures to assess any identified water quality problems. The plan and the policy recommendations derived from the proposed monitoring plan will provide a template for the City of Santa Barbara and other coastal locales as they design and implement non-point source pollution monitoring and control programs.

EXECUTIVE SUMMARY

Background Information

The City of Santa Barbara, under Measure B, established the Creeks Restoration and Water Quality Improvement Division (Creeks Division) to address water quality concerns within the city watersheds and coastal waters. The mission of the Creeks Division is to "improve creek and ocean water quality and restore natural creek systems through storm water and urban runoff pollution-reduction, creek restoration, and community education programs"[i]. Effective management for water quality improvement requires knowing the current state of the watersheds, and being able to measure the performance of management actions over time. An important step in achieving the goals of the Creeks Division is a water quality monitoring plan that measures pollutant patterns and provides insights into possible sources of identified pollution.

Problem Statement

Since 1995, the City of Santa Barbara has collected extensive data on levels of indicator bacteria in the following urban stream channels: Arroyo Burro, Mission, Laguna, and Sycamore. Elevated bacteria concentrations have been consistently detected in sections of each watershed. The cause has not been definitively established although several source characterization studies are underway.

Little data has been collected that characterizes the presence or distribution of other types of pollution, such as elevated nutrient concentrations, toxicants, or sedimentation. Therefore, the Creeks Division desires a monitoring protocol to acquire the data needed to support decisions for protecting human and ecological health. The monitoring plan must address the following fundamental questions:

- What types and concentrations of pollution are in the creeks that could threaten ecological and human health?
- What are the spatial and temporal patterns of the constituents of concern?
- How does different land use impact creek water quality?
- What other correlating factors might be important?

Methods

First, an analysis of the watersheds in the city of Santa Barbara evaluated the topographic contours and storm drain infrastructure to characterize specific drainage basins. Using a GIS geodatabase, the hydrologic flow delineation for each watershed was overlain by a land use map which followed a commonly used classification scheme developed by Anderson et al. in 1976. Land use designations were verified using the City of Santa Barbara's geospatial browser and, when further accuracy was necessary, site visits. In addition, estimates of impervious surfaces in each drainage area were done, as literature research revealed the significance of possible connections between water quality conditions and impermeable surfaces[ii].

The group conducted a literature survey and performed case studies of other monitoring programs in Southern California. The literature review focused on studies that evaluated the connection of pollutant sources with specific types of land use. The case studies evaluated methods and constituents included in other monitoring programs and the detection rates of each pollutant. This information was useful for the selection of constituents of concern for this monitoring plan.

As a supplement to develop expectations about pollutants present in the creeks, and to further evaluate watershed conditions, a modeling exercise was completed. The Soil and Water Assessment Tool (SWAT) model in the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) modeling framework was selected for this purpose. SWAT has predicted the impact of land management practices on hydrology, sediments and water quality in the region. The analysis was performed for only one of the creeks in the city; Arroyo Burro. The model was calibrated for the prediction of stream flow and nitrate concentration using data for the water year 2003.

Spatial and temporal patterns of the constituents of concern were considered in designing the monitoring plan. Site selection was based on achieving spatial distribution throughout the watersheds, and in the case of indicator sampling, to best represent areas that drained one particular type of land use. The recommended sampling frequency balances cost effectiveness with being able to measure trends and variation in pollutant concentrations over time. Intensive storm event sampling is recommended for several storms each year to measure the transport of pollution during these critical times.

Significance of Project

By identifying spatial and temporal patterns of pollutants, management approaches can be targeted to areas which will yield the most improvement of water quality. Overall, data generated from the monitoring plan is designed to provide necessary information to generate policy and management decisions aimed at improving water quality in the creek systems, and then evaluate whether the policies are achieving their goals over time.

Monitoring Plan

The monitoring plan outlines recommended sampling sites, constituents of concern, and sampling frequency during dry weather and storm events. The design of the monitoring plan is adapted from the US Geological Survey's National Ambient Water Quality Assessment (NAWQA) program, which has been created "to develop long-term consistent and comparable information on streams, ground water, and aquatic ecosystems to support sound management and policy decisions"[iii]. The purposes of the NAWQA program are closely related to the objectives of the proposed monitoring plan, and the use of NAWQA protocols provides a nationally recognized methodology that allows for data to be compared to other regions and across time-scales.

The occurrence and distribution of water quality conditions is evaluated with a combination of integrator and indicator sites. Integrator sites are located in heterogeneous large basins, affected by a wide range of land use and hydrologic settings. Indicator sites, in contrast, are chosen at the base of smaller, specific, drainage basins with homogeneous land use and hydrologic conditions. Indicator sites are designed to capture areas predominantly influenced by a particular land use, while integrator sites are meant to be more representative of the overall conditions at key points in the watershed. Integrator sites are useful to identify constituents that are problematic at broad scales and indicator sites provide further insights on sources and pollutant hot spots.

Constituents of concern fall into the following general categories: suspended sediments, pesticides and herbicides, organic matter, metals, hydrocarbons, bacteria, and nutrients. The choice of specific constituents of concern is based on literature review, results from case studies, and previous sample results in Santa Barbara.

To characterize pollutant variation, monthly sampling of integrator sites is recommended, at least for the initial two-year study period (as recommended by NAWQA). After that time, the appropriate frequency for long-term monitoring should be evaluated. Indicator sites, on the other hand, generally only experience enough flow to be tested during and immediately after storm events. Indicator sampling is a method to determine the relative magnitude of the contributions different land uses make for pollutants which have been consistently detected above levels of concern during integrator sampling or past sampling programs. The goal of indicator sampling is to obtain a mean concentration of pollutants emanating from a particular land use type during storms, within a set goal for the range and level of confidence (e.g. find the mean storm event concentration of a given pollutant from a given land use, plus or minus 25% at a 95% level of confidence).

Recommendations

It is the recommendation of the group to perform the proposed monitoring plan for a two year characterization period, followed by ongoing sampling at a possibly reduced period. For constituents that have been established to be consistently above levels of concern during past sampling (e.g. indicator bacteria), or are so established during the two year characterization period of integrator sampling, perform indicator sampling to characterize land use loadings. Other correlating factors may be tested for, depending on the policy goals of the city and possible sources for the detected pollutant.

The group strongly recommends expanding upon the use of GIS-linked databases to store and organize all city water quality sampling results. The SWAT model developed for the Arroyo Burro watershed should be adapted to the other watersheds in the City and further calibrated to provide predictive capability for flow and pollutant loading scenarios. In addition to its predictive value, the SWAT model is an important tool to develop TMDLs if and when this is required by the Regional Water Quality Control Board.

Due to limited data availability for the calibration process, the results obtained from the SWAT model are not yet sufficient to accurately predict flow and pollutant distribution patterns and should only be taken as an example of how computer model simulations may be used in the future to analyze land use-pollutant relationships. For future modeling, the use of more accurate land-use, soil, and topographic maps as well as weather, streamflow and sample data from the watersheds will achieve more accurate results and increase the usefulness of predictive modeling as a tool for management analysis.

Conclusions

The integrator sampling outlined in this plan will provide a characterization of pollutant concentrations at key points in each watershed at different times of the year and flow conditions. For constituents consistently detected at a level of concern, indicator sampling will provide information on which land uses contribute the most to the problem. Other correlating factors, such as the amount of impermeable area represented in a sample, should also be considered and those factors most likely to produce predictable correlations and also be most useful in crafting policy, should be sampled for in order to quantify the correlation. Indicator sampling should continue until the desired precision has been obtained. After the initial two year characterization period, integrator sampling should continue into the future (although not necessarily monthly) in order to track pollutant trends over time and signal if new sources or areas of the watershed are becoming problematic.

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I. INTRODUCTION

1 PROJECT DEFINITION

1.1 *Research Objectives and Approaches*

The purpose of this project is to design a monitoring plan that will assess the spatial and temporal distribution of pollutants in the watersheds as a whole and measure inputs from specific land uses in particular. The plan is applicable to the creeks of the following watersheds: Arroyo Burro, Mission, Sycamore, and Laguna. It focuses on sampling in the urban environment with attention to site selection, choice of constituents of concern, and performance aspects such as sampling frequency and data management. Policy recommendations focus on implementation of the monitoring plan.

Specifically, six objectives have been identified:

- Measure current water quality and trends over time
- Identify areas of impaired water quality that may adversely affect human or ecological health in the creek corridors (as defined by comparing sample results to existing benchmarks developed based on human and ecological toxicology studies)
- Provide information needed to relate creek water quality to inputs of pollutants by different land uses
- Provide data in a format compatible with 'clearinghouses' for water quality data maintained by the state or federal government (e.g. EPA STORET database)
- Report on water quality conditions as required by federal and state regulations or requested by others
- Provide data needed to assist in framing the planning process for Watershed Action Plans and design of appropriate Best Management Practices.

In order to achieve these objectives, the group completed the following:

- Created a geographically referenced database coupling land use (e.g. zoning, use category by parcel) with infrastructure (storm drain, sanitary sewer) patterns and watershed delineation. The geographic information systems (GIS) database will be delivered with the final report.
- Delineation of land use categories within the watersheds and percentages of impermeable area.
- Case studies of other monitoring programs in the region and evaluation of methods, constituents and detection rates for applicability to Santa Barbara.
- Two field sampling events applying the proposed indicator sampling methodology.
- Modeling of the Arroyo Burro watershed utilizing the SWAT model in the BASINS framework.

- Research on national water quality monitoring programs, applicable regulatory guidance, and sampling techniques and technologies.

1.2 *Project Significance*

Insufficient information is currently available regarding types and sources of pollutants and the impact of specific types of land use in the watersheds. The City of Santa Barbara considers water quality in its urban creeks a priority, and is committed to managing land use and development in a manner protective of the creeks. Effective land use management requires the characterization of ambient pollutant levels and the relative impacts of different urban land uses. Therefore, the proposed monitoring plan contains a concrete strategy for obtaining information about land use inputs and pollutant distribution throughout the watersheds. This project provides recommendations about some of the most important aspects of water quality monitoring such as site selection, costs, constituents of concern, and data management.

The data obtained from the implementation of the monitoring plan should quantify inputs from specific land uses or drainages and this information can be utilized to formulate effective policy measures.

1.3 *Stakeholders*

The primary stakeholder is the Creeks Division, represented by Jill Zachary, although the Creeks Division represents the aggregate interests of city residents and visitors who use or recreate around the creeks. Other important stakeholders include businesses (hotels, restaurants, retail shops, and other businesses which are subject to clean water regulations) within the City of Santa Barbara and the outlying region that are heavily dependent on tourists attracted by the clean beaches and coastal waters. Tourists and Santa Barbara residents (including landowners) stand to gain from the outcome of the project if their experience of the environment is enhanced through cleaner creek corridors and enhanced creek and beach water quality, and their health better protected by effective monitoring protocols.

Specific organized groups that also represent an aggregate of stakeholders include: the Urban Creeks Council, Environmental Defense Center, Heal the Ocean, ChannelKeepers, Community Environmental Council, Greater Lodging Association of Santa Barbara, the Conference and Visitors Bureau, Santa Barbara Chamber of Commerce, and the Downtown Organization of Santa Barbara.

2 BACKGROUND

The following sections provide background information and context for the proposed monitoring plan, and outline the research and guidance that the protocol is based on. Readers who are primarily interested in the monitoring protocol itself, and less concerned about research and background information, may wish to skip directly to Part III of this report beginning on page 76.

2.1 *City of Santa Barbara Creeks Restoration and Water Quality Improvement Division*

The current creeks monitoring program is administered by the City of Santa Barbara Creeks Restoration and Water Quality Improvement Division (Creeks Division). Goals for the program include establishing baseline data and determining suitable locations for treatment measures (City of Santa Barbara, 2003). The monitoring plan presented in this report is designed to assist and refine the city's efforts.

Originally, the Creeks Division focused primarily on assessing levels of indicator bacteria and field measurements of dissolved oxygen, temperature, pH, turbidity, conductivity, and salinity. In 2004-2005, the Creeks Division further expanded and adapted the program to include increased monitoring of restoration projects. This included sampling for chemical constituents in addition to collection of indicator bacteria data.

Some of the elements of this expanded sampling program may be redundant with the sampling program presented in this report. This is an important consideration as the proposed monitoring plan is adapted by the Creeks Division and requires further investigation before implementation commences.

The current city program is comprised of four components:

- Creek Water Quality Monitoring:
- Ocean and Lagoon Water Quality Monitoring
- Storm Event Sampling
- Creek Walks

Creek, lagoon, and ocean water quality monitoring consists of field work to assess indicator bacteria levels and water quality parameters such as dissolved oxygen, pH, turbidity, conductivity, and salinity. It serves to demonstrate seasonal fluctuations, locate hot spot areas, and assess the spatial distribution of indicator bacteria. Results thus far indicate that the lower and middle portions of Arroyo Burro and Mission Creeks, in general, exceed water recreation standards for median levels of indicator bacteria. However, observed values fluctuate greatly, even for consecutive sampling events (City of Santa Barbara, 2003).

Between June of 2001 and May of 2003 the Creeks Division sampled four storm events for an expanded suite of constituents including: nutrients, oil and grease, and metals. The results did not demonstrate unusually high concentrations of any of the constituents and were inconclusive as far as whether the street sweeping program, initiated in December 2001, was measurably improving water quality (City of Santa Barbara, 2003).

The limited amount of data prevented the formulation of strong conclusions about ambient pollution levels.

Creek walks serve to visually identify hot spots for green waste, human waste, trash, homeless encampments, and dry weather flows, which often exhibit elevated concentrations of indicator bacteria. The creek walks begin at the beaches, end in upper reaches, and cover all watersheds within city limits. They also allow the Creeks Division to observe visual impairments to water quality, such as oil sheen on water surfaces or the presence of foam, scum, or algae growth that are not easily identified from roadways or established sampling locations.

In addition to these key program elements, the Creeks Division is implementing and monitoring restoration projects and sponsoring research on microbial source tracking. The Creeks Program is planning to install a UV filtration device at Old Mission Creek and has a restoration site at Bohnett Park () which has won several awards for innovative environmental practices. The UV device is designed to reduce bacterial contamination and the purpose of the restoration site is to decrease bacteria, turbidity, and total suspended solids as well as improve aesthetics and re-establish native plant communities. Monitoring sites above and below these treatment locations are in place to appraise the efficacy of the projects. The microbial source tracking research is a joint effort with UCSB, led by Dr. Patricia Holden. The project involves tracking of the DNA of microbial communities to better characterize sources of bacteria in the creeks. Results from the source tracking research coupled with results from specific land use drainages may be able to identify the areas most responsible for the observed indicator bacteria levels.

Figure 2-1 - Bohnett Park Restoration Site

Construction -- September 17, 2003

Post-Construction – April 16, 2004

(Creeks Division Images, 2004, 2004)

2.2 *Santa Barbara Watersheds*

Arroyo Burro Creek

Arroyo Burro begins in the Santa Ynez Mountains, is joined by Barger Canyon, San Roque, and Las Positas Creek drainages and flows south until it empties into the lagoon at Arroyo Burro Beach (Figure 2 2). There are various engineered modifications to the creeks and drainages to prevent bank erosion, channel bed scouring, and/or overbank flooding, some of which have been removed or modified to improve the creek flow dynamics and make the creek more accessible to spawning steelhead trout. The Santa Barbara urban creeks are mostly unlined earthen channels with cobbly substrate and scattered to dense riparian vegetation, often abutting landscaping associated with adjacent residential areas (URS Corp., 2002). The lower portion of the Arroyo Burro creek, adjacent to Las Positas Road, contains a fully lined concrete channel. An estuary, inhabited by endangered tidewater goby and a host of bird-life, is present at the end of the creek at Arroyo Burro County Park.

Mission Creek

Mission Creek begins in the Santa Ynez Mountains in Rattlesnake Canyon and winds its way down through the City of Santa Barbara until it reaches the ocean east of Stearns Wharf (Figure 2-3). Upstream of Highway 101, Mission Creek is an earthen channel with a cobbly substrate and varying density of oak and riparian woodland on the banks. Downstream of State Street, there are various bank and bed modifications. A manmade uniform trapezoidal channel is located along the Highway 101 corridor in two locations: from below Pueblo Street to below Mission Street and from above Arrellaga Street to Canon Perdido Street (URS Corp., 2002). Below Canon Perdido, Mission Creek contains a highly modified rectangular or trapezoidal channel constructed of various materials including concrete or rock retaining walls, rock rip-rap, concrete banks, gabion walls, and earthen banks. The bed of the channel is mostly unlined, consisting of cobbles and sand substrate. Dense vegetation on the banks includes both native and non-native riparian plants and landscaping from adjacent residences and businesses. A lagoon at the creek mouth near Stern's Wharf seasonally connects Mission Creek with the Pacific Ocean.

Laguna Channel

Nestled between the Mission watershed to the west and the Sycamore watershed to the east, Laguna Channel is the channelized remains of wetlands that existed before urbanization (Figure 2-4). Laguna is formed by overland flow generated in the Riviera and Bungalo Haven neighborhoods which enters the stormdrain system and flows south into the channel. The channel flows to an outlet at East Beach.

Sycamore Creek

Sycamore Creek is the confluence a number of creeks, including Parma, Westmont, and Coyote, that converge along Sycamore Canyon Road (Figure 2-5). Much of the upper watershed is public land, including Los Padres National Forest and Parma Park, and has remained largely unaltered in this area except for modification of the natural stream corridor parallel to Mission Canyon Road. However, downstream of the Salinas roundabout Sycamore Creek becomes more channelized, with artificial reinforcement to banks and occasional concrete lining. Sycamore Creek ends in a long stretch of slack water and a small lagoon at East Beach that connects to the Pacific Ocean during periods of high flow.

Figure 2-2 - Arroyo Burro Watershed

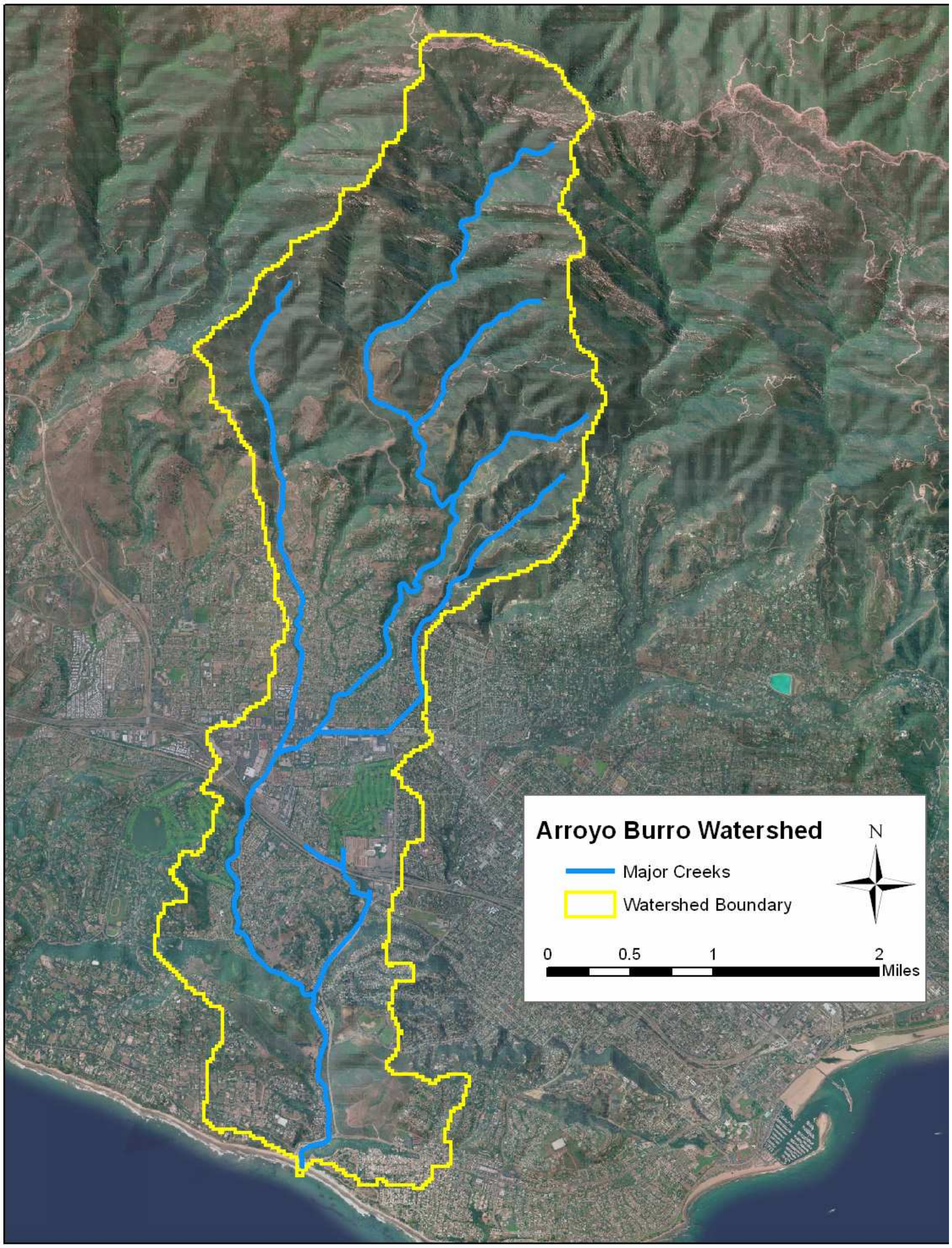


Figure 2-3 - Mission Creek Watershed

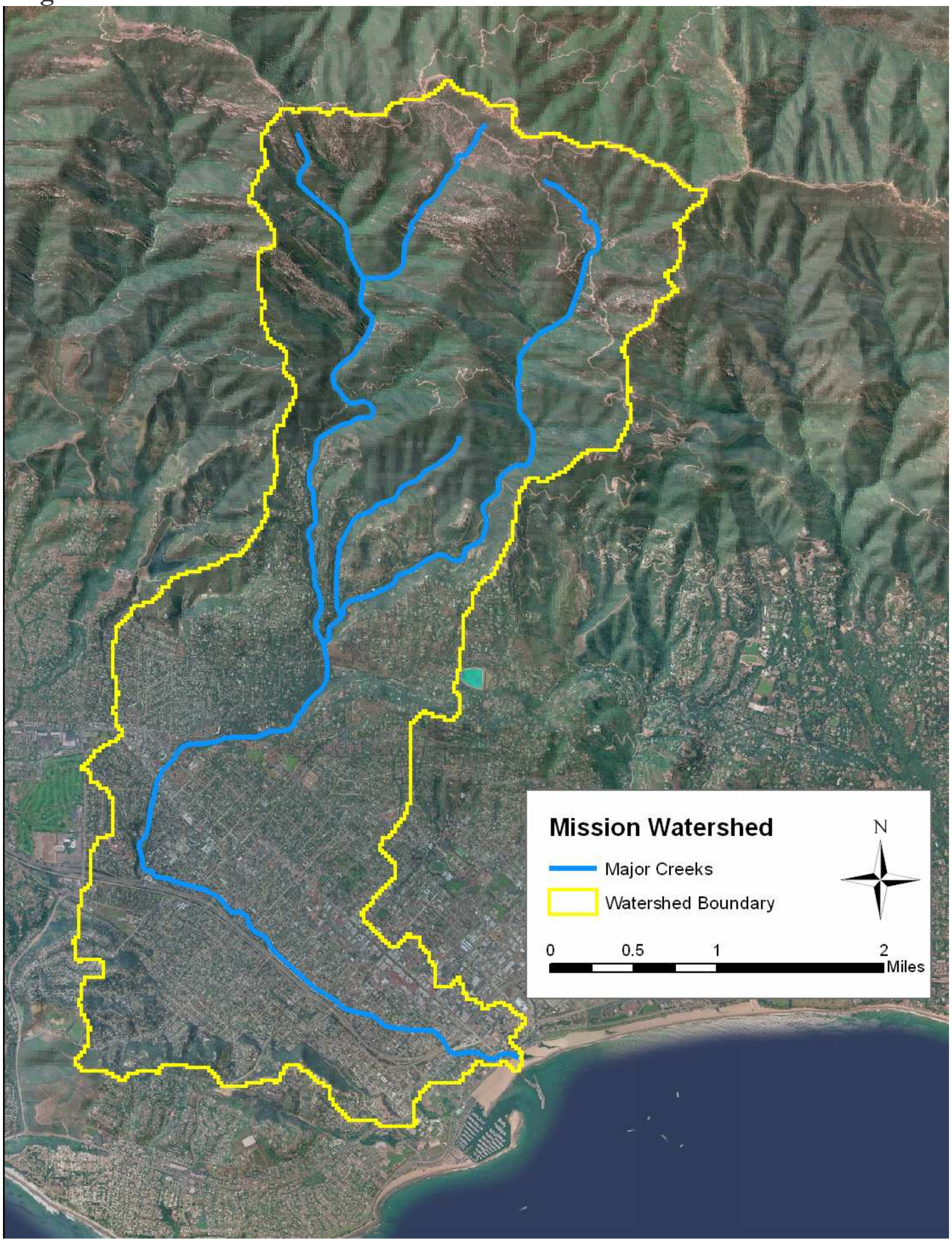


Figure 2-4 - Laguna Channel

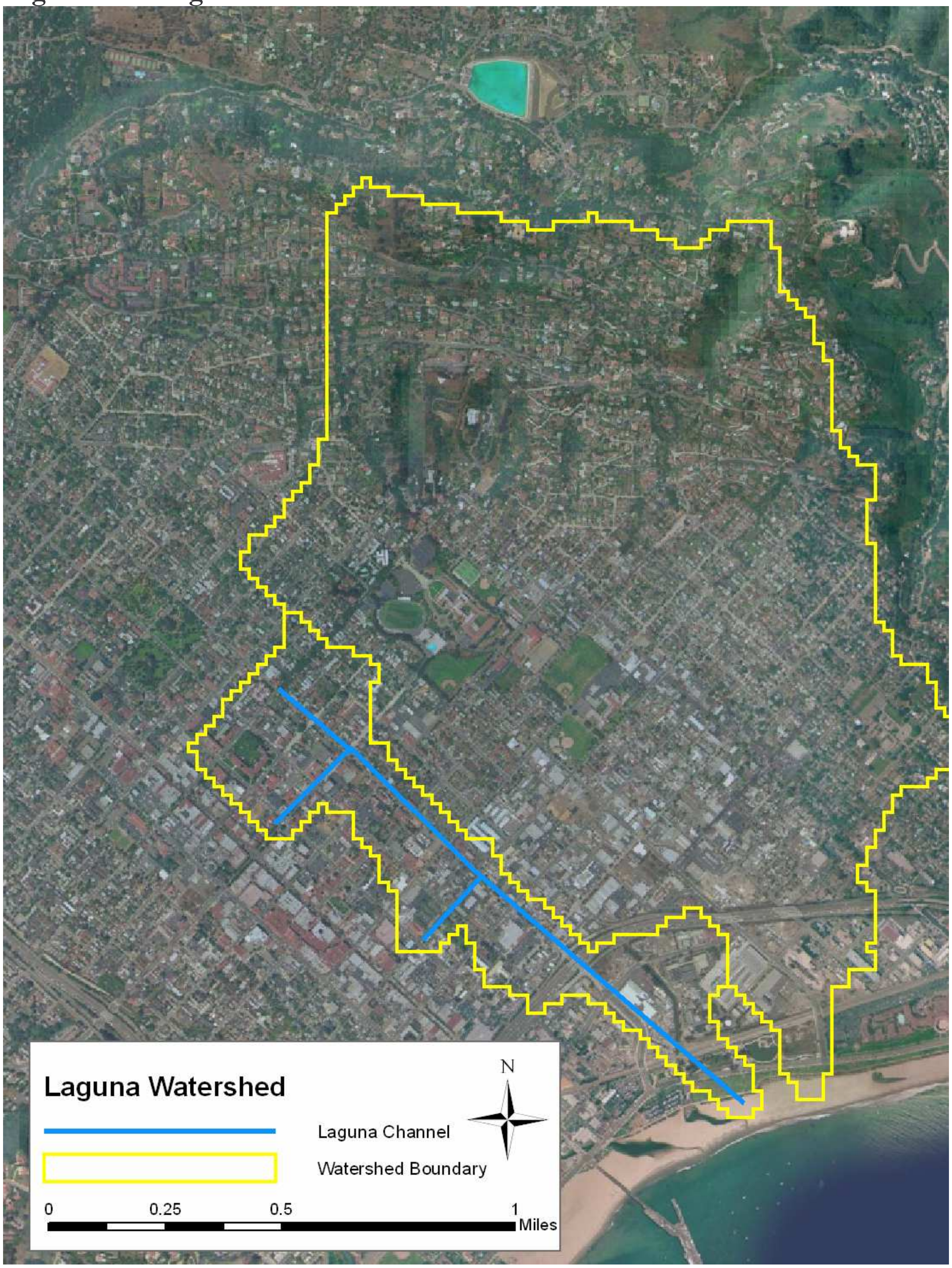
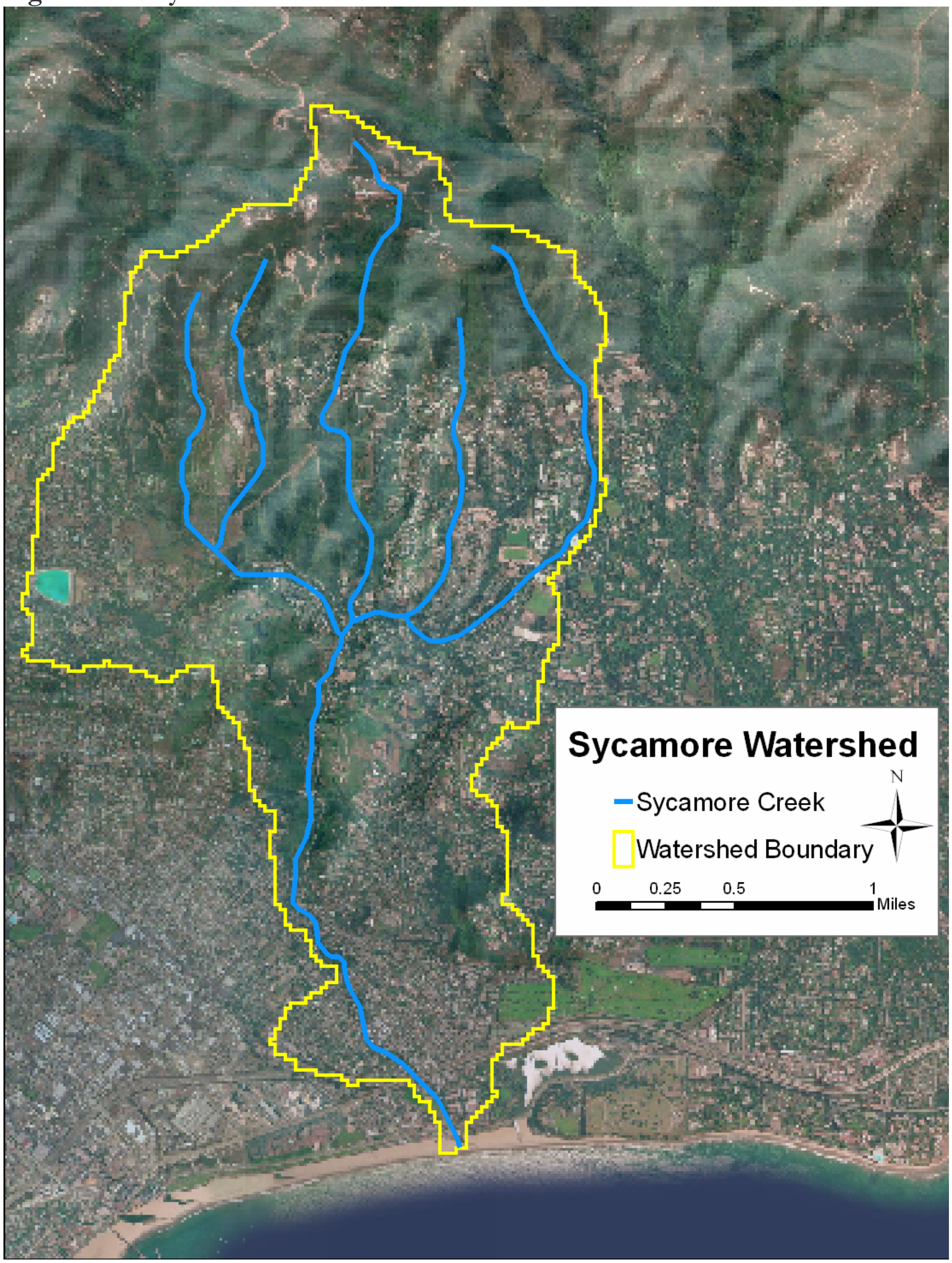


Figure 2-5 - Sycamore Creek



2.3 *Central Coast RWQCB Basin Plan*

The Regional Water Quality Control Board (RWQCB) Plan for the Central Coast, commonly referred to as the Central Coast Basin Plan, has been formulated to address water quality management throughout the region. Each RWQCB must formulate and adopt water quality control plans for areas within its jurisdiction. The water quality control plan consists of "three components: beneficial uses which are to be protected, water quality objectives which protect those uses, and an implementation plan which accomplishes those objectives" (Central Coast RWQCB, 1994). The creeks that flow through the city of Santa Barbara must meet the water quality objectives prescribed in the Basin Plan. Beneficial uses designated by the Central Coast RWQCB for the waters of the creeks in Santa Barbara (Table 2-1) guide the specific water quality criteria guidelines.

Table 2-1 - Beneficial Uses of Santa Barbara Creeks

Use Designation	Arroyo Burro	Mission	Sycamore
Municipal and Domestic Supply	X	X	X
Agricultural Supply			X
Industrial Process Supply			
Industrial Service Supply			
Ground Water Recharge	X	X	X
Water Contact Recreation	X	X	X
Non-water Contact Recreation	X	X	X
Wildlife Habitat	X	X	X
Cold Fresh Water Habitat		X	X
Warm Fresh Water Habitat	X	X	X
Migration of Aquatic Organisms		X	X
Spawning, Reproduction, and/or Early Development	X	X	X
Preservation of Biological Habitats of Special Significance	X		
Rare, Threatened, or Endangered Species	X	X	X
Estuarine Habitat		X	X
Marine Habitat			
Freshwater Replenishment	X	X	X
Navigation			
Hydropower Generation			
Commercial and Sport Fishing	X	X	X
Aquaculture			
Inland Saline Water Habitat			
Shellfish Harvesting			

Source: Central Coast RWQCB Basin Plan, 1994

The Basin Plan also outlines implementation procedures and monitoring programs administered by the region and state. The Central Coast RWQCB conducts monitoring programs throughout its designated region, which spans from just above Big Sur to the border of Santa Barbara and Ventura counties.

2.4 *Regulations Pertaining to Surface Water Quality*

The monitoring plan accompanying this report is designed to assist the Creeks Division in meeting the water quality objectives of the Central Coast Basin Plan. However, there are several other regulations that are pertinent to the management of water quality in creek systems. The Clean Water Act outlines the Total Maximum Daily Load (TMDL) requirements and the National Pollution Discharge Elimination System (NPDES), both of which are potentially applicable to the creek systems. The California Toxics Rule (CTR) also provides guidance on numeric quality criteria that is utilized in the Central Coast Basin Plan.

The Clean Water Act and TMDLs

The Clean Water Act, adopted in 1972, is a federal regulation aimed at restoring water quality problems caused by years of unregulated dumping and lack of proper municipal sanitation systems. § 303(d) of the Clean Water Act requires that every state identify surface water bodies or lengths of those bodies that do not meet water quality standards for pollutants and therefore cannot support their beneficial use classifications. Under §303(d) states must first develop the list of impaired water bodies, prioritize them, then devise management strategies to improve their water quality to restore their designated beneficial uses.

Two of Santa Barbara's creeks are listed as impaired water bodies on the 303(d) list for the Central Coast:

- Arroyo Burro Creek – Identified as being impaired by pathogens, likely sourced from urban runoff/storm sewers, and non-point sources. It is ranked as low on the priority list on the 303(d) list prepared by the State Water Resources Control Board (SWRCB, 2002).
- Mission Creek – Identified as being impaired by pathogens likely sourced from urban runoff/storm sewers and transient camps; and unknown toxicity (as detected in laboratory toxicity testing) likely sourced from runoff/storm sewers. It too is ranked low on the priority list (SWRCB, 2002).

As a component of the management strategy to attain designated uses, a Total Maximum Daily Load (TMDL) must be calculated for a particular pollutant. It loosely translates to the quantity of a pollutant a water body can receive and attenuate without experiencing impairments of beneficial uses. The determination of a TMDL is frequently assessed using modeling programs, such as the SWAT program employed in this study. As part of the development of a TMDL, a source analysis is conducted to determine point and non-point source contributions to the water body. Although the development process of TMDLs are still in the process of being refined as a regulatory method, the USEPA and State Water Resources Control Board are proceeding with enforcement by requiring regional boards, and the municipalities in their jurisdiction, to submit and implement TMDL programs.

The calculation of TMDLs is not yet the focus of City creeks programs, but will continue to gain attention as the state begins to require action. The monitoring plan outlined in this report will develop essential data for developing TMDLs if they are required in Santa Barbara. The indicator site methodology outlined in Section 2.6 may satisfy some of the point source sampling requirements for TMDL development.

NPDES Small Municipal Separate Storm Sewer System Permit

Santa Barbara collects and expels its storm water runoff through a municipal separate storm sewer system, frequently abbreviated as an MS4. Section 402 of the Clean Water Act requires certain MS4s to acquire permits under the National Pollution Discharge Elimination System to allow discharges of storm runoff into surface waters.

Under the 40 CFR § 122.26(b)(8) description, the entire Santa Barbara urban landscape classifies as an MS4, as the streets themselves act as a collection and conveyance system to waters of the United States. Phase I of the 1990 NPDES promulgation only applies to industrial facilities, large construction operations, and large or medium sized MS4s. Large and medium MS4s are defined as those serving over 100,000 people. As Santa Barbara did not fit these criteria at the time of promulgation, the city is not considered a large or medium MS4. Phase II of the NPDES system, enacted in 1999, includes regulations for small MS4s and is applicable to Santa Barbara. The city recently developed a Storm Water Management Plan (SWMP) as required by the state's small MS4 general permit to manage discharges of urban runoff to receiving waters.

The SWMP is a key aspect of the NPDES general permit scheme and summarizes the MS4's management plans and strategies to maintain compliance in all applicable discharge and effluent prohibitions. It addresses six minimum control measures:

- Public Education and Outreach on Storm Water Impacts
- Public Involvement/Participation
- Illicit Discharge Detection and Elimination
- Construction Site Storm Water Runoff Control
- Post-Construction Storm Water Management in New Development or Redevelopment
- Pollution Prevention / Good Housekeeping

The City of Santa Barbara is currently implementing measures to achieve these objectives. Use of the proposed monitoring plan may be useful to attain the final four control measures.

40 CFR Part 131 - California Toxics Rule

In 1994 a California state court rescinded many of the state-designated priority toxic pollutants standards required under §303(c)(3)(B) of the Clean Water Act. This rescission by the State Water Board was attributed to a legal challenge of the *Inland Surface Waters Plan* and *Enclosed Bays and Estuaries Plan* (Marshak, 2003). As a result, the state went without standards for six years until April of 2000 when EPA approved the new priority pollutant standards promulgated by the State Water Resources Control Board (SWRCB) to replace the overturned standards. Known as the California Toxics Rule (CTR), it applies to all inland surface water, enclosed bays, and estuaries within California. In conjunction with any other applicable state and federal standards, these are the levels to which sample results should be compared to in order to determine whether contaminant concentrations are exceeding regulatory thresholds.

The CTR regulates priority toxic pollutants and differentiates between the criterion continuous concentration (CCC) and the criterion maximum concentration (CMC). The CCC is based on risks associated with chronic exposure to a toxic pollutant and is set at the highest instream concentration of a toxicant or effluent to which aquatic organisms can be exposed without experiencing long term chronic effects (CTR, 2000). The acute toxicity standard, the CMC, is defined as the highest instream concentrations of toxicant or effluent to which aquatic organisms can be exposed for a brief period of time without experiencing adverse acute effects (CTR, 2000). The CCC standards are more easily enforceable, as monitoring results can be based on mean concentrations over time. It is more difficult to assess whether the CMC is being violated, since it is often not feasible to continuously monitor toxicant concentrations. However, the CMC does provide a method of understanding whether measured concentrations pose significant health risks and can be useful in assessing measured spikes of pollutants during storm runoff sampling.

Beach Environmental Assessment and Coastal Health Act

Passed in 2000, the Beach Environmental Assessment and Coastal Health Act (BEACH Act) requires that all coastal states and states bordering the Great Lakes adopt EPA - designated indicator bacteria criteria designed to protect human health. While most indicator bacteria species are not human pathogens, they are indicative of fecal matter in the water which may contain pathogens not easily detectable themselves. Following this rationale, the presence of indicator bacteria denotes an increased probability of human pathogens. The EPA criteria, established in 1986, are considered applicable to all coastal recreation waters and estuaries officially recognized or designated for swimming, bathing, surfing, or similar activities. Under the BEACH Act, by 2004 states had to either adopt the EPA's 1986 criteria, or develop criteria of their own that could be considered at least as protective as the EPA's.

In 2004 the EPA "final rule" established criteria for those states that had not adopted indicator bacteria standards of their own (Table 2-2). The EPA final rule specifies that assessment criteria set by TMDL and/or NPDES programs may be used in lieu of the

EPA standards. In several instances states are adopting the EPA's criteria for some of their beaches while implementing criteria of their own for others; California is amongst them.

Table 2-2 - EPA Beach Act Bacteria Count

Bacteria	Count (cells/100 mL)
E. coli (Fresh Water)	126
Enterococci (Fresh Water)	33
Enterococci (Marine Water)	35

<u>Assembly Bill 411</u>

Passed in 1997, California Assembly Bill 411 (AB 411) established criteria for monitoring indicator bacteria levels at the state's public beaches (Table 2-3). Under AB 411, beaches frequented by 50,000 or more visitors per year and adjacent to a storm drain that flows during the summer require weekly testing between April 1st and October 31st. Testing required includes total coliform, E. coli and Enterococci indicator bacteria. Should levels exceed regulatory standards, public notices are required to be posted to warn the public against entering the water. The bacteria sampling required under AB 411 is conducted by the Santa Barbara County Department of Environmental Health Services and has resulted in frequent beach warnings.

Table 2-3 - AB 411 Bacteria Standards

Total coliform	Instantaneous count – *MPN/100mL ≥ 10,000
Total coliform	Geometric mean of 5 samples within 30 days – MPN/100mL ≥ 1,000
Fecal coliform	Instantaneous count – MPN/100mL ≥ 400
Fecal coliform	Geometric mean of 5 samples within 30 days – MPN/100mL ≥ 200
Enterococcus	Instantaneous count – MPN/100mL ≥ 103
Enterococcus	Geometric mean of 5 samples within 30 days – MPN/100mL ≥ 35

*MPN refers to the statistically based bacteria counting method known as: "Most Probable Number" per 100mL. This is the reporting methodology used by the IDEXX test kits employed by the city.

2.5 *Non-Point Source Pollution Research*

Research on work that has been completed on non-point source pollution and water pollution assessment in urban areas and California creeks is presented here to evaluate studies pertinent to the design of the proposed monitoring plan and subsequent recommendations. This information is useful for providing a context for the proposed monitoring protocol to related efforts, and provides further depth on current perceptions of water pollution assessment in urban areas.

Nationwide Urban Runoff Program

The most comprehensive study of non-point source pollution was conducted by the EPA from 1978 to 1983. The Nationwide Urban Runoff Program (NURP) was designed to address the impacts of urbanization on water quality. The stated goals of the project were to examine the:

- Characteristics of urban runoff and similarities or differences among urban land uses.
- Extent to which urban runoff contributes to water quality impairments.
- Performance and effectiveness of management practices to control pollution loads from urban runoff (US EPA, 1983).

The study focused on nutrients, total suspended solids, oxygen-demanding substances (organics) and metals. Event mean concentrations (average values from storm sampling results) were calculated from four land use categories: residential, mixed, commercial, and open/non-urban and are shown in Table 2-4. The coefficient of variation (COV- the standard deviation divided by the event mean concentration), was included to illustrate the variability of the median value. While the results from NURP indicated that clear trends linking pollutant concentrations to specific land uses were unobservable, pollutant levels differed when comparing urban runoff to runoff produced in non-urban areas. The conclusion drawn from these results was that concentration of pollutants was more closely correlated with the amount of urbanization and the conversion of open space into impervious surfaces (US EPA, 1983).

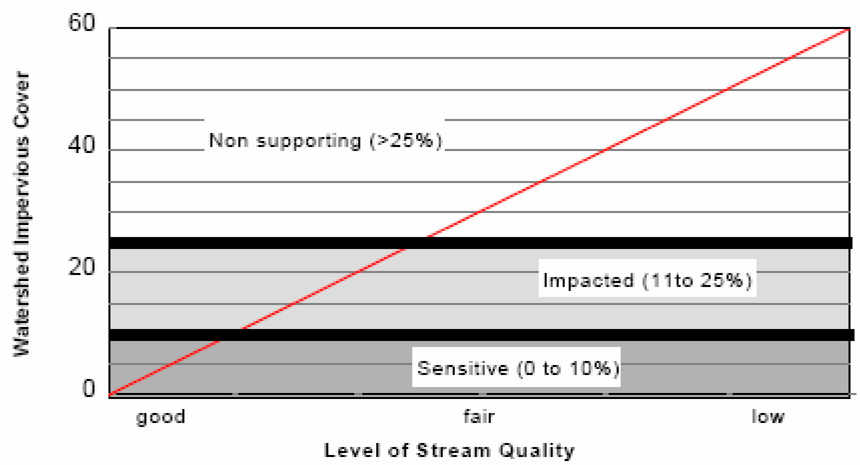
Table 2-4 - Median Event Mean Concentrations for Urban Land Uses

Pollutant	Units	Residential		Mixed		Commercial		Open/ Non-Urban	
		Median	COV	Median	COV	Median	COV	Median	COV
BOD	mg/l	10	0.41	7.8	0.52	9.3	0.31	--	--
COD	mg/l	73	0.55	65	0.58	57	0.39	40	0.78
TSS	mg/l	101	0.96	67	1.14	69	0.85	70	2.92
Total Lead	µg/l	144	0.75	114	1.35	104	0.68	30	1.52
Total Copper	µg/l	33	0.99	27	1.32	29	0.81	--	--
Total Zinc	µg/l	135	0.84	154	0.78	226	1.07	195	0.66
Total Kjeldahl Nitrogen	µg/l	1900	0.73	1288	0.50	1179	0.43	965	1.00
Nitrate + Nitrite	µg/l	736	0.83	558	0.67	572	0.48	543	0.91
Total Phosphorus	µg/l	383	0.69	263	0.75	201	0.67	121	1.66
Soluble Phosphorus	µg/l	143	0.46	56	0.75	80	0.71	26	2.11

COV: Coefficient of variation
Source: Nationwide Urban Runoff Program (US EPA 1983)

The importance of impervious surface cover was accentuated by Schueler (1994a) when he proposed to establish percentages of impermeable surface as the common theme of urban watershed protection. Schuler has argued that impervious surfaces can serve as a "common currency" that allows watershed managers, city planners, landscape architects, and other interested parties to manage and mitigate impacts on natural waterways. Further work by Schueler and Claytor (1995) demonstrated that a relatively small percentage of impervious area affects stream quality (Figure 2-6). Stream quality is generally supportive of biota when impervious cover was less than 10% of the watershed, but became impacted when even 11 to 25% of the watershed was covered in impermeable surfaces. The study further demonstrated that the stream was no longer able to support biota once impervious cover exceeded 25%. Indeed, many watershed models have relied upon impervious surfaces as a key input for calculating pollutant loads and runoff volumes. Given the results of NURP and Schueler and Claytor, the land use analysis detailed in Section 8810 also included estimating the amount of impervious surfaces in the watershed drainages. This information has future possible applications to statistical analyses on the relationship between water quality and impermeable surfaces.

Figure 2-6 - Relationship between Impervious Cover and Stream Quality



Source: Schueler and Claytor, 1995

As the percentage of impervious surfaces increases, the volume and rate of surface runoff entering the water system increases and raises the mass of pollutants transported with the runoff (Schueler and Claytor, 1995). Impermeable areas also lead to higher rates of erosion, stream channel scouring and sedimentation problems (Table 2-5). In addition, imperviousness has been linked to stream warming and loss of biodiversity (US EPA, 1997).

Table 2-5 - Impacts from Increases in Impervious Surfaces

Increased Imperviousness Leads to:	Resulting Impacts				
	Flooding	Habitat loss	Erosion	Channel Widening	Stream bed Alteration
Increased Volume	✔	✔	✔	✔	✔
Increased Peak Flow	✔	✔	✔	✔	✔
Increased Peak Duration	✔	✔	✔	✔	✔
Increased Stream Temp.		✔			
Decreased Base Flow		✔			
Changes in Sediment Loading	✔	✔	✔	✔	✔

Source: EPA, 1997

The First Flush Concept

Storm water sampling results have traditionally indicated that pollutant concentrations were greater during the beginning of a storm as compared to the middle or end of the storm, even though greater runoff volumes are experienced during the latter stages of the event. Schueler (1994b) presented the first flush concept, which contended that 90% of the pollutants accumulated on impervious surfaces were washed away in the first half-inch of runoff. It followed that management measures capturing the first half-inch of runoff could prevent a significant portion of storm water impacts to water quality. More detailed investigation into the first flush phenomenon revealed that imperviousness had a strong influence. Results indicated that the half-inch rule was generally valid when the percentage of imperviousness in the drainage area was less than 50% (Chang, 1990). Once the percentage exceeded 50%, capture of the first half-inch of runoff was not sufficient to sequester 90% of pollutant loads. While not completely refuting the first flush concept, the results provided further refinement for storm event sampling methods and management actions.

National Water Quality Assessment Inventory

As part of the Clean Water Act, the EPA is required to review and summarize water quality assessments submitted by each state and several Native American tribes. The most recent version of the National Water Quality Assessment Inventory is from a report released in 2000. In general, the states indicate that the primary causes of water quality impairments are siltation, nutrients, bacteria, metals (primarily mercury) and oxygen-depleting substances. The main cause of these impairments is identified as non-point source pollution (US EPA, 2000). Habitat alteration is also quoted as having a significant impact on the water systems studied. The reported impairments for the state of California's rivers and streams in the 211,513 miles assessed are to aquatic life use support (85%), primary contact (80%), and fish consumption (80%). Silviculture, habitat modification, agriculture, and hydrologic modification are cited as the primary causes of these impairments. This information relates to the choice of priority constituents and reinforces the need for further research on non-point source pollution.

Long Term Ecological Research Project

The Santa Barbara Channel Long Term Ecological Research Project (SBC LTER) is part of the National Science Foundation's LTER network. The NSF LTER program is a network of 26 research sites designed to assess ecological phenomena over large spatial scales and diverse environments "through well-designed and documented long-term experiments and observations" (NSF LTER, 2005). Since April of 2000, the SBC LTER has studied the relative importance of land and ocean processes in structuring the giant kelp forest ecosystems in the Santa Barbara Channel (SBC LTER, 2005). To meet this objective, the SBC LTER team is trying to determine the correlation between land use patterns and the distribution and movement of nutrients, sediments, organisms, and toxic substances in the coastal watersheds of the Santa Barbara Channel. The SBC LTER aims to determine information on fate and transport of constituents of concern in the creeks, estuaries, and ocean outflows. Research conducted by the SBC LTER that is specifically pertinent to this group project is the runoff modeling, time series sampling, correlating factors statistics, and development of a sampling protocol that is tailored to Santa Barbara County's meteorology and landscape. Data collected by SBC LTER is utilized in the SWAT modeling exercise for the Arroyo Burro watershed described in Section 5.

2.6 *NAWQA Protocol*

The National Water-Quality Assessment (NAWQA) program has been developed by the U.S. Geological Survey (USGS) to provide a nationally recognized framework to "assess the status of and trends in the quality of the Nation's ground- and surface- water resources and to link the status and trends with an understanding of the natural and human factors that affect the quality of water" (USGS, 1995). The NAWQA program is used as a general template for this proposed monitoring plan because it offers a consistent and demonstrated methodology. However, as NAWQA is based upon the division of major hydrologic systems into 10,000 km^2 study unit areas, which are much larger than the watersheds within the city limits of Santa Barbara, the program was tailored to the specific objectives of the proposed monitoring plan for the Creeks Division.

- **Retrospective Analysis**: review of historical water quality data; deemed inappropriate as little historical data exists on constituents besides indicator bacteria and extensive reviews of indicator bacteria data have already been performed by the Creeks Division
- **Case Studies**: detailed studies of specific contaminants and hydrologic systems; performed on hydrologic systems in Southern California and discussed in detail in Section 7.2
- **Occurrence and Distribution Studies:** broad scale characterization of geographic and seasonal distributions of water quality conditions; this aspect of NAWQA was the focus of the design of the proposed monitoring plan

Occurrence and Distribution Studies

There are three components of the occurrence and distribution studies recommended by NAWQA: water-column, bed sediment, and ecological studies. The combination of these approaches allows for a more complete description of water quality conditions, hydrologic regimes, and anthropogenic impacts. Water-column studies are directly applicable to the purposes of the proposed monitoring protocol. Bed sediment studies are recommended due to results of sediment sampling results gathered by the Central Coast Regional Water Quality Control Board (RWQCB), discussed in Section 7.2. Ecological studies are not within the scope of the current monitoring program but are recommended for consideration by the Creeks Division at a later date.

Sample types for these studies are divided into integrator and indicator sites. This approach is the basis of the proposed monitoring plan site selection process. Integrator sites are located in heterogeneous large basins, affected by a wide range of land use and hydrologic settings. Indicator sites, in contrast, are chosen at the base of drainage basins with fairly homogeneous land use and hydrologic conditions. Indicator sites are designed to capture areas predominantly influenced by a particular land use or point source, while integrator sites are meant to be more representative of the overall ambient conditions of the water system. The integrator/ indicator sampling approach and sites are discussed in detail in Section 10.

Water-Column Studies

The focus of the water-column study as defined by NAWQA is to assess physical and chemical characteristics of the study area. There are three primary sampling strategies employed: basic fixed-site, intensive fixed-site, and water-column synoptic studies. Basic fixed sites are chosen as a basis for an integrated assessment of spatial and temporal water quality conditions and are sampled continuously, at fixed-intervals, and during extreme-flow conditions. Intensive fixed sites are similar, but also include weekly dissolved pesticide sampling for one year. Due to the much smaller size of the Santa Barbara watersheds as compared to the 10,000 km^2 study unit utilized by the USGS, only basic fixed-sites are included in this protocol. Both site classifications consist of a combination of indicator and integrator sites.

Continuous sampling measures streamflow, specific conductance, and temperature. The weekly measurements of conductivity and temperature performed by Santa Barbara's weekly indicator bacteria sampling program should be adequate for tracking trends in these parameters. However, if continuous streamflow data is desired, installation of a gauging station maintained by the Creeks Division would be necessary, as outlined in Section 11.4.

Synoptic studies are performed on a short-term basis to evaluate the spatial distribution of selected water quality conditions and influences. Their design is dictated by the specific circumstances in the study unit, although general guidelines are provided by the USGS. Synoptic studies may serve the purposes of the Creeks Division in the future, but are not included in the proposed monitoring plan as more data is needed to choose the specific water quality conditions that are of the highest priority. Intensive indicator site sampling for bacteria could be considered a synoptic study if the Creeks Division performs sampling in a short time interval, such a month, as opposed to sampling over the course of a year in varying flow regimes and weather patterns.

Bed Sediment Studies

Sediment sampling is designed to address the sequestration of metals and hydrophobic organic pollutants in sediments. As suspended sediments transported by the creeks settle out of suspension in eddies, pools, or lagoon areas where the water velocity slows, contaminants bound to sediment particles can be sequestered in the accumulated bed sediments. This dynamic is confirmed in sampling conducted by the Central Coast RWQCB (see Appendix D), which documented levels of semivolatile organic contaminants, insectides, and metals in Santa Barbara creek sediments. The NAQWA protocol recommends collecting sediment samples annually during the summer or autumn low flows to minimize seasonal variability. The sample locations should be situated in areas of natural deposition zones during low flow conditions, where fine-grained sediments are accumulated. In Santa Barbara creeks, these locations are near outlets to the ocean. Sample collection consists of compositing samples from several points in the stream at various depths to capture a range of time scales.

II. METHODS

3 LAND USE ANALYSIS

The primary objective of the land use survey and GIS review was to examine the particular characteristics of the watersheds of Santa Barbara. By utilizing existing GIS data sets for land use and hydrology, it was possible to:

- Determine the drainage patterns of each watershed.
- Estimate the amount of impervious surface in each sub-watershed.
- Verify or modify land uses designated by the Anderson Level III GIS layer.

The Anderson land use classification scheme (Table 3-1) utilized for the report was developed in 1976 as a method to classify results from remote sensing (Anderson et. al, 1976) and is divided into three categories of increasing detail. The Anderson Level III dataset was chosen for comparison to the city's geospatial browser maps (based on parcel data) and on-the-ground surveys, as this level of detail was both possible to determine and applicable to the geographic scope of the project.

The geospatial browser is a GIS tool on the Public Works' Server accessible from the City's intranet. The various layers include just about all the City infrastructure and other useful information including sewer systems, stormdrain network, trees, elevation contours, aerial photos, zoning, and parcel data (who owns the property and who the tenant is). The geospatial browser allowed a building-to-building audit to determine ownership, review the general structure and size of the buildings, and validate land use with a reasonable degree of certainty. The geospatial browser was also used to review the contour and storm drain network overlays to determine runoff patterns. In some areas the Anderson Level III data was very accurate and more precise than zoning maps, but small discrepancies were common. The source of most of the discrepancies derives from the finer differences between commercial, mixed-use, and multi-family residential where these land uses overlap. Other discrepancies were found when there were clearly distinct commercial and multifamily land uses. It seemed that where there was only the potential of mixed use development, Anderson Level III categorized it as mixed use. The discrepancies noted were not significant enough to discard the existing GIS datasets for future use, but did merit obtaining greater precision by conducting block by block surveys, particularly for areas where discrepancies were noted.

Table 3-1 - Anderson Land Use Scheme

Level I	Level II	Level III
1 Urban/Developed	11 Residential	111Single unit
		112 Multiple Unit
		113 Mobile Home Park
		114 Mixed Single & Multiple
	12 Commercial & Services	121 Retail Trade

Level I	Level II	Level III
	(facilities with obvious structures)	122 Institutions
		123 Recreation
		124 Professional Services
	13 Industrial	131 Extraction
		132 Processing
		133 Fabrication
	14 Infrastructure	141 Transportation
		142 Communications
		143 Utilities
	15 Industrial & commercial complexes	
	16 Mixed urban or built-up land	161 Mixed Residential-Commercial
		162 Mixed Residential-Industrial
		163 Mixed Commercial-Industrial
		164 Construction
	17 Open urban (facilities with minimal structures)	171 Undeveloped
		172 Tent Campgrounds
		173 Golf Courses
		174 Cemeteries
		175 Parks w/open space
2 Agricultural	21 Croplands and pasture	211 Row Crops
		212 Field Crops
		213 Improved Pasture
	22 Orchards, groves, vineyards, nurseries, & ornamental horticulture areas	221 Orchards
		223 Nurseries, Ornamental Horticulture
		224 Vineyards
		225 Greenhouses
	23 Confined feeding operations	231 Cattle
		232 Horses w/training & exercise areas
	24 Other agricultural land	241 Fallow fields & ag in transition
		242 Buildings & storage areas
3 Rangeland	31 Herbaceous rangeland	311 W/o livestock
		312 With livestock
	32 Shrub and brush rangeland	321 W/o livestock
		322 With livestock
	33 Mixed rangeland	331 W/o livestock
		332 With livestock
4 Forest	41 Mixed Broadleaf and Needleleaf forest	411 Not open to livestock
		412 Open to livestock

Level I	Level II	Level III
	42 Needleleaf forest	421 Not opent to livestock
		422 Open to livestock
	43 Broadleaf forest	431 Not open to livestock
		432 Open to livestock
5 Open Water	51 Streams and canals	511 Not Open to Livestock
		512 Open to Livestock
	52 Lakes/Ponds	521 Not Open to Livestock
		522 Open to Livestock
	53 Reservoirs	531 Municipal
		532 Private
	54 Bays and estuaries	541 Not Open to Livestock
		542 Open to Livestock
6 Wetland & Riparian Zone3	61 Forested wetland	611 Not Open to Livestock
		612 Open to Livestock
	62 Shrub-Scrub Wetland	621 Not Open to Livestock
		622 Open to Livestock
	63 Herbaceous Wetland	631 Not Open to Livestock
		632 Open to Livestock
	64 Forested Riparian Zone	641 Not open to livestock
		642 Open to livestock
	65 Shrub-Scrub Riparian Zone	651 Not Open to Livestock
		652 Open to Livestock
	66 Herbaceous Riparian Zone	661 Not Open to Livestock
		662 Open to Livestock
7 Barren land	71 Dry slat flats	710
	72 Beaches	721 Sand Beach
		722 Pebble Beach
		723 Rocky Beach
	73 Sandy areas except beaches	
	74 Bare exposed rock	
	76 Transitional areas	
	77 Mixed barren land	

Source: Andersen et al., 1976

Contracted by the Creeks Division, URS Corporation completed an in-depth drainage delineation of Mission and Arroyo Burro watersheds by designating the sub-basins within each watershed. This delineation more accurately predicts how runoff in these areas flows into the storm drain network and creeks. The URS delineations were evaluated using the compiled land use information and found to be quite accurate. This information was used to identify distinct drainage basins with a large percentage of a single type of land use. The point in the creek where the flow from a particular drainage basin terminated was located as a possible site to accumulate testing data and correlate it to a given land area, permeability, and type of use. This is the origin of indicator sampling locations included in the proposed monitoring plan.

- To confirm topography and contour data, storm drain networks, and surfaces shown in the Geospatial Browser, on-the-ground surveys were conducted. When a specific runoff network could not be clearly defined, consultation with city staff (Public Works, Creeks, and Waterfront), residents of the neighborhood, or the developers of a project within the drainage was conducted. Specifically, the following process was followed:
- Surveyed GIS images of land-use (Anderson Level III categories) layered with URS delineated boundaries to the drainages.
- Where URS delineations did not exist, mapping of the storm drain network, contours for overland flow, and consultations with city staff or others familiar with the drainage were completed to determine the boundaries of new delineations.
- Verified the accuracy of the Anderson Level III data by using the city's Geospatial Browser to spot check ownership and lease status of properties, corrected as necessary.
- Inspected aerial photos of the city to estimate permeability for each drainage.
- When possible to divide into discrete units, such as roughly equivalent blocks, a permeability percent was determined for each unit and then applied to similar units in the drainage.
- Confirmed land-use, permeability, and drainage with visual checks.

The land-use analysis has produced useful information that is the basis for indicator sampling, but it is not yet comprehensive. While the drainages that were chosen as sampling sites and surrounding areas were mapped, land-uses confirmed, and permeability estimated, this is not done for the entire city. If the analysis performed by this project and URS were extended, better comparisons in general, and statistical analysis of the relationship between permeability and pollution inputs in particular, could be performed.

4 GIS GEODATABASE

As an integral step in the land use analysis, a GIS geodatabase for Arroyo Burro, Mission, and Sycamore Creeks, and Laguna Channel, was developed. By incorporating raster grids (pixel based data layers), and shape files (vector based data layers) gathered from UCSB, the City of Santa Barbara, LTER, USGS and URS Corp., a high resolution database was assembled that incorporates:

- Digital Elevation Model (DEM)
- Stream maps including tributaries
- Storm sewers and their respective outfalls into the primary channels
- A refined land-use layer that utilizes Anderson Level III designations

- Delineations of the watersheds based on topography, storm sewers, and street collection
- Previous city sampling sites from bacteria testing programs
- Recommended indicator and integrator sites
- CAD files delineating locations of structures, streets, and storm sewer lines
- Aerial ortho-photos that provide visual context for the raster and vector data sets.

5 WATERSHED MODELING

The following section describes the implementation and calibration processes and results of a watershed model. The model was completed to develop expectations about the kind of pollutants present in the creeks that flow through the city of Santa Barbara, their concentrations, and the time they come off the land. Due to the short amount of time available to implement the model, analysis focuses only on Arroyo Burro Creek. The Soil and Water Assessment Tool (SWAT) model, developed by the Agricultural Research Service (ARS) of the United States Department of Agriculture (USDA), was selected for this purpose.

5.1 *BASINS & SWAT*

SWAT is a continuous-time model which operates on a daily time step to predict the impact of land management practices on hydrology, sediment, and water quality in complex watersheds with varying soils and land uses over long periods of time (Neitsch et al, 2002). The Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) system, developed by the EPA's Office of Water, is a watershed management model which has incorporated SWAT in its system to support the development of total maximum daily loads (TMDLs) for specific pollutants. BASINS is a multipurpose environmental analysis system developed to help regional, state, tribal, and local agencies perform watershed-based point and nonpoint source analysis for a variety of pollutants at a watershed level.

BASINS contains data on water quality and quantity, land uses, soil, topography, weather, and monitoring information, as well as site specific point and non-point source loading. These data were integrated into a customized geographic information system (GIS) under ArcView 3.1. Data sources were compiled from different federal sources including United States Geological Survey (USGS), United States Army Corps of Engineers and the Federal Emergency Management Agency, USEPA, United States Department of Agriculture (USDA), University of California, Santa Barbara (UCSB), and the National Oceanic and Atmospheric Administration (NOAA). The BASINS model has been widely used across the U.S. and some international locations because it offers one of the best integrated modeling frameworks for examining management alternatives. The BASINS system was used to develop the SWAT model input files. One of the benefits of using SWAT in BASINS is that SWAT allows the user to model decades of natural processes, which the model requires as part of a large amount of input data. Much of the input data is already in existing BASINS databases, and it must only be formatted correctly to integrate SWAT. This is done automatically by the BASINS program (Schneider, 2002).

SWAT subdivides the watershed first into sub-basins and then into areas having a unique combination of soil, land use, and management practices. These areas are referred to as hydrologic response units (HRUs). This enables the model to reflect differences in evapotranspiration and other hydrologic conditions for various crops and soils. With the SWAT model, runoff is predicted separately for each HRU and routed to obtain the total runoff for the watershed. This process increases the prediction accuracy and gives a much better physical description of the water balance (USEPA, 2001).

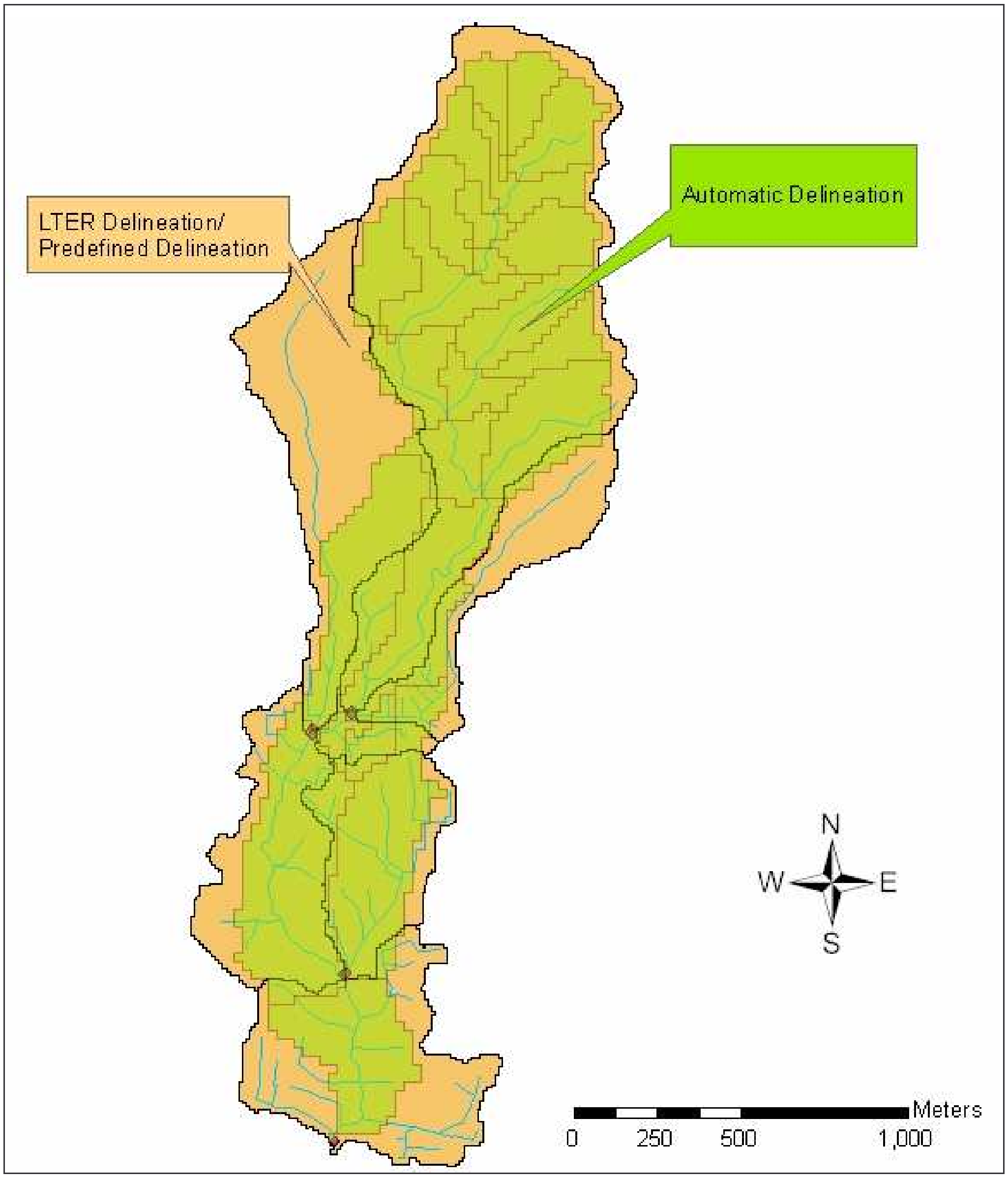
Although the SWAT model operates in a daily time step, it is not designed to simulate detailed, single-event flood routing. However, it does allow the user to develop predictive scenarios using alternative input data (e.g. climate, chemical fate and transport, and land use).

5.2 *Watershed Delineation*

The first step to set up the Arroyo Burro SWAT model was to generate and define the watershed boundary, sub-basins, stream network, and point source discharge 'themes', or layers. BASINS provides a watershed delineation tool which allows the user to perform the delineation through three different procedures: 1) an automatic delineation using DEM data, 2) a manual delineation based on the user's knowledge of the watershed's drainage topography, and 3) a predefined delineation by importing existing sub-watershed boundaries, along with stream and outlet themes into the current BASINS project. Once the delineation is performed in BASINS, it is exported to the SWAT model.

Initially, an automatic delineation was carried out for this project. However, because the Arroyo Burro sub-watershed delineation and stream network resulting from the automatic delineation inside BASINS created unrealistic drainage patterns, we decided to use a predefined delineation for the model. The themes for the delineation that were used in SWAT were created based on the LTER sub-watershed delineation. The LTER delineation in turn was determined based on digital elevation maps and drainage areas from the City. Each polygon and polyline of the GIS layers from the LTER delineation and stream network was edited and modified to be used in BASINS. In addition, the fields of the attribute tables required for the predefined delineation/LTER delineation (such as stream reach length, sub-basin slope, latitude of the sub-basin centroid, elevation of the sub-basin centroid, etc.) were calculated using GIS data from the LTER project and the sub-watershed characteristics described in the Creek Inventory and Assessment Study completed by URS in 2002. Figure 5-1 shows the watershed delineations resulting from the automatic and predefined delineations, whereas Figure 5-2 presents the SWAT subbasins.

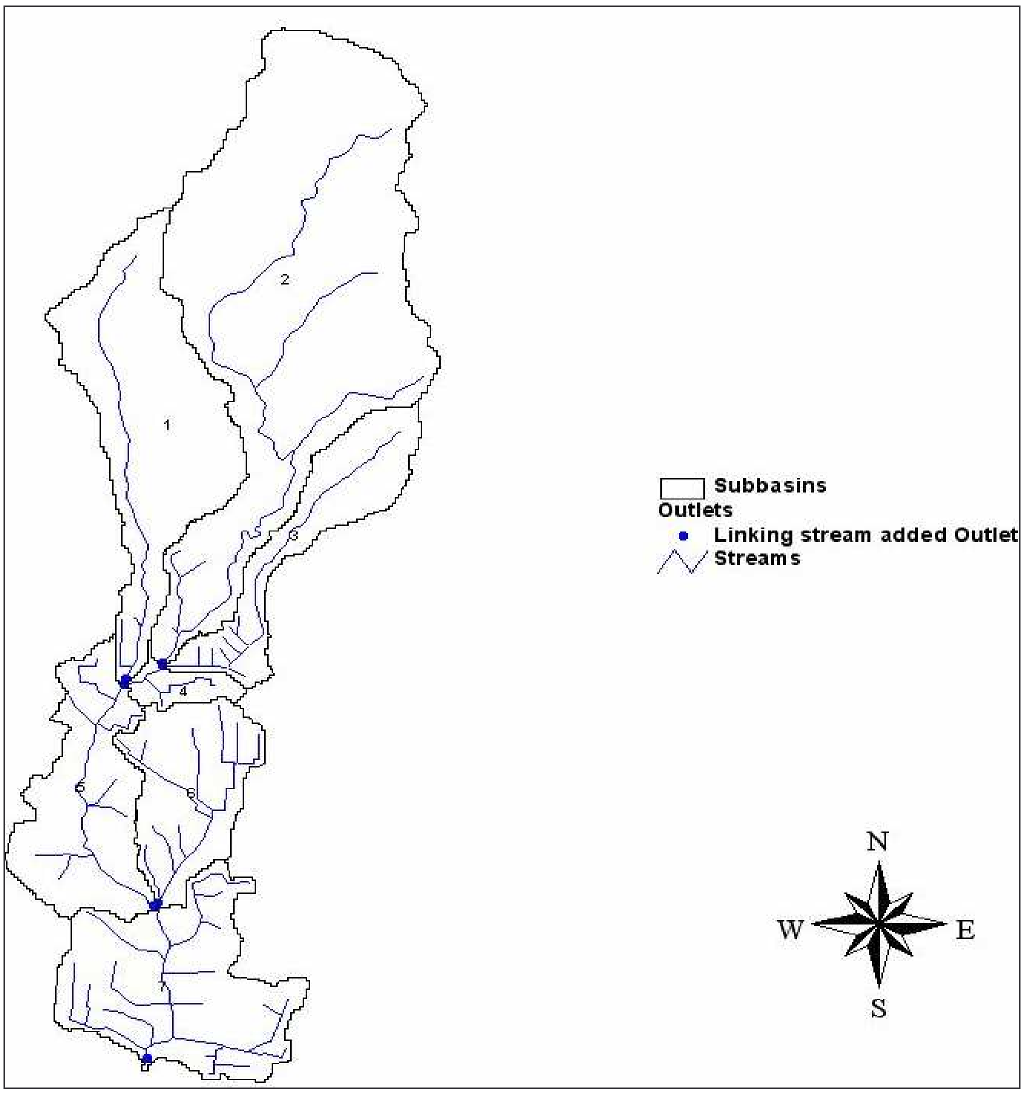
Figure 5-1- Watershed and Subwatersheds Delineations from the LTER project and BASINS Automatic Delineation



(BASINS/SWAT, 2005)

After the sub-watershed delineation was performed, HRUs were calculated by the Model Input File Generation using the SWAT2000 Arcview Interface (AVSWAT) based on user-specified land use and soil area threshold levels. In this project, the land use and soil area threshold levels were uniform for all sub-watersheds, where a minimum 3% area of a specific land use type and 13% area of a specific soil type must be present in a sub-watershed to be considered in the model. The application of thresholds eliminated land uses and soil types that covered less than 3% and 13% of the area of the subwatershed, respectively. The AVSWAT processing converted the eliminated areas to other land uses and soils in the sub-watershed, proportional to their sizes that were above the thresholds. The land use and soil area threshold levels were selected in order to keep the number of HRUs to a reasonable number while modeling the most of the important types of vegetation cover.

Figure 5-2 SWAT Subbasins



(BASINS/SWAT, 2005)

5.3 *Model Input Data*

The SWAT model requires spatial information about the watershed topography, river/stream reaches, land use, and climate to accurately simulate streamflows and pollutant loadings. Since BASINS databases have no climate stations in the entire watershed and provide very broad data for small watersheds, most of the information such as land use, temperature, precipitation, and stream reaches was loaded in ASCII format from records of climate stations located close to the Arroyo Burro watershed and GIS maps from existing studies. Other data such as DEM information was extracted from the database provided by BASINS in the form of GIS maps.

5.3.1 Weather Data

Table 5-1 shows the geographical information of the weather stations (with daily data available) used in the model. Daily maximum/minimum temperature measurements were obtained from the Santa Barbara Municipal AP station, and daily precipitation data was obtained from the Santa Barbara-Downtown FCD Office station. Radiation, wind speed, relative humidity, or potential evapotranspiration measurements were not available in these two stations, therefore they were generated using the SWAT weather generator based on long-term historic records from the CASantaBarbara weather station.

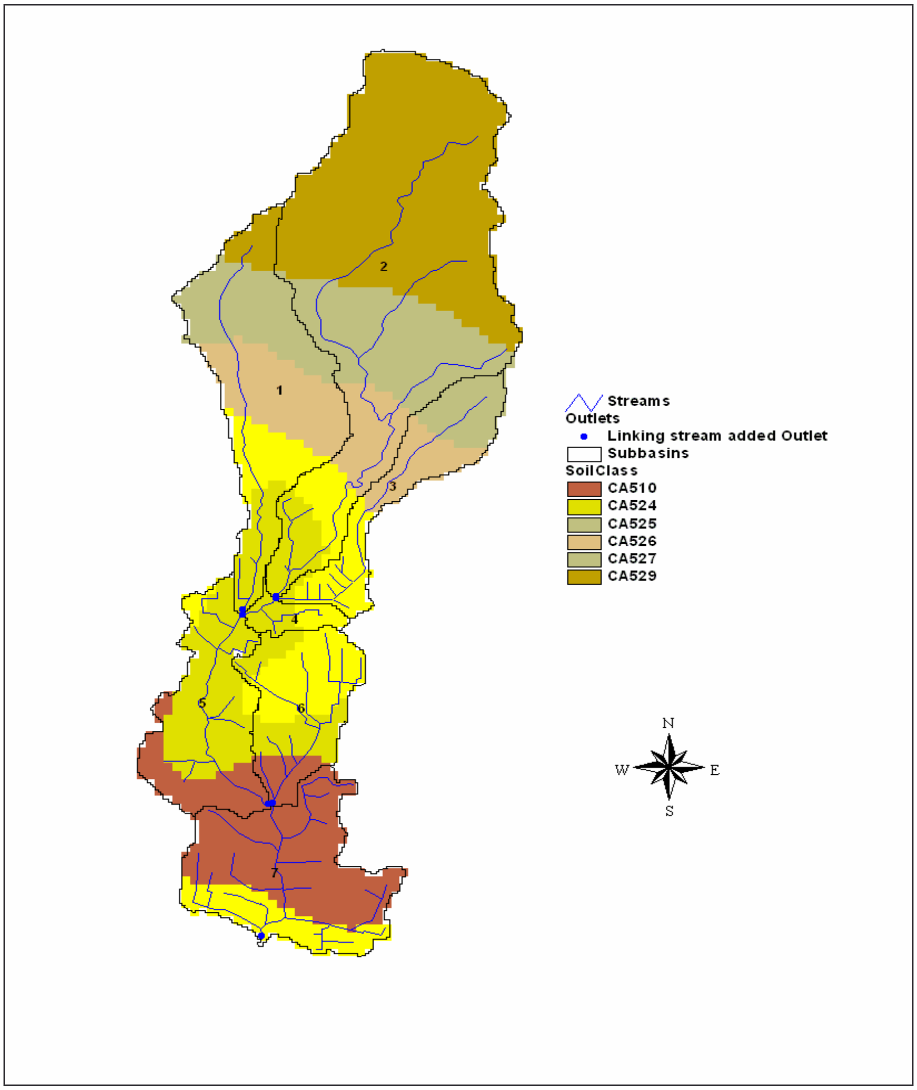
Table 5-1- Weather Stations

Station name	Coordinates		Elevation (m)	Period of Record
	Latitude	Longitude		
Santa Barbara Municipal AP, California	34.433	-119.840	3.66	1940-2004
Santa Barbara-Downtown FCD Office	34.425	-119.703	100	1962-2004
CASanta Barbara	34.420	-119.720	36.6	1962-2004

5.3.2 Soil Data

Soil data used in the model and provided by the BASINS database corresponds to the State Soil Geographic (STATSGO) database from the U.S. National Resources Conservation Service (NRCS). The STATSGO database was produced according to the National Cooperative Survey of 1994 (USDA, 1995). The mapping scale for STATSGO is 1:250,000. The level of mapping is designed to be used for broad planning and management uses covering state, regional, and multi-state areas. Figure 5-3 illustrates the soil map for the Arroyo Burro watershed. The Soil Survey Geographic (SSURGO) database can also be used with SWAT instead of the standard SWAT method using the STATSGO database. The SSURGO database provides the most detailed level of information and was designed primarily for farm and ranch, landowner/user, township, county, or parish natural resource planning and management.

Figure 5-3- Soil Map from SWAT Model



(BASINS/SWAT, 2005)

The U.S. NRCS classifies soils into four hydrologic groups based on water infiltration characteristics of the soils. NRCS Soil Survey Staff defines a hydrologic group as a group of soils having runoff potential under similar storm and cover conditions. Soil properties that influence runoff potential are those that impact the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen (such as depth to seasonally high water table, saturated hydraulic conductivity, and depth to a very slowly permeable layer) (Neitsch et al, 2001). The four groups of soils are defined as A, B, C, and D.

Definitions of the hydrologic groups of soils are:

A: Low runoff potential. The soils have a high infiltration rate even when thoroughly wetted. They chiefly consist of deep, well drained to excessively drained sands and gravels.
B: The soils have a moderate infiltration rate when thoroughly wetted. They chiefly are moderately deep-to-deep, moderately well-drained to well-drained soils that have moderately fine to moderately coarse textures.
C: The soils have a slow infiltration rate when thoroughly wetted. They chiefly have a layer that impedes downward movement of water or have moderately fine-to-fine texture.
D: High runoff potential. The soils have a very slow infiltration rate when thoroughly wetted. They chiefly consist of clay soils that have a high swelling potential soils that have a permanent water table, soils that have a clay layer at or near the surface, and shallow soils over nearly impervious material.

In the Arroyo Burro watershed, soils for groups B and D were identified only. Soils from group B represent approximately 29%, whereas the soils from group D represent 71% (See Table 5-2). Most of these soils are characterized by a high runoff potential and a slow rate of water transmission.

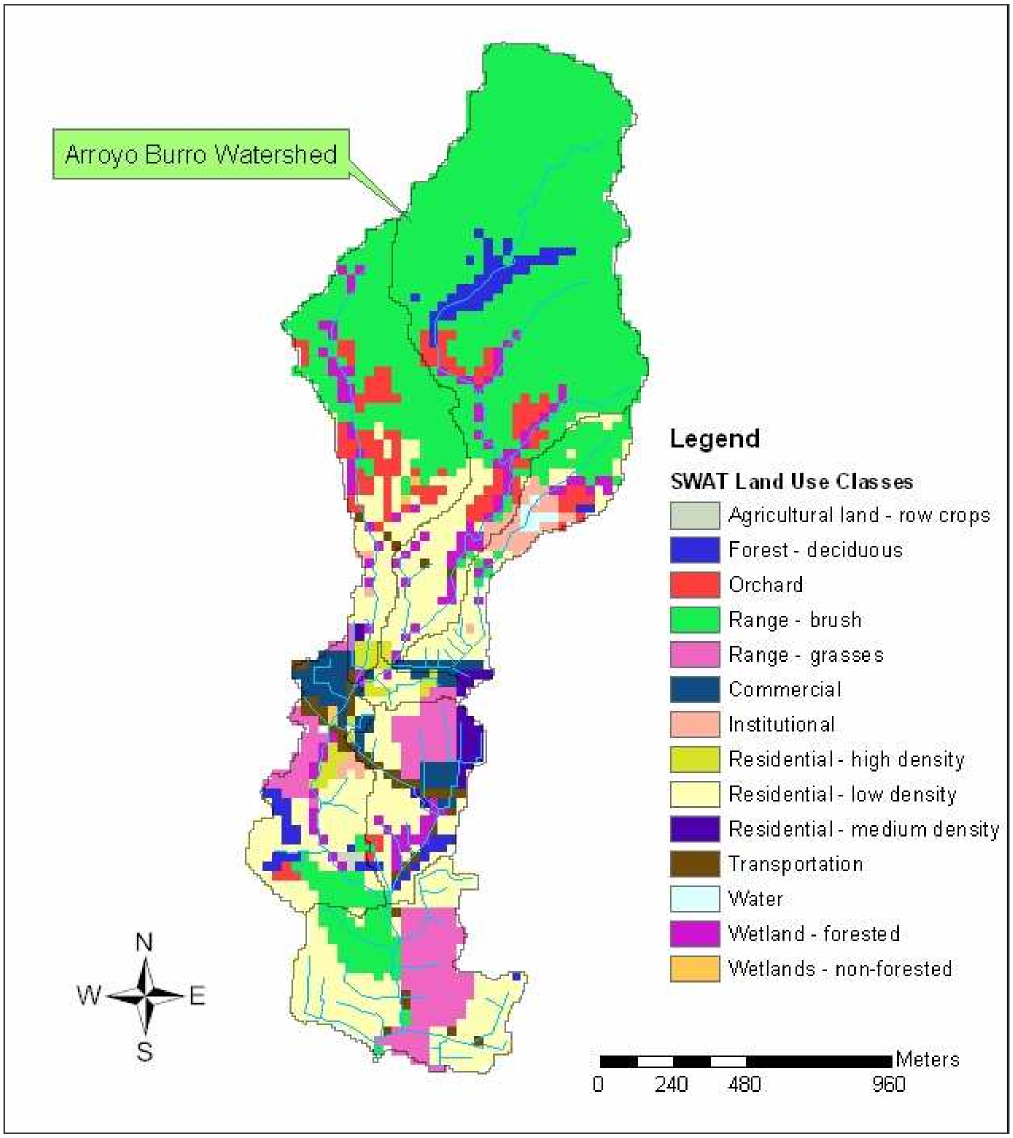
Table 5-2- STATSGO Soil Classification

STATSGO Map Unit	Soil Name	Hydrologic Group	Area (ha)	Area (%)
CA524	ELDER	B	363.5	14.3
CA525	CONCEPCION	D	389.1	15.4
CA526	AYAR	D	256.7	10.1
CA527	LODO	D	472.8	18.7
CA529	MAYMEN	D	684.5	27.0
CA510	ARUJO	B	368.3	14.5

5.3.3 Land Use Data

Accurate land use data for the watershed was essential to develop expectations about the kind of pollutants present in Arroyo Burro creek. Land use types are very different in terms of hydrological and biological processes, management practices, and pollutant generation and transport. The latest modified Anderson level III land use classification produced by the LTER project for the Arroyo Burro creek was used and adapted to the Geographic Information Retrieval and Analysis System (GIRAS). LTER land use classification was modified based on digital elevation maps and natural drainage areas from the City. As GIRAS is the only classification system accepted by SWAT, LTER Anderson land use classes were adapted to SWAT model classes as shown in Figure 5-4 and Table 5-3.

Figure 5-4- SWAT Land Use Classes for the Arroyo Burro Watershed



(BASINS/SWAT, 2005)

Table 5-3- LTER Anderson Land Use Designations vs. SWAT Land Use Classes

Anderson Level 3 Code	Area* (%)	Modified Anderson Class	SWAT Class
111	24.30	Residential - Single unit	URLD (Residential-low density)
112	1.23	Residential - Multiple unit	URHD (Residential-high density)
113	0.16	Residential – Mobile Home Park	URMD (Residential-medium density)
114	1.03	Residential – Mixed single and Multiple	URMD (Residential-medium density)
121	2.22	Commercial & Services – Retail Trade	UCOM (Commercial)
122	0.40	Institutions	UINS (Institutional)
123	0.47	Recreation	UCOM (Commercial)
124	4.03	Municipal Parks	RNGE (Range-grasses)
141	1.90	Transportation	UTRN (Transportation)
143	1.31	Utilities	UINS (Institutional)
164	0.08	Construction	RNGB (Range-brush)
171	0.24	Undeveloped Urban Lots	RNGB (Range-brush)
173	3.01	Golf Courses	RNGE (Range-grasses)
174	0.20	Cemeteries	RNGE (Range-grasses)
212	0.16	Field crops	AGRR (Agricultural Land-row crops)
221	5.42	Orchards	ORCD (Orchard)
241	0.28	Fallow fields & agriculture in transition	RNGB (Range-brush)
321	39.08	Shrub and brush rangeland W/o livestock	RNGB (Range-brush)
331	4.91	Mixed rangeland W/o livestock	RNGB (Range-brush)
431	3.20	Broadleaf forest - Not open to livestock	FRSD (Forest-deciduous)
531	0.32	Reservoirs – Municipal	WATR (Water)
641	5.02	Forested Riparian Zone - Not open to livestock	WETF (Wetland-forested)
651	0.16	Shrub-Scrub Riparian Zone – Not open to Livestock	WETN (Wetlands-non-forested)
721	0.04	Sand beaches	RNGB (Range-brush)
740	0.83	Bare exposed rock	RNGB (Range-brush)

*Area of each specific land use type present in the Arroyo Burro watershed

Most of the land in this watershed is under range brush species (46%), followed by low density residential areas (24.3%). Range brush land mainly covers the north area of the watershed and only a small part of its south area. Low density residential areas are located in the central and southern areas of the creek.

5.3.4 Topographic Data

Topographic data available in the BASINS database corresponds to the USGS Digital Elevation Model (DEM) elevations. DEM data is used to calculate watershed and sub-watershed boundaries, stream network, and point source discharge themes, as well as watershed and stream characteristics needed for modeling including slopes, elevations, and stream width and depths. Although the data for all of the watershed and sub-watershed boundaries, stream networks, and point source discharges (needed for the delineation process) was imported into the model by using a predefined delineation, the DEM data available in BASINS helped in estimating additional topographical features required to implement the model. The DEM resolution was 300m * 300m horizontally and 30-m elevation contour intervals.

5.3.5 Management Practices

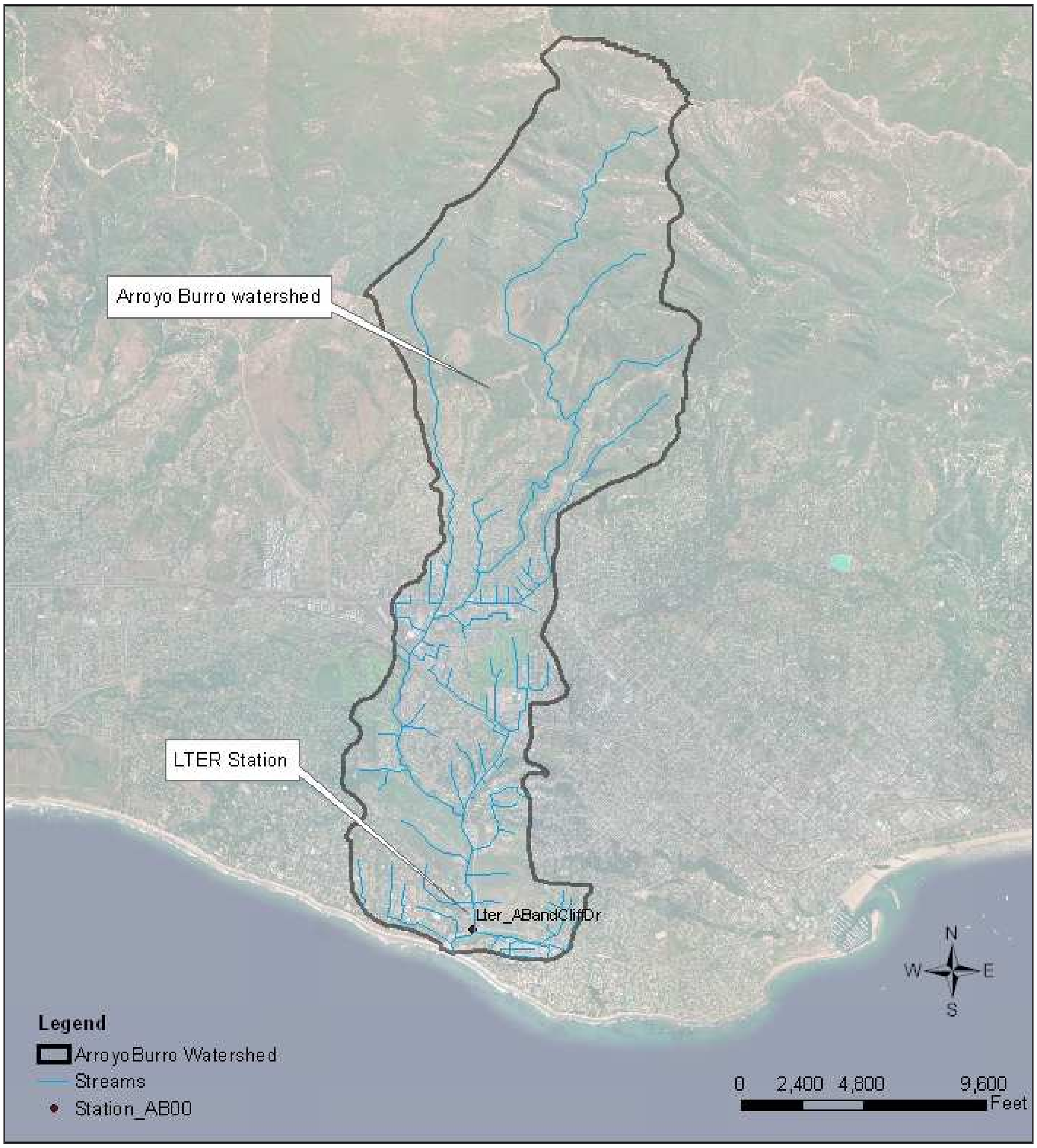
SWAT allows the user to define agricultural and landscape management practices taking place in every HRU by defining the beginning and the ending of the growing season and specifying timing and amounts of fertilizer, pesticide, tillage operations, and irrigation applications.

Due to the fact that there are no records of the use of fertilizers and pesticides by the general public in the city, and records for pesticide use held by the County Agricultural Commissioners Office are not broken down by watershed, information on fertilizer and pesticide use in the Arroyo Burro watershed was not input to the model. Fertilization, however, is automatically applied by the SWAT auto–application fertilizer tool. SWAT assumes surface runoff interacts with the top 10 mm of soil, and fertilizer is applied in this 10 mm of soil. Whenever actual plant growth falls below the nitrogen stress threshold (a fraction of potential plant growth assumed by SWAT), the model automatically applies fertilizer to the agricultural areas in analysis (Neitsch et al, 2001).

5.4 *Model Calibration*

The model was calibrated and validated for the prediction of stream flow and nitrate only using data for the water year 2003 from the LTER station AB00 at the watershed outlet, located on Cliff Drive in the Southern area of the Arroyo Burro Watershed (Figure 5-5). Difficulties in calibrating the model were attributed to a lack of continuously measured stream flow, sediment, and nutrient data. The model was run for 3 years, from October 2000 through September 2003. The first two years were used for stabilization of the model and only the last year was used for the calibration.

Figure 5-5- LTER Station AB00



5.4.1 Hydrologic Calibration

In order to analyze the quality of measured stream flow at AB00 (LTER Station in Figure 5-5), a comparison between measured stream flow and observed precipitation was performed. Figure 5-6 shows that observed precipitation and measured stream flow data matched reasonably well, therefore stream flow data at AB00 was used to calibrate the model.

Figure 5-6- Observed Precipitation vs. Measured Stream flow at LTER_AB00

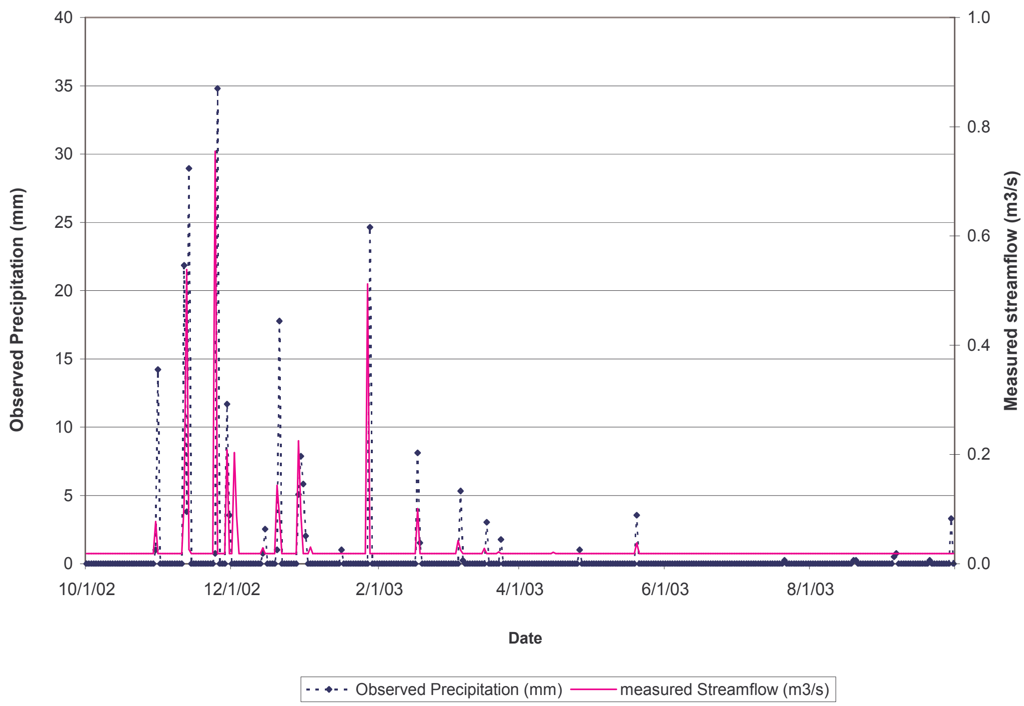


Table 5-4 presents the parameters which were adjusted during the hydrologic calibration. The calibration process sought to adjust certain SWAT parameters to obtain the smallest difference between simulated and measured streamflows and the maximum R-squared value.

The SWAT model did a fairly good job of capturing the big storm events (Figure 5-7), although it failed to simulate some peak flows generated by moderate storms. In addition, SWAT over-predicted some peaks and failed to calculate flow between storm events. SWAT limitations may be explained by the fact that SWAT was designed to assess the effect of long-term land use change on water quality, and not intended to be responsive to individual rainstorms. Despite these limitations, SWAT predictions were in good agreement with the measured flows. The R-squared coefficient between observed and simulated streamflow was 0.71 and the difference between observed and simulated streamflow was about 9% during the validation period. Cumulative and daily simulated streamflow matched well to measured streamflow (See Figure 5-8 and Figure 5-9), therefore the simulation results were considered a reasonably good fit (Table 5-5).

Table 5-4- Parameters Modified During Hydrologic Calibration

Adjusted Parameters	Final Value (default value)
Initial SCS runoff curve number for moisture condition II (CN2)	CN2 values were reduced by 15% (their values vary by HRU)
Available water capacity of the soil layer (mmH_2O/mm Soil) (SOL-AWC)	0.02 (0.0)
Threshold depth of water in the shallow aquifer required for return flow to occur (mm H_2O) (GWQMN)	750 (0.0)
Groundwater "revap" coefficient (GW_EVAP)	0.5 (0.02)
Slope	0.34 (0.28)
Soil evaporation compensation factor (ESCO)	0.20 (0.0)

Figure 5-7- Simulated Streamflow vs. Measured Streamflow at LTER_AB00

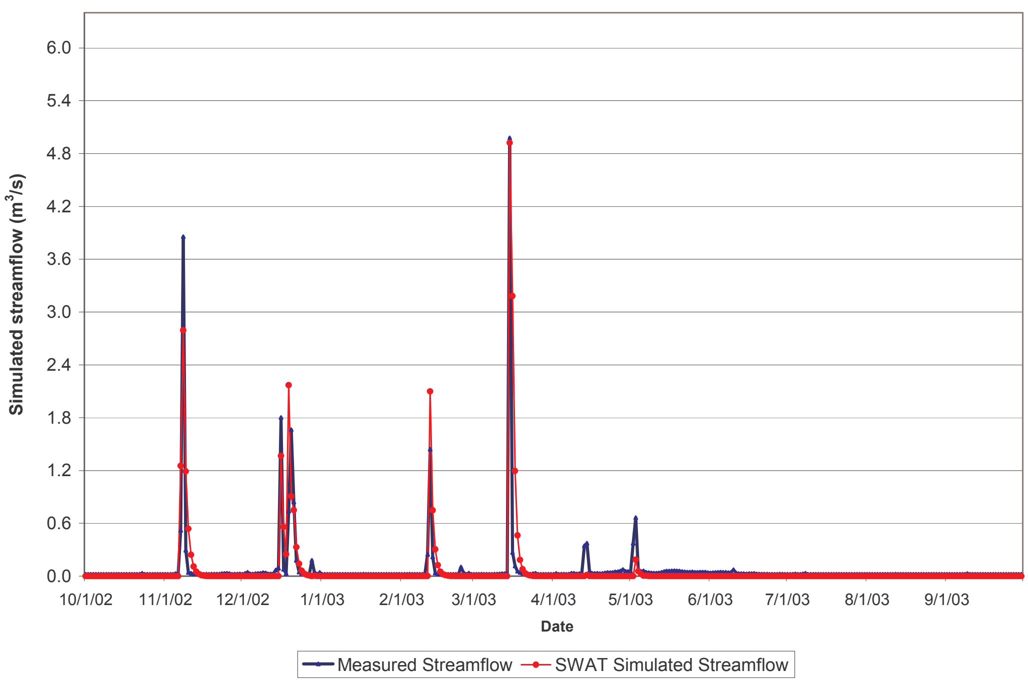


Figure 5-8- Cumulative Simulated Streamflow vs. Measured Streamflow at LTER_AB00

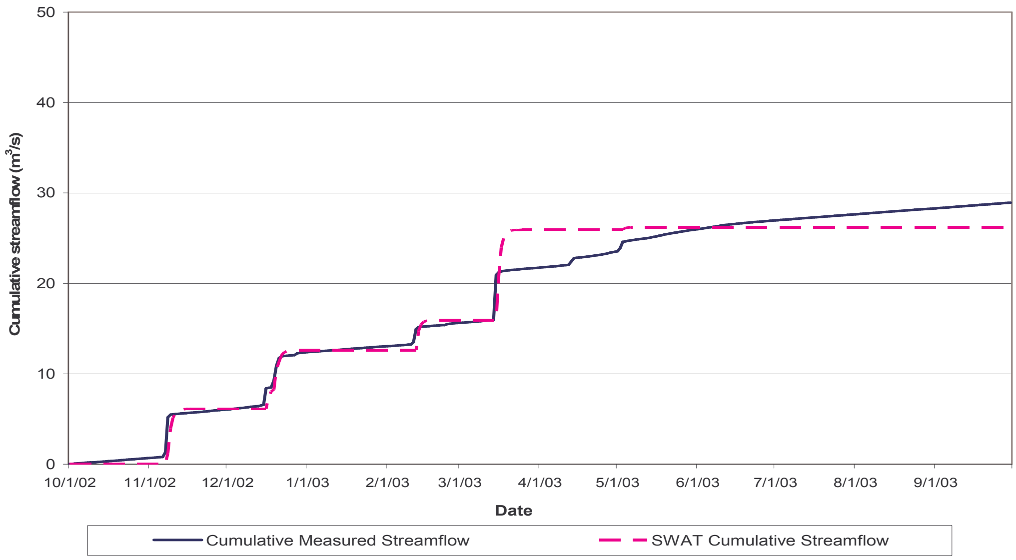


Figure 5-9- SWAT Simulated Streamflow vs. Measured Streamflow at LTER_AB00

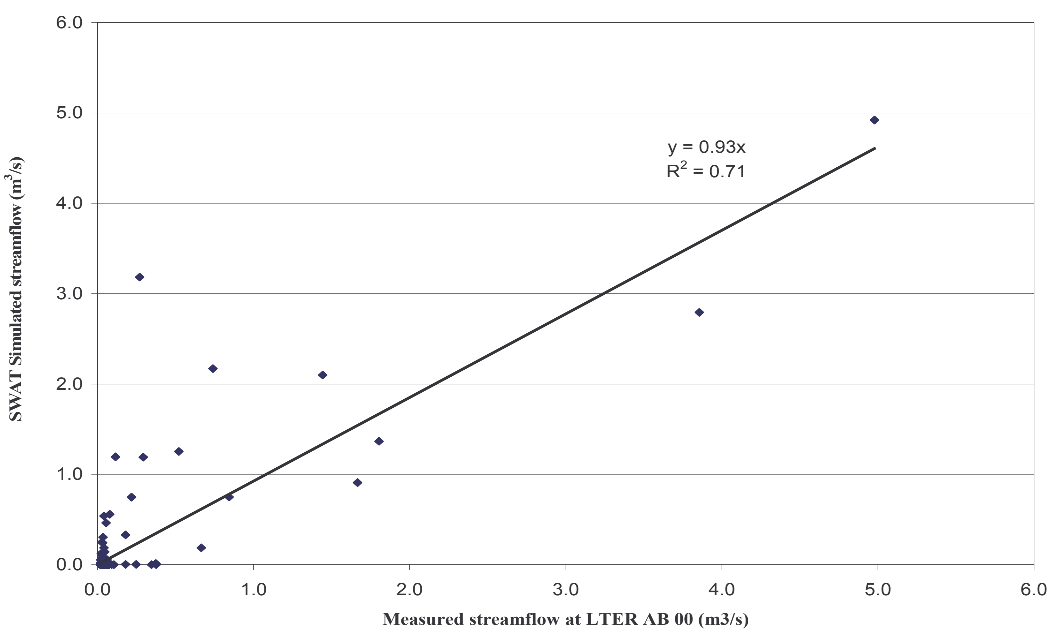


Table 5-5- Results of Hydrology Simulation for the Arroyo Burro Watershed

Parameter	Measured streamflow at AB00 (Oct. 2002 – Sept. 2003)	SWAT simulated streamflow (Oct. 2002 – Sept. 2003)
Mean (m^3/s)	0.079	0.072
Minimum (m^3/s)	0.00	0.00
Maximum(m^3/s)	4.98	4.87
R-Squared		0.71

5.4.2 Nutrient Calibration

Due to the lack of availability of sufficient nutrient data for the Arroyo Burro watershed, nitrate was the only parameter that could be calibrated. Table 5-6 presents the parameters which were adjusted during the nitrate calibration.

Table 5-6 Parameters Modified During Nitrate Calibration

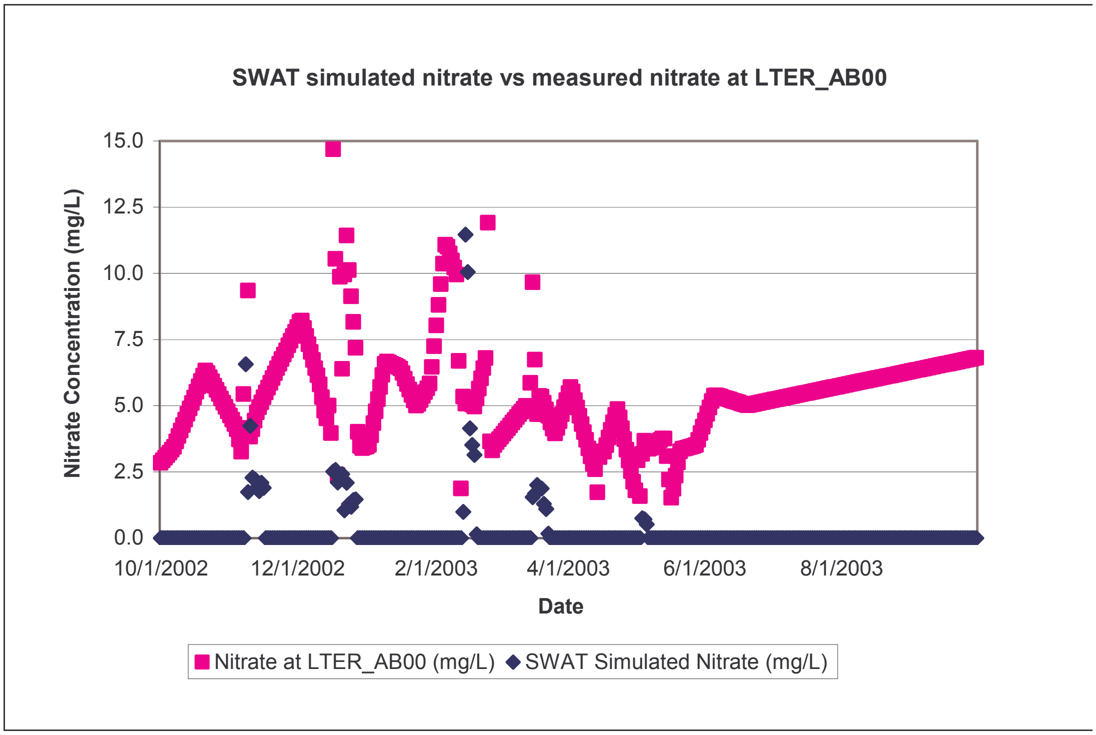
Adjusted Parameters	Final Value (default value)
Nitrogen Percolation Coefficient (NPERCO)	0.20 (1)
Initial NO_3 concentration in the soil layer (mg/kg) (SOL- NO_3)	10 (0)
Biological mixing efficiency (BIOMIX)	0.45 (0.20) for range, forest and agricultural land
Concentration of nitrate in groundwater contribution to streamflow from subbasin (GWNO3)	5.4 (0) for range and agricultural land and 1.5 (0) for urban land
Fraction of fertilizer applied to the top 10 mm of soil (FRT_LY1)	1 (0.20)

Figure 5-10 shows that SWAT underestimated nitrate values for the calibration period. This is because the applied fertilizer rate used in the model does not accurately reflect the actual practice in the Arroyo Burro watershed. In addition, because the model failed to calculate flow between storm events, no nitrate values were estimated between those events. Nitrate concentrations were only simulated during rainstorms. Due to both limited time and data availability to work on the calibration process, the nitrate calibration could not generate better, more accurate results (See Table 5-7). However, we expect that with a hydraulic calibration which can appropriately simulate baseflow and with accurate fertilizer and pesticide application rates, the model can predict appropriate nitrate values which can be used to develop expectations about nutrient loadings in the watershed.

Table 5-7 - Results of Nitrate Simulation for the Arroyo Burro Watershed

Parameter	Measured Nitrate at AB00 (Oct. 2002 – Sept. 2003)	SWAT simulated Nitrate (Oct. 2002 – Sept. 2003)
Mean (mg/L)	5.41	0.25
Minimum (mg/L)	1.52	0.00
Maximum(mg/L)	14.69	11.46

Figure 5-10- SWAT Simulated Nitrate vs. Measured Nitrate Concentrations at LTER_AB00



5.5 *SWAT Results*

The SWAT model provides estimates of sediment, nitrogen, and phosphorus non-point source loading rates to streams for each land use. Figure 5-11 indicates that Subbasin 3 is the major contributor of sediments to the creek. Subbasin 3 has an area of 192 ha, which represents only 7.6% of the entire watershed. As shown in Table 5-9 and Figure 5-12 , forested wetlands contribute the most to the generation of sediments to the Arroyo Burro watershed. Even though forested wetlands cover about 5% of the watershed area, the model predicts that this land use accounts for 42% of the total watershed sediment load. Conversely, although the range-brush land use covers about 46% of the entire watershed, the model predicts that it accounts for only 11% of the total sediment load. Deciduous forests and transportation areas generate the lowest sediment loads.

The SWAT model predicts that orchard lands are the major source of total phosphorus, accounting for 32% of the total organic phosphorus load and for 31% of the total soluble phosphorus load to the creek. Subbasins 1 and 2 are the major contributors of organic and soluble phosphorus. Subbasins 1 and 2, which are 17% and 5% covered by orchard lands, account for 17% and 41% of the watershed area, respectively. Low density residential areas and range brush lands are also major sources of soluble phosphorus, accounting for 22% and 20% of the total soluble phosphorus load, respectively. Deciduous forests produce very little surface runoff, therefore they generate one of the lowest soluble phosphorus loads in the watershed. High and medium density residential areas also generate very low soluble phosphorus loads.

Range-brush lands and orchard areas are the major sources of organic nitrogen. The SWAT model predicts that these land uses account for 27% and 31% of the total organic nitrogen load in surface runoff. Range-brush lands and low density residential areas are, however, the major sources of nitrate. The SWAT model predicts that these land uses account for 31% and 30% of the total nitrate in surface runoff. Subbasins 1 and 2 are the major contributors of organic nitrogen and nitrate to the creek. Subbasins 1 and 2 generate 31% and 54 % of the total organic nitrogen load, and 22% and 30% of the total nitrate load, respectively. Table 5-9 , Table 5-10 , and Table 5-11 show the sediment, soluble phosphorus, and organic nitrogen loads by land uses and subbasins, whereas, Figure 5-12 , Figure 5-13, and Figure 5-14 present the organic phosphorus and nitrate loads.

Figure 5-11 - Sediment, Organic Nitrogen, and Soluble Phosphorus Loads for Water Year 2003

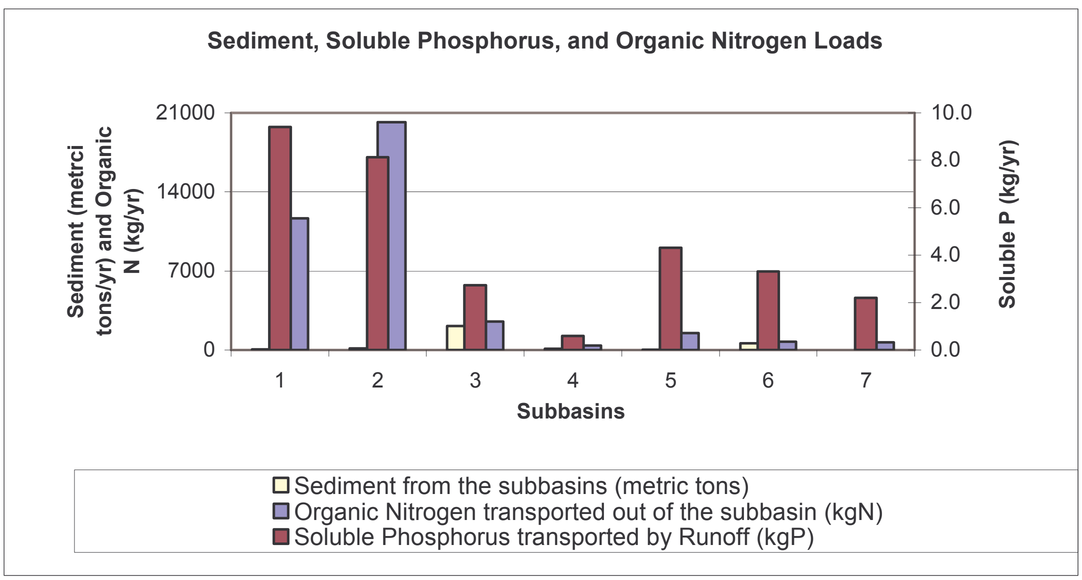


Table 5-8 - Subbasin Areas in the Arroyo Burro Watershed

Land Use	Area (hectares)								
	1	2	3	4	5	6	7	Total	Percentage contribution
RNGB	240.0	790.9	53.6		35.1		56.2	1175.8	46.4%
RNGE				4.4	31.9	47.2	104.2	187.7	7.4%
URLD	87.7	94.2	66.0	15.1	105.2	74.5	193.1	635.8	25.1%
WETF	33.8	53.7	11.4	1.8	12.7	17.8		131.2	5.2%
UCOM			11.4	6.2	32.9	17.8		68.3	2.7%
FRSD		48.6			20.1	11.5		80.2	3.2%
UTRN					18.1	19.9		38.0	1.5%
URHD				10.6	10.6			21.2	0.8%
URMD				1.8		22.0		23.8	0.9%
WATR			8.2					8.2	0.3%
UINS			30.9					30.9	1.2%
ORCD	74.0	49.6	10.3					133.9	5.3%
Total	435.5	1037.0	191.8	39.9	266.6	210.7	353.5	2535.0	100.0%
Percentage contribution	17.2%	40.9%	7.6%	1.6%	10.5%	8.3%	13.9%	100.0%	

Figure 5-12 - SWAT Simulated Percentage of Total Land Area and Stream Loading for Water Year 2003

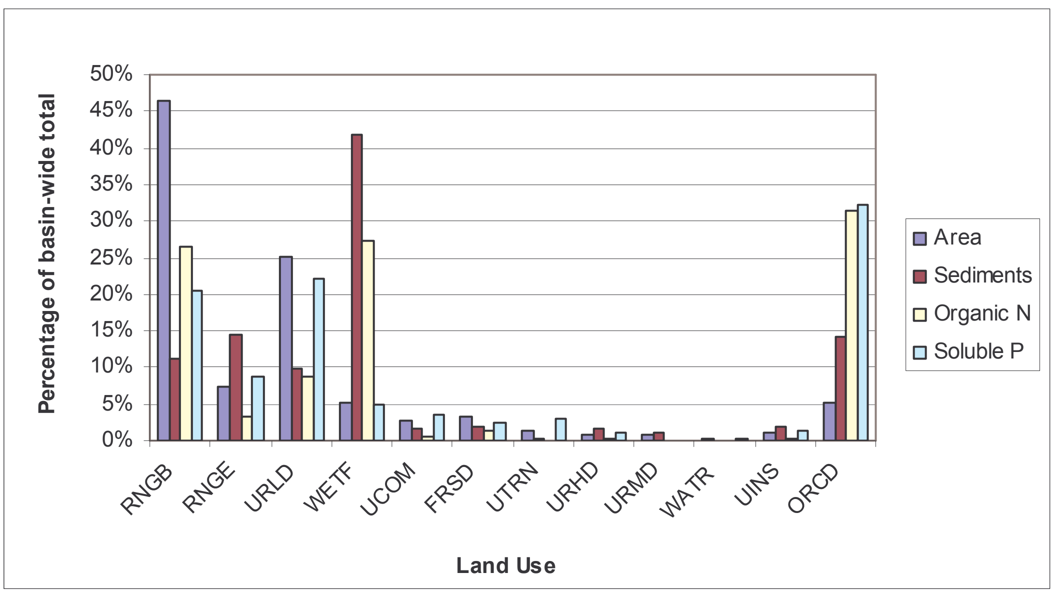


Table 5-9 - SWAT Estimated Annual Average Sediment Load (metric tons/year)

Land Use	Subbasin							
	1	2	3	4	5	6	7	Total
RNGB	20.1	22.8	295.9		2.1		1.9	342.8
RNGE				12.6	1.6	423.2	7.1	444.5
URLD	9.3	21.8	237.6	5.9	1.0	20.2	2.5	298.2
WETF	28.3	66.5	1097.3	1.2	0.3	86.8		1280.4
UCOM			20.0	16.9	3.6	5.6		46.2
FRSD		8.2			0.8	52.4		61.3
UTRN					1.1	5.5		6.6
URHD				47.5	5.4			52.9
URMD				23.3		8.7		32.0
WATR			0.0					0.0
UINS			62.4					62.4
ORCD	9.1	13.6	413.4					436.1
Total	66.9	132.8	2126.5	107.4	15.9	602.4	11.5	3063.4
Percentage contribution	2.2%	4.3%	69.4%	3.5%	0.5%	19.7%	0.4%	100%

Table 5-10 - SWAT Estimated Annual Average Soluble Phosphorus Load (kg P/year)

Land Use	Subbasin							
	1	2	3	4	5	6	7	Total
RNGB	1.6	3.6	0.2		0.5		0.3	6.3
RNGE				0.1	0.6	0.8	1.3	2.7
URLD	1.2	1.2	0.7	0.2	1.6	1.1	0.6	6.8
WETF	0.4	0.4	0.1	0.0	0.2	0.3		1.5
UCOM			0.2	0.1	0.5	0.3		1.1
FRSD		0.2			0.3	0.2		0.8
UTRN					0.3	0.6		0.9
URHD				0.2	0.2			0.3
URMD				0.0				0.0
WATR			0.0					0.0
UINS			0.4					0.4
ORCD	6.2	2.6	1.1					9.9
Total	9.4	8.1	2.7	0.6	4.3	3.3	2.2	30.7
Percentage contribution	30.6%	26.5%	8.9%	1.9%	14.1%	10.8%	7.2%	100.0%

Table 5-11- SWAT Estimated Annual Average Organic Nitrogen Load (kg N/year)

Land Use	Subbasin							
	1	2	3	4	5	6	7	Total
RNGB	2875.0	6207.6	617.2		234.2		50.0	9984.0
RNGE				35.5	500.1	585.1	150.2	1270.9
URLD	661.9	1275.9	504.4	122.6	167.0	59.5	485.3	3276.6
WETF	2903.0	6088.6	979.1	94.5	235.0	0.3		10300.6
UCOM			52.0	51.0	69.4	0.3		172.7
FRSD		260.4			241.9	47.8		550.1
UTRN					35.3	15.8		51.1
URHD				85.0	19.2			104.2
URMD				14.7		25.1		39.8
WATR			27.4					27.4
UINS			115.9					115.9
ORCD	5221.0	6359.0	233.3					11813.3
Total	11661.0	20191.5	2529.3	403.2	1502.2	734.0	685.5	37706.7
Percentage ontribution	30.9%	53.5%	6.7%	1.1%	4.0%	1.9%	1.8%	100%

Figure 5-13- SWAT Estimated Organic Phosphorus Loads by Land Use for Water Year 2003

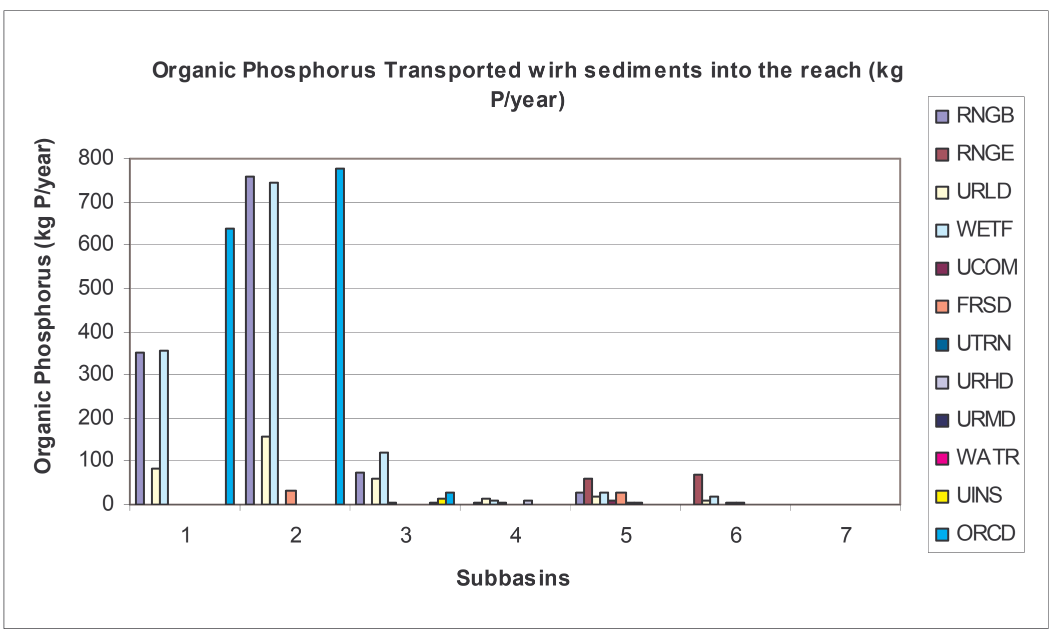
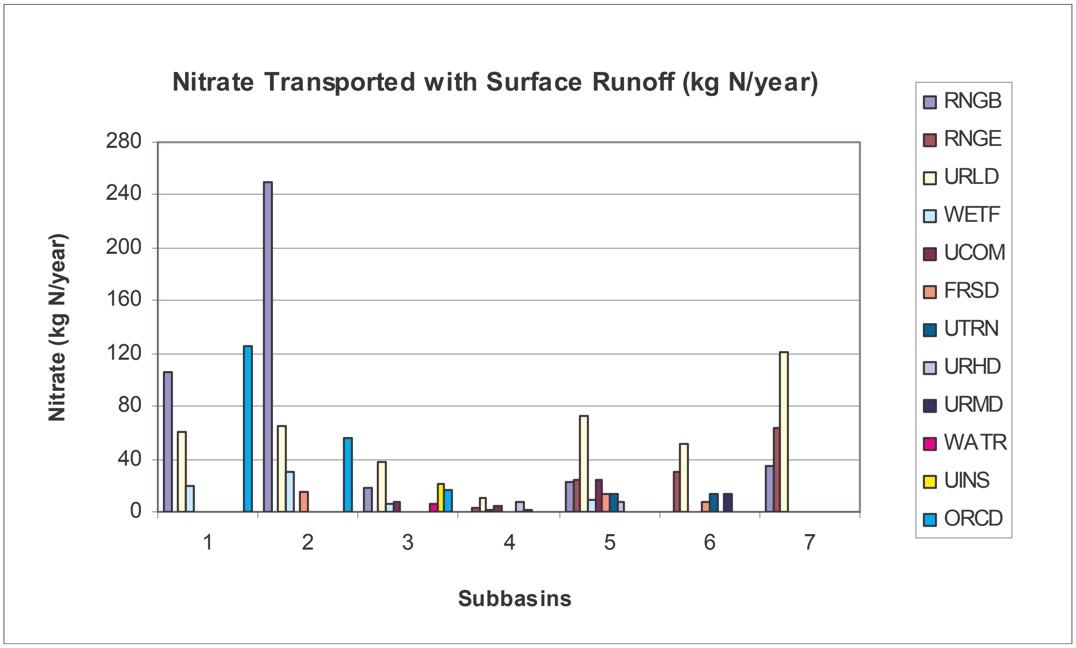


Figure 5-14- SWAT Estimated Nitrate Loads by Land Use for Water Year 2003



6 PROJECT FIELD SAMPLING

The group project team conducted creek sampling to test the concept of indicator site sampling. One of the main objectives of conducting field sampling during the course of the project was to give team members a better appreciation of the procedures and work involved with choosing sampling sites, selecting constituents of concern, and preparing the necessary materials to execute a sampling plan. This activity allowed the project members to better understand the logistical requirements associated with conducting creek sampling with limited resources at multiple locations under time constraints dictated by unpredictable meteorological conditions. The group used literature review and analysis of existing water quality monitoring programs in South California to determine which potential constituents of concern should be sampled. Samples were collected during two separate storm events in the 2004-2005 storm season.

6.1 *Constituents Sampled*

The following analytes were determined potential constituents of concern in Santa Barbara watersheds, and were tested at each sampling location during the project's field sampling events:

- Glyphosate
- Diazinon
- Oil and Grease

- Total Recoverable Petroleum Hydrocarbons
- Nitrate as Nitrogen (NO3-N)
- Total Phosphorus
- Biological Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- MBAS (surfactants)
- Total coliform (MPN)
- E. coli (MPN)
- Enterococcus (MPN)

In addition, the following physical parameters were measured at each location:

- Temperature
- pH
- Dissolved Oxygen
- Turbidity

6.2 *Sampling Locations*

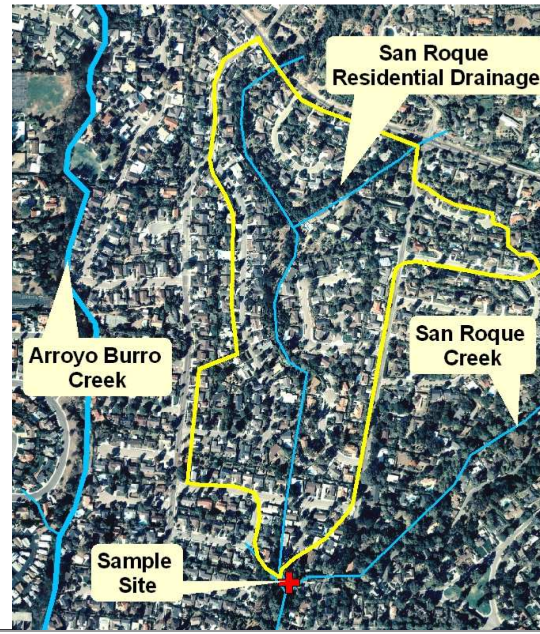
Three sampling locations based on land use were selected for the project's storm sampling series. The first location, a storm drain that empties into San Roque Creek (a tributary to Arroyo Burro Creek) represented medium density residential housing. The second location was a storm drain that empties into Arroyo Burro Creek near La Cumbre Plaza and represented commercial land use. The third sampling location was on Laguna Channel and represented industrial land uses.

<u>Storm Drain to San Roque Creek – Single Family Residential</u>

This is an indicator sampling location for medium density residential housing. Samples were collected at this location from a 24-inch storm drainpipe that empties into San Roque Creek. San Roque Creek joins Arroyo Burro Creek as a tributary near the intersection of State Street and Hope Street. The storm drain pipe used for sampling collects runoff from this single family residential (zoning designation R-1) of low to medium density (Figure 6-1). This location was chosen because it was easily accessible during low to moderate flows and drained the runoff from a clearly delineated sub-basin that is composed of a single type of land use – 100% single family residential. This sampling location can be accessed during low and moderate flows by entering the San Roque Creek channel where it crosses under Ontare Street. The storm drainpipe where samples were taken is approximately 400-meters downstream from the Ontare Street bridge and empties directly onto a concrete apron in the creek channel. During the reconnaissance of this sampling location the storm drainpipe was concealed by bushes and was only located through a close comparison of the creek channel and maps containing storm drain networks and orthophotography. During periods of high flow this sampling location is only accessible from private property due to unsafe conditions that exist in the creek channel. This type of sampling location would be expected to potentially show high levels of nutrients and traces of pesticides from the medium density, heavily landscaped residences in the area.

Figure 6-1 – San Roque Creek Storm Drain Sampling Location

Location Name:	San Roque Drainpipe
Grid Coordinates:	N34.44402, W119.74037
Sample Type:	Indicator



<u>**Arroyo Burro Creek at La Cumbre Shopping Center – Commercial**</u>

An indicator site for commercial land use, the second sampling location utilized for the storm sampling is a drain that empties into Arroyo Burro Creek near La Cumbre Plaza. The storm drain where samples were taken empties into Arroyo Burro Creek where the creek flows under Hope Avenue (Figure 6-2). The site was chosen to be representative of commercial land use in a clearly defined drainage area. This sampling location is accessed by climbing down a concrete embankment into the Arroyo Burro Creek channel from the East side of Hope Avenue and proceeding downstream. The storm drain used for sampling is located on the channel wall about six feet above the channel floor on the creek's right bank as you look downstream. The sampling location is in the creek under a crossing and can only be safely accessed during low to moderate flows.

Due to the large amounts of impervious surfaces and parking areas, expectations were that samples taken from this location would potentially document detectable concentrations of oil and grease, total recoverable hydrocarbons, and surfactants.

Figure 6-2 – Arroyo Burro Creek at La Cumbre Plaza Sample Location

Location Name	Arroyo Burro at La Cumbre Plaza
Grid Coordinates:	N34.43625, W119.74787
Sample Type:	Indicator

Laguna Channel – Industrial Land Use

The final sampling location utilized for the project's storm sampling exercise was located on Laguna Channel at El Estero Waste Water Treatment Plant (Figure 6-3). Draining most of the industrial land uses in the City, a sampling location in Laguna Channel was chosen under the assumptions that the industrial land use runoff would potentially contain different constituents of concern than would be found in any other part of the City. This specific location along the channel was chosen because it is easily accessible during any level of flow and is located on City property. This sampling location is at the western end of the El Estero Wastewater treatment plant.

Due to the large amounts of impervious surfaces and industrial land uses represented in this sample, expectations were that samples from this location would indicate higher concentrations of oil and grease, total recoverable hydrocarbons, and turbidity.

Figure 6-3 – Laguna Channel Sampling Location

Location Name:	Laguna Channel at El Estero
Grid Coordinates:	N34.43625, W119.74787
Sample Type:	Integrator

6.3 *Sampling Events*

Sampling was conducted by the project team during two rain events in the fall and winter of 2004. The group chose to sample two storm events reasonably early in the 2004-2005 water year to allow findings from the sampling exercise to be included in the drafting of the project report and development of the proposed water quality sampling plan. Consequently, the most noteworthy storms of the season which occurred during the first week of January were not sampled by the project team.

<u>October 16, 2004 Sampling Event</u>

Prior to October 16, 2004, there was no flowing water at the San Roque and Arroyo Burro Creeks sampling locations and the Laguna Channel sampling location had very low flow. With these antecedent conditions in the creek channels, expectations were that during the first storm event of the season, a flush of pollutants could be expected. The last recorded rainfall in Santa Barbara prior to October 16, 2004 was 0.01-inch on April 10, 2004 and 0.48-inch on March 2, 2004 (SB County Flood Control District, 2004). Recorded daily average flows at the United States Geological Survey gauging station on upper Mission Creek had not exceeded 0.10 cubic feet per second since March 26, 2004 (USGS, 2005). With approximately seven months since the last significant rainfall and increased flows in upper Mission Creek, the project team recognized the potential value in capturing flow from the first storm of the 2004-2005 water year. This was bolstered by both the potential for high pollutant levels in the first flush, and the challenge of accurately predicting when the optimal time to sample from a hydrograph that was being produced by runoff from very dry soil conditions.

The prediction of the timing and magnitude of the storm was done through observation of Doppler radar from standard weather services such as the Weather Channel or the National Oceanic and Atmospheric Administration's National Weather Service web sites. In addition to weather radar, flow data for the Mission Creek USGS gauging station was monitored during the storm to assess trends in the rising or falling of the storm hydrograph. There are three USGS maintained gauging stations in the vicinity of the City of Santa Barbara. Stage and flow measurements for each of these gauging stations can be accessed online. A significant drawback to this USGS website source is the approximate 90 minute to 2 hour delay in posting measurements. Use of the USGS gauging stations online would be more appropriate for tracking hydrograph trends during a storm that lasts more 3 to 4 hours.

It began raining in Santa Barbara on October 16, 2004 at approximately 9:00 pm and continued until approximately 4:00 am on October 17, 2004. Heavy rainfall occurred from approximately 9:30 pm to 10:30 pm and 2:00 am to 3:00 am. The total rainfall amount for October 16 - 17, 2004 was 0.57 inches (SB County Flood Control District, 2004). During the storm it was observed that creek stage quickly rose at the San Roque Creek and Arroyo Burro Creek sampling locations, but also subsided rapidly to very low flows or no flow at these locations. This extremely quick rise and fall in the hydrograph can be attributed to the short duration and intensity of the storm and the large amounts of impervious surface within these drainages promoting rapid conveyance of heavy rainfall. When the rainfall lessened, and eventually stopped, the initial abstraction of moisture to the dry soils and pervious areas in the sub-watersheds contributed to the rapid reduction in creek stage. Near the Laguna Channel sampling location a more steady and sustained flow was maintained throughout the storm. This can be attributed to the larger size of this drainage area. The pattern of these flows indicates that channel flows were primarily from runoff of impervious surfaces in the urbanized areas of the watershed. The quick changes in creek stage and rapid conveyance of runoff resulted in samples being taken during what was likely the tail end of the storm hydrograph. The USGS gauging station on Mission Creek, which is located above any major urban development, did not shift during this storm event, although significant flows were physically observed in the lower reaches of the creeks in the city.

Initial abstraction, the amount of precipitation that is absorbed by the surrounding landscape and soils before runoff is generated, was more evident from data recorded at the USGS gauging station on upper Mission Creek where the 0.57 inches of rainfall on October 16 - 17 produced an increase of only 0.02-cfs (daily average) in creek flow, but a subsequent 0.43 inch rainfall on October 18 - 19 recorded average flows increasing from a base flow of 0.10-cfs to 2.6-cfs (SB County Flood Control District, 2004 and USGS, 2005). Initial abstractions in the upper Mission Canyon, where the gauging station is located, were more significant due to the large amounts of pervious land cover in this portion of the watershed.

Other noteworthy impacts from this initial storm were physical changes to the channelized portions of Arroyo Burro Creek, where macrophytes and sediments that had accumulated during the spring and summer were scoured from the channel bed. Figure 6-4 shows images taken before and after the October 16 storm event. The lagoon for Mission Creek and Laguna Channel was also breached for the first time since the May 2004 event when unusually high tide conditions resulted in a partial breaching of the Mission Creek lagoon.

Figure 6-4 – Arroyo Burro Creek Channel Modifications

Pre-Storm Event – October 11, 2004

Post-Storm Event – October 23, 2004

<u>December 7, 2004 Sampling Event</u>

The second storm event sampling was conducted on December 7, 2004. Between the October 16 storm and December 7, there were two series of storms. These storms aided in maintaining moisture in local soils, but were still characterized by episodic flows that quickly subsided after the conclusion of the rainfall. Tracking of weather conditions for the second sampling exercise was done as described above for the first storm. The storm that began on late December 6 and concluded early December 8 resulted in 0.45-inches of total rainfall and was characterized by steady and continuous rain through December 7 (SB County Flood Control District, 2004). During this storm, San Roque and Arroyo Burro Creeks maintained more persistent flows, both in the channels and from the storm drains where samples were collected. This change in observed hydrologic conditions can potentially be attributed to the continuity of the rainfall during the storm and the antecedent moisture conditions in pervious land cover. There was no significant increase in creek flow at the USGS gauging station on Mission Creek during this storm event (USGS, 2005).

6.4 *Sampling Results*

In general, the field sampling results documented relatively high indicator bacteria, as expected, but lower levels than expected for the other constituents of concerned sampled (Table 6-1). It is important to recognize that these results represent a limited sampling and should not be interpreted as definitive results for the watershed. Changes in temperature from each sampling event are logically explained by the lower air temperatures that occurred on December 7. The warmer water temperatures found in Laguna Channel are also logical taking into account the source of runoff from a more urbanized area than the other sampling locations. Among all of the sampling sites and between both storm events, pH remained fairly stable. Lower levels of dissolved oxygen in Laguna Channel indicate that runoff in this basin, and the channel itself, is laden with more oxygen demanding constituents. Turbidity levels were significantly higher in Laguna Channel, indicating the possibility that there are more particulates coming from this more impermeable watershed. Non-detects for pesticides in all samples can potentially be attributed to the fact that limited amount of pesticides are generally used during the fall and winter.

6.5 *Sampling Lessons Learned*

After executing the sampling plan during two storm events, the project team determined that the following are important factors to take into consideration:

Site Selection

Sampling sites should be accessible during any level of flow. Sampling sites where creek-bank access is used during low flows, and sampling from bridges during high flows, are very suitable. Sampling locations that utilize storm drains as indicator sample sites are particularly difficult in this regard. When sampling locations are located adjacent to private property, it is beneficial to notify property owners that sampling will be occurring in the vicinity. This is especially helpful if sampling is going to be occurring during late evening or early morning, because in the middle of the night individuals taking samples are less likely to be aware of property boundaries and other potential hazards.

Sampling Occurrence

Some constituents have short holding times that may preclude sampling over the weekend if sufficient time is not available for the contract laboratory to pick up and analyze the samples within the holding time. Holding times and laboratory availability should be addressed before sampling.

Sampling Thresholds

For storm event sampling, sampling coordinators should set a threshold of rainfall amount, or increase in flow, to determine when sampling should occur. The EPA recommends waiting until at least 0.1 in. of rain has fallen (US EPA, 1997b).

Volunteer Instruction

If volunteers take samples during storm events, explicit directions should be provided for each volunteer. Volunteers should have clear and concise directions so that they could potentially do the sampling without having to talk to the individual that is coordinating the sampling effort. Training of volunteers is crucial to the collection of reliable data and training methods and responsibilities should be included in a quality assurance plan. Guidance on the preparation of training programs is provided by the EPA on their website (US EPA, 1997b).

Table 6-1 – Field Sampling Results

Sampling Location	San Roque Creek	Arroyo Burro Creek	Laguna Channel	San Roque Creek	Arroyo Burro Creek	Laguna Channel
Date Collected	10/17/04	10/16/04	10/16/04	12/7/04	12/7/04	12/7/04
Time Collected	0:20	23:50	22:50	17:44	17:28	17:01
Temperature (^{0}C)	17.7	17.5	19.1	12.6	13	16
pH	7.33	7.12	6.59	7.73	7.53	7.47
Dissolved Oxygen (mg/L)	9.3	9.12	8.3	9.73	10.05	4.62
Turbidity (NTU)	26.3	53.6	171	20	98	115
Glyphosate (mg/L)	ND	ND	ND	ND	ND	ND
Diazinon (mg/L)	ND	ND	ND	ND	ND	ND
Oil and Grease (mg/L)	ND	ND	5.3	ND	8.2	ND
Total Recoverable Petroleum Hydrocarbons (mg/L)	ND	ND	ND	ND	4.5	2.7
Nitrate as Nitrogen (NO3-N) (mg/L)	6.4	4.9	5.9	ND	0.4	2.1
Total Phosphorus (mg/L)	2	1.5	1.2	0.34	0.51	0.78
Biological Oxygen Demand (BOD) (mg/L)	>17	>17	>17	8.5	19.1	19.9
Chemical Oxygen Demand (COD) (mg/L)	383	339	543	64	158	145
MBAS (surfactants) (mg/L)	ND	ND	ND	0.3	ND	0.8
Total coliform (MPN)	>24,192	>24,192	>24,192	>24,192	>24,192	>24,192
E. coli (MPN)	>24,192	>24,192	19,863	8,390	>24,192	>24,192
Enterococcus (MPN)	>24,192	24,192	>24,192	8,860	>24,192	12,460

Material Preparation

Sufficient materials to conduct sampling should always be maintained and pre-packaged for each sampling location to allow for quick response to storm systems that may develop rapidly, or during holidays and weekends. Coordination should also be made in advance for any lab procedures that need to be performed by contract laboratories within a specific amount of time after samples are taken.

Currently, the Creeks Division monitoring program is recruiting volunteers to assist with stormwater monitoring, although a formal training program or sampling procedure have not been developed. Decisions regarding when to begin stormwater sampling have been inconsistent, and without a clearly defined threshold, several sampling opportunities have been missed. Material preparation and notification of laboratories prior to sampling events are essential for efficient sampling events.

7 CONSTITUENT RESEARCH

One of the most vital aspects of a monitoring program is the choice of constituents for analysis. Constituent selection focuses on compounds that are commonly found in the urban environment and may be deleterious to human and/or ecological health. In addition, results from neighboring communities reviewed in the case studies provided further context for constituent selection.

7.1 *Pollutant Sources in the Urban Environment*

Nutrients

Nitrogen and phosphorous-containing compounds are known collectively as nutrients. Ammonia, nitrates and phosphates are commonly applied to soils as a fertilizer. As most fertilizers are soluble, surface runoff from irrigation or storm events can easily transport fertilizers to surface waters. Percolation of nutrient-enriched runoff can also impact ground water. Excessive nutrient loading leads to the eutrophication of surface waters. This manifests itself as prolific plant growth in the water column and/or algal blooms, both of which can severely degrade ecological integrity and impact water quality, as well as reducing aesthetics and lowering dissolved oxygen concentrations.

While agricultural areas are sparse in the watersheds covered by the proposed monitoring plan, urban area water bodies can also have elevated nutrient levels due to fertilizer use in parks, city landscaping and private residences. Santa Barbara is predominantly suburban with low density residential areas prevalent in the non-downtown areas; thus nutrient contamination could be a problem from residential landscaping. Additionally, there are several large parks and golf courses, although the city's integrated pest management program significantly reduces the amount of chemical pesticides and fertilizers used in these areas.

There are numerous forms of nitrogen and phosphorous that can be analyzed. Listed below are explanations of the variants recommended in the proposed monitoring plan. Note that all the constituents listed below can contribute to eutrophication if allowed to persist at elevated levels.

- Nitrate (NO_3^-) – Nitrate fertilizers are among the most widely utilized fertilizers on the market and are commonly used in agriculture, parks, and household gardens.
- Ammonia (NH_4^+) – Ammonia, like nitrate, is an inexpensive, nitrogen-rich fertilizer frequently used in agriculture and urban settings.
- Total Kjeldahl Nitrogen (TKN) – Total Kjeldahl nitrogen, named after the scientist who developed the analytical method, is a measure of ammonia and organic based nitrogen sourced from cellular breakdown. The nitrogen measured by this test is derived from protein decomposition products and ammonia, but does not include nitrate or nitrite. When used in conjunction with ammonia quantification, TKN can be used to estimate the proportion of nutrients originating from organic sources like leaf litter and detritus compared to fertilizers.
- Ortho-Phosphate (PO_4^{3-}) – Phosphate fertilizers, like nitrate and ammonia, are commonly used in agriculture and gardens.

<u>Pesticides</u>

Pesticides include insecticides, herbicides and fungicides and are often applied in a manner similar to fertilizers in agricultural areas, city landscaping, and private residences. They can be introduced into surface waters by being dissolved in runoff, or transported while sorbed to particulates, especially organic materials (Watts, 1998).

- Organochlorine pesticides (OCPs) – These pesticides are largely being phased out and replaced by the more expensive, but less toxic and persistent, organophosphate pesticides. DDT is an example of an OCP, and while it is no longer in use in America, many OCPs still are. Because OCPs tend to be persistent in the environment, historical applications could still be present in sediments.
- Organophosphate pesticides (OPPs) – OPPs generally exhibit lower toxicity and persistence than OCPs. Diazinon is an example of an OPP. It is likely that most garden pesticides used in Santa Barbara today are OPPs.

<u>Metals</u>

Tsihrintzis & Hamid (1997) suggest that industrial and commercial land uses are the highest contributors to heavy metal contamination in urban water bodies. They also hypothesize that lead oxide and zinc are released from tire wear and copper, chromium, and nickel are commonly shed through brake wear. Another study by Owe et al. (1982) found elevated levels of metals in precipitation runoff from a large shopping mall parking lot in Syracuse, NY. The concentrations measured were several times greater than secondary treatment outfalls in the area. They concluded that the elevated metal concentrations were attributable to deposition from vehicle emissions.

Toxicity is the main risk associated with the accumulation of metals in surface waters and sediments. Pitt et al. (1995) estimated the toxicity risk of metals washing off roads parking lots and vehicle service areas during storm events in the Birmingham, AL area. Not only were metals detected nearly every time, but also the storm water runoff was found to be toxic 41% of the time, using the Microtox® Toxicty-Screening Procedure. Parking lots contained the highest percentages of toxic values.

Indicator Bacteria & Pathogens

Indicator bacteria and pathogens have frequently been observed in urban surface waters (US EPA, 1992). The human health concern is that bacterial and viral contamination in the creeks runs the risk of spreading infection to those exposed to the pathogens. Sources of contamination are variable, but may result from leaking sewer lines, malfunctioning septic systems, manure based fertilizer, animal fecal material, or human inputs. Runoff can collect bacteria from soils and sediments and carry them into water bodies.

Unfortunately, the true source of contamination and resulting health hazards are generally difficult to predict. This is because the methods currently used to quantify the contamination level employ "indicator" bacteria as a surrogate for all fecal-based bacteria, and while pathogens may be among them, results do not indicate this directly. The city's current methodology utilizes selective media and growth conditions to isolate and culture taxonomic groupings normally found in the human intestines – typically *E. coli, Enterococci* and total coliform bacteria. The theory is that the presence of these organisms in surface water can be correlated with the presence of fecal matter and other human pathogens. While these assays are effective "indicators" of contamination, the organisms they are quantifying are not typically the bacteria that are pathogenic. The pathogenic species are normally much lower in concentration and more difficult to culture. The species typically used as indicators are not limited to human intestines, but are commonly found in many warm-blooded animal intestinal tracts and some even in soil. Therefore, indicator counts higher than regulatory thresholds may or may not be the result of human contamination, but instead can be from animal or soil microbes that are similar in taxonomy, and capable of growing in the test assays.

Nonetheless, the indicator bacteria sampling system is the only methodology for which there are established regulatory criteria, and despite the imprecise connection between indicators and pathogens, the methodology is considered sufficiently conservative in protecting human health objectives. More advanced methodologies for detecting human-specific fecal contamination are being developed, but none have been implemented in a regulatory capacity yet.

Solids, Sediment, & Floatables

Water-borne solids take several forms. The most conspicuous consists of floating debris and garbage. More pertinent to water quality are suspended solids, particles of sufficiently small size or mass that they do not rapidly settle out of the water column, allowing for transport significant distances downstream. The primary source of suspended sediment to stream channels is storm runoff, which can collect sediment from impervious areas, construction sites and eroding banks and landscape (Burton &

Pitt, 2002). Excessive sediment can cause turbidity, reducing sunlight in the water column and the phytoplankton which depend on it, as well as clogging gravel pore spaces, which are important areas for insect and fish breeding and shelter.

Organic Compounds & Petroleum Hydrocarbons

Hydrocarbons encompass a large group of synthetic and natural compounds primarily composed of carbon and hydrogen. While some hydrocarbons pose health risks, most do not but can create aesthetics problems such as odor and reduced water clarity. Petroleum products are used in all facets of society, making them particularly prevalent in urbanized areas.

Automobile use releases hydrocarbons through combustion of gasoline and diesel, as well as dripping and washing off of moving parts. A one year study by Owe et al. (1982) found elevated levels of petroleum hydrocarbons in precipitation runoff from a large shopping mall parking lot in Syracuse, NY. Concentrations were measured to be several times greater than secondary treatment outfalls in the area. The study hypothesized that the elevated hydrocarbon concentrations are the result of leaking vehicles.

An important subgroup of hydrocarbons generally included in monitoring programs is polycyclic aromatic hydrocarbons (PAHs). PAHs have an immense amount of non-fuel applications in industry. Additionally, they too are an undesirable byproduct released from internal combustion engines. High concentrations have been detected in major urban centers, such as Paris, France (Gromaire-Mertz et al, 1999). Bomboi and Hernandez (1991) revealed that automobiles were the primary contributors of n-alkanes and aliphatics contaminating the urban runoff in and around Madrid. N-alkanes are saturated hydrocarbon chains of any length, the most common being methane. Aliphatics are other open carbon chains. Both of the hydrocarbon forms include lubricants and fuel oils typically used in automobiles. Results further suggested that automobiles were a primary contributor PAHs due to incomplete combustion. Industrial areas and heating systems were also considered significant sources.

Pitt et al (1995) measured the toxicity risk of PAHs washing off roads, parking lots, and vehicle service areas during storm events in the Birmingham, AL area. PAHs were detected 15-20% of the time. The storm water runoff was found to be toxic 41 % of the time in conjunction with metals also contained in the runoff. Parking lots contained the highest percentage of the toxic values.

Another important subgroup of hydrocarbons are known as volatile organic compounds (VOCs). This class of organic compounds includes a wide range of gasoline components, solvents, and disinfection by-products (Hughes et al., 2000). Commonly detected VOCs include benzene, dichloromethane (also known as methylene chloride), trichloroethylene, and tetrachloroethylene (also known as perchloroethylene). Benzene is commonly found in gasoline and can enter ground water supplies from leaking underground storage tanks. Dichloromethane is a common industrial solvent and trichloroethylene is used in cleaning septic systems. Tetrachloroethylene, used in the dry-cleaning industry, is frequently detected in urban environments (Jennings et al., 1996).

Physical Characteristics

The water quality measurement parameters recommended for field sampling are ubiquitous to surface waters and characterize water quality conditions. Observations of physical characteristics can be indicative of urban impacts and water quality impairment. For example, loss of riparian vegetation reduces shading in stream corridors and consequently increases average water temperatures. Lower than average dissolved oxygen values can reveal sewage or other illicit discharges to stream corridors. Fluctuations in pH values convey conditions that affect fate and transport of other constituents, such as variations of nitrogen. Accordingly, observations of field parameters provide clues to what is occurring in the urban environment and influence water quality conditions.

7.2 *Results of Case Studies*

To gain background information on sampling methods already in place in surrounding Southern California communities, four other surface water monitoring programs were chosen for evaluation and comparison. It was deemed appropriate to choose programs within coastal Southern California due to the similarity of climate conditions and precipitation patterns. Whenever possible, monitoring programs located within the limits of the city or county of Santa Barbara were selected as the results from these programs are most directly applicable to the watersheds examined for the proposed monitoring plan. Programs outside of Santa Barbara County were chosen for availability of data and applicability of monitoring methods to assessing sources of pollutants in the urban environment. Los Angeles County has completed a study of the relation of land use to pollutant concentrations and Orange County has implemented a similar program, although results weren't released at the time of report preparation. The programs evaluated are:

- County of Santa Barbara – Project Clean Water (PCW) Water Year 2002/2003 San Jose Creek Storm Monitoring (County of Santa Barbara, 2003)
- Los Angeles County – 1994-2000 Integrated Receiving Water Impacts Study (Los Angeles County, 2001)
- Orange County – Drainage Area Management Program (DAMP) (County of Orange, 2003)
- Central Coast Regional Water Quality Control Board – Central Coast Ambient Monitoring Program (CCAMP) (Central Coast RWQCB, 1998)

A literature review of the results of these programs was used to ascertain constituents that the city would be most likely to encounter in their urban creeks and evaluate how other organizations in the area are approaching the assessment of water quality in urban areas. For more detailed information on each sampling program please refer to Appendix D.

The following observations have been derived from the water quality data collected by the County of Santa Barbara, Los Angeles County, and Orange County. The Central Coast Ambient Monitoring Program (CCAMP) water quality data was not utilized for comparative purposes as no indications of detection rates were available, but results from sediment sampling provide the best available baseline data on sediment pollutant concentrations.

The following constituents were either detected infrequently or not at all by at least two groups:

- Chlorpyrifos
- Dissolved Arsenic
- Dissolved Cadmium
- Dissolved and Total Chromium
- Dissolved and Total Lead
- Dissolved Mercury
- Dissolved Nickel
- Dissolved and Total Silver

(Note: Total arsenic, cadmium, mercury, and nickel are not listed because they were not examined by more than one group. Total detection rates for these species were also low based on the LA County study.)

The following constituents were detected frequently by at least two groups:

- Total Kjehdahl Nitrogren (TKN)
- Nitrate (NO_3) [This constituent also frequently exceeded EPA regulatory criteria.]
- Ammonia (NH_3)
- Total Phosphorous
- Total Copper
- Dissolved and Total Zinc [This constituent often neared EPA regulatory criteria.]

The following constituents exhibited inconsistent results among monitoring programs:

<u>Herbicides and Insectides</u> - For LA County, glyphosate, the active ingredient in the popular herbicide Roundup™, detection rates are zero for most sites and do not exceed 50% at any site, while PCW in Santa Barbara reports glyphosate detection rates of over 50% at each site except for the mixed agricultural and residential site.

A similar pattern is noted for diazinon, whereby Orange County observes the insecticide frequently and LA does not. The minimum detection rate in Orange County is 63%, with the maximum rate reaching 92%. For LA County, the maximum detection rate is 43% for the mixed use land designation, and all other sites are 25% or less.

Metals - Orange County detects total cadmium rather sporadically; although two sites have 100% detection rates. Total cadmium detection rates are much lower for the LA area, reaching a maximum of 50% detection rate at the high density residential land use designation.

Dissolved copper detection rates are the highest out of all metals sampled in Orange County and also found very frequently in the Los Angeles sampling. However, data from Santa Barbara County indicates that the maximum detection rate of dissolved copper is 25%.

Nutrients - Project Clean Water reports that total phosphate was not detected at any site or sampling event. Conversely, total phosphate was detected at all sampling sites and events in Orange County.

In sum, the reports indicated a few key results utilized in protocol design and choice of constituents. They are:

- Nitrogen containing compounds are rather ubiquitous in Southern California
- Dissolved and total metal concentrations were negligible in the water column for most sample sites
- Diazinon and malathion are the only pesticides sampled that demonstrated appreciable mean concentrations and detection rates
- Copper and zinc appear to be the most commonly detected metal species in the water column
- CCAMP results in Santa Barbara indicate the sequestration of metals and organic substances in the bed sediments
- Differences in data from Santa Barbara County versus LA and Orange Counties are likely attributed to the varying degrees of developed area in their respective watersheds. The differences in results from Project Clean Water versus the more urbanized LA and Orange County watersheds appears to support the assertion of the NURP study results that increasing amounts of impervious surfaces in a watershed increases pollutant loading, as discussed in Section 2.4.
- Concrete channelization may lead to faster pollutant flushing, greater pollutant loading to the ocean and beaches, and may require earlier sampling in storm events than natural channels.

In general, the methods followed by each program do not differ greatly from the proposed monitoring plan, as it addresses both general watershed conditions and land use considerations. The CCAMP monitoring program is designed to assess general watershed conditions, therefore sampling locations are near the outlet of the streams. In contrast, the sampling programs of PCW Santa Barbara, Los Angeles and Orange

Counties are intended to provide insights on land use impacts. The approach taken by Project Clean Water entails sampling at transition points in the watershed, as opposed to sampling specific drainages of homogeneous land uses as performed by Los Angeles County. Orange County is following a similar technique as PCW, as their land use correlation study focuses on sediment transport as land use changes from agricultural areas to developed neighborhoods. Sampling specific drainages of homogeneous land uses appears to yield more precise results, but transition point sampling does offer estimates of how water quality varies as land use changes throughout the watershed.

The most robust land use study, completed by Los Angeles, demonstrates the complexities associated with this type of monitoring plan. Although a large amount data has been collected, it is difficult to draw concrete conclusions from this study. However, general trends can be discerned. For example, ions such as chloride and sodium are generally found at the greatest concentrations in the retail/commercial land use category, while suspended solids and turbidity are greatest in the light industrial category. Several similar observations can be made about LA's data and are explained in further detail in Appendix D. The main issue is the interpretation of the results. Do increased concentrations of total dissolved solids in retail areas merit policy action? The answer depends upon two factors. The first is the number of sampling events that have been utilized to obtain the mean concentrations. Results that consistently show the same trends year after year provide greater confidence in the reliability of the data and subsequent decisions. Additionally, use of data for policy decisions relies upon whether appropriate policy measures exist to reduce observed pollutant concentrations. While land use studies may not always be able to provide definite details on pollutant sources, previous studies demonstrate that the data obtained from them can provide useful information on appropriate policy actions and further characterization of identified problems.

III. MONITORING PLAN

The following sections present and discuss the key areas of the monitoring plan, including the underlying research and reasoning upon which each section is based. A complete version of the monitoring plan, which can be used as a sampling plan, is included as Appendix A.

8 CONSTITUENTS OF CONCERN

The constituents recommended for the monitoring plan are provided in Table 8-1 below with suggested methods, detection limits and regulatory or screening criteria. Whenever possible, EPA analytical methods are recommended to provide definitive category results. Standard Methods for the Analysis of Water and Wastewater (SM) are also an accepted industry standard and cited frequently by the EPA (US EPA, 1992). Regulatory or screening criteria are included as a reference for levels of concern. The most applicable water quality criteria for the Santa Barbara creeks are derived from the Central Coast Basin Plan (RWQCB).

8.1 *Constituent Selection Rationale*

This section provides a discussion of each constituent included in this monitoring plan and the reasons for its inclusion. Justification ranges from historical monitoring by the city, case study analysis, and literature review.

<u>Nutrients</u>

High nutrient levels can be detrimental to aquatic health due to toxicity (Toxnet, 2005), and from conditions associated with eutrophication. This monitoring plan recommends screening four different categories of nutrients: nitrate, total Kjeldahl nitrogen (TKN), ammonia, and orthophosphate. All three forms of nitrogen containing compounds are reported found in at least two other Southern California monitoring programs.

Three different nitrogen-containing compounds are designated for screening in this plan: Nitrate, TKN, and Ammonia. Elevated levels of nitrate can be toxic to humans and animal life at high concentrations (Toxnet, 2005) and can be a key contributor to eutrophication. Recent city sampling efforts have reported several instances where nitrate concentrations exceed ambient water quality standards. TKN analysis, when used in conjunction with ammonia quantification, can be used to estimate the proportion of nitrogen originating from organic sources like leaf litter and detritus compared to fertilizers. This can be helpful in investigating whether observed nitrogen concentrations in creek samples are primarily the result of decaying organic matter in or around the creeks, chemical inputs like fertilizers, or a combination of the two. Sufficiently high concentrations of ammonia can indicate sewage leaks to creek systems and can be toxic to aquatic life (Toxnet, 2005).

Table 8-1 - Recommended Constituents for Santa Barbara Creeks Monitoring Program

Constituent	Method Number	Detection Limit	Regulatory or Screening Criteria		
			Arroyo Burro Creek	Mission Creek	Sycamore Creek
Field Parameters					
Dissolved Oxygen	NA-Use meter	0.1 mg/L	>5.0 mg/L (BP- W FH)	>7.0 mg/L (BP – CFH)	>7.0 mg/L (BP-CFH)
pH	NA-Use meter	0.01 mg/L	6 – 9.5 (EPA CCC) 7.0 – 8.5 (BP) No exceedance >0.5 above normal ambient levels		
Temperature	NA-Use meter	Varies	No increase >5⁰F above natural receiving water temp.		
Specific Conductance	NA-Use meter	4 µS/cm	<900 µS/cm (CA DHS Secondary MCL)	<900 µS/cm (CA DHS Secondary MCL)	<700 µS/cm (BP-AG)
Turbidity	EPA 180.1 or meter	0.05 NTU	Waters shall be free of changes that cause nuisance or adversely affect beneficial uses If turbidity is between 0 – 50 NTU, increases shall not exceed 20% If turbidity is between 50 – 100 NTU, increases shall not exceed 10 NTU If turbidity is greater than 100 NTU, increases shall not exceed 10%		
Laboratory Analyses					
Oxygen Demanding Substances & Solids					
Biological Oxygen Demand (BOD)	SM 5210B	2 mg/L	N/A		
Total Suspended Sediment (TSS)	EPA 160.2	4 mg/L	The suspended sediment load, settleable material, and suspended sediment discharge rate shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses. (BP)		

Constituent	Method Number	Detection Limit	Regulatory or Screening Criteria		
			Arroyo Burro Creek	Mission Creek	Sycamore Creek
			Suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonally established norm for aquatic life. (EPA Ambient H2OQuality Criteria- instantaneous max.)		
Metals					
Total Copper	EPA 200.8 (ICP-MS)	0.36 µg/L	N/A	N/A	200 µg/L (BP-AG)
			9.0 µg/L (EPA CCC)		
			1300 µg/L (CA DHS and EPA Primary MCL)		
			1000 µg/L (CA DHS and EPA Secondary MCL)		
Total Lead	EPA 200.8 (ICP-MS)	0.6 µg/L	N/A	N/A	5000 µg/L (BP-AG)
			2.5 µg/L (EPA CCC)		
			15 µg/L (CA DHS and EPA Primary MCL)		
			0 µg/L (EPA MCL goal)		
Total Zinc	EPA 200.8 (ICP-MS)	1.8 µg/L	N/A	N/A	2000 µg/L(BP-AG)
			120 µg/L (EPA CCC)		
			5000 µg/L (CA DHS and EPA Secondary MCL)		
			5000 µg/L (EPA Ambient H_2O Quality Criteria)		
Nutrients					
Nitrate (NO_3)	EPA 300.0	0.002 mg/L	45 mg/L (BP)		
			10 mg/L (EPA Primary MCL)		
Total Kjedahl Nitrogen (TKN)	EPA 351.4	0.03 mg/L	N/A		
Ammonia (NH_3)	EPA 350.3	0.03 mg/L	30 mg/L (EPA suggested SNARL)		
Ortho-Phosphate (PO_4)	EPA 300.0	0.003 mg/L	N/A		
Hardness	EPA 130.2	0 mg/L	Hardness values are utilized by the CA Toxics Rule to determine metal toxicity.		
Indicator Bacteria					
Total coliform	Colilert 24 hour	10 MPN/100 mL	Instantaneous count – *MPN/100mL ≥ 10,000 (AB 411)		
			Geometric mean of 5 samples within 30 days – MPN/100mL ≥ 1,000 (AB 411)		
Fecal coliform	Colilert 24 hour	10 MPN/100 mL	Instantaneous count – MPN/100mL ≥ 400 (AB 411)		
			Geometric mean of 5 samples within 30 days – MPN/100mL ≥ 200 (AB 411)		

Constituent	Method Number	Detection Limit	Regulatory or Screening Criteria		
			Arroyo Burro Creek	Mission Creek	Sycamore Creek
Enterococcus	Enterolert 24 hour	10 MPN/100 mL	Instantaneous count – MPN/100mL ≥ 103 (AB 411)		
			Geometric mean of 5 samples within 30 days – MPN/100mL ≥ 35 (AB 411)		
Pesticides					
Organochlorine Pesticides	EPA 8081A	Varies	Total identifiable chlorinated hydrocarbon pesticides shall not be present at concentrations detectable with the accuracy of the latest prescribed methods. (BP)		
Organophosphorous Pesticides	EPA 8141A	Varies	0.1 µg/L (EPA Ambient H_2OQuality Criteria)		
Organic Substances, Hydrocarbons, and Surfactants					
Volatile Organic Compounds (VOCs)	EPA 8260	Varies	Varies by constituent – see Appendix C		
Surfactants (MBAS)	EPA 425.1	Varies	0.2 mg/L (BP)		
Polycyclic Aromatic Hydrocarbons (PAHs)	EPA 610	0.025 mg/L	Varies by constituent – see Appendix C		

Notes:

SM – Standard Methods, BP- Basin Plan (WFH- Warm Freshwater Habitat, CFH- Cold Freshwater Habitat, AG- Agriculture); NTU – Normal Turbidity Units; EPA CCC – Recommended Continuous Criteria Concentration; DHS – Department of Health Services; MCL – Maximum Contaminant Level SNARL – Suggested No-Adverse-Response Level; AB 411 – Assembly Bill 411

In some respects elevated phosphorous levels are more damaging to surface waters than elevated nitrogen because it is frequently the limiting nutrient in freshwater aquatic systems (Heathcote, 1998). In other words, high inputs of dissolved nitrogen will not necessarily lead to eutrophication in a phosphorus-limited system, but if phosphorus loading is increased then eutrophication is more likely to develop. This relationship can be reversed if nitrogen concentrations are much lower than phosphorous concentrations, but this is fairly uncommon. Ocean waters tend to be nitrogen limited, however, and nitrogen-rich creek or lagoon inputs to the ocean can contribute to algal or planktonic blooms such as red tides (Heathcote, 1998). Orthophosphate is the preferred phosphorous containing nutrient to screen for because phosphate based fertilizers (like ammonium phosphate) are frequently used in garden and agricultural settings (Schlesinger, 1997).

Pesticides

The city has implemented pesticide reduction and elimination plans in public areas through integrated pest management programs, and while it is still unclear as to whether or not pesticide contamination truly represents a threat to the creeks within Santa Barbara, there is sufficient risk and public concern to warrant investigating the problem. Results from case studies do indicate that pesticides are present in other Southern Californian creeks.

The majority of pesticides in circulation today fall into tow categories of similar chemical structures: ogano-chlorine based pesticides and organo-phosphate based pesticides. EPA Method 8081A is a broad spectrum test that is used for the detection of a variety of organochlorine pesticides. EPA Method 8141A is used to detect organophosphate and organonitrogen classes of pesticides. This will allow the City to perform a broad spectrum approach that reduces the risk of missing possible contaminants because they are not included on a list of individual chemicals.

Metals

Based on the results from similar studies in other Southern California communities and scientific literature on land use; copper, lead and zinc are the three metals most likely to constitute a problem for Santa Barbara in surface waters. Copper and zinc are frequently present in sampling results from several of the case studies. Literature reviewed for this project also suggests a link between copper and zinc to urban sources such as automobile use. Although lead was not detected frequently in other Southern California monitoring programs, research indicates lead poses a significant toxicological risk (Toxnet, 2005). Moreover, reviewed literature also identifies automobiles in urban settings can be a source of lead in runoff. For more detailed descriptions of these sources please consult Section 7.1.

Indicator Bacteria

Bacteria are a well-known contaminant to Santa Barbara creeks (City of Santa Barbara, 2003). The DNA study mentioned in Section 2.1 describes current efforts by the city to track and isolate bacteria sources.

Solids
Total suspended solids (TSS) measures the amount of particulate matter present in the water column. Excessive siltation can be detrimental to habitat health. While the creeks within Santa Barbara do not have a history of siltation problems, suspended solids will frequently bind pollutants. This is particularly true for metals and hydrophobic organic compounds. Deposition of pollutant laden particles can produce harmful effects, particularly if the contaminant laden particles are allowed to accumulate. While bound to particles the pollutants are relatively benign, but if they are liberated at a later time (for example due to a change in redox state such as might occur in the lagoons), a large increase in aqueous concentrations over a short period of time can result.

The TSS analysis provides a quantitative measurement of suspended solids, floatable material, and settleable matter by trapping these materials on a 0.45-μm filter, which is then dried and weighed.

Hydrocarbons
The human and ecological health effects from significant exposure to many hydrocarbons, including petroleum combustion byproducts and PAHs (Toxnet, 2005), makes them an important constituent of concern for this monitoring program. In addition to measuring pesticides and PAHs, VOCs have also been recommended to provide a more comprehensive accounting of organic chemicals (USEPA 1983).

It is important to note that the results from an oil and grease analysis are method-defined analytes in that the measurement of oil and grease is not an absolute quantity of a specified substance, but instead an aggregate of substances with similar physical characteristics. The method also quantifies other materials, such as chlorophyll and sulfur compounds, that are extractable in the solvents used for the test (Franson, 1985). Therefore, results from oil and grease analyses can be difficult to interpret and if harmful constituents are contributing appreciably to an observed concentration, it is likely to be more accurately quantified in analyses for PAHs, VOCs or pesticides.

Physical Characteristics
There are several water quality parameters that do not consist of a particular contaminant or species of pollutants, but rather are broader measures of physical or chemical characteristics. These water quality parameters include the following:

pH – The pH of a water body is a critical habitat quality consideration. Benthic organisms, protozoa, and fish, particularly in the egg and juvenile life cycle stages, can have narrow pH range tolerances. Excessively high or low pH levels, or frequent fluctuations, could be indicative of larger contamination problems, making it an important parameter to incorporate. Furthermore, changes in pH can have important influences on contaminant fate and transport, such as increasing the solubility of metals.

Temperature – As with pH, many organisms have narrow bands of ambient temperature tolerances. This makes temperature an important consideration in ecosystem quality. While it is not normally linked to chemical contamination, thermal pollution is a common problem when heated water is discharged from power generation plants or industrial operations into surface waters.

Biochemical Oxygen Demand – Biochemical Oxygen Demand (BOD) measures the biodegradable organic load in the creeks. The most common test measures the amount of oxygen consumed in a sample over the course of five days (BOD_5). Surface water is a collection of chemicals, and detritus, much of which is suitable for microbial consumption. The continual oxidation of consumable constituents, both chemically and by microbes, continues until either the consumables are depleted or the dissolved oxygen supply is exhausted. The depletion of dissolved oxygen can have a severe impact on a water body by eliminating aerobic organisms.

To further illustrate this concept, consider a case where a sudden loading of biologically degradable pollutants caused the BOD to rise, such as a sewage spill. This results in accelerated growth of aerobic microbe communities due to the introduction of additional food sources. After a brief lag time, the dissolved oxygen in the water is depleted by the increased aerobic metabolism of the microbes. If the oxygen is depleted enough, a fish kill occurs as fish are suffocated. This is the most conspicuous aspect, but protozoa, arthropods, mollusks and other oxygen requiring organisms also suffer the same fate.

Conditions associated with varying levels of BOD can influence the redox potential of the water, which in turn can dictate whether certain metal species are liberated from sediments, or precipitate out of the water column into the sediments. Also, should the water column become anoxic, anaerobic bacteria are able to thrive, some of which are lithotrophs, meaning they utilize metal based compounds as an energy supply. These metabolic mechanisms can liberate metals sorbed in sediments into the water column. Thus, a sudden influx of BOD elevating material may drive dissolved metal concentrations above safe levels in the water column as well as depleting oxygen in the water.

Dissolved Oxygen – Dissolved Oxygen (DO) is a vital parameter to include in any stream surveying effort to gauge water quality conditions. Oxygen is a necessity to all forms of aerobic life. The DO values are related to BOD as described above, and the higher the DO concentration of a system, the greater the load of BOD can be assimilated without diminishing ecological integrity.

9 SAMPLING APPROACH

Two separate types of water column sampling are included in the proposed monitoring plan for the creeks within Santa Barbara. The sample locations are selected throughout the watershed to provide a general representation of water quality. These locations aim to provide suitable spatial distribution and, where possible, have been located near important junctions in the stream network. The NAWQA protocol labels this type of sampling as 'integrator' sites because each sample represents an integration of the water-quality influences in the watershed above it. This is also an example of systematic sampling, wherein evenly spaced sample locations are investigated for an extended period of time to evaluate trends (SWRCB, 2002).

The purpose of the second type of sampling is to differentiate between separate land-use category impacts on water quality. The sample locations are selected to be as representative as possible of one specific type of land use. The NAWQA protocol labels this type of sampling as 'indicator' sampling because its purpose is to indicate the nature of pollutant loading by a specific land use. In this form of sampling a specific subset of locations are being sampled to obtain information to test the hypothesis that land use type affects the contaminant concentration, as opposed to acquiring more universal data about the watershed.

9.1 *Sampling Frequency*

Integrator Sites

Since the purpose of integrator sampling is to gain a picture of both spatial and temporal patterns of pollutants, the integrator locations should be sampled at different times of year as the amount of flow in the creeks and the patterns of human chemical usage change. For the initial two-year characterization phase of the monitoring protocol, monthly sampling will provide detailed information on the creek water quality throughout the year. This matches the frequency recommended in the NAWQA protocol. After the two-year characterization phase, an evaluation can be made of how often sampling should be conducted in the future based on the observed variation in pollutant concentrations. Possibly, quarterly sampling would provide a reasonable balance of cost efficiency while tracking trends over time and alerting managers to new sources or hot spots of pollution.

Storm runoff is a special condition during which comparatively large masses of pollutants can be transported through the creeks in a short time. For this reason, our protocol recommends sampling the integrator locations during four storm events each year during the initial two-year characterization phase. The storm sampling should obtain periodic samples throughout the event hydrograph, particularly focusing on the 'first flush' and rising limb when contaminants are most likely to be mobilized. After the two-year characterization phase, future storm sampling can be re-evaluated based on the type of information generated during the characterization phase.

Indicator Sites

The goal of indicator sampling is to measure (for constituents that have been demonstrated to consistently exceed levels of concern) the amount of pollutant input from each category of land use. The most useful quantitative measure to compare land-use categories is a statistical mean, with a quantified confidence interval around that mean. Thus, the goal of indicator sampling should be to obtain a mean with a given 95% confidence interval equal to or less than a set goal. For example, the Los Angeles land use study discussed in Section 2.7 used the goal of establishing an event mean concentration with a confidence interval of plus or minus 25%. Thus, if the goal of the indicator sampling is to obtain a mean concentration with a confidence interval of plus or minus 25%, the number to times each indicator site will need to be sampled depends on the sampling variability encountered. In our opinion, each indicator site should be sampled until the mean concentration (during storm runoff) has been established to a 95% confidence interval less than or equal to plus or minus 25%.

9.2 *Sampling Technology and Technique*

The Bren group project has investigated various options for utilizing sampling technologies and techniques to optimize data quality and/ or reduce costs.

Water Quality Meters

There are a variety of field water quality meters on the market, each with its own advantages and disadvantages. Past experience has revealed that the YSI lines of meters are exceptionally rugged, versatile, and accurate. However, any number of water quality meters will obtain the desired information and the group was not able to conduct a comprehensive field test of the various meters on the market to definitively recommend one above the others. Key field parameters to measure when collecting water samples are:

- pH
- Conductivity
- Dissolved Oxygen
- Temperature
- Oxygen reduction potential (ORP).

These water quality parameters provide information on ecological conditions in the creek and can affect the fate and transport of different chemical pollutants.

Autosamplers

Autosamplers can be installed at a creekside location with a conduit (e.g. ½-inch pipe) to a sample collection point in the creek. The autosampler can be locked in a stainless steel box on the creek bank and programmed to pump a sample of creek water into containers at specified intervals. The inside of the sampler contains a rack of 500mL sample bottles (up to 24) and the remaining space can be filled with ice to preserve the samples once collected. The autosampler is then digitally programmed to collect the samples at specified times and can be left until the sampling program is completed. This is a very efficient means of sampling a storm hydrograph, where samples may be desired from several locations at numerous intervals throughout the storm. Instead of a group of volunteers sampling frantically during a storm when conditions may be dangerous and heaviest rainfall is often in the middle of the night, the autosampler only requires a technician to visit sites at the onset of the storm to program the sampling intervals and check that the equipment is working properly.

The Bren group has only had experience with the ISCO, Inc. autosamplers (Figure 9-1). This brand is being used effectively in local creeks by the LTER research group.

Figure 9-1 - ISCO Autosampler

Pressure Transducers

Pressure transducers are instruments which can be placed in a creek and used to measure and record water pressure at set times. The pressure transducer measures the pressure placed on a diaphragm open to the water, and translates this into an electrical signal which can be recorded by a data logger. Thereby, an accurate log can be generated of the vertical height of water over the transducer over a given period. If the cross sectional area of the stream channel has been mapped at the point where the tranducer is placed, then a ratings curve can be calculated which will specify the flow (volume per time) of the creek at any given stage or pressure transducer reading. Data from a pressure transducer can be combined with sample data (such as that obtained by an autosampler) to generate an accurate picture of pollutant flux (*mass* transported in the water column per unit of time) as opposed to only knowing concentrations over time.

9.3 *Chemical Analysis: Laboratory vs. Test Kits*

It is important to recognize that the methods employed to obtain data vary in their degree of accuracy and precision, as well as cost. For example, an EPA-certified lab following EPA Methods and an immunoassay field test kit may both obtain a sample analysis result of 10 mg/L for a given contaminant. The test kit is likely many times cheaper than the lab and might present an attractive choice as an analytical tool. But the margin of error for the test kit might be ±5 mg/L while the EPA method might be accurate to ±0.005 mg/L. If the applicable regulatory standard for that chemical was 8 mg/L, you could be confident you had exceeded the standard using the EPA method, but have no such certainty with the test kit. Test kits can be an effective cost-control strategy for an environmental sampling program, but their suitability for a particular task should be judged on a case by case basis depending on the data quality needs and objectives.

The EPA Office of Solid Waste and Emergency Response (OWSER) recognizes two types of data: screening level data and definitive level data. They are described as follows:

> Screening level data are generated by rapid, less precise methods of analysis with less rigorous sample preparation. Screening data provide analyte (or at least chemical class) identification and quantification, although the quantification may be relatively imprecise. For definitive confirmation, at least 10 percent of the screening data are confirmed using analytical methods and quality control procedures and criteria associated with definitive data. Screening data without associated confirmation data are generally not considered to be data of known quality. Screening data without confirmation data are only allowed under limited circumstances.
>
> Definitive data are generated using rigorous analytical methods, such as EPA reference methods. Data are analyte-specific, with confirmation of analyte identity and concentration. Methods generating definitive data produce tangible raw data (e.g., chromatograms, spectra, digital values) in the form of paper printouts or computer-generated electronic files. Data may be generated at the site or at an off-site location, as long as the quality control requirements are satisfied. For the data to be definitive, either analytical or total measurement error must be determined.
> - EPA OWSER Publication 9360.4-21FS

One effective technique for obtaining the cost savings of test kits without completely giving up the quality control and documented, quantifiable, quality assurance measures of certified laboratory analysis is to use test kits but submit duplicates of 10% of the screening level samples to an EPA-certified lab for confirmatory analysis. This provides a statistical means to measure the quality of the entire data set generated by the test kits.

The Bren group was not able to conduct field testing of analytical test kits ourselves. However, our research discovered an EPA Office of Water-sponsored study conducted by a group of University of Alabama graduate engineering students who did a detailed analysis of the different commercially-available test kits at the time (July 1999). Their report can be accessed at:

http://unix.eng.ua.edu/~rpitt/Publications/MonitoringandStormwater/evaluation%20of%20commercial%20water%20quality%20test%20kits.PDF.

Table 9-1 has been updated and adapted from Table 2-1 contained in the University of Alabama report. It should be noted that the University of Alabama study was conducted in 1999 and test kit technology choices may have advanced significantly in subsequent years.

Table 9-1 – Test Kit Recommendations

Parameter	Screening Test Recommended	Time Required (min)	Expertise Required	Quantitation Level	Screening Level[2]	Capital Cost	Expendible Cost ($/sample)	Comparable Laboratory Quantitation Level	Comparable Laboratory Cost	Notes
Bacteria	IME KoolKount	30 to 13hr	little	1 fecal coliform/100mL	400 fecal coliform/100mL (water recreation)	none	$4	1 fecal coliform/100mL	$ 80.00	Non-selective test
BTEX	EM Science Dtech Immunoassay	45	extensive	By analyte	Per analyte, see Table XX	$500 (optional)	$25 water, $50 sediment	By analyte; generally, 0.0002 mg/L	$ 80.00	time consuming, complex, short shelf life
Copper	HACH Bicinchonate, AccuVac	5	little	0.5 to 5 mg/L	4.8 mg/L CMC	Uses DR 800s	$0.28	0.001 mg/L	$ 18.00	
Copper alternative	Palintest SA-1000	3	little	70-300 ug/L	4.8 mg/L CMC	$2,300 (for lead also)	$5.50 (for both lead and copper)	0.0004 mg/L	$ 18.00	expensive instrument
Hydrocarbon Screening	PetroSense	5	little	0.1 to 10 mg/L	NA	$6,900	None	0.1 mg/L	$ 80.00	Recommended alternative to immunoassay tests; expensive instrument, not specific
Lead	HACH LeadTrak	45	extensive	5 to 150 ug/L	15 mg/L MCL	also uses DR 800s	$ 4.61	0.0012 mg/L	$ 18.00	time consuming and complex test
Lead alternative	Palintest SA-1000	3	little	5 to 300 ug/L	15 mg/L MCL	$2,300 (for copper also)	$5.50 (for both lead and copper)	0.0012 mg/L	$ 18.00	
Nitrate	HACH MR, AccuVac	7	little	2.8 to 18 mg/L	10,000 MCL	also uses DR 800s	$0.56	.015mg/L	$ 12.50	Cadmium waste
PAHs	EM Science Dtech Immunoassay	45	extensive	very sensitive	NA	same as BTEX	$25 water, $50 sediment	By analyte	$ 120.00	Time consuming, complex, short shelf life
pH	Horiba Twin pH meter	1	little	0-12 pH units	NA	$235	None	NA	$ 20.00	Replacement probe ($70) every 6 months
Zinc	LaMotte	15	moderate	0.14 to 3 mg/L	6.5 to 8.5	Can use DR 800s	$ 0.59	0.001 mg/L	$ 18.00	Can be used with HACH spectrophotometer
Surfactants	HACH DE-2	5	little	0 to 1 mg/L	NA		$6	By analyte	na	
Phosphate	Hach PhosVer	5	little	0 to 2.5 mg/L	NA	also uses DR 800s	$ 0.25	0.001 mg/L	$ 40.00	

[1] This table is an updated and adapted version of Table 2-1 from Evaluation of Field Screening Kits, Pitt et. al., University of Alabama, July 1999.
[2] The more conservative of either the Federal Maximum Contaminant Level for Drinking Water, or
California Toxics Rule Criteria Maximum Concentration for Freshwater Aquatic Life

10 SAMPLING SITES

Utilizing the NAWQA approach of indicator and integrator sampling, locations for water column samples were selected throughout the city of Santa Barbara. A total of seven integrator and 13 indicator sampling locations were selected. Figure 10-1 and Table 10-1 provide an overview of all of the recommended integrator and indicator sampling locations. In this section a description of each sampling location and detailed directions to the sampling location are provided.

10.1 *Integrator Sampling Locations*

For each watershed, one primary integrator location was selected as close to the ocean outlet as possible. Most of the streams enter low-flow lagoons before reaching the ocean and the integrator site was chosen above slack water where there was still visible stream flow. The different water quality of the lagoons as opposed to the flowing streams (e.g. redox state, pH, temperature, turbidity) can affect pollutant behavior and make comparing samples from the lagoon to samples higher in the watershed problematic. For each of the three creeks, several additional integrator locations were chosen at progressively higher points in the watershed to provide information on how the creek water quality changes as it flows from the upper hillsides through the urban landscape. Efforts were also made to locate integrator sampling locations: 1) near major confluences or inputs to the creeks, 2) where access is safe, 3) near indicator locations for efficiency of sample collection, and 4) near current city sampling sites and/or USGS or LTER stream flow gauges.

Figure 10-1 - Recommended Indicator Sampling Locations and Associated Drainages

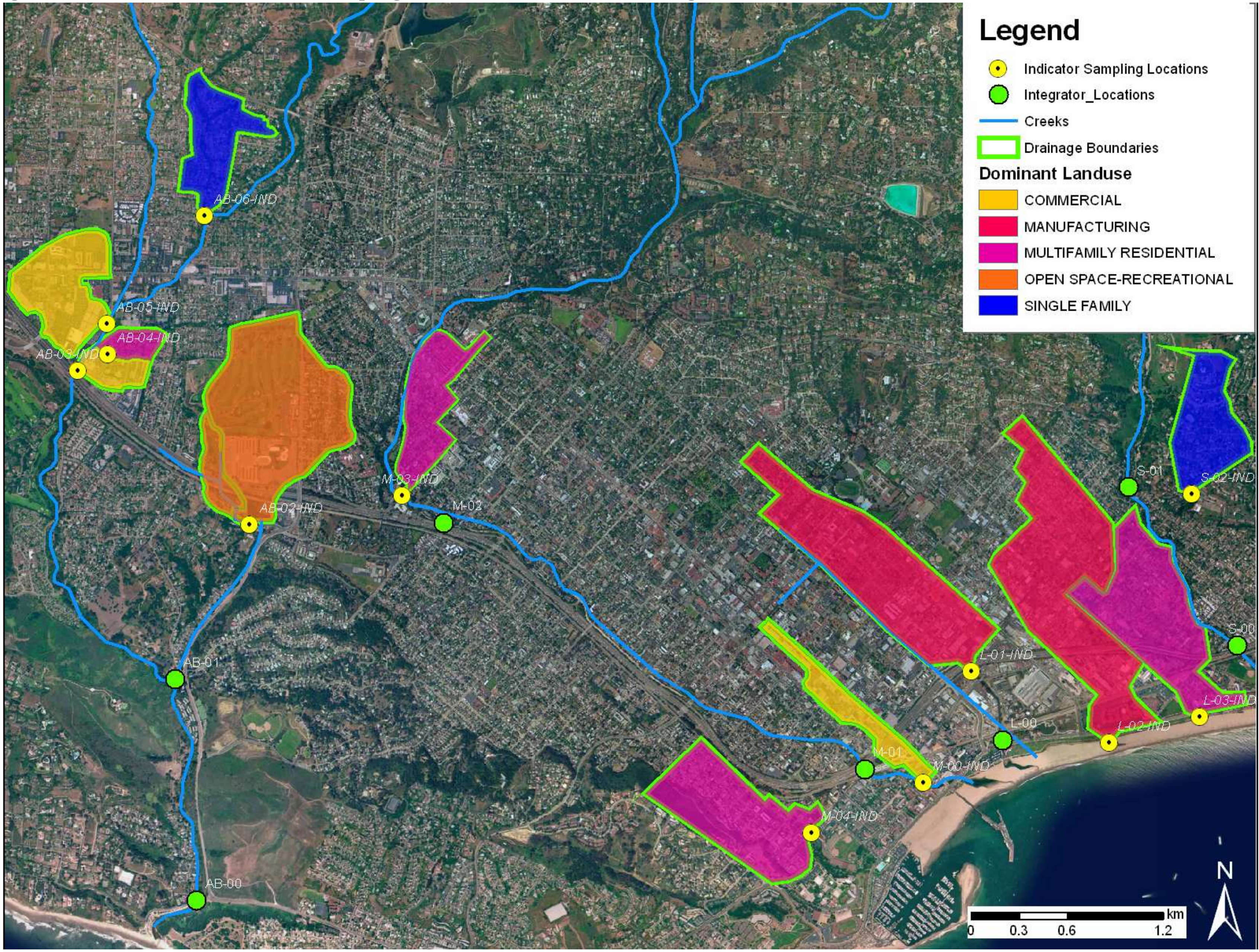


Table 10-1 - Integrator and Indicator Sampling Location Information

Sampling Location #	Watershed	Sampling Location	Sampling Location Type	Drainge Area (square km)	Dominant Land Use in Drainage	Percent of Dominant Land Use in Drainage	Sub-Basin Percent Impervious	Latitude	Longitude
AB-00	Arroyo Burro	Arroyo Burro Creek at Cliff Drive	Integrator	n/a	n/a	n/a	n/a	34.40496	-119.74027
AB-01	Arroyo Burro	Arroyo Burro at Confluence with Las Positas Creek	Integrator	n/a	n/a	n/a	n/a	34.41773	-119.74144
L-00	Laguna Channel	Laguna Channel at Chase Palm Park	Integrator	n/a	n/a	n/a	n/a	34.41488	-119.68572
M-01	Mission	Mission Creek at Montecito Street	Integrator	n/a	n/a	n/a	n/a	34.41320	-119.69506
M-02	Mission	Mission Creek at Los Olivos Street	Integrator	n/a	n/a	n/a	n/a	34.42683	-119.72371
S-00	Sycamore	Sycamore Creek at Highway 101	Integrator	n/a	n/a	n/a	n/a	34.41999	-119.66925
S-01	Sycamore	Sycamore Creek Above Salinas Roundabout	Integrator	n/a	n/a	n/a	n/a	34.42873	-119.67740
AB-03-IND	Arroyo Burro	Arroyo Burro Creek at Camino Real (storm drain / manhole)	Indicator	0.08	Commercial	100%	96%	34.43493	-119.74877
AB-05-IND	Arroyo Burro	Arroyo Burro Creek at La Cumbre Plaza (storm drain)	Indicator	0.30	Commercial	95%	94%	34.43625	-119.74787
M-00-IND	Mission	Mission Creek at Mason Street Bridge (storm drain)	Indicator	0.16	Commercial	98%	95%	34.41248	-119.69097
L-01-IND	Laguna Channel	Laguna Channel at Highway 101	Indicator	0.69	Manufacturing	52%	72%	34.41882	-119.68771
L-02-IND	Laguna Channel	Storm Drain Outflow at Fess Parker Doubletree Hotel	Indicator	0.82	Manufacturing	50%	78%	34.41506	-119.67820
AB-04-IND	Arroyo Burro	Arroyo Burro Creek at Hope Avenue (storm drain / manhole)	Indicator	0.06	Multifamily Residential	100%	84%	34.43604	-119.74669
L-03-IND	Laguna Channel	Milpas Storm Drain Outfall at East Beach	Indicator	0.51	Multifamily Residential	74%	82%	34.41645	-119.67238
M-03-IND	Mission	Mission Creek at Junipero Street (storm drain)	Indicator	0.25	Multifamily Residential	55%	82%	34.42820	-119.72684
M-04-IND	Mission	Westside Drainage Channel at Pershing Park	Indicator	0.45	Multifamily Residential	66%	45%	34.40945	-119.69883
AB-02-IND	Arroyo Burro	Las Positas Creek at Modoc Road	Indicator	0.84	Open Space/Recreational	82%	27%	34.42635	-119.73685
S-03-IND	Sycamore	Sycamore Creek Before Confluence	Indicator	0.00	Open Space/Recreational	93%	3%	34.44690	-119.68251
AB-06-IND	Arroyo Burro	San Roque Creek at Ontare Road	Indicator	0.23	Single Family	99%	50%	34.44382	-119.74036
S-02-IND	Sycamore	Sycamore Creek Tributary Channel at Cleveland Elementary School	Indicator	0.27	Single Family	93%	50%	34.42833	-119.67384

Arroyo Burro Creek at Cliff Drive

Drainage Description: This sampling location represents the entire Arroyo Burro Watershed. At this point in Arroyo Burro Creek, samples will be taken before the convergence of Mesa Creek with Arroyo Burro Creek. Upstream from this sampling location, Arroyo Burro Creek flows through the Las Positas Valley in a natural channel with low density residential housing and large amounts of open space. This is noteworthy because after flowing through the more urbanized portions of Santa Barbara where the largest amounts of pollutants inputs potentially occur, Arroyo Burro Creek flows through an area where input of pollutants is expected to be much lower. Unlike like Arroyo Burro Creek, the other creeks in the city are highly urbanized near their outlets to the ocean.

Directions to Sampling Location: This sampling location is near the intersection of Cliff Drive and Las Positas Road. From this intersection proceed west on Cliff Drive, then turn right onto Alan Road and park. Walk east on Cliff Drive to the creek bridge. During low flow periods the creek can be accessed downstream of the Cliff Street Bridge and samples taken from the creek channel. This area of the creek channel is comprised of concrete slabs and grouted boulders. During periods of high flow samples should be taken from the upstream side of the bridge using a clean bucket. On the upstream side of the bridge there is also a stage gauge that is presently being used by the city for bacteria sampling and the SBC LTER project.

Figure 10-2 - Arroyo Burro Creek at Cliff Drive

Location Number:	AB-00
Grid Coordinates: (Latitude-Longitude)	34.404957 -119.740272
Sample Type:	Integrator

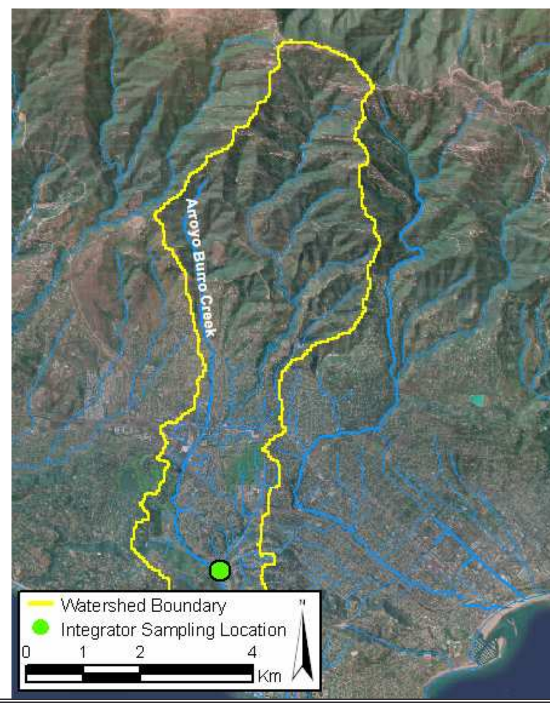
Arroyo Burro Creek Confluence with Las Positas Creek

Drainage Description: The predominant land uses found upstream of this sampling location in the Arroyo Burro Watershed include the largest contiguous area of single-family homes in the city, multifamily housing, an entire golf course, parkland, and a large commercial district. Sample taken at the confluence of these two creeks provides the best representation of runoff coming from the urbanized portions of the Arroyo Burro Watershed without including the runoff inputs that occur from the undeveloped flood plain downstream from the confluence.

Directions to Sampling Location: Proceed south on Las Positas Road from Modoc Road to Portesuello Avenue. Immediately past the intersection of Las Positas and Portesuello Avenue park in the dirt lot on the right side of the road. From the dirt parking area walk westward through a clearing in the vegetation. Follow the trail that leads to the Arroyo Burro Creek channel. Sample from the creek channel below the merging of the two creeks.

Figure 10-3 - Arroyo Burro Creek Confluence with Las Positas Creek

Location Number:	AB-01
Grid Coordinates: (Latitude-Longitude)	34.41773 -119.74144
Sample Type:	Integrator



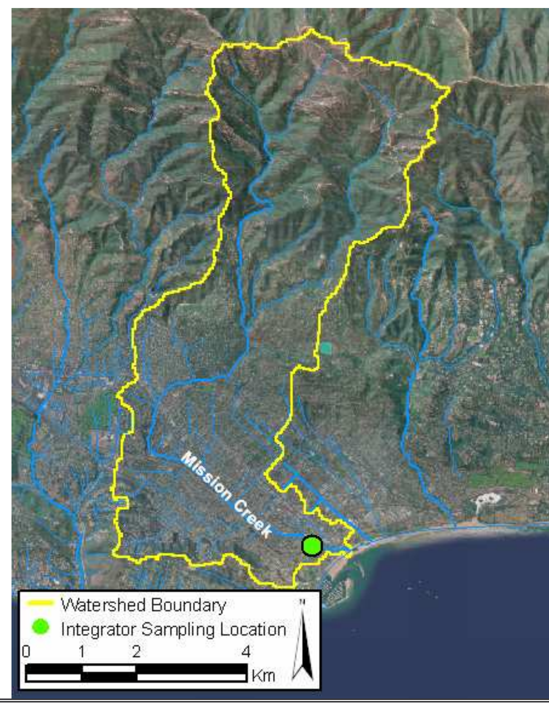
Mission Creek at Montecito Street

Drainage Description: The area upstream from this sampling location represents nearly the entire Mission Watershed. Because at certain times of the year Mission does not flow to the ocean, the area further downstream becomes a lagoon. If a current plan to restructure the channel to flow to the ocean permanently is implemented, we recommend sampling farther downstream, such as the bridge that connects the Harborview Inn properties and the California Hotel.

Directions to Sampling Location: Proceed to Montecito Street between State Street and Bath Street (this is adjacent to the Santa Barbara Train Station parking lot). Park next to the Montecito Street bridge over Mission Creek. During periods of low flow samples can be taken from the creek channel. During periods of high flow samples should be taken from the downstream side of the bridge. Underneath the bridge is a guage and sampling location currently in use by the city for bacteria and by the LTER project.

Figure 10-4 - Mission Creek at Montecito Street

Location Number:	M-01
Grid Coordinates: (Latitude-Longitude)	34.413199 -119.695056
Sample Type:	Integrator



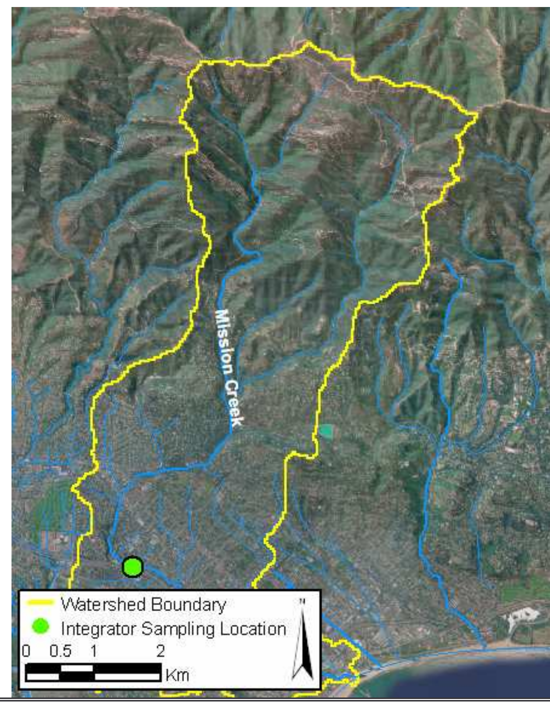
<u>Mission Creek at Los Olivos Street</u>

<u>Drainage Description:</u> The Mission watershed at this point is a mix of multi-family, commercial, single family, and parkland uses.

<u>Directions to Sampling Location:</u> Exit 101 at Mission Street, go towards State, and turn immediately left onto Castillo. Two blocks up Castillo Street turn left onto Los Olivos Street. Park at the end of the cul-de-sac street. The creek is visible from the road and easily sampled from the banks.

Figure 10-5 - Mission Creek at Los Olivos Street

Location Number:	M-02
Grid Coordinates: (Latitude-Longitude)	34.42683 -119.72371
Sample Type:	Integrator



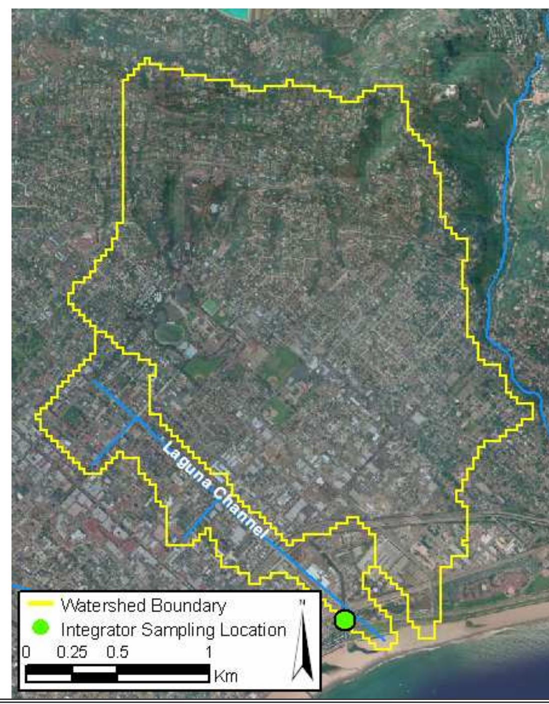
Laguna Channel at Chase Palm Park

Drainage Description: This site is the confluence of the three major drainages of the Laguna watershed: the western portions L-1 and L-2 come through storm drains and empty in Chase Palm Park, joining the flow from L-3. This represents some of the densest housing in the city, most of the industrial land-use, and largely impermeable commercial areas.

Directions to Sampling Location: Park in the small lot on the north side of Cabrillo at Chase Palm Park. During periods of low to medium flow samples can be taken from the channel. To access the channel walk west on the concrete path until you get to the channel. Sample the channel below where a large storm drain outlet empties into each side of the channel. During periods of high flow samples should be taken from Cabrillo Street.

Figure 10-6 - Laguna Channel at Chase Palm Park

Location Number:	L-00
Grid Coordinates:	34.41488 -119.68572
Sample Type:	Integrator



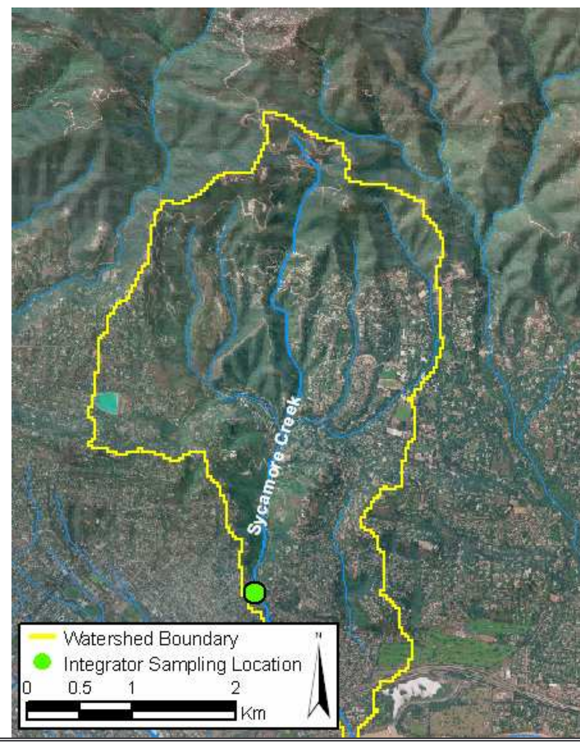
<u>Sycamore Creek Above Salinas Roundabout</u>

<u>Drainage Description:</u> At this point, the upper part of the Sycamore Watershed is a mix of National Forest, open space parkland, and very low density housing.

<u>Directions to Sampling Location:</u> From Milpas Street turn right on Montecito Street and proceed six blocks to the roundabout. Turn right onto Salinas and park immediately. Walk up to the roundabout, and past the roundabout to Alameda Padre Serra (APS) toward the Riviera (not up the hill towards Montecito). There is a concrete slab that leads down to the creek in front of the APS bridge. Sample in the creek channel on the side nearest the roundabout.

Figure 10-7 - Sycamore Creek above Salinas Roundabout

Location Number:	S-01
Grid Coordinates: (Latitude-Longitude)	34.428732 -119.677395
Sample Type:	Integrator



Sycamore Creek at Highway 101

Drainage Description: In contrast to the upper watershed, this lower portion contains increasingly dense single family and multi-family residential development right up to the creek banks in many places. From visual inspection, it has been found that this location is the farthest downstream location that has very little stagnant water that could potentially skew sample results.

Directions to Sampling Location: From Milpas Street proceed east on Carpinteria Street to Voluntario Street. Turn right onto Voluntario Street until it ends and curves left to become Indio Muerto. Park close to the bridge. Walk along entrance to the trailer park, go down stream embankments to a concrete pillar in the creek channel and before where bank erosion is collapsing from under a home. Sample before the still water.

Figure 10-8 - Sycamore Creek at Highway 101

Location Number:	S-00
Grid Coordinates: (Latitude-Longitude)	34.419989 -119.669251
Sample Type:	Integrator

10.2 *Indicator Sampling Locations*

Indicator locations were selected by first generating detailed GIS layers of land use and surface drainage for each watershed, which were overlaid on an aerial photograph of the city taken in 2002. The percentage of each type of land use in each sub-watershed was calculated, and sub-watersheds which best represented a particular category of land use were chosen. Following the NAWQA protocol, only sub-watersheds which contained at least 50% of the target land use were considered for indicator sampling (Alley, 1990). However, in most cases, we found drainages that had at least 95% of one type of land-use.

After the most representative sub-watersheds for each category of land use were identified, group members visited each location to determine if an appropriate drainage point (storm sewer or tributary) could be accessed for sampling. Every sub-basin of each watershed was also evaluated for permeability through a variety of methodologies, and land-use was verified using parcel maps. A total of 13 indicator sampling locations are recommended. The locations include 3 sub-watersheds representing commercial land-use, 2 representing industrial/manufacturing, 2 single-family residential, 4 multi-family residential, and 2 open space/parkland.

10.2.1 Commercial Land Use Indication Sites

Mission Creek at the Mason Street Bridge (Stormdrain)

Drainage Description This sampling location receives storm drain inputs from the commercial corridor between State Street and Chapala Street, South of Carrillo. Samples should be taken from the storm drain that empties into Mission Creek south of the Mason Street bridge. This sampling location provides characterization of runoff from a heavily trafficked retail commercial area.

Directions to Sampling Location: From State Street, proceed East on Mason Street for approximately 100 meters. From the Mason Street bridge, walk 10 meters downstream on the left bank of the creek. Descend the sandbag steps to the storm drain that empties into the creek channel. Samples should be taken from the storm drain flow.

Figure 10-9 - Mission Creek at Mason Street Bridge

Location Number:	M-00-IND
Grid Coordinates (Latitude-Longitude):	34.41248 -119.69097
Sample Type:	Indicator
Subwatershed Area:	0.16 km²
Percent Target Land Use:	98% commercial
Percent Impervious:	95%

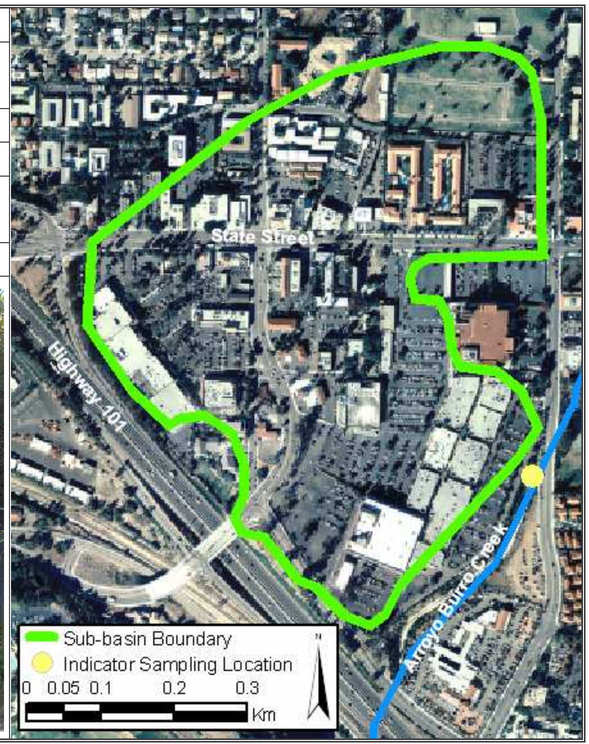
Arroyo Burro Creek at La Cumbre Plaza Outflow (Storm Drain)

Drainage Description : A review of City Public Works Department storm drain maps, 10-foot contour intervals of the area, consultation with City Public Works Staff, and an in depth visual survey of the drainage indicate that a 12-inch diameter storm drain accounts for most of the La Cumbre Plaza and 5 Points Plaza inputs to Arroyo Burro Creek. This drainage contains a significantly greater proportion of impervious land cover than other commercial land use in the city, which can be attributed to the La Cumbre Plaza and 5- Points Plaza parking lots.

Directions to Sampling Location: Arroyo Burro Creek flows under Hope Avenue between States Street and Camino Real/Highway 101. The sampling location is the storm drain that empties from the down stream end of the Hope Street bridge (the drain flows through and is built into the bridge). Samples will need to be collected with a long arm sampling device from either side of the creek or directly above where the storm drain inputs to the creek. The La Cumbre Plaza parking lot or street parking can be utilized at this sampling location.

Figure 10-10 - Arroyo Burro Creek at La Cumbre Plaza Outflow

Location Number:	AB-05-IND
Grid Coordinates: (Latitude-Longitude)	34.43625 -119.74787
Sample Type:	Indicator
Subwatershed Area:	0.30 km²
Percent Target Land Use:	95% commercial
Percent Impervious:	94%



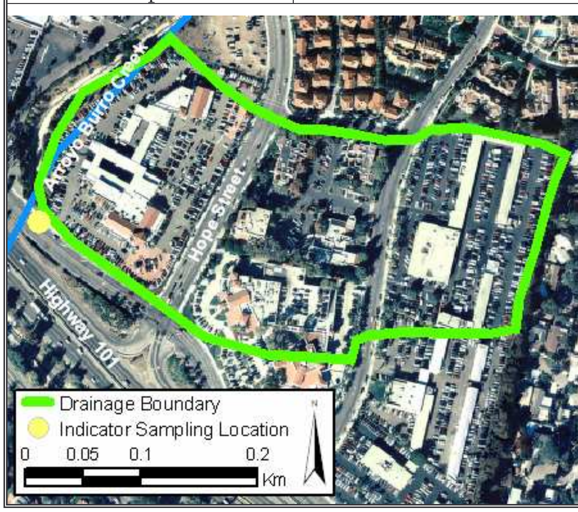
Arroyo Burro Creek at Calle Real (Storm Drain)

Drainage Description: This drainage is comprised of the automobile dealerships near the intersection of Hope Avenue and Camino Real. This sampling location will be a rare example of an entirely homogenous land use within a sub-basin. The storm drain that collects the water from this drainage will be accessed by removing a manhole cover located on Camino Real. Access to the storm drain via a manhole cover is being utilized because where the storm drain empties into Arroyo Burro Creek cannot be safely accessed for sampling.

Directions to Sampling Location: This storm drain is accessed for sampling through a manhole cover located on Camino Real between Hope Avenue and La Cumbre Plaza. The manhole cover is located in a landscaped area on Camino Real, adjacent to the Cutter Infiniti automobile dealership on the corner of Camino Real and Hope Ave. Water flows in this storm drain approximately twelve feet below the manhole entry point. To collect samples from this location, two individuals with confined space entry qualifications or a rope and bucket are required.

Figure 10-11 - Arroyo Burro Creek at Calle Real

Location Number:	AB-03-IND
Grid Coordinates: (Latitude-Longitude)	34.43493 -119.74877
Sample Type:	Indicator
Subwatershed Area:	0.08 km²
Percent Target Land Use:	100% commercial
Percent Impervious:	96.25%



10.2.2 Multifamily Land Use Indication Sites

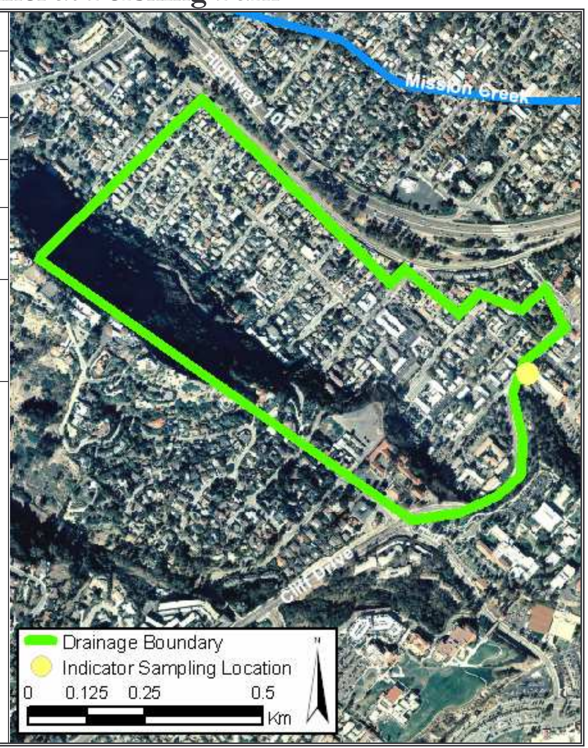
Westside Drainage Channel at Pershing Park

Drainage Description: This drainage captures runoff from a predominately dense, multifamily residential area that is south of Carrillo Street, between Highway 101 and the Mesa area. The storm drain network for this sub-basin converges near Cliff Drive into a single open-channel along the western perimeter of Pershing Park. The channel is approximately 3-feet wide and 2-feet deep. From Pershing Park the channel flows under Cabrillo Street and the Santa Barbara Harbor parking lot, where empties directly into the harbor.

Directions to Sampling Location: This sampling location is accessed near the intersection of Montecito Street and Rancheria Street. Street parking is available either on Montecito Street or Rancheria Street. From the sidewalk near the intersection of Montecito Street and Rancheria Street, proceed down the bike and foot path that is at the base of the hill that Santa Barbara City College is located on. Where the path starts, the storm drain becomes an open channel and can be accessed.

Figure 10-12 - Westside Drainage Channel at Pershing Park

Location Number:	M-04-IND
Grid Coordinates: (Latitude-Longitude)	34.413199 -119.695056
Sample Type:	Indicator
Subwatershed Area:	0.0206 km²
Percent Target Land Use:	66% multifamily residential
Percent Impervious:	44.5% (due to undeveloped hillside)



<u>Milpas Storm Drain Outfall at East Beach (Storm Drain)</u>

<u>Drainage Description:</u> This drainage captures runoff from the Milpas Street commercial district and portions of the residential area between Milpas Street and Sycamore Creek. From watershed delineation based solely on topography, the upper portion of this sub-drainage would flow directly into Sycamore Creek. As a result of urbanization of the watershed, the runoff from this area now goes to storm drains and ultimately the Milpas outfall. Although this storm drain does not input to one of the city's creeks, it is a suitable indicator sampling location due to the high percentage of commercial land use in this drainage.

<u>Directions to Sampling Location:</u> This storm drain outfall to Santa Barbara's East Beach is located near the intersection of Milpas Street and Cabrillo Boulevard. For this sampling location, the East Beach parking lot, or street parking on Cabrillo Blvd, can be utilized. The storm drain outfall is located adjacent to where the bike path crosses Cabrillo Boulevard. In the vicinity of the outfall pipe is approximately six large granite boulders and ice plant patches between the beach sand and the bike path. For most of the spring and summer months this sampling location is filled in with sand and has no flow. Occasionally during the spring and summer pooled water can occur at this sampling location without any rainfall occurring.

Figure 10-13 - Milpas Storm Drain Outfall

Location Number:	L-03-IND
Grid Coordinates: (Latitude-Longitude)	34.41645 -119.67238
Sample Type:	Indicator
Subwatershed Area:	0.51 km²
Percent Target Land Use:	74% multi-family
Percent Impervious:	82.2%

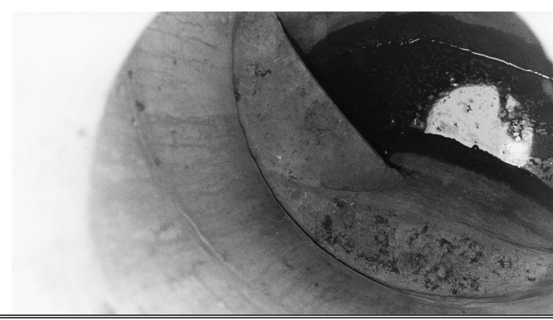
Arroyo Burro Creek at Hope Avenue (Storm Drain)

Drainage Description: Similar to drainage W-1 (Westside Drainage Channel at Pershing Park Sampling Location), this drainage is comprised primarily of multifamily condos and senior housing facilities. The properties in this watershed tend to have higher property values than drainage W-1 and E-3 sampling location. With higher property values, in general there is a greater amount of common areas and yard spaces with more landscaping.

Directions to Sampling Location: This storm drain will be accessed for sampling through a manhole located on Hope Avenue between La Cumbre Plaza and Camino Real. The storm drain manhole cover is located in the sidewalk adjacent to a parcel of undeveloped open space and across the street from a multi-family housing development. Water flows in this storm drain approximately twelve feet below the manhole entry point. To collect samples from this location, two individuals with confined space entry qualifications or a rope and bucket are required.

Figure 10-14 - Arroyo Burro Creek at Hope Avenue

Location Number:	AB-04-IND
Grid Coordinates: (Latitude-Longitude)	34.43604 -119.74669
Sample Type:	Indicator
Subwatershed Area:	0.3 km²
Percent Target Land Use:	100% multifamily residential
Percent Impervious:	84%



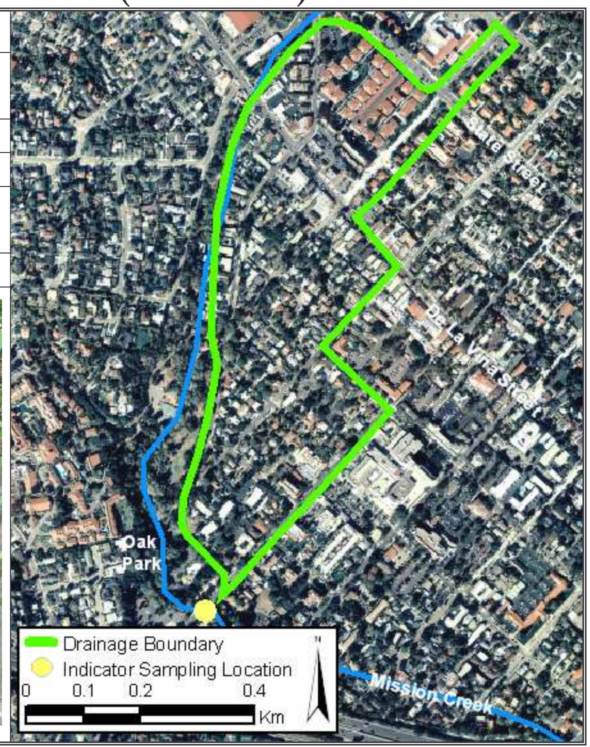
Mission Creek at Junipero Street (Storm Drain)

Drainage Description: This drainage is comprised of an area known as the Oak Park neighborhood. It is a small area of dense, predominantly multi-family residential development located southwest of State Street, east of Mission Creek and Alamar and northwest of Junipero. Runoff from this drainage area sheetflows to a storm drain on Junipero Street, then to Mission creek.

Directions to Sampling Location: From highway 101 North exit at Pueblo Street, turn right onto Junipero Street, and park in the parking lot for Oak Park. From the parking area of Oak Park, proceed to the apartment building across the street. The storm drain empties from a concrete pipe into the creek adjacent to the apartment building across Junipero Street from Oak Park.

Figure 10-15 - Mission Creek at Junipero Street (Storm Drain)

Location Number:	M-03-IND
Grid Coordinates: (Latitude-Longitude)	34.4282 -119.72684
Sample Type:	Indicator
Subwatershed Area:	0.25 km^2
Percent Target Land Use:	55 % multifamily residential
Percent Impervious:	82%



10.2.3 Single-Family Residential Land Use Indication Sites

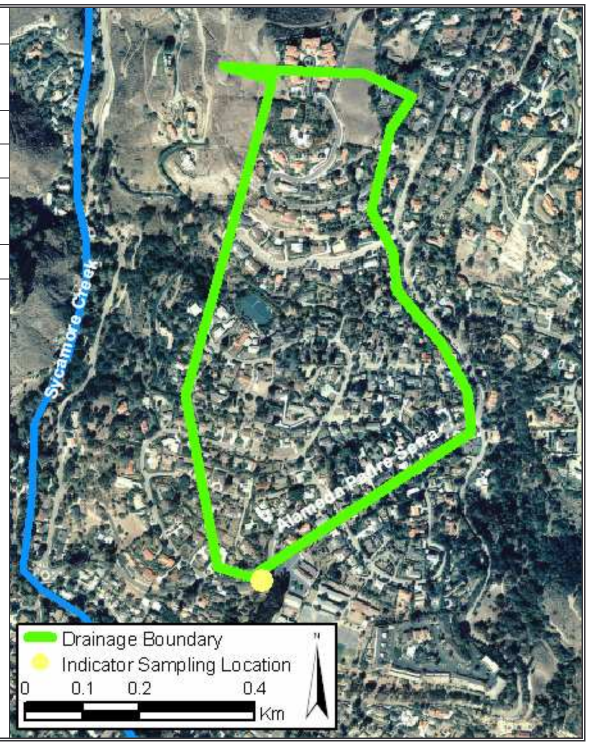
<u>Sycamore Creek Tributary Channel at Cleveland Elementary School</u>

<u>Drainage Description:</u> This drainage is comprised of medium density single-family homes on the hillside between Cleveland Elementary School and Sycamore Creek. Properties in this drainage tend to have yards and gardens that are highly landscaped with moderate-sized dwelling units for the area.

<u>Directions to Sampling Location:</u> Go to the Salinas/Montecito roundabout. Take Alameda Padre Serra halfway up the hill. Before you pass Cleveland Elementary turn right onto Terrace Vista. Park at the end of the street. There is a trail partially shrouded by brush that leads to the channel formed at the outflow of two closed drains, sample as far downstream as possible. Watch out for poison oak!

Figure 10-16 - Sycamore Creek Tributary Channel at Cleveland Elementary School

Location Number:	S-02-IND
Grid Coordinates: (Latitude-Longitude)	34.42833 -119.67384
Sample Type:	Indicator
Subwatershed Area:	0.27 km²
Percent Target Land Use:	93% single family residential
Percent Impervious:	50%



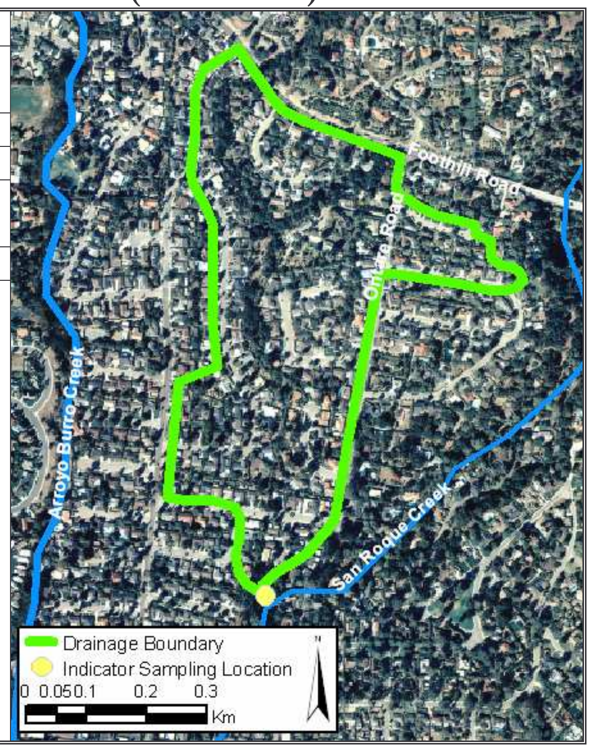
San Roque Creek at Ontare Road

Drainage Description: This drainage is primarily composed of medium density single-family residential housing with a limited amount of open space near the upper portions of the drainage. The primary storm drain from this area empties into San Roque Creek; which is a primary tributary to Arroyo Burro Creek. San Roque and Arroyo Burro Creeks merge adjacent to La Cumbre Plaza just below upper State Street.

Directions to Sampling Location: From upper State Street proceed north on Ontare Road. The creek channel will be accessed where Ontare Road crosses San Roque Creek. After crossing San Roque Creek, park in the surrounding residential neighborhood. While facing downstream, climb down the right bank into the creek channel adjacent to the bridge. Approximately 200-meters down the creek channel from the bridge is a concrete apron in the channel where a 24-inch storm drain empties into the creek. Take samples from the outflow of this storm drain. This sampling location can only be accessed during low to moderate flows.

Figure 10-17 - San Roque Creek at Ontare Road (Storm Drain)

Location Number:	AB-06-IND
Grid Coordinates: (Latitude-Longitude)	34.44382 -119.74036
Sample Type:	Indicator
Subwatershed Area:	0.23 km²
Percent Target Land Use:	99% single family residential
Percent Impervious:	45.9%



10.2.4 Industrial/Manufacturing Land Use Indication Sites

Laguna Channel and Highway 101

Drainage Description: The Laguna Channel drainage is comprised of a variety of land uses and a complicated network of storm drains. This drainage is relatively small in relation to the larger Sycamore, Arroyo Burro, and Mission Watersheds in the city. The Laguna Channel is noteworthy for its extremely fast conveyance of surface runoff directly to the ocean. A majority of the channel is concreted lined. Land uses in this drainage include Housing Authority multifamily projects, commercial development, and the majority of the industrial and manufacturing land uses in the city.

Directions to Sampling Location: This sampling location is near the Highway 101 on-ramp for Garden Street. To access the sampling location, proceed up the Garden Street onramp for Highway 101 South. Do not enter the highway; instead pull over to the right near the top of the onramp before it merges with the highway's regular flow of traffic. From the shoulder of the onramp, Laguna Channel can be accessed on the southern side of the highway. Samples should be taken directly from the channel.

Figure 10-18 - Laguna Channel at Highway 101

Location Number:	L-01-IND
Grid Coordinates: (Latitude-Longitude)	34.418816 -119.687705
Sample Type:	Indicator
Subwatershed Area:	0.69 km^2
Percent Target Land Use:	52% industrial/ manufacturing
Percent Impervious:	75%

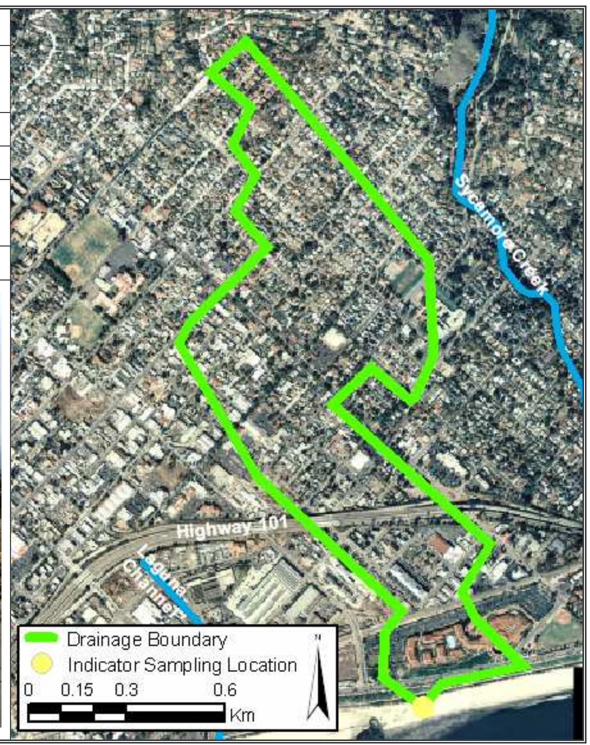
<u>Storm Drain Outflow across from the Fess Parker Doubletree Hotel</u>

<u>Drainage Description:</u> This drainage accounts for the eastern and southern portions of the Laguna Watershed. The drainage contains a large amount of the manufacturing land use in the city. The manufacturing and industrial uses in the drainage are located in the upper reaches of the drainage. The portion of the drainage closest to the outflow to the ocean is comprised of the Fess Parker Doubletree Hotel.

<u>Directions to Sampling Location:</u> The storm drain outflow is located on the beach along Cabrillo Boulevard between Milpas and Calle Cesar Chavez; near the public restrooms. Parking for this sampling location is available on Cabrillo Boulevard. The storm drain outfall is a concrete structure located further up on the beach near the iceplant landscaping adjacent to the bike path. During the summer and fall this storm drain is frequently covered with sand. During episodic storm events the high flows in the storm drain will create a channel from the drain to the ocean. During periods of lower storm drain flow and less intense rainfall, runoff will seep through the sand from the drain and form a pool adjacent to the concrete drain structure.

Figure 10-19 - Storm Drain Outflow at the Fess Parker Doubletree Hotel

Location Number:	L-02IND
Grid Coordinates: (Latitude-Longitude)	34.41506 -119.6782
Sample Type:	Indicator
Subwatershed Area:	0.82 km²
Percent Target Land Use:	50% industrial
Percent Impervious:	77.5%



10.2.5 Open Space/Recreation Land Use Indication Sites

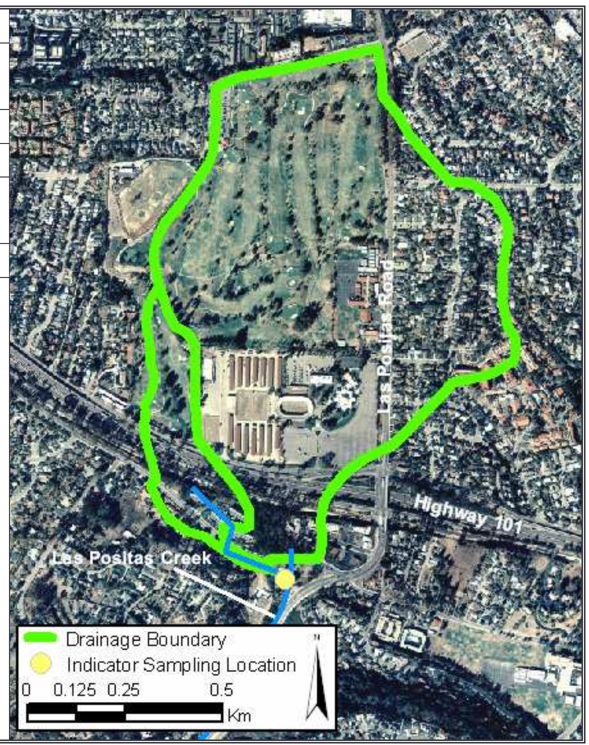
Las Positas Creek at Modoc Road

Drainage Description: The drainage area for this sampling location is comprised of two separate drainages. The smaller of the two drainages contains a small portion of the City of Santa Barbara Municipal Golf Course. The larger drainage area is primarily comprised of the City of Santa Barbara Municipal Golf Course, the Earl Warren Showgrounds, and a limited amount of high density residential development adjacent to Las Positas Road.

Directions to Sampling Location: From the intersection of Las Positas and Modoc Road proceed west on Modoc Road towards Hope Ranch. Approximately 50-meters past the intersection of Las Positas and Modoc Road park in the dirt lot on the left hand side of the road. West of the parking lot is the convergence of two large storm drains that flow under Modoc Road. These storm drains come from each of the drainages described above. In channel samples can be taken from flow created by the convergence of these two storm drains. Climbing into the channel will be required to capture flow from each of the drainages.

Figure 10-20 - Las Positas Creek at Modoc Road

Location Number:	AB-02-IND
Grid Coordinates: (Latitude-Longitude)	34.42635 -119.73685
Sample Type:	Indicator
Subwatershed Area:	0.84
Percent Target Land Use:	67% open space/ 15% rec/school
Percent Impervious:	27%



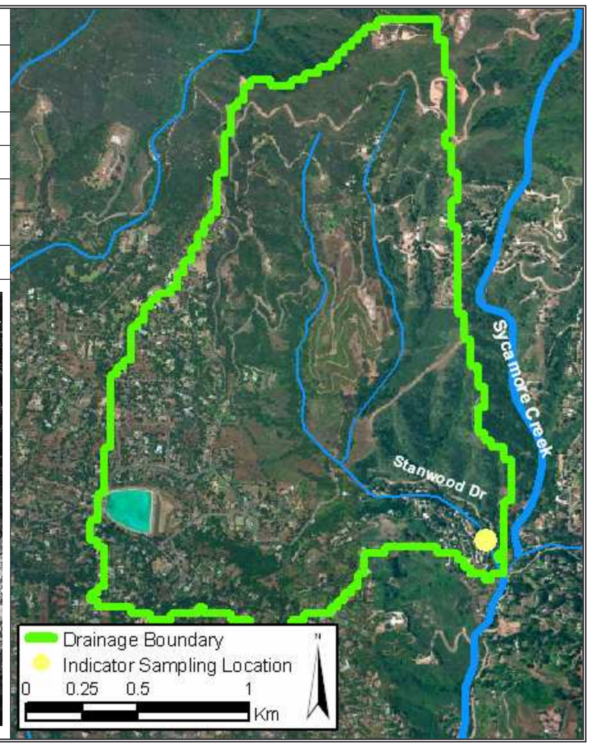
<u>Sycamore Creek Before Confluence</u>

<u>Drainage Description:</u> This drainage is comprised of the upper west portion of the Sycamore Watershed. Samples will indicate what water quality is like before any human inputs or changes in land use occur. The majority of this portion of the watershed is undeveloped open space. Samples taken at this location will be an ideal indicator of constituents that are found in runoff from completely undeveloped areas and a large open space park. Sampling will also show if any potential hydrocarbon seeps exist in the region (possibly influencing downstream results).

<u>Directions to Sampling Location:</u> From the Salinas roundabout proceed North on Sycamore Canyon Road to Highway 192. Turn left from Sycamore Canyon Road onto Highway 192 (Stanwood Drive) towards Parma Park. Sample from the Sycamore Creek Channel near the last houses built along Highway 192 before Parma Park.

Figure 10-21 - Sycamore Creek Before Confluence

Location Number:	S-03-IND
Grid Coordinates: (Latitude-Longitude)	34.42833 -119.67384
Sample Type:	Indicator
Subwatershed Area:	n/a
Percent Target Land Use:	93%
Percent Impervious:	3%



IV. CONCLUSIONS

11 RECOMMENDATIONS

The following section provides recommendations for the City of Santa Barbara to pursue for future water quality sampling in the creeks that flow through the city. While the Bren group project did not determine the exact costs of sampling, each recommendation is made with cost reduction and efficient allocation of Creeks Division funds in mind. The cost to process an individual water sample can vary significantly depending on the total number of samples being processed, the source of lab analysis, and the constituents being screened in the sample.

11.1 *Sampling Technologies and Techniques*

For analyses that are expected to be run many times, the group recommends generating screening level plus 10% definitive confirmation-category data using field test kits when available. Before taking this step, the city should consider what accuracy is desired from the sample results, and whether the cost-savings of using test kits justifies the decrease in accuracy. Test kits often utilize a laboratory procedure which requires training personnel, but the city has both the facility and the skilled personnel to take advantage of the cost savings offered by this technology. The use of test kits can generate more environmental information for a given amount of money, and if used properly the data can still be of exceptional quality and precision. In addition, a subset of the samples may be submitted for laboratory analysis to confirm results.

11.2 *Indicator sampling*

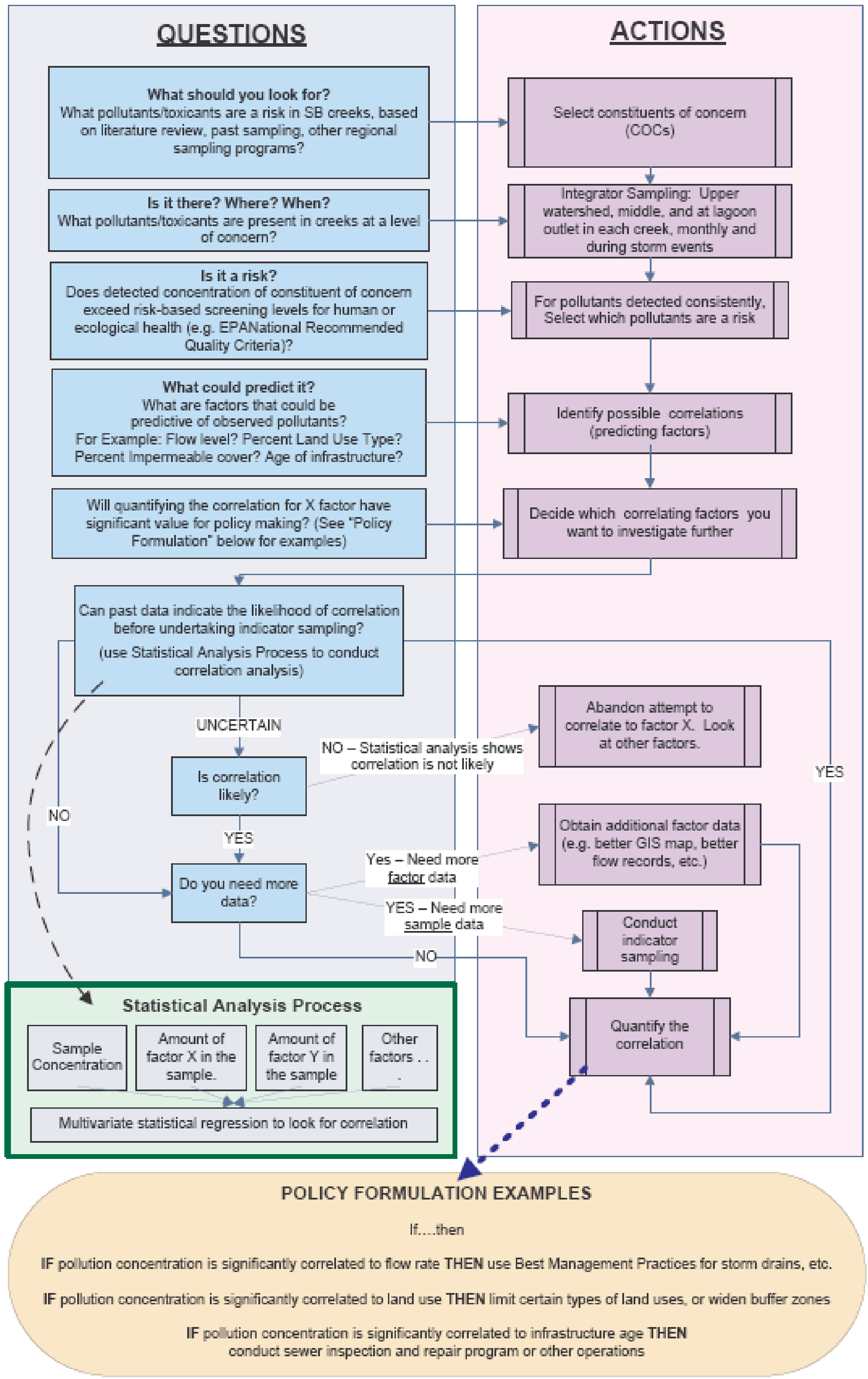
The group recommends not undertaking the effort and expense of indicator sampling until a constituent has been consistently detected above thresholds of concern, establishing it as a problem in the watershed. This criterion may be met by evaluation of past sampling data (e.g. indicator bacteria) or during a recommended two-year characterization phase of monthly integrator sampling.

Before initiating indicator sampling, we recommend considering the following questions:

- Is land use the best pollutant correlation to look for? What other correlations should be tested for (e.g. impermeability, age of infrastructure, acreage of open space, average slope surrounding the creek, etc.)? The best indicator locations may change based on the correlation looked for, but in general the most important factor is being able to calculate the area covered by the factor of interest in each sample.
- How beneficial will an established correlation be to policy (i.e. is it worth spending the effort to quantify it)?

Figure 11-1 outlines recommended questions and actions that should be taken to proceed with integrator and indicator sampling.

Figure 11-1 - Recommended Monitoring and Data Evaluation Process



11.3 *Sample Screening and Scaling of Parameters over Time*

This monitoring plan prescribes sampling for a diverse array of constituents. The analytes selected are commonly found in urban runoff in the region, as supported through case studies and scientific literature. However, is unlikely that all of them will appear in the Santa Barbara creek sampling results. While we feel that it is important to look for each of the constituents we have recommended, it would not be practical to continue to sample for analytes that are not detected in the watersheds over the long term. For this reason, we recommend re-assessing the analyte list after the two-year characterization phase of monthly integrator location sampling.

For reference, LA county has initiated constituent-screening criteria for their monitoring plan using the following criteria:

> If a constituent is not detected at the method detection limit (MDL)… in more than 25 percent of the first ten sampling events or on a rolling basis using ten consecutive sampling events, it will not be further analyzed unless the observed occurrences show high concentrations and are cause for concern. (County of Los Angeles, 2004)

It is our recommendation that after two years of monthly sampling the city revaluate the monitoring plan based on the LA criteria. However, there is a caveat – elimination of analytes from further screening should not necessarily be permanent. Annually performing a comprehensive integrator sampling event that includes the original recommended analytes would help ensure that new sources are not introducing constituents that were previously undetected.

11.4 *Gauging Stations*

A limitation of the present sampling and reporting practices being conducted by the city of Santa Barbara is that total load (or flux) of pollutants is not being derived from sampling results. Establishing gauging stations on each of the creeks in the city will allow the Creeks Division to make estimates of constituent loads and better predict when the best time to sample during episodic events is.

Pollutant loads as a planning and regulatory tool continue to gain attention for urban watersheds through the implementation of Total Maximum Daily Loads requirements. Beyond the regulatory requirements, calculation of loads will provide the city with a better estimate of when the greatest input of constituents to the creeks is occurring. To calculation loads, an efficient and accurate method to measure flow volumes through the creeks is necessary. Measured flow volumes can also serve as a tool for determining increases in flow rates during storm events. Tracking flow rates on a real time basis will enable individuals taking samples to assess when the best time to sample during episodic storm events is. In addition, flow data is essential for further implementation of the SWAT model.

The only gauging station that is continuously monitored in the city is a USGS station located on Mission Creek near the Santa Barbara Mission. Since this gauging station is located above the urban center of the city, it is very likely that the flows measured at this gauging location are not indicative of flows that occur on the lower reaches of the creek. Additionally, the Mission Creek USGS gauging does not provide real time sampling information.

11.5 *Storm Event Sampling*

Stormwater sampling should generally follow USEPA stormwater-sampling criteria: (1) the dry period preceding the storm is at least 72 hours; (2) the depth of precipitation over the basin is at least 0.10 in.; and (3) if possible, precipitation does not vary by more than 50 percent from the average precipitation amount and duration(US EPA, 1997b). The depth of precipitation can be checked via the internet at the weather station at the Santa Barbara airport and verified at the NOAA weather station at the El Estero wastewater treatment plant. Given the distance between the airport and the creek systems, it is highly recommended to confirm precipitation amounts at El Estero before commencing a sampling event. This is convenient, as the City of Santa Barbara Water Resources Laboratory, the likely location for storage of sampling equipment, is located at El Estero.

Stormwater sampling can provide key insights into sources of pollutants. In general, if a pollutant is entering a creek system from urban runoff, the observed concentration during a rain storm will increase as more of the constituent is transported from the land to the stream. However, if ground water is the most significant source of a particular pollutant, then concentrations will tend to decrease as the storm progresses because the runoff is diluting the ground water discharge (Hughes et al., 2000). Stream flow in the creek systems in Santa Barbara is often augmented by ground water discharges, particularly in low flow conditions. Therefore, pollutants released from soil into ground water may be detected with integrator sampling.

11.6 *Sediment Studies*

Examination of contaminant levels in the sediments of Arroyo Burro, Mission and Sycamore Creeks, as well as Laguna Channel is recommended. This recommendation stems from data collected by the Central Coast RWQCB and the likelihood that constituents with hydrophobic properties will bind to sediments, which will settle out of the water column in low flow areas. The NAQWA protocol recommends testing sediments for metals, semi-volatile organic compounds (SVOCs), and organochlorine pesticides.

Bed sediment studies begin with an occurrence survey to evaluate constituents present. Sampling occurs during low-flow conditions, typically in the summer months. Collection of sediment samples should be done in the 100 meter reach upstream of the water-column study sites, in areas that are identified as depositional zones. The left and right banks, as well as the center channel, are all sampled at different depths to produce a composite sample within a specific reach.

Once the occurrence survey has been completed, a spatial distribution study may be implemented to enhance the geographic coverage of the bed sediment study. The sites are chosen based upon further representation of key environmental settings. The sampling strategy is similar to the bed sediment study, but the analytes evaluated are of a more limited scope, based upon the fixed sites results. If results from the occurrence survey display low contaminant concentrations and little variance, a spatial distribution study is not likely to provide additional useful data.

11.7 *Relation of Monitoring Protocol to Land Use Planning*

Results from this water quality monitoring plan are intended to serve two primary purposes: assess and track the general health of the watersheds in the City of Santa Barbara and provide insight into pollutant sources. General water quality information is useful to planning purposes by understanding how the pressures of urbanization are impacting watersheds over time. Results from the indicator site monitoring and/or statistical analyses could prove valuable in guiding planning decisions specifically related to land use. If different land uses demonstrate detectable differences in their contribution to pollutant loads, steps may be taken to reduce those impacts by managing land use or zoning patterns. This could include setting limits on certain land uses in a sub-watershed and/or requiring best management practices when new developments are approved.

For rough estimates of changes in pollutant loads and runoff amounts due to a proposed change in land use, it is recommended to utilize the University of Purdue's Long Term Hydrologic Impact Assessment (L-THIA) model. In the model, state and county information is entered followed by the various land use designations, dominant soil class within each land use, and surface area in the drainage. The original condition is first input, and then three scenarios are available to assess the change in area of the land uses provided. The model then utilizes its pre-programmed database to provide the meteorological data needed to estimate runoff and pollutant loading.

L-THIA is most appropriate for substantial land use changes over large areas, as there are many estimated variables in its calculations. The model does not incorporate topography and evaporation to compute runoff, both of which can have significant impacts on overland flow. The model also does not incorporate point sources. However, to understand the general trends associated with a change in land use, the L-THIA model may prove useful. Please see the following website for more information on L-THIA: http://www.ecn.purdue.edu/runoff/Index.html.

11.8 *Modeling*

The implemented SWAT model may provide predictive capacity for flow and pollutant loading scenarios and assist the city in the development of TMDLs in the future. Even though the calculation of TMDLs are not yet the focus of city creeks programs, TMDLs will continue to gain attention as the state begins to require action. The SWAT model developed for the Arroyo Burro watershed, therefore, should be adapted to the other watersheds in the city and serve as an essential tool for developing TMDLs. Although the SWAT model has been designed for big watersheds, the implementation of this model for Arroyo Burro has served to demonstrate that SWAT can successfully be adapted to small watersheds through a predefined delineation and careful calibration.

Due to both limited time and sample data availability to work on the calibration process, the results obtained from the SWAT model are not yet the best that could be generated to accurately predict flow and pollutant patterns. However, we expect that with a hydraulic calibration which can appropriately simulate baseflow, accurate fertilizer and pesticide application rates, and more sampling data for calibration, the model will predict loading scenarios closer to reality. The use of the most accurate land-use, soil, and topographic maps as well as weather, streamflow and water quality data will be critical for achieving more accurate results and increasing the usefulness of this predictive model in the future. When fully implemented and calibrated, the model has the potential to take a given scenario of precipitation amount and duration and generate a prediction of the concentration and spatial pattern of pollutants throughout the watershed. For example, the model might achieve the capacity to predict which creek outlets (or even beach reaches) will have a bacteria count above recreational contact standards for any given amount of rainfall.

If the city decides to further expand upon the model by inputting observed data collected by this monitoring protocol, it may be desirable to compare obtained results to larger projects (Table 11-1). The land use classifications utilized by this EPA-funded study conducted by the Terrene Institute differ somewhat from those of the Anderson scheme, but the data can be useful to examine how inputs from Santa Barbara relate to national averages.

Table 11-1- Typical Loadings from Runoff by Urban Land Use (lbs/acre-yr)

Land Use	TSS	TP	TKN	NH_3-N	NO_2+NO_3-N	BOD	COD	Pb	Zn	Cu
Commercial	1000	1.5	6.7	1.9	3.1	62	420	2.7	2.1	0.4
Parking Lot	400	0.7	5.1	2	2.9	47	270	0.8	0.8	0.04
HDR	420	1	4.2	0.8	2	27	170	0.8	0.7	0.03
MDR	190	0.5	2.5	0.5	1.4	13	72	0.2	0.2	0.14
LDR	10	0.04	0.03	0.02	0.1	NA	NA	0.01	0.04	0.01
Freeway	880	0.9	7.9	1.5	4.2	NA	NA	4.5	2.1	0.37
Industrial	860	1.3	3.8	0.2	1.3	NA	NA	2.4	7.3	0.5
Park	3	0.03	1.5	NA	0.3	NA	2	0	NA	NA
Construction	6000	80	NA	NA	NA	NA	NA	NA	NA	NA

HDR: High Density Residential, MDR: Medium Density Residential, LDR: Low Density Residential
NA: Not available; insufficient data to characterize loadings
Source: Horner et al, 1994

11.9 *Quality Assurance and Quality Control Plan*

A preliminary Quality Assurance Project Plan (QAPP) has been prepared in conjunction with the proposed monitoring plan. The QAPP outlines specific measures necessary for proper data collection and analysis. Upon finalizing details of protocol implementation, it is strongly recommended that the Creeks Division complete this document. The QAPP has been designed in accordance with the SWRCB's Surface Water Ambient Monitoring Program (SWAMP) requirements. The purpose of SWAMP is to provide consistent and objective monitoring, sampling, and analytical methods. Therefore, the Creeks Division would be able to cite use of procedures that are in accordance with regulatory agency guidelines, which provides greater defensibility of data collected. In addition, the adoption of written quality assurance practices promotes proper handling procedures by personnel and ensures that data collected is evaluated for applicable QA/QC requirements, such as duplicate samples and comparison of results to blank and standard samples. The draft QAPP is included with this report as Appendix B.

11.10 *Data Management*

The proliferation of water quality data has spurred a desire to standardize datasets to facilitate comparison across regions and time. It is recommended to utilize the data management templates in Appendix F for data entry of results from the proposed monitoring plan. These templates are compatible with the EPA's STORET (STOrage and RETrieval system) database and the RWQCB database. The advantage of using this data management system is ease of data submission to regulatory agencies if requested, and a standardized, comparable format for data entry. It also allows the Creeks Division to compare data with other water quality monitoring programs.

11.11 *GIS Database*

We recommend a strong commitment to using database formats for all data entry and storage (i.e. building on the provided excel-type spreadsheets). Assuming the city continues to utilize ESRI GIS software, the ESRI Spatial Database Engine (SDE) provides a live link to information in a database in a manner that is not possible with information in spreadsheets. The advantage of this is that sample results, creek flow, sampling dates and other tabulated information can be tied to a point on a digital map and displayed visually with a mouse click, as opposed to looking at a map on the one hand and a spreadsheet on the other. Standardized report diagrams can be created monthly, quarterly, or annually which automatically retrieve the most current sampling results from the database and display them on a map or figure. In this type of GIS-enabled database, the map is a live link so that as new data is entered in the database, or old data corrected, the maps are automatically updated as well. The GIS/ database format will enable city water quality managers to visually compare sample results with patterns of land use, impermeability, wastewater/sewer infrastructure network, and other geographic information.

Databases are more easily queried for specific information than spreadsheets or hard copy reports. For instance, with a GIS-linked database, if a water quality manager is presented with an unusually high sample result for a chemical, they can in a few minutes form a query which instructs the GIS to find and display on a map all instances in which that chemical has been found above a threshold level during the same time of year, in any of the city's past sampling. Performing the same task by scrolling through spreadsheets or hard copy reports would take hours to days. Another advantage of storing data in a GIS-enabled database is that if the city wishes to make some or all of the water quality information stored in the database accessible to the public, ESRI's ArcIMS extension enables the publishing of database-linked maps to a web page with selectable layers.

11.12 *Implementation Timeline*

Ideal implementation of the protocol, sampling technologies, and preparation for storm-event sampling would be previous to the first storms of next season. This would include the autosamplers, indicator sites for bacteria and nitrate, integrator sites for all recommended constituents, and linkage of every test to a land-use and permeability index for the corresponding drainage. These first recommendations could be examined by staff and brought to the Creeks Advisory Committee for discussion, vetting, and approval in the summer of 2005. Since deliberations are already underway for the FY 2005-2006 and FY 2006-2007 budget, a budget amendment would have to be submitted to the Creeks Committee and City Council this summer. Purchase and installation of autosamplers, as well as dissemination of protocol throughout those staff implementing it, should be done by the beginning of the fall 2005. Indicator sampling should last for two years, unless an additional constituent of concern is found in the watershed, in which case that constituent should also be tested for a full two years.

Those recommendations that require the acquisition of new staff or skills, including use of a GIS technician and performance of a statistical analysis, might take longer to implement. However, by the end of the 2005-2006 storms, if the protocol is implemented, there will be a wealth of additional testing data that could be used to calibrate the SWAT model and to perform a statistical analysis on permeability and land-use. Therefore it would be advisable to have the staff person to address this analytic need by that time.

12 Further Research Needs

12.1 *Best Management Practices*

The primary goal for implementing a water quality monitoring program is to identify and map potentially problematic constituents. If present, the next logical step is to make efforts to either reduce the constituent inputs by controlling the source, or implement Best Management Practices (BMPs) from the most problematic areas to treat runoff water prior to its entry into receiving waters. The second option may be the only alternative if sources can not be located. Throughout the country structural BMPs are used to help effectively control pollutant inputs into urban receiving waters. Indeed, Santa Barbara has implemented a number of structural BMPs to help reduces bacteria inputs - the bioswale at Bohnett Park is an example.

Different pollutants require different BMPs to effectively reduce constituent concentrations. Once the city has gathered enough monitoring data to reliably ascertain if there are pollutants, in addition to bacteria, that present a problem it will likely desire to install structural BMPs to help control them. Indicator sampling may help to identify the land uses or other regional areas which should be the highest priority for BMP installation. To ensure the appropriateness of a specific structural BMP further research is needed depending on the given situation. However, a fairly extensive preliminary research effort focused on the applicability and relative cost of BMP classes has been performed. This research is presented in Appendix E.

12.2 *Statistical Analyses – Land Use, Permeability, Flow*

The utility of recording each drainage or sub-basin's permeability is thus far only anecdotal, but if each sampling result was linked to this permeability index, it would be possible to perform a statistical analysis that could determine to what degree permeability relates to pollutant outputs. If the City has access to standard statistical computer applications, S-Plus or SPSS for instance, and a couple hundred samples of a single pollutant or indicator with corresponding permeability percentage, than the process is quite simple. Once the two columns of data are inputted, a hypothesis is proposed that forms the basis of a regression plot. From the "P" and "T" values of the relationship, or visually seeing how well the plots correspond to the fitted line, it can be determined if the relationship between permeability and pollutants is statistically significant.

Additionally, the calculation outputs a co-efficient that can be used to predict pollutant values based on changes in permeability.

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Appendix A:
Abbreviated Reference Sampling Protocol

1. INTRODUCTION

This appendix is designed to provide the sampler with an abbreviated summary of the procedures required to execute this monitoring plan. Contained herein is:

1. The list of constituents to be collected along with the materials and handling methodologies required for proper sampling.
2. The list of sample collection locations along with an aerial photograph reference map with a reference grid system.
3. Sampling frequency for integrator sites, and preferable conditions for sampling storm events.

2. CONSTITUENTS

As presented in the complete text contained in the monitoring plan section, a number of constituents and water quality parameters are designated for sampling. Collection vessels and handling techniques vary by constituent. A table is provided summarizing these (Table A-1). Failure to ensure that samples are collected and handled by their prescribed methodologies can result in inaccurate data.

Table A-1 – Constituent list and handling procedures

13 Parameter	Sample Type	Recommended Containers	Typical Sample Volume	Initial Field Preservation	Maximum Holding Time
Total Zinc Total Copper Total Lead	Integrator	60 mL plastic or glass bottle (for each)	60 mL (for each)	Cool to 4^0 C, dark; Acidify in lab within 48 hours with 2 mL ultra-pure HNO_3 to pH <2	Once acidified, samples can be stored up to 6 months at room temperature
Total Suspended Solids	Integrator	500 mL amber glass jar	1000 mL (two jars)	Cool to 4^0 C, dark	7 days at 4^0 C, dark
Hardness as $CaCO_3$	Integrator	200 mL polyethylene or glass bottle	200 mL	Cool to 4^0 C, dark	48 hours at 4^0 C, dark
Biological Oxygen Demand (BOD)	Integrator	1-L polyethylene bottle	2000 mL (two bottles)	Cool to 4^0 C, dark	48 hours at 4^0 C, dark
Nitrate (NO_3) Nitrogen	Integrator & Indicator	250 mL Polyethylene bottle	150 mL	Cool to 4^0 C, dark	48 hours at 4^0 C, dark
Ammonia (NH_3)	Integrator & Indicator	500 mL Polyethylene bottle	500 mL	Cool to 4^0 C, dark	48 hours at 4^0 C, dark If acidified, 28 days at 4^0 C
Total Kjedahl Nitrogen (TKN)	Integrator & Indicator	1-L Polyethylene bottle	600 mL	Cool to 4^0 C, dark	Recommended: 7 days Maximum: 28 days Both at 4^0 C, dark
Ortho-phosphate	Integrator & Indicator	250 mL Polyethylene bottle	150 mL	Cool to 4^0 C, dark	48 hours at 4^0 C, dark
Total coliforms Fecal coliforms	Integrator & Indicator	125 mL sterile plastic (high density polyethylene or polypropylene) container	100 mL (sufficient for both total and fecal)	Sodium thiosulfate is pre-added to the containers in the lab or by the manufacturer. Cool to 4^0 C, dark	6 hours at 4^0 C, dark (if data is for regulatory purposes) 24 hrs at 4^0 C, dark (if non-regulatory purpose)
Enterococcus	Integrator & Indicator	125 mL sterile plastic (high density polyethylene or polypropylene) container	100 mL (sufficient for both total and fecal)	Sodium thiosulfate is pre-added to the containers in the lab or by the manufacturer. Cool to 4^0 C, dark	6 hours at 4^0 C, dark (if data is for regulatory purposes) 24 hrs at 4^0 C, dark (if non-regulatory purpose)
Volatile Organic Compounds (VOCs)	Integrator	40 mL VOA vials	120 mL (3 VOA vials)	All vials are pre-acidified (50% HCl or H_2SO_4) at lab before sampling. Cool to 4^0 C, dark	14 days at 4^0 C, dark
Chlorinated Pesticides Organophosphorous Pesticides	Integrator	1-L amber glass bottle with Teflon lid liner	1000 mL (for each sample type)	Cool to 4^0 C, dark	Keep at 4^0 C, dark, up to 7 days. Extraction must be performed within 7 days; analysis must be conducted within 40 days
Surfactants (MBAS)	Integrator	500 mL polyethylene bottle	500 mL	Cool to 4^0 C, dark	48 hours at 4^0 C, dark

3. SAMPLING LOCATIONS

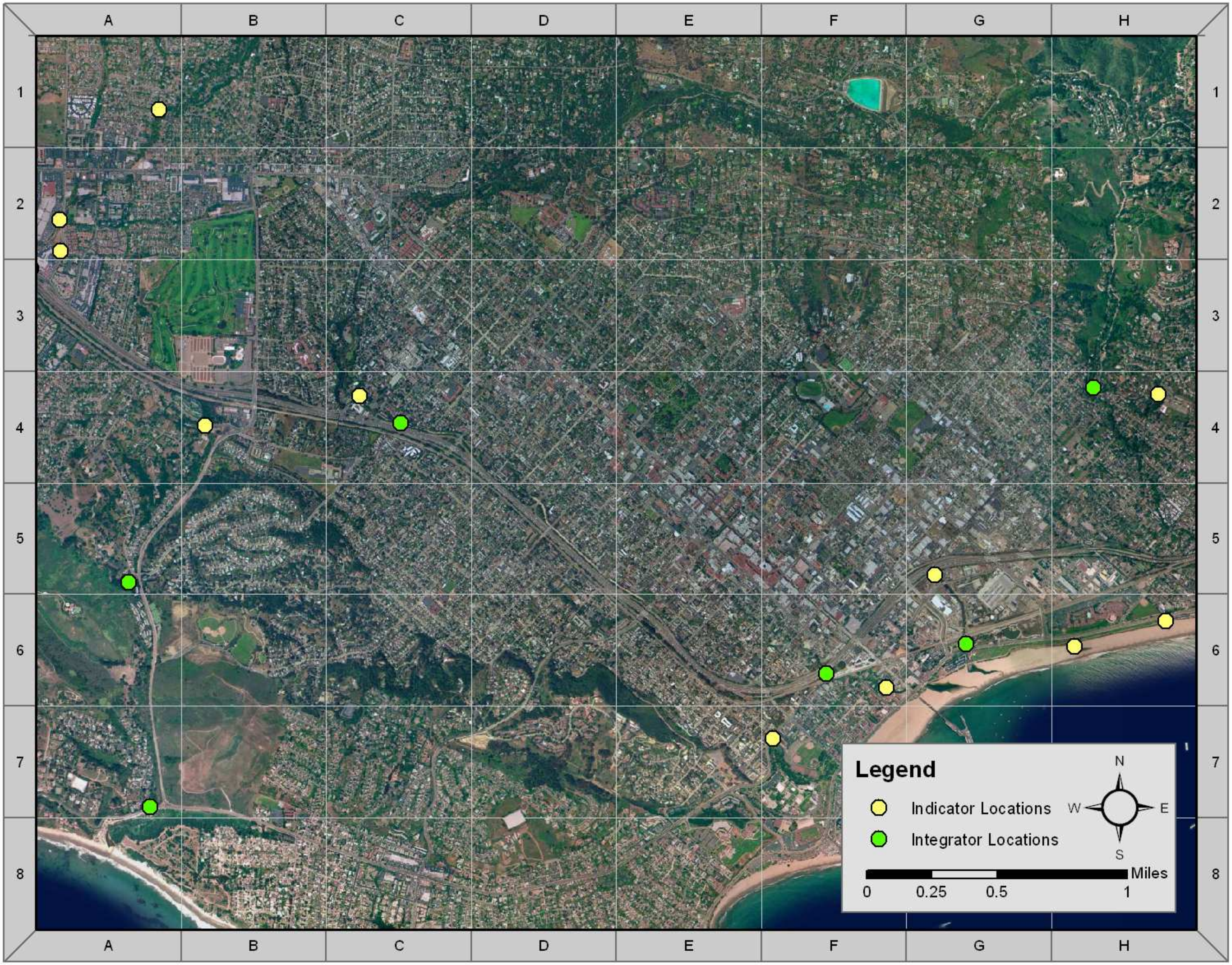
The following is a summary of integrator and indicator locations including the name and grid coordinate location of each sampling location. its grid coordinates on reference maps.

Indicator Sampling Sites

Mission Creek at Mason Street Bridge – F6
Arroyo Burro Creek at La Cumbre Plaza Outflow – A2
Arroyo Burro Creek at Calle Real – A2
Westside Drainage Channel at Pershing Park – F6
Milpas Storm Drain Outfall – H6
Arroyo Burro Creek at Hope Avenue – A2
Mission Creek at Junipero Street (Storm Drain) – C4
Sycamore Creek Tributary Channel at Cleveland Elementary School – H4
San Roque Creek at Ontare Road (Storm Drain) – A1
Laguna Channel at Highway 101 – F6
Storm Drain Outflow at the Fess Parker Doubletree Hotel – G6
Las Positas Creek at Modoc Road – B4
Sycamore Creek Before Confluence (not shown on map below) – N1

Integrator Sampling Sites

Arroyo Burro Creek at Cliff Drive – A7
Arroyo Burro Creek Confluence with Las Positas Creek – 5A
Mission Creek at Montecito Street – 4H
Sycamore Creek above Salinas Roundabout – H4
Mission Creek at Los Olivos Street – C4
Sycamore Creek at Highway 101 – F6
Laguna Channel at Chase Palm Park – G6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Indicator Locations
Integrator Locations
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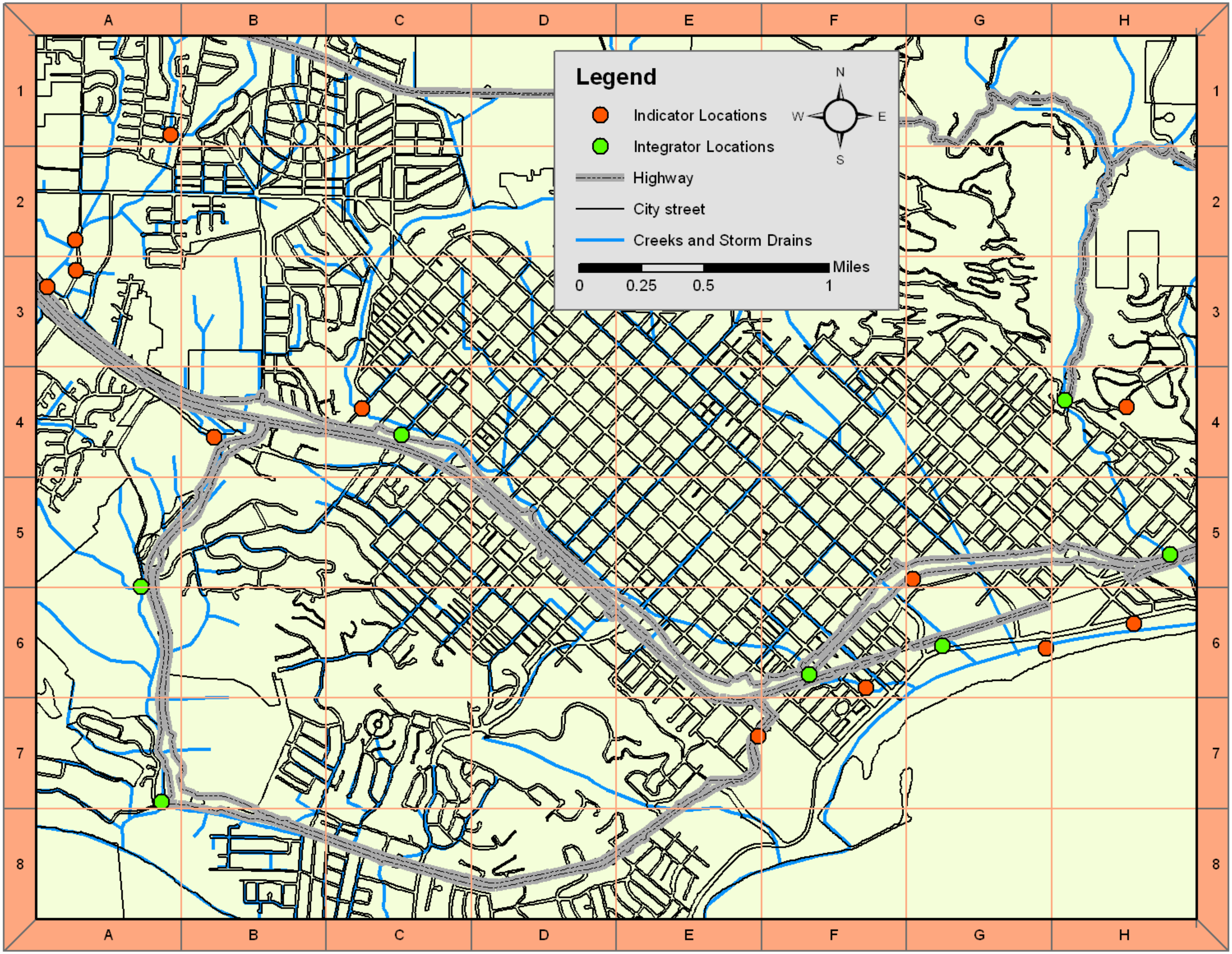
1
Miles



Legend
Indicator Locations
Integrator Locations
Highway
City street
Creeks and Storm Drains
Miles
0
0.25
0.5
1
N
S
E
W
A
B
C
D
E
F
G
H
1
2
3
4
5
6
7
8

4. SAMPLING FREQUENCY

Indicators Site

Indicator locations are to be sampled during two different storm events. Ideally sample collection should commence immediately after 0.1 inches of rain has fallen. Utilize a realizable precipitation gauge for this measurement.

Integrator Site

Integrator locations are to be sampled quarterly. A standardized schedule should be implemented and followed precisely to ensure the consistency of the temporal characteristic of collected data. Future data analysis incorporating temporal progression of will be more accurate if the schedule is adhered to.

Appendix B:
Quality Assurance Project Plan (QAPP) for Environmental Monitoring and Assessment Santa Barbara Creeks Division

ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM MANAGEMENT APPROVALS:

PROJECT LEADER

____ DATE ______________

PROJECT MANAGERS

____ DATE ______________

____ DATE ______________

QA OFFICER

____ DATE ______________

Distribution List
[To be completed by Creeks Division]

A. PROJECT DEFINITION

1. BACKGROUND

The purpose of this document is to provide a quality assurance project plan (QAPP) for the City of Santa Barbara's water quality monitoring program for Arroyo Burro, Mission, and Sycamore Creeks, as well as Laguna Channel. Previous monitoring efforts have indicated problematic levels of bacteria in these water bodies, however little data exists on other constituents and sources of contamination.

Implementation of this monitoring protocol is intended to guide the policy formulation and selection process. The choice of appropriate policies and/or Best Management Practices (BMPs) based on the data generated by this protocol is meant to improve water quality conditions in Santa Barbara's creeks. It is also hoped that water quality improvements will also provide benefits to coastal receiving waters and beach water quality.

In the mid 1990's, El Niño storms generated large amounts of surface runoff and creek flow in Southern California. The impacts of this runoff were experienced at many of the beaches in Santa Barbara and the region, mainly due to bacterial contamination. In order to examine the problem further, funding for research and pollution control, as well as a sufficiently coordinated and comprehensive sampling approach, was needed. The funding was secured in the Fall of 2000 with the passage of Measure B. Measure B implemented a 2% increase in bed tax (transient occupancy tax – TOT) with revenue dedicated to the newly formed Creeks Restoration and Water Quality Improvement Division. The mission of the Creeks Program is "to improve creek and ocean water quality and restore natural creek systems with the implementation of storm water and urban runoff pollution reduction, creek restoration and community education programs". The program has been sampling regularly since its inception, but this protocol represents the first attempt by the Creeks Division to characterize pollutants other than bacteria and examine the links between land use and pollutant concentrations.

The City of Santa Barbara is located in the boundaries of the Central Coast Regional Water Quality Control Board. Therefore, the water resources of the region are guided by the Basin Plan. The plan lists beneficial uses for waters contained in the region and specifies the water quality objectives that must be met for each particular beneficial use. The Basin Plan also outlines implementation procedures and monitoring programs administered by the region and state.

2. PROJECT DESCRIPTION

This sampling protocol entails sampling at integrator locations on a quarterly basis to determine baseline watershed conditions. It also recommends sampling both integrator and indicator sites during at least two storm events. Details regarding sample locations and frequencies are in the report entitled "A Water Quality Monitoring Plan for Santa Barbara's Urban Creeks". The primary goal of this monitoring regime is to characterize the health of the watershed and understand the dynamics of pollutant sources and their transport throughout the watershed.

3. ORGANIZATION

The City of Santa Barbara Creeks Restoration Division will administer organization of the monitoring program. Should the city decide to implement this QAPP, it will need to provide further details on how the program will be structured and managed.

3.1 TRAINING
It is the responsibility of the Creeks Division to arrange for proper training and/or certifications by those participating in this water quality monitoring program.

4. DATA QUALITY OBJECTIVES (DQOs)

Data quality objectives (DQOs) address the degree of precision desired for parameters examined in the protocol. The DQOs for this program are consistent which those presented in the *Quality Assurance Management Plan for the State of California's Surface Water Ambient Monitoring Program* (Puckett, 2002). Specifically, Appendix C of Puckett 2002 outlines data acceptability criteria, target reporting limits, and sampling handling requirements. The DQOs for measurements included in the protocol, expressed in terms of accuracy, precision, and completeness goals, are presented in Tables B-1 and B-2. These DQOs were established by empirically by laboratory and field technicians and are obtained from the National Environmental Methods Index (www.nemi.gov). Accuracy (bias) goals are expressed either as absolute difference (+/- value) or percent deviation from the "true" value. Precision goals are measured as relative percent difference (RPD) or relative standard deviation (RSD) between two or more replicate measurements. The recovery (designated Rec in Table B-2) is the amount of the analyte that is detected in the analysis of a standard sample of a known concentration. The completeness goal is the percentage of expected results that are obtained successfully and has been set at 80% to allow for occasions when not all sites have sufficient flow for sampling purposes, samples are handled improperly, and/or laboratory results are suspect.

Representation is addressed with the inclusion of integrator sites. These sites are chosen to characterize water quality conditions of streams in heterogeneous drainage basins. The inclusion of sites that are designed to address the various impacts present in the watershed assists in the minimization of variability within the watershed.

Table B-1 - DQO's for Field Parameters

Parameter	Method	Units	Detection Limit	Precision	Accuracy	Complete-ness
Temperature	Thermometer	^oC	-5	± 0.5 ^{O} C	±0.5 ^{O} C	80%
pH	pH meter	pH units	2.0	± 0.5 units	± 0.5 units	80%
Dissolved Oxygen	DO probe	mg/L	0.5	± 0.5 units	± 0.5 units	80%
Conductivity	Conductivity probe	µS/cm	10	±10%	±10%	80%
Turbidity	Turbidimeter	NTUs	5	±5 NTUs	NA	80%

Table B-2 - DQO's for Laboratory Analyses

Parameter	Method	Units	Detection Limit	Precision	Accuracy	Complete-ness
Zinc	EPA 200.8	µg/ L	1.8	22 RSD	104% Rec	80%
Copper	EPA 200.8	µg/ L	0.36	1 RSD	87% Rec	80%
Lead	EPA 200.8	µg/ L	0.6	41 RSD	100% Rec	80%
Total Suspended Sediment	EPA 160.2	mg/ L	4	6 RSD	91% Rec	80%
Hardness as $CaCO_3$	EPA 130.2	mg/ L	0	5 RSD	100% Rec	80%
Biological Oxygen Demand (BOD)	SM5210B	mg/L	2	NA	NA	80%
Nitrate (NO_3) Nitrogen	EPA 300.0	mg/ L	0.002	2 RSD	103% Rec	80%
Ammonia (NH_3)	EPA 350.3	mg/L	0.03	12 RSD	102% Rec	80%
Total Kjedahl Nitrogen (TKN)	EPA 351.4	mg/L	0.03	32 RSD	108% Rec	80%
Orthophosphate as Phosphorous	EPA 300.0	mg/L	0.003	2 RSD	99% Rec	80%
Total coliforms	Colilert 24 hour	MPN/ 100 mL	10	Duplicates within 95% confidence limits	Positive standard within ½ of an order of magnitude	80%
E. Coli (Fecal coliforms)	Colilert 24 hour	MPN/ 100 mL	10	Duplicates within 95% confidence limits	Positive standard within ½ of an order of magnitude	80%
Enterococcus	Enterolert 24 hour	MPN/ 100 mL	10	Duplicates within	Positive standard	80%

Parameter	Method	Units	Detection Limit	Precision	Accuracy	Complete-ness
				95% confidence limits	within ½ of an order of magnitude	
Volatile Organic Compounds (VOCs)	EPA 8260	μg/ L	Varies – consult method			80%
Chlorinated Pesticides	EPA 8081B	μg/ L	Varies – consult method			80%
Organophosphorous Pesticides	EPA 8141B	μg/ L	Varies – consult method			80%
Polycyclic Aromatic Hydrocarbons (PAHs)	EPA 610	μg/ L	Varies – consult method			80%
Surfactants (MBAS)	EPA 425.1	mg/L	0.025	15 RSD	89% Rec	80%

5. DOCUMENTATION AND RECORDS

In general, documentation and recordkeeping for this monitoring protocol follow the guidelines established in the *Quality Assurance Management Plan for the State of California's Surface Water Ambient Monitoring Program* (Puckett, 2002) and the *National Field Manual for the Collection of Water Quality Data* (USGS, 2000). Data will be entered into the excel spreadsheets that follow the Central Coast's Regional Water Quality Control Board's template. This provides a standardized format for the city's data that is also compatible with the SWAMP and STORET systems. All data will also be coded for date of data collection and data collector. Examples of data sheet templates to be used are given in Appendix F. All raw data from completed field data sheets will be transcribed into the computer database maintained by the city for each sample site within a reasonable time following data collection (target period one week). It is preferable that one person be responsible for all data entry. It is recommended that a supervisor check the accuracy and completeness of data entry from field sheets to the database. Electronic documents may also be printed and stored in a binder to retain hard copies of results.

Original data sheets and duplicates of all electronic data files can be archived by state and federal agencies. All electronic data files that have passed initial review by data collectors can be transferred to the local RWQCB for validation and for formatting review prior to being transmitted to their centralized database and the EPA STORET database.

B. MEASUREMENT/DATA ACQUISITION

1. SAMPLING PROCESS DESIGN

Sampling process design is discussed in detail in Sections 5.4 and 5.5. This protocol has been based upon the USGS National Water-Quality Assessment program, commonly referred to as NAWQA. The basic framework of the NAWQA design was scaled down to the smaller size of the Santa Barbara watersheds and augmented with a detailed study of land use and constituent occurrence in the region. All of the information to be collected by this protocol is meant to serve the overall purpose of guiding the Creeks Division in formulating sound watershed management decisions.

Site inaccessibility poses different challenges based upon whether the site is an integrator or indicator location. Integrator locations may be sampled at the nearest upstream site that can safely be accessed, if the new location does not exceed 100 yards of the original site. If possible, it may also be feasible to sample the site from an overpass or bridge using specialized equipment to lower sample vessels into the stream flow. Otherwise, the site may not be included for that sampling event. Indicator sites that can no longer be reached safely by field personnel also must be eliminated for the sampling event, as the sampling sites have been chosen specifically for their drainage outlets.

One of the greatest sources of natural variability for this protocol is the sporadic nature of precipitation events. Comparison of results from a wet year as opposed to a dry year may lead to inaccurate conclusions. This can be minimized with the collection of hydrologic data and continuation of sampling events over several years to allow for some reflection of inter-annual variability.

2. SAMPLING METHODS

2.1 FIELD COLLECTION OF ENVIRONMENTAL DATA

Standard operating procedures (SOPs) for all field methods follow those established in the *National Field Manual for the Collection of Water Quality Data* (USGS, 2000) and in Appendix E of the *Quality Assurance Management Plan for the State of California's Surface Water Ambient Monitoring Program* (Puckett, 2002). Field personnel must bring field data sheets on each sampling event and transfer the results into the database upon return to the laboratory.

2.2 COLLECTION OF WATER QUALITY CONTROL SAMPLES

The procedures outlining the collection of quality control samples, sampling design, and data management of QC samples are provided in the *Quality-Control Design for Surface-Water Sampling in the National Water-Quality Assessment Program* (Mueller et. al, 1997). The collection frequencies are summarized in Table B-3.

Table B-3 - Quality Control Sample Frequencies

[--, no samples required]

Constituent or group	Number of quality-control samples per total number of environmental samples (at all surface-water sites, each year)			
	Field blanks	Trip blanks	Replicate field matrix spikes	Replicates
Major ions	1 per 30[a]	--	--	1 per 20[a]
Nutrients	1 per 20[a]	--	--	1 per 20[a]
Suspended sediment	1 per 30[a]	--	--	With each inorganic or pesticide replicate
Dissolved and suspended organic carbon	1 per 15–20[a, b]	--	--	1 per 15–20[a, b]
Pesticides	1 per 20[a, c]	--	1 set per site	1 per 10[d]
Volatile organic compounds	1 per 10–20[b, c, e]	1 per 20[f]	1 set per site	1 per 10–20[b, c, d]
Trace elements	1 per 10–20[a, b, c]	--	--	1 per 10–20[a, b, c, d]

[a] If a large number of environmental samples are collected in a short period of time, reduce the quality-control sampling frequency to one per month during that period.

[b] If concentrations of interest are low (less than 10 times the detection limit), collect more blanks; if expected concentrations are high, collect more replicates.

[c] Minimum three per year.

[d] If concentrations of all target analytes are expected to be less than detection, collection of replicates should be deferred until conditions are more favorable for detection.

[e] Prepare a canister blank with each field blank.

[f] Minimum two per year. Send with a volatile-organic-compound field blank.

Source — Mueller et. al, 1997

2.3 COLLECTION OF STORM DATA

Samples collected during storm events are also subject to the same requirements as for regularly scheduled field sampling events. However, use of autosamplers provides additional measures to be taken to ensure sample integrity. Manufacturer instructions for maintenance and calibration procedures must be implemented and documented if such equipment will be utilized in the field.

3. SAMPLE HANDLING AND CUSTODY REQUIREMENTS

Sampling handling and custody requirements for this protocol follow those established in Appendix C of the *Quality Assurance Management Plan for the State of California's Surface Water Ambient Monitoring Program* (Puckett, 2002). Sample container, holding times, and preservation guidelines (Table B-4) must be followed at all times. If the holding time is exceeded for a sample, analysis results must be invalidated.

Table B-4 - Sample Handling Requirements

Parameter	Recommended Containers	Typical Sample Volume	Initial Field Preservation	Maximum Holding Time
Total Zinc Total Copper Total Lead	60 mL plastic or glass bottle (for each)	60 mL (for each)	Cool to 4^0 C, dark; Acidify in lab within 48 hours with 2 mL ultra-pure HNO_3 to	Once acidified, samples can be stored up to 6 months at room

Parameter	Recommended Containers	Typical Sample Volume	Initial Field Preservation	Maximum Holding Time
			pH <2	temperature
Total Suspended Solids	500 mL amber glass jar	1000 mL (two jars)	Cool to 4^0 C, dark	7 days at 4^0 C, dark
Hardness as $CaCO_3$	200 mL polyethylene or glass bottle	200 mL	Cool to 4^0 C, dark	48 hours at 4^0 C, dark
Biological Oxygen Demand (BOD)	1-L polyethylene bottle	2000 mL (two bottles)	Cool to 4^0 C, dark	48 hours at 4^0 C, dark
Nitrate (NO_3) Nitrogen	250 mL Polyethylene bottle	150 mL	Cool to 4^0 C, dark	48 hours at 4^0 C, dark
Ammonia (NH_3)	500 mL Polyethylene bottle	500 mL	Cool to 4^0 C, dark	48 hours at 4^0 C, dark If acidified, 28 days at 4^0 C
Total Kjedahl Nitrogen (TKN)	1-L Polyethylene bottle	600 mL	Cool to 4^0 C, dark	Recommended: 7 days Maximum: 28 days Both at 4^0 C, dark
Ortho-phosphate	250 mL Polyethylene bottle	150 mL	Cool to 4^0 C, dark	48 hours at 4^0 C, dark
Total coliforms Fecal coliforms	125 mL sterile plastic (high density polyethylene or polypropylene) container	100 mL (sufficient for both total and fecal)	Sodium thiosulfate is pre-added to the containers in the lab or by the manufacturer. Cool to 4^0 C, dark	6 hours at 4^0 C, dark (if data is for regulatory purposes) 24 hrs at 4^0 C, dark (if non-regulatory purpose)
Enterococcus	125 mL sterile plastic (high density polyethylene or polypropylene) container	100 mL (sufficient for both total and fecal)	Sodium thiosulfate is pre-added to the containers in the lab or by the manufacturer. Cool to 4^0 C, dark	6 hours at 4^0 C, dark (if data is for regulatory purposes) 24 hrs at 4^0 C, dark (if non-regulatory purpose)
Volatile Organic Compounds (VOCs)	40 mL VOA vials	120 mL (3 VOA vials)	All vials are pre-acidified (50% HCl or H_2SO_4) at lab before sampling. Cool to 4^0 C, dark	14 days at 4^0 C, dark
Chlorinated Pesticides Organophosphorous Pesticides	1-L amber glass bottle with Teflon lid liner	1000 mL (for each sample	Cool to 4^0 C, dark	Keep at 4^0 C, dark, up to 7 days. Extraction must be

Parameter	Recommended Containers	Typical Sample Volume	Initial Field Preservation	Maximum Holding Time
		type)		performed within 7 days; analysis must be conducted within 40 days
Surfactants (MBAS)	500 mL polyethylene bottle	500 mL	Cool to 4^0 C, dark	48 hours at 4^0 C, dark

All materials that must be shipped to a contract laboratory must also contain a chain of custody. The person who collected the sample(s) and is preparing for their shipment completes the chain of custody. The person relinquishing the samples must sign the chain of custody before they are shipped, and a copy must be made and kept by the city for record-keeping purposes.

4. ANALYTICAL METHODS, QUALITY CONTROL, INSTRUMENT TESTING AND MAINTENANCE REQUIREMENTS

4.1. Field Measurements and Equipment
To assure quality control in the collection of field data, proper functioning of equipment is essential. Probes, such as those designed to measure pH, dissolved oxygen, or conductivity, must be calibrated according to manufacturer's instruction before each field-sampling event. Maintenance of this equipment must also be completed as per manufacturer's instructions.

4.2. Laboratory Measurements and Equipment
It is not anticipated that staff from the Creeks Division will also perform the laboratory analyses for the constituents included in this protocol. Therefore, it is the responsibility of the Creeks Division to ensure that the contract laboratory utilized is properly certified and following the correct QA/QC measures. The anticipated analytical methods to be employed by the laboratory are given in Table B-2. The project manager is tasked with examining all laboratory results to ensure that the data quality objectives outlined in Tables B1-B3 have been met, as well as confirming that the proper number of duplicate, spiked, and standard samples are present and meet the DQO's. If a problem in the data is identified, the contract lab must be contacted immediately. If the discrepancy cannot be resolved, the data must be invalidated for that particular sample or analyte.

5. DATA MANAGEMENT

Data management begins with the use of field survey sheets and the subsequent entry of this data into a database. The format of the database has been established to comply with the data standardization methods employed by regional, state, and federal agencies. The project manager is tasked with ensuring that data is entered expediently and accurately into the database and is responsible for the submission of results to regulatory agencies, should the city desire to do so. It is recommended that data be kept in both electronic and hard copy formats. Field results, analytical results from contract laboratories, chains of custody, and QA/QC measures should all be maintained both on the city's database and in files located at the project office. Appendix J of the *Quality Assurance Management Plan for the State of California's Surface Water Ambient*

Monitoring Program (Puckett, 2002) outlines data management procedures associated with the SWAMP program.

C. DATA VALIDATION AND REVIEW

Data validation rules for this monitoring protocol are outlined in Section B.4. Data sheets or data files should be reviewed annually to verify that the data collected meets the data quality objectives given in Tables B-1 and B-2. Other items to identify in the data include outliers, questionable results or omissions.

Data that does not comply with the given objectives will be flagged and the source of the error will be investigated. If the source cannot be identified, the result will be removed from the data records. Possible actions attributable to problems with data include equipment failure, calibration/maintenance techniques, or monitoring/sampling techniques. It is the responsibility of the Project Manager to address the source of data problems and suggest corrective action.

REFERENCES

Mueller, D.K, Martin, J.D., and Lopes, T.J., 1997, Quality-Control Design for Surface-Water Sampling in the National Water-Quality Assessment Program. U.S. Geological Survey Open-File Report 97-223.

Puckett, M., 2002, Quality Assurance Management Plan for the State of California's Surface Water Ambient Monitoring Program ("SWAMP"). California Department of Fish and Game, Monterey, CA. Prepared for the State Water Resources Control Board, Sacramento, CA.

U.S. Geological Survey. 2000. National Field Manual for the Collection of Water-Quality Data. U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1-A9.

Appendix C:
Constituent Standards for Volatile Organic Compounds and Polycyclic Aromatic Hydrocarbons

The following tables outline applicable regulatory criteria to constituents analyzed by EPA Methods 8260 and 610. Sampling results should be compared against these threshold values. Title 22 of the California Code of Regulations designates the state of California's numeric criteria and the Basin Plan lists local criteria of the Central Coast RWQCB. The EPA criteria are from the National Ambient Water Quality Criteria recommendations.

Table C-1: EPA 8260 Regulatory Criteria	**MDL**	**Title 22**	**Basin Plan**	**EPA**
Analyte	**µg/L**	**µg/L**	**µg/L**	**µg/L**
1,1,1,2-Tetrachloroethane	0.05			
1,1,1-Trichloroethane	0.08	200	200	
1,1,2,2-Tetrachloroethane	0.04	1	1	
1,1,2-Trichloroethane	0.1	5	32	
1,1-Dichloroethane	0.04	5	5	
1,1-Dichloroethene	0.12	6	6	
1,1-Dichloropropene	0.1			
1,2,3-Trichlorobenzene				
1,2,3-Trichloropropane	0.32			
1,2,4-Trichlorobenzene	0.04	5	5	
1,2,4-Trimethylbenzene	0.13			
1,2-Dibromo-3-chloropropane	0.26		0.2	
1,2-Dibromoethane	0.06			
1,2-Dichlorobenzene	0.03	600	600	2.7
1,2-Dichloroethane	0.06	0.5	0.5	
1,2-Dichloropropane	0.04	5	5	
1,3,5-Trimethylbenzene	0.05			
1,3-Dichlorobenzene	0.12			0.32
1,3-Dichloropropane	0.04			
1,4-Dichlorobenzene	0.03	5	5	0.4
1,4-Dioxane				
1-Chlorohexane	0.05			
2,2-Dichloropropane	0.35			
2-Butanone				
2-Chloroethyl vinyl ether				
2-Chlorotoluene	0.04			
2-Hexanone				
4-Chlorotoluene	0.06			
4-Methyl-2-pentanone				

Table C-1: EPA 8260 Regulatory Criteria	MDL	Title 22	Basin Plan	EPA
Acetone				
Acetonitrile				
Acrolein				0.19
Acrylonitrile				5.10E-05
Allyl chloride				
Benzene	0.04	1	1	0.0022
Benzyl chloride				
Bromobenzene	0.03			
Bromochloromethane	0.04			
Bromodichloromethane	0.08			0.00055
Bromoform	0.12			0.0043
Bromomethane	0.11			
Carbon disulfide				
Carbon tetrachloride	0.21	0.5	0.5	0.00023
Chlorobenzene	0.04			0.68
Chloroethane	0.1			
Chloroform	0.03			0.0057
Chloromethane	0.13			
cis-1,2-Dichloroethene	0.12	6	6	
cis-1,3-Dichloropropene	--			
cis-1,4-Dichloro-2-butene				
Dibromochloromethane	0.05			0.0004
Dibromomethane	0.24			
Dichlorodifluoromethane	0.1			
Ethyl methacrylate				
Ethylbenzene	0.06	300	680	
Hexachlorobutadiene	0.11			0.00044
Iodomethane				
Isopropylbenzene	0.15			
Methacrylonitrile				
Methyl methacrylate				
Methylene chloride	0.03			
m-Xylene	0.05		1750*	
Naphthalene	0.04			
n-Butylbenzene	0.11			

Table C-1: EPA 8260 Regulatory Criteria	MDL	Title 22	Basin Plan	EPA
n-Propylbenzene	0.04			
o-Xylene	0.11		1750*	
Pentachloroethane				
p-Isopropyltoluene	0.12			
Propionitrile				
p-Xylene	0.13		1750*	
sec-Butylbenzene	0.13			
Styrene	0.04	100	100	
tert-Butylbenzene	0.14			
Tetrachloroethene	0.14	5	5	
Toluene	0.11	150	150	
trans-1,2-Dichloroethene	0.06	10	10	
trans-1,3-Dichloropropene				
trans-1,4-Dichloro-2-butene				
Trichloroethene	0.19	5	5	
Trichlorofluoromethane	0.08	150	150	
Vinyl acetate				
Vinyl Chloride	0.17	0.5	0.5	

* Value applies to a single form of xylene or the sum of all forms

Table C-2: EPA 610 Regulatory Criteria	MDL	Title 22	Basin Plan	EPA
Analyte	**µg/L**	**µg/L**	**µg/L**	**µg/L**
Acenaphthene	1.8			0.67
Acenaphthylene	2.3			0
Anthracene	0.66			8.3
Benzo(a)anthracene	0.013			3.80E-06
Benzo(a)pyrene	0.023			3.80E-06
Benzo(b)fluoranthene	0.018			3.80E-06
Benzo(ghi)perylene	0.076			
Benzo(k)fluoranthene	0.017			3.80E-06
Chrysene	0.15			3.80E-06
Dibenzo(a,h)anthracene	0.03			3.80E-06
Fluoranthene	0.21			0.13
Fluorene	0.21			1.1

Table C-2: EPA 610 Regulatory Criteria	**MDL**	**Title 22**	**Basin Plan**	**EPA**
Indeno(1,2,3-cd)pyrene	0.043			
Naphthalene	1.8			
Phenanthrene	0.64			
Pyrene	0.27			

Appendix D:
Case Studies of Similar Urban Creek Monitoring Programs

To gain background information of sampling methods already in place in surrounding Southern California communities, four other surface water monitoring programs were chosen for evaluation and comparison. The programs evaluated are:

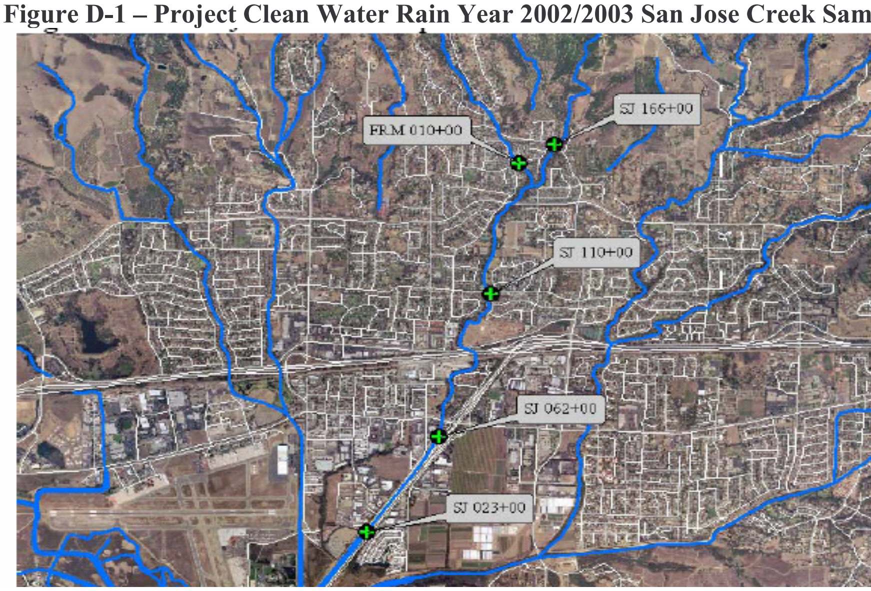
- County of Santa Barbara – Project Clean Water (PCW)
- Los Angeles County – Storm Water Management Program
- Orange County – Drainage Area Management Program (DAMP)
- Central Coast Regional Water Quality Control Board – Central Coast Ambient Monitoring Program (CCAMP)

The results of these programs were compared to results from literature review to comprehensively select constituents that the city would be most likely to encounter in their urban creeks.

<u>County of Santa Barbara: Project Clean Water</u>

The County of Santa Barbara first initiated Project Clean Water (PCW) in 1998 to improve water quality in streams and coastal waters. The PCW program maintains a water quality monitoring program for beaches and stormwater runoff and conducts sampling in creeks during storm events. This program fulfills requirements outlined by Assemby Bill 411 and implemented by the Department of Environmental Health and Services. For the rain year of 2002/2003, PCW focused on the San Jose, Santa Ynez, and Orcutt watersheds. The Santa Ynez and Orcutt watersheds were sampled only during storm flows, while time-series longitudinal sampling (as described below) was conducted at San Jose Creek.

Figure D-1 – Project Clean Water Rain Year 2002/2003 San Jose Creek Sampling Sites



(County of Santa Barbara, 2003)

The data analysis focuses primarily upon the San Jose Creek sampling effort, as this study most closely resembles the objectives of the city's monitoring program. The purpose of the study is the observation of changes in water quality as the watershed becomes more urbanized. The San Jose Creek sampling effort consisted of time-series longitudinal sampling. Grab samples were collected along the creek at specified time intervals at transition points between land uses. Therefore, the data from downstream sites is not entirely indicative of the designated land use, as persistent pollutants introduced further upstream could appear at these sites. The land-use categories employed in this study were industrial (SJ 023), commercial (SJ 062), residential (SJ 110), agricultural (SJ 166), and a mixed residential/agricultural (FRM 010) category. The inclusion of agricultural land use is interesting for comparison purposes, as the watersheds in the city of Santa Barbara do not have large agricultural land use designations. The results from this study show that water quality does not significantly differ at different sites in the stream channel (Table D-1). Sampling occurred from November 2002 to March 2003 and focused on four storm events. During each of the four storm events, each site was sampled three times.

Data Analysis

The following constituents were not detected at any locations or sampling events:

- Pesticides: Demeton and Parathion
- Dissolved Metals: Arsenic, Cadmium, Lead, Mercury, and Nickel
- Nutrients: Nitrite (as Nitrogen) and Phosphate (as Phosphorous)

In contrast, the following were detected at every site and sampling event:

- Nutrients: Nitrate (as Nitrogen NO3-N), Total Phosphorus and Total Kjeldahl Nitrogen (TKN)
- Indicator Bacteria: Total coliform, E. Coli, and Enterococci

There is a discrepancy in the nutrient data, as one form of nitrogen and phosphorous is dominant over another. TKN and total phosphorous may be prevalent over other forms due to impacts from biological systems in the streams. Phosphate may be absent due to rapid uptake by macrophytes, phytoplankton, and periphyton in the creek. TKN represents organic forms of nitrogen (such as amino acids) and ammonia, which may indicate biologic activity. The absence of nitrite indicates an oxygenated environment, and the dissolved oxygen values recorded support this conclusion.

Other observations include:

- Zinc had the most dominant observable difference among land use types, showing up approximately 50% of the time at industrial and commercial sites while less than 15% of the time at agricultural and residential sites.

- Glyphosate was found at all sites and detected over half of the time at all land use classifications except for the mixed agriculture and residential site (FRM 010). Because glyphosate is widely used by the general public, this is not surprising, but does indicate that this product may be impacting the watershed.
- Diazinon was detected over half the time at all sites excluding the agriculture site (SJ 166). It is important to note that this site is upstream of the others and that the transport of diazinon through the watershed may have more impact on its prevalence instead of each site acting as a source. The concentration increases at sites further downstream.
- Hydrocarbons, chromium, copper, and chlorpyrifos were detected infrequently and near the detection limit at all sites.

Data Source: County of Santa Barbara. 2003. Rain Year 2002/2003 Water Quality Analysis Report. Department of Public Works. Santa Barbara, CA.

Orange County: Drainage Area Management Program

The 2003 Drainage Area Management Program (DAMP) administered by Orange County was updated in order to address the regulatory requirements of the NPDES Stormwater Program Third Term Permit. The DAMP methodology utilized the following program elements:

- Mass Emissions Monitoring: Evaluates the total mass emissions of pollutants over time and investigates water quality standard exceedances.
- Estuary/Wetlands Monitoring: Specific monitoring program to evaluate whether urban runoff is impacting beneficial uses of Upper Newport estuary, Talbert Marsh, and Bolsa Chica wetlands.
- Water Column Toxicity Monitoring: Collection of water samples to test for toxicity affects on marine and freshwater organisms.
- Bacteriological/Pathogen: Assessment of total coliform, E. Coli, and Enterococcus levels in coastal waters and six inland locations.
- Bioassessment: Exploration of the usefulness and efficacy of the biological index approach, which evaluates biological communities in the watershed.
- Reconnaissance: Illicit discharge detection program.
- Land Use Correlation: Program to investigate impacts and sediment discharges from agricultural areas in the upper watershed to developed areas further downstream.
- TMDL/303(d) Listed Waterbody Monitoring: San Diego Creek Nutrient TMDL program and monitoring of other 303(d) listed waterbodies.

The County of Orange Environmental Resources Section is currently implementing the Land Use Correlation program. The project is driven by NPDES permit requirements to evaluate the reduction of sediment load from undeveloped/agricultural areas on water bodies of beneficial use. The program is focusing on the creeks and channels in the Newport Watershed that drain into the

Upper Newport Bay. The water column sediment load is currently monitored by at designated stations in the watershed, which may differ from water quality monitoring stations due to program requirements. The desire is to discern the influence of urbanization upstream of the Sediment TMDL stations by assessing the change in pollutants from undeveloped areas to urban areas. There are three assessments at each monitoring station:

- Physical parameters (DO, conductivity, pH, and temperature)
- Q value (hydrologic flow)
- Chemical analysis of water and benthic sediment
    - Water: Nutrients, Orthophosphates, Trace Metals (total and dissolved), and Organophosphate Pesticides
    - Sediment: Total Nitrogen and Total Phosphorus, Trace Metals (Ag, Cd, Cr, Cu, Fe, Ni, Pb, Zn), Total Organic Carbon, and PHP (Pesticides-Herbicides-PCBs)
        - PHP: Organophosphate (Malathion, etc.), OrganoNitrogen (Atrazine, Simazine, etc.), Organochlorine (DDT, HCB, etc.), PCBs

Iron is included in the sediment analysis for normalization of the other metal concentrations. Total Organic Carbon (TOC) is done for sediment samples as empirical data has indicated that excessive loading above 2 standard deviations of the site average indicate input from anthropogenic sources.

Although sufficient results have not yet been collected to make quantitative or qualitative evaluations, some general trends have been noticed regarding physical parameters. As the land use transitions from agricultural to residential, more consistent flow for a greater number of days has been experienced at the downstream station that typically was dry in the past. At the rural to residential transition, the runoff at the upstream site is predominantly natural. Compared to urban runoff, the upstream site exhibits lower dissolved oxygen values (5-9 ppm), very slightly basic pH (~7.2) and relatively high conductivity. The rural site is also showing a significant increase in flow volume as development continues to grow. The Creeks Division may desire to monitor the department's website, www.ocwatersheds.com, for more results as they are made available to the public.

Data Analysis

Data analyzed was obtained at five separate sampling locations from November 2003 to February 2004. This encompassed the mass emissions monitoring for the Laguna, Aliso, San Juan, and San Clemente creek watersheds (Table D-2).

The following observations can be made from the Orange County data:

- Ammonia was the least commonly detected form of nitrogen, while total phosphate and ortho-phosphate were both detected at each location and sampling event.
- Diazinon and malathion were the most frequently detected pesticides.

- Of the metal analytes, lead, cadmium and silver were detected infrequently, copper, nickel and zinc were prevalent, and zinc had the highest mean concentrations.
- The means and detection rates observed did not appear to have any sharp discrepancies among sites for nutrients, pesticides, and metals.

Data Source: County of Orange. 2003. Drainage Area Management Program (DAMP). Watershed & Coastal Resources Division, Public Facilities & Resources Department. Santa Ana, CA.

Los Angeles County: Watershed Monitoring Program

From 1994 to 2000, the Los Angeles County Watershed Monitoring Program examined inputs from 8 distinct land use designations. The purpose of this program is very similar to the city of Santa Barbara's objectives, to identify pollutant sources from specified land use activities. Site selection began with an evaluation of land use categories present in the four watersheds of the county. Next, the top twelve urban uses were selected based on total area. A watershed model was then employed to rank land uses based upon the probability of pollutant loading. The resulting choices encompassed 86% of the possible land use categories identified. The land use designations selected for the study were:

- Vacant: undeveloped areas, predominantly vegetated open space also including abandoned public land.
- Educational Facilities: pre-school, daycare centers, elementary schools, high schools, colleges, universities, and trade schools.
- High Density Single Family Residential: single family residential units at >2 units/acre.
- Light Industrial: manufacturing and assembly, wholesaling and warehousing, motion picture lots, and packing houses and grain elevators.
- Retail/Commercial: shopping malls, strip malls, skyscrapers, golf courses, orchards, vineyards, nurseries, hotels and motels, office buildings, storage facilities, medical health care facilities, religious facilities, and retail stores.
- Transportation: airports, railroads, freeways, major roads, bus terminals, and park and ride lots.
- Multifamily Residential: mixed multifamily duplexes, triplexes, condominiums and apartment buildings.
- Mixed Use: areas where a combination of land uses are occurring together without one designation dominant over another.

Data Analysis

The results from the LA County sampling were analyzed to differentiate among land use classifications (Vacant, Education, High Density Residential, Light Industrial, Retail/Commercial, Transportation, Multi-family Residential, and Mixed Use). Eight land use stations and five mass emissions stations were sampled; each was categorized by percentages of land use type within its drainage area. The sampling results were used to develop event mean concentrations, which estimate the average concentration of a substance over a specified period of time at a particular station.

Los Angeles employed two methods whereby a constituent may be removed from the land use study. The first is if once the objective of obtaining an EMC is reached (with an error rate of <25%). The error rate rule only applies to specific constituents and can use the mean standard error instead of the error rate. The other method is if constituent is detected less than 25% of the time in 10 consecutive samples.

Observations made by County staff include the following:

- Bacteria samples taken at all locations and during dry and weather flows exceeded public health criteria, though wet weather samples yielded densities of three to four orders of magnitude greater than dry weather.
- Bacteria levels from the first storm did not significantly exceed levels in later storms, thereby indicating that bacteria sources are relatively constant.
- Total and dissolved zinc were found at the highest median concentrations in the light industrial, transportation, and retail/commercial land uses. The maximum was in the light industrial category, with a median concentration of approximately 300 μg/L for dissolved zinc and 360 μg/L for total zinc. Values for the remaining land use types were significantly less.
- Total and dissolved copper were detected at the highest median concentrations in the light industrial and transportation categories, the greatest being transportation. Median concentrations in the transportation land use were measured at approximately 28 μg/L for dissolved copper and 40 μg/L for total copper.
- Light industrial land use also had the highest median concentrations of total suspended solids, at approximately 130 mg/L.
- The following parameters were not detected at any sites or sampling events: bentazon, carbofuran, 2,4-D, 2,4,5-TP, chlorpyrifos, PCBs, all other SVOCs, and dissolved thallium, silver, mercury, selenium, hexavalent chromium (chrome 6), beryllium, and arsenic.
- The most ubiquitous metals were total aluminum, barium, boron, copper, and zinc. However, copper and zinc were detected infrequently at the vacant land use designation. The education land use designation exhibited the greatest frequency of metal species overall.
- Most of the metals sampled were not detected at all, and most others were found at low rates. Of the metals sampled, 76% were found infrequently. 53% were not detected at all at any of the land use designations.
- Bis(2-ethylhexyl)phthalate had a detection rate ranging from 44% to 100%. This compound is used in the production of polyvinyl chloride (PVC) and has been classified by the EPA as a probable human carcinogen. Its prevalence in the water samples collected may be due to

industrial inputs and/or corrosion of PVC piping present in the LA county stormwater infrastructure system.

Data Source: Los Angeles County. 2001. 1994-2000 Integrated Receiving Water Impacts Report. Department of Public Works. Los Angeles, CA.

CCAMP: Central Coast Ambient Monitoring Program

The local Regional Water Quality Control Board (RWQCB) oversees California's Central Coast Region, which spans from just north of Big Sur to Santa Barbara. The RWQCB runs the Central Coast Ambient Monitoring Program, which is comprised of a monitoring strategy for watershed characterization. The CCAMP protocol divides the region into five watershed rotation areas and conducts tributary based sampling each year in one of the areas. Over a five year period all of the hydrologic units in the region are monitored and evaluated. In addition to the sites selected for even spatial representation, additional monitoring sites are established in each area to provide focused attention on watersheds and water bodies of special concern. The CCAMP strategy of establishing and maintaining permanent long term monitoring sites provides a framework for trend analysis and detection of emergent water quality problems. CCAMP uses a variety of monitoring approaches to characterize the status and trends of coastal watersheds, including:

- Rapid bioassessment using benthic invertebrates
- Conventional water quality parameter analysis
- Chemical analysis of tissue, water, and sediment
- Toxicity evaluations
- Habitat assessments
- Sedimentation evaluations

1. CCAMP Data Analysis

The data provided by CCAMP provides important background information for this group project because it was collected from the same creeks as those included in this monitoring protocol and also because it provides sediment sampling data. The water column sampling of Arroyo Burro, Mission, and Sycamore Creeks occurred from January 2001 to March 2003 (Table D-4) and the sediment samples were collected in March of 1998 (Table D-5). The data from this study was presented differently from the other studies examined. Maximum, minimum, and mean values were given for each constituent analyzed. Non-detect values were not listed for any constituent, although it is unclear whether non-detect values were not obtained for any constituent in the study or omitted from the calculation of the reported values.

Water Sampling

- Sycamore Creek, the only Santa Barbara creek with agriculture designated as a beneficial use, exceeded the dissolved boron Basin Plan water quality objective for this use. The maximum value reported for dissolved boron at Sycamore was 0.89 mg/L, exceeding the objective concentration of 0.75 mg/L.
- Arroyo Burro, Mission, and Sycamore all exceeded total and fecal coliform objectives set by the Basin Plan. Both maximum and mean values exceeded the standard.
- The total dissolved solids (TDS) standard for agriculture is 1000 mg/L. Sycamore samples documented a maximum value of 1468 mg/L.
- The Basin Plan objectives for dissolved oxygen and pH for cold water fish habitats are >7.0 mg/L and a range from 7.0 to 8.5, respectively. The minimum dissolved oxygen values for both Mission and Sycamore Creeks were much lower than the objective. Mission Creek exceeded the upper pH value slightly for its maximum value.

Sediment Sampling

- None of the samples analyzed from the Santa Barbara creeks exceeded the applicable NOAA guidelines.
- The lowest value detected for any of the constituents was 0.5 μg/kg.
- Of the 46 constituents tested, all were detected in the sediment samples collected. This indicates the sequestration of sorbed chemicals in the sediments, particularly substances that have a high soil affinity, such as metals and organic compounds.

Data Source: Central Coast RWQCB. 1998. 1998 Coastal Confluences Sediment Chemistry Assessment. State of California, State Water Resources Control Board, Central Coast Division. San Luis Obispo, CA.

Table D-1: Project Clean Water Sampling Results		**SJ 023 Industrial**		**SJ 062 Commercial**		**SJ 110 Residential**		**SJ 166 Agricultural**		**FRM 010 Res. / Ag**	
Analyte	Units	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean
Physical Parameters											
pH	pH units	100%	8.16	100%	8.15	100%	8.11	100%	7.96	100%	8.06
Dissolved Oxygen	%	100%	102.8	100%	105.2	100%	103.6	100%	93.3	100%	102.1
Dissolved Oxygen	mg/L	100%	10.50	100%	10.7	100%	10.7	100%	9.67	100%	10.5
Conductivity		100%	461	100%	1039	100%	382	100%	683	100%	409
Temperature	Degree C	100%	14.4	100%	14.4	100%	14.1	100%	13.7	100%	14.1
Bacteria											
Total coliform	MPN	100%	620908	100%	452411	100%	501201	100%	720792	100%	872022
E. coli	MPN	100%	24743	100%	12869	100%	9621	100%	7395	100%	17904
Enterococcus	MPN	100%	40525	100%	42735	100%	31419	100%	26008	100%	38379
Pesticides											
Malathion	µg/L	13%	0.1	13%	1.9	14%	0.1	33%	8.0	33%	0.15
Demeton	µg/L	0%	ND	0%	ND	0%	ND	0%	ND	0%	ND
Glyphosate	µg/L	100%	275	67%	178	56%	40	75%	27	38%	23
Diazinon	µg/L	75%	2.2	88%	0.2	57%	0.21	0%	ND	67%	0.16
Chlorpyrifos	µg/L	0%	ND	0%	ND	13%	0.05	17%	0.06	0%	ND
Parathion	µg/L	0%	ND	0%	ND	0%	ND	0%	ND	0%	ND
Nutrients											
Ammonical Nitrogen	mg/L	78%	2.50	89%	1.56	67%	0.3	63%	0.22	63%	0.3
Nitrite as Nitrogen	mg/L	0%	ND	0%	ND	0%	ND	0%	ND	0%	ND
Nitrate as Nitrogen	mg/L	100%	11.9	10.0%	1.73	100%	2.5	100%	3.4	100%	4.4
Phosphate as Phosphorous	mg/L	0%	ND	0%	ND	0%	ND	0%	ND	0%	ND
Total Kjeldahl Nitrogen	mg/L	100%	27.9	100%	3.52	100%	3.58	100%	4.20	100%	3.65
Total Phosphorous	mg/L	100%	17.7	100%	4.56	100%	4.89	100%	5.27	10.0%	5.00
Metals											
Dissolved Arsenic	µg/L	0%	ND	0%	ND	0%	ND	0%	ND	0%	ND

Table D-1: Project Clean Water Sampling Results		SJ 023 Industrial		SJ 062 Commercial		SJ 110 Residential		SJ 166 Agricultural		FRM 010 Res. / Ag	
Analyte	Units	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean
Dissolved Cadmium	µg/L	0%	ND	0%	ND	0%	ND	0%	ND	0%	ND
Dissolved Chromium	µg/L	33%	0.05	22%	0.02	44%	0.01	38%	0.01	38%	0.013
Dissolved Copper	µg/L	11%	0.01	33%	0.013	11%	0.01	25%	0.015	0%	ND
Dissolved Lead	µg/L	0%	ND	0%	ND	0%	ND	0%	ND	0%	ND
Dissolved Mercury	µg/L	0%	ND	0%	ND	0%	ND	0%	ND	0%	ND
Dissolved Nickel	µg/L	0%	ND	0%	ND	0%	ND	0%	ND	0%	ND
Dissolved Zinc	µg/L	56%	0.1	56%	0.032	11%	0.02	13%	0.02	25%	0.02
Hydrocarbons											
Oil and Grease	mg/L	11%	2.2	22%	1.9	0%	ND	0%	ND	13%	1
Total Recoverable Petroleum Hydrocarbons	mg/L	11%	1.2	11%	1.5	0%	ND	0%	ND	0%	ND

ND = Non-Detect (analyte was not present above the detection limit for this test)

Table D-2: DAMP Storm Sampling Results 2003-2004		San Juan Creek		Trabuco Creek		Prima Deschecha		Aliso Creek		Laguna Canyon	
	Units	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean
Physical Parameters											
Specific Conductance	µS	100%	1568	100%	1362	100%	6010	100%	2229	100%	2161
pH	pH units	100%	8.02	100%	8.22	100%	8.02	100%	7.90	100%	8.22
Temperature	Degree C	100%	13.9	100%	13.8	100%	12.8	100%	13.3	100%	11.0
Dissolved Oxygen	mg/L	100%	11.7	100%	13.9	100%	11.5	100%	12.0	100%	15.2
Turbidity	NTU	100%	54.0	100%	178	100%	55.9	100%	48.1	100%	127
Total Suspended Solids	mg/L	92%	151	82%	812	91%	142	67%	137	57%	671
Volatile Suspended Solids	mg/L	58%	52	55%	94	36%	43	44%	35	29%	125
Hardness as CaCO3	mg/L	100%	549	100%	446	100%	1387	100%	665	100%	341
Nutrients											
Nitrate as NO3	mg/L	91%	4.87	100%	4.21	100%	14.8	100%	7.19	100%	2.52
Ammonia as N	mg/L	55%	0.258	54%	0.306	83%	0.487	89%	0.229	0%	ND
Total Kjehdahl Nitrogen	mg/L	91%	2.21	100%	1.72	100%	2.59	100%	1.96	100%	1.16
Total Phosphate as P	mg/L	100%	1.31	100%	1.51	100%	1.17	100%	1.76	100%	1.40
Ortho-Phosphate as P	mg/L	100%	0.220	100%	0.118	100%	0.172	100%	0.325	100%	0.208
Pesticides											
Diazinon	µg/L	69%	113	92%	185	92%	245	90%	136	63%	76.5
Chlorpyrifos	µg/L	0%	ND	0%	ND	0%	204	0%	ND	0%	ND
Dimethoate	µg/L	8%	161	0%	ND	0%	ND	0%	ND	0%	ND
Malathion	µg/L	23%	615	46%	249	67%	921	80%	212	13%	16.6
Metals											
Total Cadmium	µg/L	23%	3.0	38%	2.02	100%	10	100%	6.9	0%	ND
Dissolved Cadmium	µg/L	0%	ND	0%	ND	0%	9.7	20%	1.3	0%	ND
Total Chromium	µg/L	15%	21	38%	15	17%	17	30%	12	13%	76
Dissolved Chromium	µg/L	0%	ND	0%	ND	0%	ND	0%	ND	0%	ND

Table D-2: DAMP Storm Sampling Results 2003-2004		San Juan Creek		Trabuco Creek		Prima Deschecha		Aliso Creek		Laguna Canyon	
	Units	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean
Total Copper	µg/L	100%	45	100%	20	100%	18	100%	18	100%	24
Dissolved Copper	µg/L	92%	6.2	100%	5.8	100%	9.1	100%	7.5	100%	19
Total Lead	µg/L	38%	11	54%	9.3	33%	5.1	60%	4.9	38%	12
Dissolved Lead	µg/L	0%	ND	0%	ND	0%	ND	0%	ND	13%	3.7
Total Nickel	µg/L	54%	17	100%	13	100%	81	100%	40	63%	18
Dissolved Nickel	µg/L	46%	8.3	92%	5.9	100%	73	100%	25	25%	4.9
Total Silver	µg/L	8%	2.6	8%	2.0	8%	3.6	0%	ND	0%	ND
Dissolved Silver	µg/L	0%	ND	0%	ND	0%	ND	0%	ND	0%	ND
Total Zinc	µg/L	69%	109	69%	96	100%	100	100%	89	88%	68
Dissolved Zinc	µg/L	54%	30	62%	53	100%	69	100%	39	75%	60

Table D-3: LA County Sampling Results		Vacant		Education		High Density Residential		Light Industrial		Retail/ Commercial		Transportation		Multi-family Residential		Mixed Use	
	Units	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean
Physical Parameters																	
Alkalinity	mg/L	100%	169	100%	52	100%	n/m	100%	34	100%	88	100%	21	100%	69	100%	20
Bicarbonate	mg/L	100%	163	100%	52	100%	n/m	100%	34	100%	88	100%	21	100%	69	100%	20
Calcium	mg/L	100%	51	100%	23	100%	n/m	100%	16	100%	34	100%	9	100%	38	86%	8
Chloride	mg/L	100%	5	100%	59	100%	n/m	100%	13.0	100%	103	100%	6	91%	22	75%	4.0
Fluoride	mg/L	100%	0.4	100%	0.2	0%	n/m	36%	0.1	86%	0.2	100%	0.1	82%	0.3	63%	0.1
Hardness	mg/L	100%	193	100%	78	100%	n/m	100%	52	100%	134	100%	30	100%	97	86%	28
Magnesium	mg/L	100%	16.1	100%	5.1	100%	n/m	100%	3	100%	12.1	100%	1.8	100%	5.9	86%	2
Potassium	mg/L	100%	2.3	100%	4.8	100%	n/m	100%	2.7	100%	6.6	100%	2.4	100%	3.6	100%	2.5
Sodium	mg/L	100%	14	100%	41	100%	n/m	100%	16	100%	69	100%	10	100%	21	100%	11
Specific Conductance	umhos / cm	100%	381	100%	409	100%	n/m	100%	177	100%	658	100%	109	100%	355	88%	117
Sulfate	mg/L	100%	12	100%	21	100%	n/m	100%	15	100%	72	100%	9	100%	31	100%	8
Suspended Solids	mg/L	100%	12	100%	45	100%	n/m	100%	152	100%	75	100%	75	100%	86	100%	62
Total Dissolved Solids	mg/L	100%	232	100%	246	100%	n/m	100%	111	100%	392	100%	68	100%	220	88%	71
Turbidity	NTU	100%	6	100%	50	100%	n/m	100%	73.1	100%	36	100%	52	100%	47	100%	36.3
Volatile Suspended Solids	mg/L	89%	5	100%	15	100%	n/m	100%	42.8	100%	33	100%	29	100%	24	100%	25.7
Nutrients and Oxygen-demanding Substances																	
Ammonia	mg/L	14%	n/m	40%	0.2	0%	n/m	79%	0.4	71%	2.5	93%	0.2	57%	0.9	88%	0.8
BOD	mg/L	86%	4	100%	22	100%	n/m	100%	22.3	92%	27	100%	22	89%	16	100%	21.5
COD	mg/L	67%	26	100%	57	100%	n/m	93%	68	100%	117	100%	53	100%	123	89%	48
Dissolved Phosphorus	mg/L	17%	n/m	100%	0.3	100%	n/m	86%	0.2	100%	0.4	100%	0.4	100%	0.4	86%	0.2
Kjeldahl-N	mg/L	100%	0.6	100%	2.1	100%	n/m	100%	3.2	100%	5.3	100%	2.4	100%	3.6	89%	2.8
NH3-N	mg/L	14%	n/m	40%	0.2	0%	n/m	71%	0.3	71%	2.1	93%	0.2	57%	0.7	75%	0.7
Nitrate	mg/L	100%	2.3	100%	4.0	100%	n/m	100%	3.2	100%	2.5	100%	2.8	100%	8.8	88%	3.1
Nitrate-N	mg/L	100%	0.5	100%	0.9	100%	n/m	100%	0.7	86%	0.5	93%	0.9	100%	2.0	88%	0.7

Table D-3: LA County Sampling Results		Vacant		Education		High Density Residential		Light Industrial		Retail/ Commercial		Transportation		Multi-family Residential		Mixed Use	
	Units	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean
Nitrite-N	mg/L	0%	n/m	40%	0.1	50%	n/m	79%	0.1	79%	0.2	100%	0.1	82%	0.2	100%	0.1
pH	mg/L	100%	8.4	100%	7.4	100%	n/m	100%	7.0	100%	7.5	100%	6.9	100%	7.5	100%	6.7
Total Organic Carbon	mg/L	100%	2	100%	14	100%	n/m	100%	12.4	100%	13	100%	9	100%	10	100%	11.2
Total Phosphorus	mg/L	17%	n/m	100%	0.4	100%	n/m	86%	0.3	100%	0.5	100%	0.4	100%	0.5	86%	0.2
Metals																	
Dissolved Aluminum	mg/L	0%	n/m	40%	72	0%	n/m	29%	68.7	7%	13	27%	31	18%	n/m	0%	n/m
Total Aluminum	mg/L	44%	94	100%	335	50%	n/m	100%	772	100%	588	87%	419	73%	318	78%	199
Dissolved Antimony	µg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	7%	n/m	0%	n/m	0%	n/m
Total Antimony	µg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	7%	n/m	0%	n/m	0%	n/m
Dissolved Arsenic	µg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Total Arsenic	µg/L	0%	n/m	0%	n/m	0%	n/m	7%	n/m	7%	n/m	0%	n/m	0%	n/m	0%	n/m
Dissolved Barium	µg/L	100%	52	100%	32	50%	n/m	86%	25	86%	42	87%	21	91%	33	78%	20
Total Barium	µg/L	100%	53	100%	39	100%	n/m	93%	43	86%	63	93%	35	91%	37	100%	31
Dissolved Beryllium	µg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Total Beryllium	µg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Dissolved Boron	µg/L	63%	117.9	100%	210	0%	n/m	64%	148	86%	213	67%	144	89%	209	50%	105
Total Boron	µg/L	75%	194	100%	260	100%	n/m	79%	213	93%	277	93%	195	100%	275	100%	176
Dissolved Cadmium	µg/L	0%	n/m	0%	n/m	50%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	11%	n/m
Total Cadmium	µg/L	0%	n/m	20%	0.6	50%	n/m	0%	n/m	7%	n/m	33%	0.9	0%	n/m	11%	n/m
Dissolved Chromium	µg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	9%	n/m	0%	n/m
Total Chromium	µg/L	0%	n/m	0%	n/m	0%	n/m	21%	4.2	21%	3.8	20%	3.5	18%	n/m	0%	n/m
Dissolved Chromium +6	µg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Total Chromium +6	µg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Dissolved Copper	µg/L	0%	n/m	100%	20	100%	n/m	93%	12.3	93%	14.4	100%	34	73%	6.8	89%	12.1
Total Copper	µg/L	22%	9	100%	25	100%	n/m	100%	22.0	100%	28	100%	48	100%	13	100%	17.4
Dissolved Iron	µg/L	0%	n/m	80%	159	0%	n/m	43%	167.6	64%	187	40%	125	9%	n/m	11%	n/m
Total Iron	µg/L	33%	102	100%	453	50%	n/m	93%	799	93%	815	93%	590	64%	362	67%	273

Table D-3: LA County Sampling Results		Vacant		Education		High Density Residential		Light Industrial		Retail/ Commercial		Transportatio n		Multi-family Residential		Mixed Use	
	Units	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean
Dissolved Lead	μg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	7%	n/m	0%	n/m	0%	n/m	0%	n/m
Total Lead	μg/L	0%	n/m	20%	4.2	0%	n/m	29%	6.7	21%	7.6	33%	5.7	9%	n/m	33%	n/m
Dissolved Manganese	μg/L	0%	n/m	0%	n/m	0%	n/m	7%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Total Manganese	μg/L	11%	n/m	0%	n/m	0%	n/m	7%	n/m	7%	n/m	0%	n/m	9%	n/m	0%	n/m
Dissolved Mercury	μg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Total Mercury	μg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Dissolved Nickel	μg/L	0%	n/m	20%	3.4	0%	n/m	21%	3.2	14%	n/m	40%	4.0	9%	n/m	0%	n/m
Total Nickel	μg/L	11%	n/m	40%	6.0	0%	n/m	50%	5.2	36%	4.2	73%	7.5	45%	7.3	0%	n/m
Dissloved Selenium	μg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Total Selenium	μg/L	11%	n/m	0%	n/m	0%	n/m	14%	n/m	14%	n/m	20%	4.3	0%	n/m	11%	n/m
Dissolved Silver	μg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	7%	n/m	0%	n/m	0%	n/m	0%	n/m
Total Silver	μg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	7%	n/m	0%	n/m	0%	n/m	0%	n/m
Dissolved Thallium	μg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Total Thallium	μg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Dissolved Zinc	μg/L	0%	n/m	100%	96	50%	n/m	93%	336.8	100%	183	100%	224	70%	61	100%	114.2
Total Zinc	μg/L	13%	n/m	100%	127	100%	n/m	100%	347	100%	219	100%	287	90%	95	100%	150
Poly-Chlorinated Biphenyls and Surfactants																	
PCBs	μg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
MBAS	mg/L	0%	n/m	50%	0.0	50%	n/m	79%	0.2	79%	0.3	100%	9.2	67%	0.1	71%	0.1
Semi-Volatile Organics																	
Bis(2-ethylhexyl)phthalate	μg/L	75%	43.8	n/m	n/m	50%	n/m	50%	3	75%	5.3	50%	3.3	100%	79	60%	4
All other SVOCs	μg/L	0%	n/m	n/m	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Pesticides																	
2,4,5-TP	μg/L	0%	n/m	n/m	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
2,4-D	μg/L	0%	n/m	n/m	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Bentazon	μg/L	0%	n/m	n/m	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m

Table D-3: LA County Sampling Results		Vacant		Education		High Density Residential		Light Industrial		Retail/ Commercial		Transportatio n		Multi-family Residential		Mixed Use	
	Units	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean	% Detect	Mean
Carbofuran	µg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Chlorpyrifos	µg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m	0%	n/m
Diazinon	µg/L	0%	n/m	0%	n/m	0%	n/m	0%	n/m	25%	0.1	7%	n/m	0%	n/m	43%	0.1
Glyphosate	µg/L	n/m	n/m	40%	35.2	0%	n/m	0%	n/m	0%	n/m	13%	n/m	9%	n/m	0%	n/m

n/m – not meaningful; insufficient data to assign a numerical value

Table D-4: CCAMP Water Column Monitoring Results		Mission Creek			Sycamore Creek			Arroyo Burro Creek		
	Units	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
% algal Cover, filamentous	%	99	1	43.1	90	5	65	95	1	42
% algal Cover, periphyton	%	95	1	62	100	5	58	75	1	36.5
Air Temperature	degrees C	22	14	16.8	20	14	16.3	23	14	17.4
Air Temperature(F)	degrees F	81	58	70.4	76	68	73.5	76	60	69.5
Ammonia as N, Total	mg/L	1.312	0.005	0.091	0.164	0.005	0.039	0.37	0.02	0.116
Ammonia as N, Unionized	mg/L	0.016	0	0.001	0.005	0	0.002	0.004	0	0.001
Bank Plant Cover	%	85	5	37.8	100	20	66	90	15	49.6
Boron, dissolved	mg/L	0.66	0.03	0.422	0.89	0.07	0.495	1.4	0.06	0.877
Calcium	mg/L	150	23	119	240	40	160	240	51	186
Chloride	mg/L	127	5	65	263	13	175	376	8	236
Chlorophyll a	µg/L	6.3	0.05	1.161	3.4	0.35	1.361	3.3	0.05	0.841
Coliform, Fecal	MPN/ 100 ml	90000	230	6133	11000	80	2025	160001	70	8001
Coliform, Total	MPN/ 100 ml	160001	800	21232	50000	2300	13236	160001	500	25050
Conductivity(Us)	uS/cm	1474	185	1234	2975	1001	2209	3060	335	2224
Dissolved Solids, Fixed	mg/L	912	119	667	1960	206	1166	1710	210	1193
Dissolved Solids, Total	mg/L	1100	172	839	2400	274	1468	2320	270	1518
Dissolved Solids, volatile	mg/L	240	51	172	450	68	302	610	60	326
Hardness as CaCO3	mg/L	614	89	492	1300	158	812	1210	188	857
Magnesium	mg/L	59	7.8	45.8	160	14	100	140	15	95
Nitrate as N	mg/L	1.881	0.1	0.923	1.61	0.039	0.714	2.24	0.43	1.187
Nitrate as NO3	mg/L	8.37	0.445	4.105	7.165	0.175	3.176	9.968	1.914	5.283
Nitrite as N	mg/L	1.14	0.005	0.069	0.041	0.005	0.015	0.1	0.005	0.05
Nitrogen, Total	mg/L	0.8	0.1	0.55				1.5	0.7	1.033
Nitrogen, Total Kjeldahl	mg/L	3.3	0.2	0.693	2.2	0.3	0.827	8	0.25	1.105
Nitrogen, Total NO3 + NO2 + NH3	mg/L	4.333	0.2	1.083	1.661	0.093	0.768	2.512	0.554	1.353
OrthoPhosphate as P	mg/L	0.31	0.01	0.089	0.595	0.005	0.148	0.46	0.01	0.075

Table D-4: CCAMP Water Column Monitoring Results		Mission Creek			Sycamore Creek			Arroyo Burro Creek		
	Units	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
OrthoPhosphate as PO4	mg/L	0.939	0.03	0.271	1.803	0.015	0.447	1.394	0.03	0.227
Oxygen, Dissolved	mg/L	15.2	2.2	8.3	18.7	3.1	11.8	14.3	6.1	9.6
Oxygen, Saturation	%	174	23	84	217	33	121	161	64	96
pH	pH units	8.66	7.21	7.71	8.51	7.47	8.037	8.32	7.2	7.55
Phosphate, total as P	mg/L	2.3	0.05	0.269	49.5	0.1	4.2	29.2	0	1.7
Phosphorus, total	mg/L	0.51	0.06	0.177	0.35	0.26	0.305	0.27	0.05	0.116
Plant Cover	%	60	1	13.6	90	2	15.8	10	1	4
Salinity	mg/L	0.78	0.08	0.647	1.61	0.17	1.155	1.65	0.16	1.192
Sodium	mg/L	140	10	90	250	21	156	260	17	169
Sulfate	mg/L	452	26	270	1060	70	619	796	80	530
Suspended Solids, Fixed	mg/L	322	1	15	1760	1	124	2580	1	109
Suspended Solids, Total	mg/L	370	1	20	2000	1	143	2900	1	126
Suspended Solids, Volatile	mg/L	48	0.5	4.2	240	1	19	320	1	16
Turbidity(NTU)	NTU	540		22	731		60	814		45
Water Temperature	degrees C	22.5	10.7	16.4	22.7	10.1	16.3	21	9.6	15.3

Table D-5: CCAMP Sediment Monitoring Results		**Mission Creek**			**Arroyo Burro Creek**		
	Units	Max	Min	Mean	Max	Min	Mean
Metals							
Cadmium in Sediment	mg/kg	0.147	0.11	0.128	1.269	0.66	0.965
Chromium in Sediment	mg/kg	25.3	19	22.2	140	73	107
Copper in Sediment	mg/kg	8.267	6.2	7.233	30.8	16	23.4
Lead in Sediment	mg/kg	13.3	10	11.7	13.7	7.1	10.4
Mercury in Sediment	mg/kg	0.023	0.017	0.02	0.04	0.021	0.031
Nickel in Sediment	mg/kg	14.7	11	12.8	75	39	57
Zinc in Sediment	mg/kg	38.7	29	33.8	148	77	113
Organic Contaminants							
Aldrin in Sediment	µg/kg	4.4	3.3	3.85	0.962	0.5	0.731
Azinphos methyl in Sediment	µg/kg	66.7	50	58.3	96.2	50	73.1
BHC, alpha in Sediment	µg/kg	0.667	0.5	0.583	0.962	0.5	0.731
BHC, beta in Sediment	µg/kg	0.667	0.5	0.583	0.962	0.5	0.731
BHC, delta in Sediment	µg/kg	0.667	0.5	0.583	0.962	0.5	0.731
BHC, gamma(Lindane) in Sediment	µg/kg	2.667	2	2.333	0.962	0.5	0.731
Bolstar in Sediment	µg/kg	3.333	2.5	2.917	4.808	2.5	3.654
Chlordane, cis in Sediment	µg/kg	2.267	1.7	1.983	0.962	0.5	0.731
Chlordane, Trans in Sediment	µg/kg	0.667	0.5	0.583	0.962	0.5	0.731
Chlorpyrifos in Sediment	µg/kg	3.333	2.5	2.917	4.808	2.5	3.654
Coumaphos in Sediment	µg/kg	33.3	25	29.2	48.1	25	36.5
DDT, Total in Sediment	µg/kg	4.933	3.7	4.317	3.846	2	2.923
Diazinon in Sediment	µg/kg	6.667	5	5.833	9.615	5	7.308
Dichlorvos in Sediment	µg/kg	6.667	5	5.833	9.615	5	7.308
Dieldrin in Sediment	µg/kg	1.867	1.4	1.633	0.962	0.5	0.731
Disulfoton in Sediment	µg/kg	0.667	0.5	0.583	0.962	0.5	0.731
Endosulfan I in Sediment	µg/kg	0.667	0.5	0.583	0.962	0.5	0.731
Endosulfan II in Sediment	µg/kg	0.667	0.5	0.583	0.962	0.5	0.731
Endosulfan Sulfate in Sediment	µg/kg	2	1.5	1.75	2.885	1.5	2.192
Endrin in Sediment	µg/kg	0.667	0.5	0.583	0.962	0.5	0.731
Endrin Aldehyde in Sediment	µg/kg	0.667	0.5	0.583	0.962	0.5	0.731
Endrin Ketone in Sediment	µg/kg	1.333	1	1.167	1.923	1	1.462
Ethoprop in Sediment	µg/kg	6.667	5	5.833	9.615	5	7.308
Fensulfothion in Sediment	µg/kg	0.667	0.5	0.583	0.962	0.5	0.731
Fenthion in Sediment	µg/kg	6.667	5	5.833	9.615	5	7.308
Heptachlor in Sediment	µg/kg	0.667	0.5	0.583	0.962	0.5	0.731
Heptachlor Epoxide in Sediment	µg/kg	0.667	0.5	0.583	0.962	0.5	0.731
Merphos in Sediment	µg/kg	6.667	5	5.833	9.615	5	7.308
Methoxychlor in Sediment	µg/kg	3.333	2.5	2.917	4.808	2.5	3.654
Mevinphos in Sediment	µg/kg	6.667	5	5.833	9.615	5	7.308
Naled(Dibrom) in Sediment	µg/kg	6.667	5	5.833	9.615	5	7.308
Parathion, methyl in Sediment	µg/kg	6.667	5	5.833	9.615	5	7.308
Ronnel(Fenchlorphos) in Sediment	µg/kg	3.333	2.5	2.917	4.808	2.5	3.654
Stirophos(Tetrachlorvinphos) in Sediment	µg/kg	2.667	2	2.333	3.846	2	2.923
Toxaphene in Sediment	µg/kg	16.7	12.5	14.6	24	12.5	18.3

Appendix E:
Best Management Practices

Best Management Practices (BMPs) is a general term that describes a broad spectrum of technologies and policies aimed at improving water quality. It can include civil codes aimed at reducing contaminant discharges, public outreach programs, land management strategies, or physical structures and facilities aimed at reducing or treating contaminated water. In this section, structural BMPs deemed possibly applicable to Santa Barbara's conditions are described. The bulk of the following information was taken from the EPA's website on BMPs at http://cfpub.epa.gov/npdes/stormwater/menuofbmps/post.cfm. Info taken from other sources is cited accordingly.

The list below is organized by BMP type. Each type includes a general description and a narrative on advantages, disadvantages and relative cost. For non-structural BMPs refer to the policy options section that follows this one.

Wet/Dry Detention Ponds and Constructed Wetlands

Dry detention ponds, basins designed to hold storm water runoff, are excellent BMPs for flood control, but have a limited pollutant removal capacity. In contrast, wet detention ponds that have a permanent pool of water year-round can be effective in removing pollutants amenable to biological, chemical, or photolytic breakdown as well as settling out suspended sediments. Constructed wetlands are similar to wet detention ponds, but incorporate more elaborate water flow-through hydrology and support an array of aquatic plants and benthic organisms. They are among the best BMPs available for pollutant removal. Unfortunately, retention ponds and wetlands require a large footprint for construction. This required space is often not available in a highly urbanized setting.

Infiltration Basins and Trenches

Storm water infiltration is the process by which storm runoff is collected into a permeable basin or trench and allowed to percolate into the soil. This method is sometimes used in conjunction with pretreatment measures like swales or constructed wetlands, but the majority of treatment is performed by filtration through the soil matrix. Like detention ponds, infiltration basins require flat open space which is not abundant in Santa Barbara's urbanized area. Additionally, infiltration of storm water can present a risk to groundwater quality if the runoff is contaminated with dissolved pollutants.

Permeable Pavement

Porous pavement is similar to infiltration basins in principle except that water is allowed to infiltrate through the surfaces of roads, parking lots, or other paved areas rather than directed from them. There are a number of types of permeable surfacing, but all allow water to flow through them, often into a gravel reservoir where it ultimately percolates into the soil.

This can be an effective means of reducing the flow of polluted runoff from paved areas into the creeks. Considering the amount of paved area in Santa Barbara, conversion of roads and parking lots into porous pavement could equate to a large reduction in the surface flow volume. A 1980 study by Gburek and Urban suggested as much as 70 to 80% of runoff from paved surfaces can be absorbed. A key advantage to the use of porous pavement is providing treatment for storm water runoff without requiring additional space.

One of the greatest setbacks associated with porous pavement is that it is highly prone to clogging. Because of this, meticulous designing is required, and once installed must be rigorously maintained. Areas with high concentrations of soluble pollutants are not recommended for porous paving due to the risk of contaminating groundwater via infiltration.

According to the EPA, it is estimated that porous pavement costs between $2.00 and $3.00 per ft2, as compared to $0.50 and $1.00 per ft2 for conventional pavement. After subtracting the cost of conventional pavement, this translates to between $45,000 and $100,000 per acre of permeable surfacing.

Porous pavement has received a great deal of attention as a viable BMP option, as the impervious nature of urban settings is greatly responsible for both flooding and contaminant transport problems. A decision to implement this BMP should keep in mind that without meticulous maintenance the surface may clog. Field tests have shown that porous pavement failure rates were as high as 75% over 2 years (Galli, 1992).

Grassed Swales

Grassed swales, often referred to as "bio-swales", consists of several design modifications to the traditional drainage ditch. Grassed channels, dry swales, and wet swales are the most common variants, but all share the common characteristic of pollutant filtration from storm water through vegetative and soil matrices during its collection and conveyance. Water is also allowed to infiltrate the subsurface, allowing for pollutant removal and recharge of groundwater. A grassed channel is essentially a drainage ditch that has been lined with grasses. The primary differences are that the grassed channel banks are flatter and the channels have a gentler longitudinal slope to slow drainage velocity. This allows greater contact time between contaminated runoff and the filtration matrices. While this is a simple modification to a drainage ditch, it is also the least effective grassed swale for the removal of pollutants. Dry swales, like grassed channels, consist of landscaped collection areas but employ a greater variety of plants designed to improve upon the limited filtration abilities of grasses. Wet swales are designed to intersect the ground water table to maintain standing water at all times. In principal they are a small channelized wetland. These systems have the highest pollutant removal capability, but are not generally feasible in much of Santa Barbara due to the depth of the water table.

Swales are a simple improvement on the traditional drainage ditch. Therefore, the retrofitting of existing conveyance ditches is often a simple and effective means of improving storm water quality with less effort and cost than alternative treatment methods. Grassed channels have received mixed reviews on their effectiveness, but studies on dry swales are generally positive as shown in Table E-1.

Table E-1 – Removal efficiencies for select constituents using dry swale BMPs		
Constituent	Efficiency	Reference
Total Phosphorous	18-99 %	Harper, 1988 & Kercher et al., 1983
Total Nitrogen	84-99 %	Harper, 1988 & Kercher et al., 1983
Nitrate	45-99 %	Dorman et al., 1989 & Kercher et al., 1983
TSS	80-99 %	Wang et al., 1981 & Kercher et al., 1983
Metals	37-99 %	Dorman et al., 1989 & Kercher et al., 1983

The pollutant removal rate for dry swales is a clear advantage to this BMP. Additionally, swales are aesthetically pleasing as compared to concrete or dirt lined ditches.

One of the biggest limitations of swales is that they have significant space requirements. Because of this they are not often utilized in urban settings. Furthermore, a swale's treatment capacity is limited to small runoff surface areas and requires low velocity flows for optimum storm water residence time. Because Santa Barbara has an arid climate, grass channels and dry swales would require irrigation to maintain plant viability. It may be judged that the water cost is not worth the treatment benefit. Most importantly, there is little research that supports a swale's ability to remove bacteria. In fact, a 1993 study by Goldberg showed a 25% increase in detectable bacteria.

It is believed that the construction cost of swales compares favorably to many other BMPs. Few studies have explored this, but the estimated cost is approximately $0.25-$0.50 per square foot. Maintenance efforts are lower as well. Grassed channels require periodic mowing, but this is relatively inexpensive compared to other treatment options.

Santa Barbara has experimented with swales, and may wish to increase their use in the future. They have the advantage of being relatively inexpensive and aesthetically pleasing. However, research has not supported their ability to remove bacterial contamination. Rather, it has been shown to exacerbate the problem in some studies. The city should consider this fact carefully, if the goal of a swale is to reduce bacteria loading.

Bioretention

Like swales, bioretention is a structural BMP targeted at small drainage areas such as parking lots. They function by collecting storm water runoff in a recessed area located within or adjacent to paved areas. The depression is filled with mulch and landscaped with a variety of plants. Under the mulch bed is a system that conveys water that has passed through the mulch into the storm drain network. Bioretention systems operate by mimicking forested systems that remove contaminants by a combination of filtration and biological breakdown.

This method can only support small drainage areas. While that makes it ideal for parking lots and small residential areas, it is not possible to support larger drainages such as several city blocks. As a result bioretention is best used in opportunistic instances, rather than as a widespread management strategy. This is because bioretention systems are only capable of treating moderate volumes of water. Once the maximum flow rate of these systems is exceeded, runoff then drains untreated via overland flow. Santa Barbara's sporadic large storm events may exceed a system's capacity and not allow for optimal treatment of storm water runoff.

Bioretention structures can be utilized almost anywhere, including arid climates. Also, they are one of the few localized treatment methods practical in an urban environment such as Santa Barbara. They are effective for storm water retrofitting, particularly during the repaving of parking lots. There is not yet extensive data on the effectiveness of bioretention systems, but the few that exist show successful removal efficiencies for metals and nutrients (Davis et al. 1997). Bioretention is an aesthetically pleasing method that incorporates attractive landscaping. Frequently, the areas selected for bioretention catchments would have been landscaped anyway, which results in no loss of land functionality. Because of this, maintenance associated with bioretention is often at no additional cost over other landscaping options.

A 1997 study by Brown and Schueler ascertained that bioretention system cost may be estimated by the following equation:

$$C = 7.3 \times V^{0.99}$$

Where:

C = Construction, design, and permitting cost ($)
V = Volume of water treated by the facility (ft^3).

For small individual surface areas that are suspected of being contaminant sources, bioretention is a viable BMP. This is particularly true for parking lots and other limited drainage areas such as a small collection of residences. Though slightly more expensive than other treatment methods, there are some distinct advantages. One, they are effective at removing several types of contaminants. They are also aesthetically pleasing. The key aspect to consider when contemplating the implementation of this BMP is the drainage area and runoff volume it will be designed to handle. Large drainages and areas with high flow rates and volume would not be appropriate for this BMP option. Additionally, bioretention has not been successfully proven to remove bacteria contamination, and therefore should not be considered as a BMP for bacteria treatment until further research establishes otherwise.

Grass/Vegetated Filter Strips

Filter strips are open space landscaped with grasses or other vegetative ground cover designed to treat sheet flow runoff. They operate by allowing sheet flow to runoff adjacent land through the filter strip and into a collection system. The treatment principles are similar to those of swales, but they are not designed to perform the collection and conveyance functions that swales do. Normally, they are used to treat runoff from roads, small parking lots, roof drainage, or act as outer buffer zones for creeks.

Filter strips have not shown high pollutant removal rates. Furthermore, the irrigation requirements to maintain the vegetation in arid climates may exceed the treatment benefit.

Lastly, they can not treat large drainage areas and require a great deal of space- sometimes as large as the area they are treating.

Sand/Organic Filters

This structural BMP generally employs a two chamber design to filter out contaminants from runoff prior to its discharge into a collection system. The first chamber provides a settling compartment where large particles and debris fall out of suspension in the runoff water through gravity. The water is then conveyed to a second chamber which contains a sand or organic filter bed. In an organic filter, the sand medium is augmented or replaced by peat or compost. This is done because the higher cation exchange capacity of organic materials is thought to enhance the removal of some constituents. The basic filter design is easily modified, allowing adaptability for a diverse array of conditions. For instance, these filter systems can be placed underground, or at the edge of parking lots (called a perimeter filter), depending on the design modifications.

Sand and organic filters are a proven BMP for removing certain constituents. Table E-2 lists a brief summary of the more effective constituent rates.

Table E-2 – Removal efficiencies for select constituents using sand and/organic filter BMPs		
Constituent	Efficiency	Reference
TSS	8-98 %	Curran, 1996 & Greb et al. 1998
Metals	34-100 %	Schueler, 1997 & Pitt, 1996
Bacteria	31-83 %	City of Austin, TX, 1990

Naturally, the efficacy of the filter depends significantly on its design and filter media. The ability of these filters to remove bacteria could be highly advantageous to the city.

In general, sand filters are not well suited for treating large drainages areas. It is possible to construct a system to handle up to 100 acres, but the systems can be prone to clogging. Sand filters constructed on the surface are not aesthetically pleasing, and though they can be constructed underground, this generally decreases the drainage area treatment capacity, and is significantly more expensive to construct and maintain. Sand filters are not often found in arid climates. They are possible, but require more extensive size requirements to handle increases in sediment loading from single events attributed to storm infrequency. This BMP mechanism is normally "off-line," meaning storm water is diverted from the main collection line into the filter, than returned to the main line. In cases where runoff volumes exceed the capabilities of the filter, excess water is not diverted to the filter. The result is incomplete treatment before discharge into receiving waters. Santa Barbara would likely have to construct quite a few throughout the city to accommodate the large volumes of runoff associated with its infrequent but high-intensity storms.

Data for sand/organic filters cost is inconsistent, because it varies based on the design, treatment capacity, and geographic region. No specific data on California was found, however one 1997 study by Brown and Schueler estimated installation costs to range from $2.50 and $7.50 per ft3 of water to be treated. Underground and perimeter variants are more expensive, but can be cost effective in urban settings where open space is limited. Maintenance costs would be lower in Santa Barbara than many other BMPs. Though frequent inspections are recommended, the infrequency of rain would require minimal servicing. Servicing would include clearing debris, ensuring filter materials remain unclogged, and flushing out the sediment basins.

Sand/organic filters are an effective, stand alone structural BMP. They are one of the few designs proven to significantly reduce bacteria loadings.

Catch Basis and Catch Basin Inserts

Catch Basins consist of grates or curb side drains that have an additional water reservoir, known as a sump, associated with them and are designed to capture sediments or other settleable solids. By themselves, the pollutant removal capacity of basins is highly variable and frequently limited to particulate matter. Catch basin inserts are a way to improve the treatment capacity while not requiring massive restructuring of the collection system. An insert is a filter system that is placed into catch basin inlets. Water is collected and conveyed using the original system but is treated by the filter, lowering potential polluting loading to receiving waters. Because of this, catch basin inserts are a popular choice for retrofitting existing storm drain systems.

Catch basins with inserts are well suited for urbanized areas where space is limited. They are a simple enhancement of existing storm drain infrastructure. While catch basins themselves are questionable in their ability to remove pollutants, inserts have been shown by a few studies to successfully remove sediments, as well as oxygen demanding substances. A summary of supporting studies is provided in Table E-3.

Table E-3 - Removal efficiencies for select constituents using Catch Basis Insert BMPs

Constituent	Efficiency	Reference
TSS	32-97 %	Pitt et al., 1997 & Aronson et al., 1983
COD	10-56 %	Aronson et al., 1983
BOD	54-88 %	Aronson et al., 1983

Little data is available regarding the removal efficiency of constituents other than those listed above. Bacteria are not amongst those studied. Catch basins and inserts are frequently not capable of removing soluble contaminants and small particles. Even ideally designed basins and inserts are not generally as effective at removing constituents as sand filters or other structural BMPs, which is why they are often used as a pre-treatment BMP rather than a stand alone type. Catch basin inserts also require frequent maintenance to ensure proper functionality, and while retrofitting storm drains may be relatively inexpensive, the upkeep can be costly. In addition, additional disposal costs may be incurred if contaminant concentrations of the collected sediments exceed regulatory thresholds.

Typical catch basins cost between $2,000 and $3,000 dollars. Retrofitting existing basins with inserts can range from $400 to $10,000 depending on the elaborateness of the design. Another important cost consideration for this BMP is the long term maintenance costs. In order to ensure proper functionality, basins and inserts require cleanings at least annually. A 1994 study in Alameda, CA by Mineart and Singh, suggests that increasing to semi-annual and even to a monthly regimen significantly improved the sediment removal efficiency in both cases. The cost of a vactor truck, the normal maintenance equipment used for cleaning, runs roughly $125,000 to $150,000 notwithstanding the costs associated city staff labor time.

Catch basins with inserts are useful for greatly reducing sediment and organic material loadings into receiving waters. The implementation costs would be high but not exorbitant compared to some other options. Maintenance would be somewhat costly, though a monthly cleaning regime would probably not be necessary due to the infrequency of storm events in this region. The most important consideration regarding the implementation of this BMP is which pollutants the city is targeting. As stated earlier, bacteria removal is not a proven control measure of this BMP. Therefore, if microbe removal is the goal of the BMP, catch basins with inserts would only be considered for a pretreatment measure, but not a stand-alone BMP.

Swirl Separators

Swirl separators, also known as hydro-dynamic structures, are a design variation on the traditional oil grit separator found in storm drain inlets. They consist of filter inserts with a cylindrical structure that facilitates swirling of storm water as it drains. The swirling action facilitates sediment settling, thus reducing the amount entering the collection system that will ultimately discharge into receiving waters. Varying filter inserts can chosen based on their pollutant removal properties. In this manner, the filters can be tailored to the specific pollutant concentrations observed in the runoff. Swirl separators are by and large proprietary and likely vary in performance between designs.

Similar to catch basin inserts, swirl separators are popular choices for retrofitting urban storm drain networks. The low space requirement makes them well suited for the urban watershed dominated by impervious topography. Many of the proprietary designs offer removal efficiency data for their products. Such datasets should be viewed with the obvious potential for bias in mind. However, limited independent data has been published on the efficacy of swirl separators, summarized in Table E-4.

Table E-4 - Removal efficiencies for select constituents using Swirl Separator BMPs

Constituent	Removal Efficiency	Reference
TSS	21-51.5 %	Greb et al., 1998 & Labatiuk et al., 1997
Total Phosphorous	17 %	Greb et al., 1998
Dissolved Phosphorous	17 %	Greb et al., 1998
Lead	24-51.2 %	Greb et al., 1998 & Labatiuk et al., 1997
Zinc	17-39.1 %	Greb et al., 1998 & Labatiuk et al., 1997
Copper	21.5-21.5 %	Labatiuk et al., 1997
PAHs	32 %	Greb et al., 1998

Based on these studies, swirl separators are fairly effective at suspended sediment removal, and have some ability to reduce phosphorous, certain metals, and PAH loadings.

As with several other structural BMPs, there is no conclusive data suggesting that swirl separators are effective at removing bacteria from runoff. Additionally, the limited pollutant removal data that does exist does not show removal efficiencies that would be effective treatment techniques by themselves. Maintenance requirements are similar to those of catch basin inserts – relatively intensive.

Typical swirl separator units cost between $5,000 and $35,000. Alternatively, the cost can be approximated to be between $5,000 and $10,000 per impervious acre. Maintenance requirements are relatively high. As with catch basins, servicing the swirl separators requires a vactor truck which requires an initial capital investment of between $125,000 and $150,000, plus long term labor costs.

Swirl separators are becoming a popular structural BMP choice throughout the U.S. for highly urbanized areas with primarily impervious surface, and little available space for treatment structures. They are very similar to catch basin inserts in that they are an easy retrofit with a high, but not exorbitant, maintenance cost. They could be a beneficial addition to Santa Barbara's BMPs. However, they have not been proven effective at reducing bacteria contamination, and their removal efficiency statistics may not be adequate to be considered a stand-alone treatment system. They would be better suited as pretreatment for a larger system. This is frequently how they are implemented in other communities throughout the nation.